

Nile Basin Initiative
Transboundary Environmental Action Project

National
Nile Basin Water Quality
Monitoring Baseline Report
for
Rwanda

Kigali, Rwanda 2005

NILE BASIN INITIATIVE

Initiative du Bassin du Nil

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I. THE OBJECTIF OF THE BASELINE STUDY

The objective is to have a national information on water quality, and to facilitate the implementation of the project NILETEAP in order to achieve significant environmental and public health benefits through reductions of water pollution.

Deposition reductions are unlikely to be met solely through national policies and measures because of the Transboundary nature of water pollution transfer.

Therefore, there is a need for inter-governmental cooperation and the development of sub-regional water quality assessment procedures and appropriate action plans.

The information collected from baseline studies will be used to develop national and sub-regional action plans and to establish a consistent water quality assessment procedure for each nation.

The assessment procedure has to begin with the collection of detailed knowledge describing the existing situation. The aim is to know which water pollutants are present and in what quantities, their origin, their dispersal patterns, the potential that they will impact on sensitive receptors, and what response measures should be taken to ameliorate the situation.

II. STRUCTURE OF THE BASELINE REPORT

1. National views on water resources in Rwanda.
2. Policies, institutional and legal setting in matter of the environment and water
3. Water pollution monitoring
4. Quality and quality assessment
5. Impacts of the aquatic pollutants
6. Resources for monitoring and technical capacity
7. Current monitoring stations
8. Research Studies into water pollution
9. National Responses to water Pollution Problems
10. Action by NTEAP on Nile water quality monitoring

Recommendation

Conclusion

III. SUMMARY

This baseline report on National Water Quality Monitoring Initiatives have ten chapters in all formulation of the structure of all line of the TORs.

The chapter 1 present a view on national water resources in the country, on surface water (rivers, lakes and reservoirs), groundwater of Nile basin, show up the key challenges and the state on water resources monitoring. On the chapter 2; analysis of principles objectives; national environment policy, policy implementation; basic principles of water resources management policy and regulation (water quality, protection and environment quality standards, Transboundary waters), legal and institutional framework, role of civil society and private sector, regional and international co-operation, monitoring and evaluation water pollution control and management and national strategy of the environment, plan of environmental actions, national vision 2020 and national agenda 21 for follow-up of quality of water resources, in conclusion no clearly the legal and regulatory instrument for pollution prevention and control.

Chapter 3 make a diagnostic on water pollution assessment , sources of water pollution, pollutants of water as coming from different pollution: liquid and strong sewage; domestic, industrial and small-scale sewage, pesticides and chemical manure. Quality and Quality assessment in chapter 4, water quality criteria, standards and water quality objective (Water quality criteria are based on variables that characterise the quality of water) on drinking water supply, surface water and groundwater and the main reasons of quality deterioration of water resources. Chapter 5 view of impacts of aquatic pollutants and human hearth.

Implementing a monitoring programme requires access to resources, including an equipped laboratory, office space, equipment for field work, transport and trained personnel, in chapter 6 a view of resources for monitoring and technical capacity in the country to identify list of laboratories equipment and facilities, human resources capacities and network communication in summary of this chapter existing national structure of water quality assessment (laboratories, staffing, equipment, expertise and low capacities but no relation of collaborations, no common system, on standardise methods of quality analysis, no geo-references of sampling sites and no co-ordination reports addressing to authorities.

Involvement of communities, NGOs in water quality management programs and nation level of awareness on the importance of water quality management in Nile basin between stakeholders a national civil society forum on Nile Basin.

The chapter 7 current monitoring stations situation on hydrological sampling stations and proposed geo-references for regular sampling stations. In chapter 8 research studies into water pollution. Different actions are valued in the chapter 9 and the needs are identify on the legislative and regulation, institutional and organisational plans, and in term of information, education and communication. challenges and stakes being of socio-economic and institutional order, to search for less polluting alternatives in economically accessible of the decentralisation of actions, struggle against the pollution of resource in water.

In chapter 10 suggestion of actions by NTEAP on water quality monitoring setting in short terms. some project are indicated or recommended for designing a Nile basin water quality monitoring program.

CHAPTER 1 : THE NATIONAL VIEW OF WATER RESOURCE

1.1. Hydrological measurements.

1.1.1. Water resources

The country of Rwanda knows a very dense hydrographic network of 2km/km² (length of the superficial out-flow network by Km² of surface).

Rwanda possesses water in abundant quantities. The country has an area under water (lakes, rivers, reservoirs, swamps and ground water) of about 211,000ha , about 8% of the national territory.

Rwanda possesses a dense hydrographic network. Lakes occupy an area of 128,190 ha, rivers cover an area of 7,260 ha and water in wetlands and valleys a total of 77,000ha. The country is divided into two major water basins, divided by a water divide line or ridge called Congo Nile Ridge. To the west of this line lies the Congo River Basin which covers 33% of the national territory and which receives 10% of the total national waters. To the East lies the Nile River Basin whose area covers 67% of the territory delivers 90% of the national waters. Waters of the Nile River Basin flow out the country through the Akagera River, the main tributary to Lake Victoria, which bears the outlet of the White Nile. Akagera River contributed 9 to 10% of the total Nile Waters.

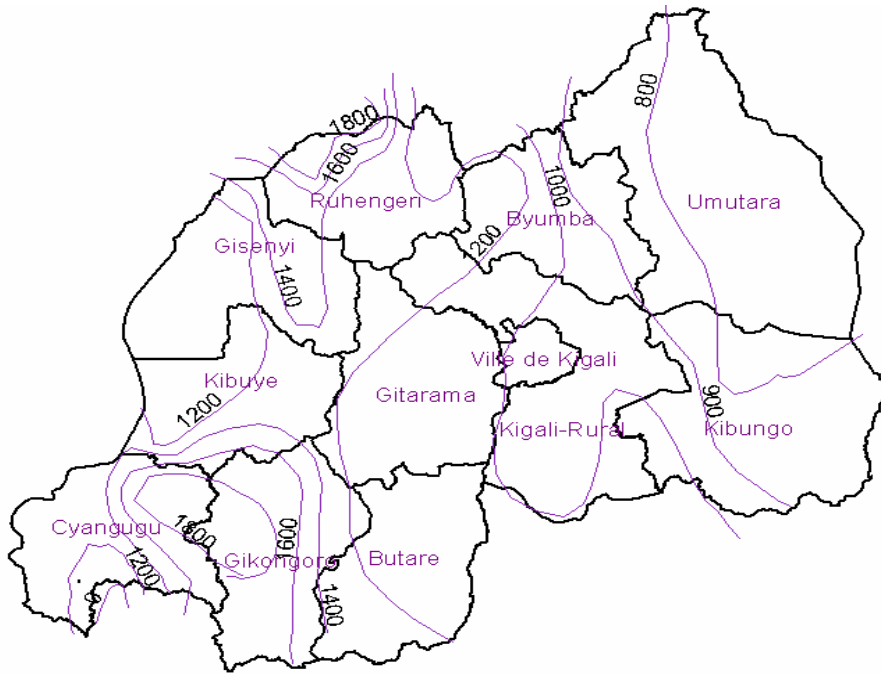
1.1.2. Surface Water Resources

Hydrological measurements are essential for the interpretation of water quality data and for water resource management. Variations in hydrological conditions have important effects on water quality. In rivers, such factors as the discharge (volume of water passing through a cross-section of the river in a unit of time), the velocity of flow, turbulence and depth will influence water quality

Rwanda is a land locked country situated in high land Equatorial region. It is characterised by abundant surface water. Surface water is hydrological defined as “ water stored or flowing on the earth’s surface.” The surface water in Rwanda is mainly due to precipitation’s. The annual rainfall varies from 700-1400mm in the East and lowlands of the West to 1200-1400mm in the high altitude region. The temperature regime is more or less constant with a temperature regime of 16°C –17°C for high altitude region, 18-21°C for the central plateau region and 20 – 24°C for the eastern plateau and lowlands of the West. The climate is of the temperate equatorial continental type (AW3) according to KOPPEN classification .

There are two rainfall seasons with the longer south-easterly monsoon rain between February and May , and the shorter north-easterly from September to November. The runoff responds to the rainfall with a higher peak in May and a smaller peak in November. However the river flows are attenuated by a number of lakes and in particular by two sets of swamps and associated lakes above and below Rusumo Falls.

Fig1.1. Annual rainfall distribution



With such amount of rainfall, it is clear that the high altitude region is susceptible to disasters of erosions, mass movements and while low rainfall areas are susceptible to flooding and drought.

Rwanda possesses also a dense hydro graphic network. Lakes occupy an area of 128,190 ha, rivers cover an area of 7,260 ha and water in wetlands and valleys a total of 77,000ha. The country is divided into two major water basins, divided by a water divide line or ridge called Congo Nile Ridge. To the west of this line lies the Congo River Basin which covers 33% of the national territory and which receives 10% of the total national waters. To the East lies the Nile River Basin whose area covers 67% of the territory delivers 90% of the national waters. Waters of the Nile River Basin flow out the country through the Akagera River, the main tributary to Lake Victoria, which bears the outlet of the White Nile. Akagera River contributes 9 to 10% of the total Nile Waters.

The water resources are mainly influenced by rainfall and evaporation and hence climate information and preparedness products are essential in management of water resources and must be included in the management policies for disasters preparedness to water resources. Some of disasters the country is facing are for examples the flooding, the droughts, landslides, mudflows.

The Akagera Basin has a general elevation of 1200-1600m but may rise above 2500 m the west with peaks reaching 4500m. Rainfall is less than 1000 mm over most of the eastern half of the basin but rises to over 1800mm in the west where most of the runoff is generated. Most of the basin has become intensively cultivated resulting in erosion and river sediment load from the high rainfall areas. The upper tributaries are generally steep but include flatter reaches where swamps have formed. The middle course of the river and its tributaries above Rusumo Falls is extremely convoluted, this reach reflecting regional warping and drainage reversal, with some tributaries retaining the appearance of flowing towards the Congo. Several side valleys enter the river with their courses filled either with lakes or swamps. Between Kigali and Rusumo Falls the slope diminishes from about 0.3m/km to 0.05m/km and the valley is filled with papyrus swamps up to 15 Km wide.

The average discharge is estimated to be 256 m³/s with a low flow of 85 m³/s at Akagera. says that the Akagera is the main affluent of the lake Victoria with a middle debit of 256m³/s and has this title considered as the source of the Nil. One will note that has the entry of the Akagera in the Victoria lake, the debit of the Akagera is of 262m³/s.

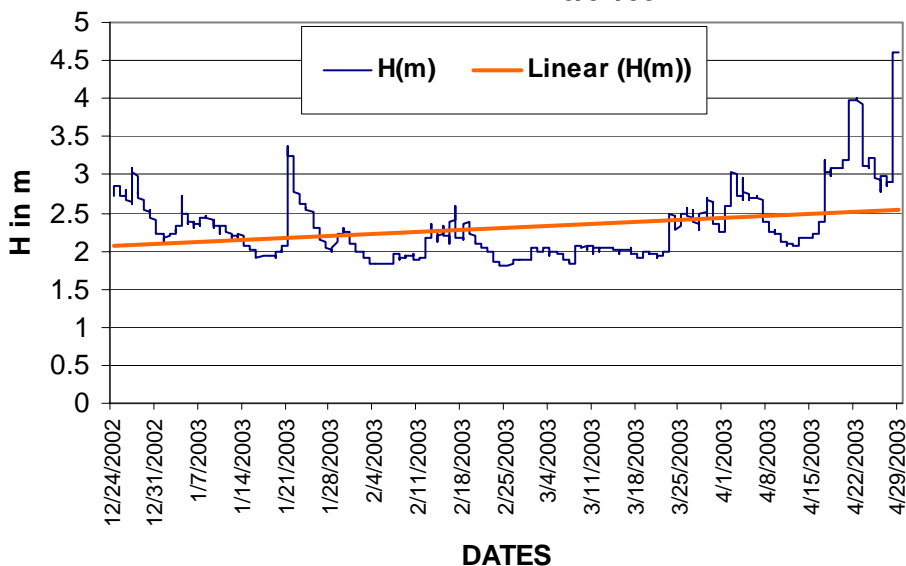
The main rivers in the Nile Basin of Rwanda are: Mwogo, Rukarara, Mukungwa, Base, Nyabarongo and the Akanyaru of which the water are drained by the Nyabarongo which becomes Akagera at the outlet of Rweru Lake.

The debits passing in transit by main hydrological stations are on average these:

Nyabarongo at Kigali :	78 m ³ /s
Nyabarongo at Kanzenze :	100 m ³ /s
Akagera at Rusumo :	232 m ³ /s
Akagera at Kagitumba :	256 m ³ /s

The main rivers for Congo Basin are : *Sebeya, Koko, Ruhwa, Rubyiro et Rusizi*. The average discharge is estimated to be 48 m³/s with a low flow of 7 m³/s.

Fig1.2. Water Level at Nyabarongo (Kigali) station from 24/12/02 to 29/04/03



The graph below (Fig.2.) shows the water level at Nyabarongo River near Kigali city. The water level varies from 1.8 meter to a maximum of 4.6 meters in April 2003. The graph illustrates the normal trend of the seasons in Rwanda with a rainfall season, which starts in March, and ends in May while the short dry season starts by end of December and ends by end of February.

1.1.3. Lakes and wetland

Apart for the lake Kivu with an area of 102.800 Ha (Rwanda area) and maximum depth of 473 m, the country has many lakes of variable dimensions with two main lakes located in North part of the country :

- Burera, area of 5280 Ha and a maximum depth of 174m,
- Ruhondo, area of 2610 Ha and a maximum depth of 68m.

The other lakes are no so deep (maximum depth varies 3 à 6.5m) are in table 1.

Fig1.3: Lakes under threat of eutrophisation

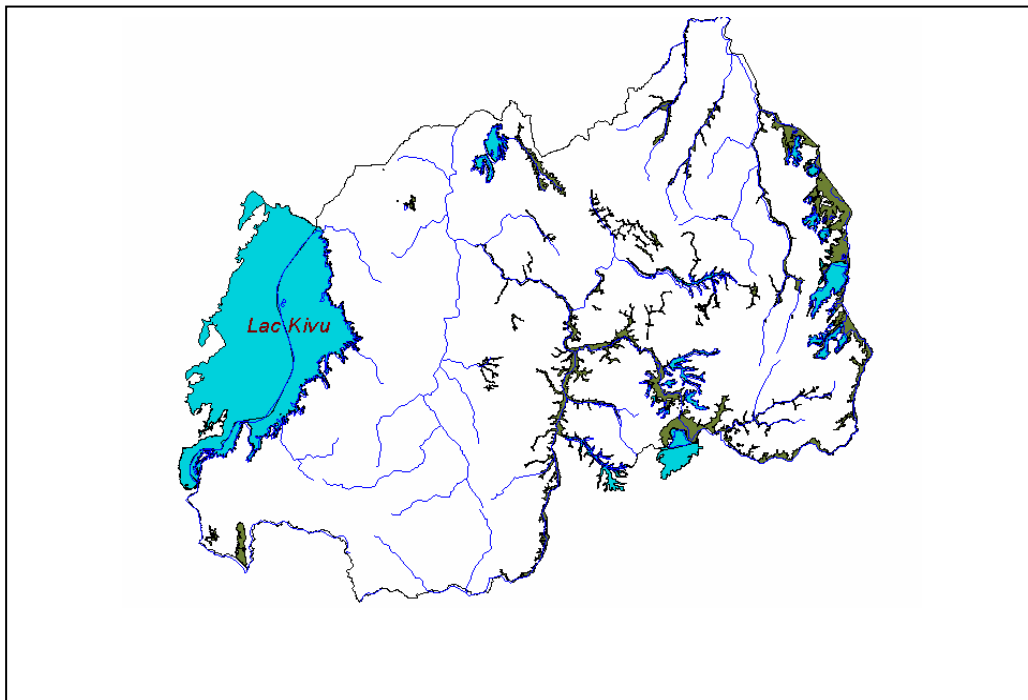


Table 1.1. Less deep Lakes (maximum depth varies 3 à 6.5m)

Area (ha)	Lakes
3920	Mugesera lake
1430	Sake lake
540	Bilira lake
1230	Cyohoha (North +South) lake
1868	Rweru lake
2000	Rwanyakizinga lake
1080	Mihindi lake
1610	Hago lake
920	Kivumba lake
7190	Ihema lake
1300	Nasho lake
2110	Rwehikama lake
900	Rwampanga lake

Some of the lakes in Southern part of the country are seriously diminishing in size, others are affected by serious problems of eutrophication by water hyacinth such as the Lake Mihindi , others are under agriculture pressure such as the lake Muhazi.

The marshland occupy an area estimated to be 165.000 Ha (around 7.5% of the national territory) with 94,000 Ha are exploited (around 57% of the total area is occupied by swamps). The managed area and equipped for a better management of water resources, allowing the cultivation through the year are estimated to be 5000 Ha. However some of these areas require some rehabilitation work.

Some of the marsh land are still covered by their natural vegetation (75,000 to 80,000 Ha), because their difficult access.

1.1.4. Ground water

There do not exist complete data on ground water of Rwanda. However with the available information from some projects, it is estimated that the discharge for the available resource is 66m³/s. In that discharge, there are 22,000 recognised sources which have a discharge of 9.0 m³/s, but the population is consuming only 0.9m³/s and the rest of the water is lost for the whole country.

The table below gives a synthesis of the available resource in dry season

Table1.2. Availability of water during the long dry season.

River	Minimum flow (m ³ /s)	Minimum flow from outside Q(m ³ /s)	Minimum flow from lacs and swamps (m ³ /s)	Ground water flow (m ³ /s)
Akagera at Rusumo (Nyabarongo + Akanyaru)	81.2	16.2	8.1(*)	56.9
Kagitumba at Kagitumba	4.0	2.0	-	2.0
Rivers from Lake Kivu	7.0	-	-	7.0
Availabe water Resources (m3/s)				66.0 (m3/s)

1.2. Key challenges for water resource development and management

Although Rwanda is well endowed with water resources, the country faces a number of problems in relation to the sustainable management and protection of these resources which will ultimately, if not adequately and timely addressed, detrimentally affect the country's economic and social development.

The issues which need to be addressed include the following:

- The establishment of an enabling environment within which sustainable water resources management can be achieved including the preparation of a comprehensive National Water resources management policy, the promulgation of legislation and appropriate regulations which will enable the implementation of the policy, and the establishment of a rational institutional framework through which appropriate levels of government can function.
- Ongoing assessment and monitoring of water resources including the collection, analysis, storage and dissemination of water related information;
- Human resources development within the water resources sector including capacity building to enhance managerial and technical skills;
- The protection of critical environmental functions to ensure the sustainability of the source of water resources;

- To address the growing effects of increasing demands for water as a result of population increase and industrialisation including pollution and catchment degradation;
- The development of water resources through investment in infrastructure to achieve multiple benefits and to enable the country to manage variability in water resource availability through such occurrences as floods and drought.

Much of Rwanda forms part of the headwaters of the international Nile and Congo River basins. As such water resource management issues have both national and international impacts.

1.3. State of Water Resources monitoring in the country

The water resources are very important for the overall development of Rwanda. Hence The Rwanda Government is putting high priority in monitoring the quantity and the quality of the water resources in the country. The Division of Hydrology and Water resource is one of the three Divisions under the Directorate of Water and Sanitation, the others are Division of hydraulic rural, Urban hydraulic, and Sanitation. The Division of Water Resources has among other duties, to monitor the quality and the quantity of the surface and ground water in all the country.

In the past, before the genocide of 1994, there used to be 47 hydrological stations in the country. However since 1994, the number has decreased due to many factors including mainly putting less priority on water resources evaluation. In 2000 with the decentralization process, the division has remained with monitoring key primary rivers, the main tributaries of Akagera River. Secondary rivers are under the responsibility of the Provinces, and third category are under the responsibility of Districts. Since the decentralization is just starting, it is evident that monitoring rivers is not yet well mastered at all sectors, at provinces or at district levels.

At the division of water resources with the assistance of FAO Capacity Building project, a modern equipment comprising Thalimedes has been installed in some key monitoring stations, Nyabarongo, Akanyaru, Kanzenze, Rusumo. The Thalimedes is a modern instrument which gives automatically the height and hence the discharge. However the equipment is very risky and subject to vandalism, it requires to have permanent watch men .

The Division of Water Resources has a solid database in which historical data have been entered, and now is being feeded by data from Thalimedes. Historical data have shown unfortunately some errors, some discrepancies, and in general data are unreliable especially after the tragic events of 1994 where more emphasize has been put on providing clean water to the population.

The Division also has a database for water quality for some areas covered by projects or NGOs; the whole country is not covered. There is also a National Company supplying water and electricity which maintains a good database on water quality especially for water resources drinking points.

The main problem in monitoring the quantity of the surface water resources in the country is lack of skilled personnel, scattered database, limited funds which are used in other main

sectors which seem to have a direct economical benefit. The hydrological data collected are not a competitive commercial product.

It is urgent that the Ministerial Department in charge of water develops an appropriate policy that could help to make marketable hydrological data collected.

CHAPTER 2: POLITICAL, INSTITUTIONAL AND LEGAL SETTING IN MATTER OF THE ENVIRONMENT AND WATER

2.1. PRINCIPLES AND OBJECTIVES OF THE NATIONAL ENVIRONMENT POLICY

2.1.1. General policy principles.

In order to resolve the above mentioned problems and ensure the protection and sustainable management of the environment, ten principles should be kept in mind:

- (i) Every individual has the right to live in a healthy and balanced environment and has the obligation of safeguarding environmental health;
- (ii) Economic growth in Rwanda should be based on a more rational utilisation of resources and take into account the environmental dimension;
- (iii) Active and effective participation of the entire population in the protection and management of environment;
- (iv) Special attention should be paid to educational and awareness creation programmes in environment at all levels with a greater involvement of women and the youth;
- (v) Introduction of the principle of prevention;
- (vi) Introduction of the principle of the polluter-pays
- (vii) Environmental impact should be analysed during consideration of developmental projects;
- (viii) The principle of equality among generations and fair share in the utilisation of resources should be respected;
- (ix) Establishment of a favourable social and economic environment for the utilisation of natural resources;
- (x) Recognition of the sub-regional, regional and global environmental interdependence.

The overall objective of the Environmental Policy is the improvement of man's well-being, the judicious utilisation of natural resources and the protection and rational management of ecosystems for a sustainable and fair development.

The policy aims at the following specific objectives:

- (i) to improve the health and the quality of life for every citizen and promote sustainable socio-economic development through a rational management and utilisation of resources and environment;
- (ii) to integrate environmental aspects into all the development policies, planning and in all activities carried out at the national, provincial and local level, with the full participation of the population;
- (iii) to conserve, preserve and restore ecosystems and maintain ecological and systems functioning, which are life supports, particularly the conservation of national biological diversity;
- (iv) optimum utilisation of resources and attain a sustainable level of consumption of resources;
- (v) to create awareness among the public to understand and appreciate the relationship between environment and development;
- (vi) to ensure the participation of individuals and the community in the activities for the improvement of environment with special attention to women and the youth;
- (vii) to ensure the meeting of the basic needs of today's population and those of future generations.

2.1.2. Policy option of Water resources

To ensure that water is used in the various economic and social sectors without endangering environment.

Strategic actions

- (i) to take necessary measures with a view to maintaining the balance of hydro-ecological processes;
- (ii) to put in place measures for the prevention of the degradation of the environment around water points;

- (iii) to control the gradual decrease of natural water reservoirs (vegetation-forest-marshes cover);
- (iv) to ensure that developmental projects include prior studies of environmental impact which will highlight the costs and benefits of the protection of watershed and other underlying ecosystems;
- (v) to promote an integrated approach by governmental and non governmental agencies involved in the implementation of protection measures of watersheds with a view to reducing erosion, silting, pollution by colluvial deposits, deforestation and other harmful factors;
- (vi) to control the water hyacinth and other invading plants;
- (vii) to promote programmes for the collection, storage and use of rain water;
- (viii) to promote regional co-operation in the management and equitable utilisation of cross-border waters;
- (ix) to ensure compliance with the regulations on water quality and management of rejects.

2.1.3. Policy option of Wetlands

To improve the conservation and management of wetlands.

Strategic actions

- (i) to develop a policy and a legislation on the conservation and use of wetlands;
- (ii) to develop a master plan for the development and conservation of wetlands;
- (iii) to draw up an inventory and characterise the components of the diversity of wetlands;
- (iv) to follow up and evaluation of the state of wetlands;
- (v) to introduce measures for the protection of watersheds with a view to prevent the degradation of marshes;
- (vi) to determine the marshes to protect and the marshes to use;

- (vii) to maintain all the marshes as public and private property of the State and entrust their management to the Government.

2.1.4. Policy option of biodiversity

To guarantee the conservation and sustainable utilisation of biodiversity of natural ecosystems and agroecosystems in compliance with the equitable share of benefits derived from biological resources.

Strategic actions

- (i) to make an inventory of endemic native and/or less known species of economic importance;
- (ii) to conserve in situ and ex situ the native genetic heritage;
- (iii) to ensure the development of alternatives for the exploitation of biodiversity;
- (iv) to conserve the genetic diversity of native plant and animal species;
- (v) to develop mechanisms for the control of imports and the dissemination of genetic materials;
- (vi) to implement identified action plans for the conservation of biodiversity in the National Strategic Plan on Biodiversity;
- (vii) to ensure the rehabilitation of sites after mining and quarrying activities.

2.1.5. Fishery and fish farming

Fishing

Fishing is practised mainly in lakes and little in rivers. Catches are currently low due to factors such as the young age of the lakes; stocks consisting of fluvial species more or less not adapted to lake harvesting; increasingly poor stocks as one moves away from the Akagera lakes system due to the presence of rapids and falls which prevent the colonisation of water situated upstream the Rusumo falls by more diversified and balanced species living downstream these falls.

In all the lakes in Rwanda, with the exception of lake Kivu, fishing, mainly Tilapia fishing, is done with fixed gill net which is laid overnight and removed in the morning. Water fauna is also threatened by bad elementary fishing techniques. Fishing by beating and using nets with very small meshes is harmful to the conservation of fish resources and other aquatic animals. The use of explosives and toxic products has also been reported.

In the lakes of the Akagera Park, fishing is also done on a small scale. Occasional fishers, uncaring for the conservation of the ichthyologic fauna, are the cause of over fishing of the most valued species with commercial value, particularly *Clarias* and *Tilapia* spp. Since fishing techniques are rudimentary and home made, fishing becomes destructive and leads to ecological imbalance of animal and plant species.

It has also been observed that when fishing, other aquatic animals are caught in the snares. These are crocodiles; hippopotamuses, ducks. Some birds and crocodiles get entangled in the nets and drown. Ospreys get also entangled in bits of nets and drown.

Fish farming

Fish farming was introduced in Rwanda since the 1950s, but it did not develop. However, environmental effects linked to fish farming have inherent risks of spreading diseases and dangers associated with the introduction of certain species.

2.1.6. Health and sanitation

Health

Health constitutes a prerequisite for the development of all the sectors, particularly the development of human resources. Rwanda's population is characterised by inadequate health.

The analysis of the health sector shows a health level that is still low in the country, whether in terms of infant diseases control, reproductive health, malnutrition, access to medical care, HIV/AIDS control and malaria.

According to the statistics from the report of the Ministry of Health of 1998, the geographical cover per distance area is 23,448 inhabitants per health centre; 64% of pregnant women had two meals a day; 17.7% one meal a day; 16.5% three meals a day and 1.7% four meals a day, when the diet recommended by WHO is 4 or 5 meals a day; 5% of pregnant women suffered from moderate or severe anaemia and 4.6% suffered from lack of moderate or severe lack of iron. Dysmaturity was 42.7% in 2000.

These statistics do not include private medical clinics. Rates are sufficiently eloquent with regard to the seriousness of malaria with 40% of consultations collected in health centres and HIV/AIDS, representing 11.2% of the total population. There are other diseases attacking adult persons such as tuberculosis, diphtheria, and those attacking children such as diarrhoea and respiratory infections.

Concerning reproductive health, less than 2% of the young aged less than 20 years use contraceptives; the rate of incidence of STD is very high; 4.5% of girls aged less than 20 years give birth each year and 31% only of women give birth in medical institutions while 72.5% give birth at home.

The main causes of this bad state of health are poverty which limits the population's level of hygiene and access to health care, the low level of education and information, the country's financial constraints which limit health services offered to the population, malnutrition which affects a sizeable part of the population, malaria and AIDS epidemics, post-genocide vulnerability, insufficient number of qualified health staff, unhealthy state of environment, poor

access to drinking water and lack of integration of traditional medicine. Yet the health state of the population should be improved since it conditions their contribution to the development of the country in general, and the environment in particular.

Sanitation

Available information on sanitation in terms of the people with latrines suggests a very high cover of about 85% in rural areas. However, only 0.8% of these latrines are “hygienic”, and the rules of good hygiene are not respected everywhere.

In rural areas, in towns and in settlements, one still finds rubbish in the streets and in the homes. Used water is often poured in the yard. This situation shows that in terms of attitude and hygienic and sanitation practices, the population is not sufficiently informed or sensitised.

Many dwelling houses in rural areas shelter various parasites, rodents and other disease vectors. No precautions are taken to protect drinking water, and consumption of unfit water for human consumption is the cause of many water borne diseases. Disorderly building of houses in towns without provision for disposal of wastewater and rain water worsens the problems of sanitation. These waters destroy public roads and stagnate, thus becoming the favourable sites for the breeding of mosquitoes and other vectors of human and animal diseases.

Human and industrial settlements reject effluents in their raw state or after transit in septic tanks into receiving environments (rivers, lakes or valleys) without caring for their impact on the environment.

Ignorance, lack of awareness and insufficient health technicians for towns are responsible for damages observed in the field of sanitation. Most of dwelling houses are situated at the top or on the slope of hills, and water sources may be regularly polluted by domestic waste and waste from human activities transported by water run-off.

2.2. POLICY IMPLEMENTATION

The environment policy covers several sectors of activity. Its implementation involves all the stakeholders in the social, political and economic life of the country. It will require the establishment of an appropriate institutional and legal framework and an adequate system for the monitoring and evaluation of impact and outcomes of the objectives set out in the policy.

In addition, the actual implementation of the policy will require the mobilisation of financial, human and material resources and, to become more effective, it will be carried out according to the participatory and decentralised approach.

2.2.1. Basic principles of water resources management policy and regulation.

Development and conservation of water resources for sustainable utilisation to improve the socio-economic development of the country is the objective of the policy. The water resource management policy will have to cover the entire water resource cycle in holistic manner (sources, water resources, environment, different sector of direct services and downstream Transboundary). This will entail policies for the protection of sources which produce the water resources, that is ground water, lakes, rivers, wetlands and other hydrological eco-systems.

The policy aims at providing guidelines for efficient utilisation of the resources in different sector that is the various sectors where water is directly used, i.e. water supply and sanitation, agriculture, fisheries, industry, etc. it addresses issues related to allocation, conservation, quality control and efficient use.

Considering the needs of Rwanda, water resources management, utilisation and development constraints, in preparation of a national water resources management policy, the following guiding principles have been adopted:

- Water is basic human need
- Water is critical to sustainable socio-economic development
- All people have a right to equitable access to water services and resources.
- Water resources development needs to be holistically integrated with all other development.
- The environment is the source of water and must be sustained in the interests of present and future generations.
- Water has value and is a social and economic good.
- Public awareness and participation is critical to proper development of the nation's water resources.
- Accessible, transparent and efficient public institutions are essential for effective water resource management.
- International co-operation and the equitable utilisation of Transboundary water resources are a requirement for regional economic development.

Water quality

- The government considers the protection and maintenance of quality of potable water as a priority.
- The policy of the government is to work towards the improvement of drinking water quality to meet minimum standards as published from time to time by the government.
- In the public interest, the government will determine suitable standards for the quality of water to be used for certain specified purposes.
- To promote the ecological integrity of water resources, the government will control point source effluent discharge from different users based on receiving water standards established from time to time.
- The government adopts the precautionary Principle by requiring potential polluters to prove that they will comply with national standards before receiving effluent permits.
- The government will ensure sustainable management of critical eco-systems which contribute to the natural treatment and prevention of pollution.
- The polluter will be held responsible for damage caused by pollution and will bear the direct cost for remedial action and indirect consequential costs.

Protection of water resources and the environment quality standards.

- The government considers the environment as resource base from which the resources is derived and will seek to protect it.

- The government will promote good watershed management practice and the protection of catchment areas to reduce erosion, siltation, pollution by nutrients, deforestation and other detrimental factors.
- Development of water resources will be encouraged and supported by the government but not at the expense of sustainability of the resource.
- Sustainable land use planning and management practices will be required in hydrologically sensitive areas.

Public safety

- The government will strictly apply water quality policy in the interests of public safety.
- The government will periodically publish regulations governing the safety of hydraulic structures including their construction, operation and maintenance in public interest.
- Operation and maintenance in industry to abide by standards and regulation regarding public health and safety in relation to water
- The government will enforce public safety regulation in the public interest.

Transboundary waters

- National development and economic growth will be pursued by the government whilst considering the interests of other riparian states.
- The policy of the government with regard to international waters is that of partnership, dialog and co-operation with other riparian states to achieve mutual benefit from common water resources.
- The government honours all agreements and commitments entered into, in the spirit of the above two statements

2.2.2. Legal framework

Existing laws protect some aspects of environment. However, most of the laws are sectoral, old and inappropriate. They are therefore not capable of ensuring the protection of environment in today's context. This state of affairs has a negative influence on the management of natural resources and environment.

In order to remedy this situation and ensure the successful implementation of the environment policy, it will be necessary to put in place an environmental law for sustainable development through sustainable utilisation of environmental resources which meets the needs of present and future generations.

This law will have to be compatible with the country's political, socio-economic and cultural framework so as to ensure improved living conditions of the entire population. It will also have to provide a framework for the formulation, review and updating of sectorial laws for a better protection of the environment both at the central and local level. Finally, it will have to contribute to capacity building and to the strengthening of existing institutions instead of creating several others which may create overlapping of roles.

Nonetheless, the law will have to include certain innovations, particularly the creation of a Rwanda Environment Management Authority and Provincial and District or Town Committees responsible for the management of environment in accordance with the new responsibilities of District and/or Towns under the policy of decentralisation and good governance introduced in the country since 2000.

2.2.3. Institutional framework

Being of a cross-border nature, environmental concerns require a multisectoral integrated management approach based on an institutional framework capable of enhancing the active and wide involvement of each and everyone.

Although there exists an institutional framework for the protection and management of the environment, the implementation of the policy will be through the establishment of an executive organ to support the Ministry responsible for environment as the conception and co-ordination body.

Therefore, the implementation of the policy will be entrusted to the Rwanda Environment Management Authority. This institution will be responsible for the following duties:

- (a) to co-ordinate various activities for the protection of environment undertaken by environment protection institutions, and promote the integration of environmental issues in the developmental policies, projects and programmes with the aim of ensuring appropriate management and rational use of environmental resources on the basis of sustainable production for the improved well-being of the people of Rwanda;
- (b) to co-ordinate the implementation of Government policies and decisions taken by the Board of Governors, and ensure the integration of environmental issues in national planning, concerned departments and institutions within the Government;
- (c) to advise the Government on legislation's and other measures relating to environment management or to the implementation of relevant international conventions, treaties and agreements in the field of environment as and when necessary;
- (d) to make proposals to the Government in the field of environmental policies and strategies;

It could be said that from the institutional and legal point of view, there exists no law on environment. However, different legal texts found here and there protect environment and define the management framework of some fields of environment. There are thus the law on woods and forests; three articles of Rwanda's criminal code relating to the management of

natural resources such as water, land and soil; the law on the conservation of soils; the law on dangerous and unsuitable settlements; the law on fishery; the law on pollution and contamination of water sources, lakes and rivers and parts of rivers. There are also texts relating to the protection and management of protected areas, natural reserves and a mining code.

There are also bills: particularly the bill on water, the draft sanitation code, the bill on the creation of the Nyungwe National Park, the bill on land scheme, the bill on the review of the border of the Akagera National Park, the bill on the development of marshland, the bill on industry and trade.

International conventions relating to environment have been signed and ratified and others will be signed and ratified soon. Rwanda participates also in regional initiatives in the protection and management of environment such as the Nile Basin Initiative, the Common Market for Eastern and Southern Africa (COMESA), the Lake Victoria Biodiversity Programme and the New Partnership for Africa's Economic Development (NEPAD).

At the institutional level, the Ministry for Land, Environment, Forests, Water and Mines is responsible for the formulation of policies and laws aimed at the protection and rational use of environment. The same Ministry is also responsible for co-ordinating and monitoring all the activities carried out in the country by different stakeholders and development partners which can have some impact on Environment.

Other Ministries are involved such as the Ministry of Agriculture and Livestock (MINAGRI), the Ministry of Industry, Commerce, Public Investment Promotion, Tourism and Co-operatives (MINICOM), the Ministry of Infrastructure (MININFRA).

There are also public institutions such as Rwanda Authority for Tourism and National Parks (ORTPN), Rwanda Bureau of Standards (ORN), as well as higher teaching and research institutes: National University of Rwanda (UNR), Kigali Institute for Science, Technology and Management (KIST), Rwanda Institute for Agricultural Science (ISAR), Institute for Scientific and Technological Research (IRST). Non Governmental Organisations, both local and international, as well as Co-operating Agencies/Organisations are also involved. These are: Global Environment Facility (GEF), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), United Nations Food and Agriculture Organisation (FAO), United Nations Children's Fund (UNICEF), World Bank, etc.

The 1994 genocide and massacres brought to a standstill the initiatives that had been launched, and they were revived by the Government of National Union. It is in this context that should be viewed the ratification of International Conventions such as:

- a. Convention on Biological Diversity (1995);
- b. United Nations Outline Convention on Climatic Changes (1998);
- c. United Nations Convention on Desertification (1998);
- d. Nile Basin Initiative (1999);
- e. Vienna Convention for the Protection of the Ozone Layer (2001);
- f. Stockholm Convention on Persistent Organic Polluting Agents (2002).
- g. The Basel Convention on control of transboundary movements of hazardous wastes and their disposal;

- h. Rotterdam Convention for the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade;
- i. Ramsar Convention on the wetlands of international importance, especially as waterfowl habitats;
- j. Cartagena Protocol on the biosafety to the convention on the Biological Diversity;
- k. Kyoto Protocol to the convention on climate change;
- l. Amendments of the Montreal Protocol on the substances that deplete ozone layer, adopted in London (1990), Copenhagen (1992), Montreal (1997) and Beijing (1999).

In 1996, the National Agenda 21 and the National Environment Strategy and Action Plan were updated. Following the Government reshuffles of 28th March 1997 and 8th February 1999, Environment was successively placed under the Ministry of Agriculture, Animal Breeding, Environment and Rural Development and the current Ministry of Lands, Resettlement and Environment, the principal mission of which was to formulate the policy and the law relating to the protection of Environment.

Moreover, in 2001, the Ministry was strengthened by the establishment of a Secretariat of State responsible for the Protection of Environment, which was operational from August 2001 till 15th November 2002. The establishment of the Rwanda Environment Management Authority (REMA 2004) is the organ responsible for the execution of policies and laws relating to Environment.

2.2.4. Role of Civil Society and private sector in the implementation of the environment policy.

Non Governmental Organisations play a vital role in the mobilisation and awareness creation among the population on environmental issues. As such, they supplement the efforts of the Government and help to ensure that the concerns of the disadvantaged levels of society are taken into account in the national development process.

The private sector too is required to take a more active part in the protection of environment by ensuring that the environment dimension is integrated in all its activities, particularly business, industrial and crafts activities.

The Government should give them a leading role in the implementation of the national environment policy with the ultimate aim of reaching local communities and grassroots organisations which are in regular contact with the population in all the corners of the country. A privileged place should be given to dialogue, discussion and exchange of views; training and capacity building.

2.2.5. Regional and International Co-operation

Environmental issues do not have borders: they are very complex and involve the whole world. The context for their resolution goes beyond a single country, a single continent and extend on the whole planet. It is in this context that Rwanda must associate itself with neighbouring and distant countries so as to control cross-border movement of waste; manage better water resources and protected areas, and other environmental issues of a regional and/or

international dimension, particularly those relating to climatic changes, ozone layer and desertification control, biotechnology and others.

Rwanda has already ratified several conventions, protocols and agreements relating to environment and started their implementation. However, a number of these instruments have not yet been ratified and their implementation has not yet started. The environmental policy offers an unequalled opportunity for the actual implementation of the legal instruments to which Rwanda has acceded and those to which it will accede in future.

During the implementation of the policy, Rwanda will need a multiform and varied assistance from international and regional co-operation institutions; UN agencies and development partners.

The Government has already included environment management in its multilateral and bilateral co-operation priorities and will take the necessary measures for the mobilisation and ensuring the efficient management of the support it receives from its partners. Environment management will receive special attention in the allocation of domestic resources earmarked for development.

The Government has taken measures to ensure a judicious allocation of budgetary resources with a view to enhancing consideration of environmental issues in the different sectors of activity. The State, the local communities and private economic operators are called upon to contribute to the cost of environment management deriving from their responsibilities in this field.

2.3. MONITORING AND EVALUATION

With a view to knowing and evaluating the impact of actions carried out in the implementation of the policy, a gradual monitoring and evaluation will be done. Policy options and strategic actions will be adjusted as and when necessary to changes dictated by various circumstances that will occur in the future. Moreover, it is important to evaluate the effectiveness of the proposed strategies and the progress achieved in their implementation as resources become available and programmes and/or projects for the protection of environment are implemented. In this context, an internal monitoring and evaluation system is fundamental for the smooth and effective operations of the Rwanda Environment Management Authority.

In this connection, it will be necessary to develop systems for monitoring and evaluating the performance of the Authority and ensure that all the programmes and activities of the Authority have information systems with adequate and up to date data. It will also be necessary to establish progress benchmarks for all the programmes and activities and define properly the annual objectives and plans. Again, it will be necessary to build the capacities of Districts or Town and local communities in the field of monitoring and evaluation.

The production and publication of periodic reports on the state of environment at the national and decentralised level will facilitate the evaluation of the progress made in the protection and management of environment and take the necessary measures each time it is needed.

2.4. WATER POLLUTION CONTROL AND MANAGEMENT

This present part will raise a portrait of the tools legislative, regulation, institutional, organisational and informational that are now use in Rwanda in the setting of struggle against the different types of water pollution. For each of these aspects, a general view of the present situation is first presented; the efficiency has relative reports and has the performance of the systems in place are then bring.

2.4.1. The legal instruments concerning the management of the quality of water resources.

Rwanda endeavors to put in place progressively so much a certain number of legal tools international that national in order to demarcate the land of the environment and especially in order to limit the perverse effects of the water pollution.

- On the international plan, Rwanda has signed the protocol of Montreal, many Conventions Centers Nations United like on the Climatic Changes, the Convention of Rotterdam, the Convention of Basel and others (see chapter 2.2.3).
- On the national plan, new Constitution of the Republic of Rwanda reserves a place on the environment; the National Environment Policy contains policy and strategic options; the frame-work law on the environment.

2.4.2. Norms of the quality of drinking water

Rwanda has since May 1992 a memento of the norms for the quality of the drinking water. But the text having to govern the norms of quality of the drinking water remains again elaborate, and should lean on the frame-work law on the environment having milked to the intended waters has the human consumption and to the domestic uses. However this frame work law is not yet adopted. In fact the drinking water is often submitted has some norms physical, chemical, biologic and bacteriological determined in order to protect the population against the effects undesirable dregs the presence of physical, chemical, microbial and radioactive pollutants in the waters of consumption.

In the application of the frame work law on the environment of the texts (or decrees) covering the majority of the problematic of water pollution while taking in account all sources possible of water pollution, must be elaborate and adopt in advice of the ministers; should be foreseen therefore of the texts governing:

- The establishments dangerous, unsanitary and inconvenient classes;
- The management of the strong garbage;
- The management of the draining matters;
- The management of the dangerous garbage;
- The principle of the " pollutant - payer " .

The code of the public hygiene;

Rwanda is endows a code of the public hygiene. This one should be actualizes to take into account the present realities of the country.

The code of purification and the code of the environment

These codes are in projects. The project of code of the controlled purification the dismissals of the industrial, domestic waste waters. All dismissal of water used industrial in a receiving

environment must be in conformity with the requirements contained in the permits of remittances.

2.4.3. The institutional and organisational constant.

The coordination

To reach the objectives of the National Strategy of the environment in Rwanda , of Plan of Environmental actions (PAE), of National vision 2020 and of the National Agenda 21 draft, as well as the setting up of the actions and systems required to assure the respect of the Rwandan legal setting concerning environment, doesn't only feel; the Ministry in charge of the environment or water, but the one of the state in whole or multiplicity, besides desirable, or even inescapable, of the intervening parties in the implementation of the actions of struggle centers the pollution of waters. Indeed, the principle of the sustainable development requires that in all project of development, the environmental shutter is also taken cumulatively in account with the economic and social shutters, whatever is the sector promoter of it.

Of this situation ensues requires it of a better intersectorial coordination in order to assure a maximal efficiency of the actions, a convergence toward a same objective and an elimination of the duplications. According to the assignments that will be to him devalue, the Rwanda Environment Management Authority will be load to play this role fundamental of coordination.

One of the main reports clearing of the present working of the institutional and organisational setting concerning struggle centers the pollution of water in Rwanda is that some hiatuses exist to the level of the coordination of the environmental actions undertaken by different ministries and organisms.

It seems, indeed, that some projects having components management of the quality of water resources escape has the coordination and has the setting in consistency that must exercise either the Direction of the environment and the Direction of water and purification. These duplications of the actions will be able to be avoid that REMA (Rwanda Environment Management Authority) will take care of the environment in all components: **Water, the Earth, the Biosphere, the Atmosphere and the Technology** (view under the angle of pollution generator and in even of supplier of technological means to fight against the pollution).

It ensues some that the possible synergy between the different projects and programs are not exploited sufficiently.

For example:

- The Direction of water is not implied in the implementation of the National Policy of Sanitation and Plan of Action on the Sanitation, which yet constitutes a shutter important of struggle centers the pollution.
- Another example is located to the level of the technicians of purification on the level of the health of the Districts and of the loads of the environment, although raising two distinct ministries and having specific assignments, act in gone path by a common clientele; *a better coordination between these two organisms of control could probably lead savings of means to reach a same door of surveillance.*

2.4.4. The follow-up of Quality of water resources

The follow-up of the water quality doesn't reread to make itself that on the basis of the existing norms. However these norms like that was expressed higher, should lean on arrangements of the frame-work law on the environment.

Also the follow-up of the quality of water resources is often confronts with insufficiency of technical means of sampling and analysis, as well as the absence of a setting standardises to achieve the samplings and the analyses required.

One of the consequences of the absence of this setting standardises is that some studies of characterisation of the water pollution can produce very different results, even though they are achieve on common topics. This situation prevents to pull clear findings and slows down the implementation of the corrective processes. Otherwise, the absence of a setting standardizes measure of the polluting parameters and the insufficiency of adequate analytic capacities has the national scale can constitute a brake has the application of the regulation setting, since the verification of Conformity to the norms must pass by a rigorous and non questionable verification of the parameters in game. Of or requires it to the national level to elaborate a manual of methodologies of samplings and measures standardised, what would permit an inter comparison of the data between different laboratories on the same type of sample in the setting the assurance/control quality {QA/QC} of the used analytic methods, so therefore to ascertain the reliability of the results of analyses.

2.4.5. Information, education and communication

In the domain of the communication there are several intervening parties (public institutions and NGOs). most projects in relation with the population have an Information, Education and Communication (IEC) shutter in their structures of intervention.

To the Ministry of Health, the IEC concerning hygiene makes itself below according to canvas:

1. to the level of the Division Public Hygiene an IEC section that identifies the problems of important hygiene exists and that, in collaboration with the Division EPS (...) of the Health Ministry, compose the messages deliver to the population. These messages arrive to the population has shortcoming the media: - Imvaho newspaper - Radios. A magazine Health is created and is public every three months: it sums up the main problems of health and hygiene. the preparation and the organization of the formation sessions also for the staff of health and other.
2. To the level of the Health Centers: There is a program of educational talks dispensed by the staff of health has the intention of the patients and other people who come with them in the center of health. In these talks the staff of health is often guide by the sanitary situation that prevails. Concerning struggle against the pollution of water, talks are centered on themes as, for example, the conservation of water has domicile in clean containers; the importance to make boil the water of drink when one doesn't have a source of drinking water, how to protect some sources. During the sessions of IEC, the access is also put on the importance to use the adequate latrines to avoid the pollution of water by excreted them. The individual hygiene especially occupies an important place in talks the washing of the hands has the exit of the toilets and before eating;

3. To the level of the sanitary districts the staff of hygiene affects in the locality is compelled has lead the activities of IEC has shortcoming the meetings that he organizes and even at the time of the visits has domicile (to see assignments).

To the local level (or communal), animators of health exist (to the level of every cell that follows the problems of health and hygiene to the level of the cell). They are loads to bring the populations has search for by themselves of the solution approaches has their problems, thanks to the sessions of formation. Of the reports regular details would be provided by the animators to the hierarchical chiefs. According to the results of investigation, sessions of formation of the formative are constantly organized in different echelons by the Ministry of Health.

Otherwise, in the setting of the conception of a national program of education has hygiene, the improvement of the provision systems in drinking water of the population and the sanitary means of evacuation of excreted them, an investigation Knowledge Convenient Attitudes has been organized from August 28 to September 08, 1995. According to the Direction of hygiene and Purification, the results of this survey have revealed of the positive elements on the knowledge, the attitudes and the practices of the Rwandan women in farming environment. However, it was noted that in this domain, the problems of the Rwandan women rather reside to the level of the attitudes and behaviors that to the level of the knowledge.

The survey shows that the actions important must be focused around four main themes to answer the needs of the Rwandan women in the domains of water, environment, hygiene and purification, it knowledge,:

- The country Clean Hands (hygiene of the hands);
- Improvement of the quality of the latrines and the systems of provision in drinking water for the population;
- The survey of the sources of accessible substitution energy the rural population having to replace the wood of heating that became rare
- The existing honest programs aiming the promotion of hygiene in the country. Programs like: **W.E.S.**: Water Environmental Sanitation. The main actors in this program are the Minitere and the UNICEF. **HAMS**: Hygiene and Purification in School Environment, whose main actors are Minitere, Minisante, Mineduc, WHO and UNICEF.

Methodologies of approaches participator are also set in motion in the setting of the hygiene promotion in the country; it is as for example the methodology called PHAST (Participatory Hygiene And Sanitation Transformation) of which the Minitere and the World Bank are the main actors, especially to the level of Program Water and Purification).

In all programs the population is implied since the national level until the basis level of the community.

2.4.6. The strategies of communication adopted and their relevance.

The strategies of influence adopted in the environmental actions of communication recorded are essentially of internal type. It is comprehensible insofar as they look for has act directly on the mental of the individuals (the public) while hoping that those here, in a logical manner, will

found their behaviors on their mental. These types of strategies, if they are led yesterday, are those that bring the changes of most lasting behaviors.

The internal strategies have been used as yesterday according to their content that according to the media. According to the content, the choices of the actions of communication can be about the logos, it is has say, of the messages that tempt to modify the knowledge of the public by logical demonstrations. These messages try to demonstrate requires it of the adoption of a certain number of behaviors pro environmental. But one already knows that this strategy is the efficient hand when it is used alone. According to the middle, the privileged strategy counts on the impersonal propaganda (the communication of mass) that uses the media of mass (radio, posters, television, big panels, etc.) to transport some contents susceptible to change the attitudes of the populations targets. However, it is known today that the impersonal propaganda maintains passive the public and is only efficient when:

1. it contributes to maintain and to reinforce the attitudes already present at the target;
2. it occupies all supports of available mass at the same time in order to attract the attention;
3. it forces the attention while making so that the promotion of other contrary behaviors has those encourage carry by any other vector;
4. it chooses a believable spokesman to increase the admissibility of the messages;
5. it targets in the surroundings aim leaders of opinion to relieve the information toward their personal contacts, etc...

Him small to arrive while, in spite of the good will and work sets against the actors, that such methodological steps don't carry the waited fruits, this because of a multitude of factors of which the main are:

- First of all, the lack concerning communication of a general vision of the pollution problems. What supposes the adoption of a national plan of communication for the development and that the document of communication of the Ministry in charge of water and purification or environment comes to fit in this plan.

- If the plans of communication in execution in the various present projects in resource in water don't present an optimal consistency for the convergence of the actions toward a common objective, therefore that the actions don't bet sufficiently on the synergy, such a gait of education of the populations has adopt pro-environmental behaviors could not succeed. In other words, the problems seen in a global way must be united in a honest plan of communication that would determine the strategic axes to be privilege for every type of target.

In the domain of the media, it is important to take account because the public is active and that it cannot submit of has what the media propose straightaway; or that he/it doesn't adopt what is to him proposes that if it corresponds has his/her/its needs and interests of the moment; or that he/it negotiates the message as there pulling certain profit if he/it only corresponds in part has his/her/its needs and interests; or will reject it simply. It means that has every message that the public receives, it makes line assessment of risk unconsciously to see if it corresponds has his/her/its needs and interests of the moment.

Besides, one should notice a certain lack of receptiveness of the messages on behalf of the public, reason in good part by the socioeconomic difficulties. The protection of resources in water brings beneficial effects long-term on health and the quality of life, but it is necessary that the effects are sufficiently concrete to cause the adherence has the reason at people whose socioeconomic preoccupations are daily: to have water for example in quantity.

Finally, if the messages are not sufficiently adapted to the different targets, nor sufficiently positive, especially as the big proportion of the population is illiterate, the approach of communication doesn't leave. It must be adapted more has this reality.

Besides, it would be necessary to avoid some messages that don't cause the sympathy and that give the picture that the protection of resources in water is rather 'a supplementary constraint has respect already in a socioeconomic context difficult.

CHAPTER 3.: WATER POLLUTION MONITORING

3.1. WATER POLLUTION LOCATION

Degradation of Water resources

Water is an essential human need of critical importance for socio-economic development. It is needed for agricultural, pastoral and industrial purposes. It is used for human consumption both in rural and urban areas. Water is also used as a source of hydroelectric energy and for river and lake transport. All these forms of use have often harmful consequences on water resources which are often characterised by physical, chemical and biological disturbances.

Sources of water pollution

Water pollution in Rwanda is mainly caused by domestic waste, agro-pastoral and industrial activities.

Pollution by domestic waste: Used domestic water mainly from septic tanks, latrines, animal waste and refuse infest drinking water and cause diseases such as epidemics of typhoid, cholera, and gastro-intestinal diseases, dysentery, etc.

Pollution from agriculture: As a result of the scarcity of land and over farming, agricultural production has declined. In order to increase soil fertility, the use of fertilisers and the application of pesticides and herbicides increase too. Yet, high concentrations of such chemical products in drinking water are dangerous for human health and environment. On the other hand, sedimentation of lakes and rivers increases due to erosion on slopes which are often bare or farmed without measures of soil conservation. Materials and sediments carried along cause chemical, biological and geological pollution of water resources due to the presence of nutrients from various sources deposited in the water.

Industrial pollution: Even though industries in Rwanda are not many and are agriculture industry based or produce detergents, breweries or other small and medium industries, they are almost all found in or near wetlands and throw all their effluents and by-products in the water. This is so with the textile industry, the iron industry which makes iron sheets, paint factories, Sugar factory and mines found in different regions of the country. The same observation can be made: all industrial discharges and effluents are thrown in the water and in nature without any form of prior treatment. This increases water pollution and the chemical components used in these industries are dangerous for human and animal consumption and for environment.

Natural pollution: There is also some kind of pollution mainly for underground water due to the parent rock of the area. This form of pollution from natural resources is found mainly in the north east of the country, and the major pollutants of the rock are ammonium nitrates, fluorides, etc.

Pollution by water hyacinth and other bad weeds: Water hyacinth and other aquatic weeds degrade the quality of water and promote the proliferation of agents carriers of diseases such as malaria, encephalitis, bilharzias, filariasis, etc. Turbidity increases and water losses are enormous following evapotranspiration.

Wetlands: Wetlands in Rwanda are generally used for agricultural and pastoral purposes as well as for quarrying for construction and trading purposes. They are generally mismanaged and used anarchically without prior studies of the impact of the activities carried out on resources and human health. A thorough analysis of the problems of wetlands in Rwanda shows that the major threats affecting ecosystems are associated with agricultural and pastoral activities, mining and quarrying, human settlements, lack of a policy and legal framework, inadequate scientific and technical knowledge of wetlands.

It is the first shutter of the diagnostic analysis. The state of the pollution to the national level presented in this chapter aims to illustrate qualitative and quantitative ray the importance of the pollution's of waters observed currently in Rwanda. This state of pollution is followed then of an analysis of the primary reasons of these pollution's, then of a brief preview of their consequences on health and on the environment

3.2. POLLUTANTS MONITORED

3.2.1. Water Pollutants

The pollutants which enter water bodies are most commonly contained in effluents derived from a wide range of human activities, as a result of soil erosion, accidental spills or illegal dumping. Eight groups of pollutants in two categories can be identified.

Physico-chemical pollutants:

- Organic residues, such as, sewage, brewery wastes.
- Inert suspensions - soil sediment, mine wastes.
- Fertilizers and detergents.
- Inorganic reducing agents - sulphides, sulphites.
- Petroleum products - waste oil, tanker spills.
- Toxic wastes - heavy metals, pesticides.

Biological pollutants:

- Micro-organism - faecal coliforms, cholera bacilli.
- Macro-organisms - parasitic worms, exotic fish species and aquatic weeds.

It has been landed, thanks to the visits done on the land, to the exchanges with the national actors and thanks to the studies previously led by different laboratories on the potential sources of aquatic pollution (domestic or industrial sewage's, strong garbage, agricultural activities, erosion,...) and on different types of water use by populations, to know, the sources, the underground waters, the waters of surface and pluvial waters.

3.2.2. The liquid sewage

In Rwanda, the main sources of liquid sewage's are the following:

- a) The domestic sewage, constituted of water floodgates and domestic water (grey waters);
- b) The industrial and small-scale sewage.

The management of the liquid garbage is confronted to the insufficiency of the collection facilities, to the difficulty of access in the spontaneous districts, to the weak involvement of the populations and to the lack of interest of the local authorities, to the weak level of drinking water consumption and to the weak rate of adjusting to the network of water of Electrogaz. This situation doesn't encourage the setting up of a collective network of purification.

a) Domestic pollution

The domestic waste waters are constituted of the water floodgate and the domestic water. The water floodgate come from the toilet and transport excreted them (faecal matters and urine's). The domestic water come from the kitchen, the laundry, the showers,...) and transport garbage of food, oils, detergents and soaps notably.

For the evacuation or the elimination of the domestic sewage, most Rwandan cities don't possess network of sewer or station of purification. The rate of adjusting of the residences to a network of sewer in the city of Kigali would be lower to 5%, and would concern some rare districts of modern status only as for example the district divided of Nyarutarama and the one of Kacyiru.

To Rwanda, with regard to purification 85% of the households in farming environment have latrines for of which 62% don't answer to the norms. In all cities, the latrines to dry pit constitute the most widespread sanitary work.

As for the domestic waters, they are most of the time, rejected either in the streets or in the courses or in the collectors of pluvial waters, where they exist. The city-dwellers to middle and high status have the septic tanks and lost wells that collect their worn-out waters (waters floodgates and domestic waters).

He is to specify that in the cities, private enterprises specialised in the draining of the septic tanks don't exist. The service of purification is the only structure in charge of the collection of the mud's of draining and septic tanks, with means very limited. The private sector begins to interest also of it.

The mud's of draining of the septic tanks are poured in the public discharge of Nyanza being in the district of Kicukiro. In other regions of the country, as for example the city of Gisenyi, the manual draining are the practices current of draining of the septic tanks. In the practice, when the septic tank is filled, the mud are disinfected, drained, transferred and buried in a hole dug in the concession.

A few small stations of treatment of the waste waters exist in the city of Kigali. It is notably the case of the stations of purification of the Academic Hospital Centre of Kigali (CHUK), of the Hotel des Milles Collines, of the Novotel Umubano Hotel, of a part of the Nyarutarama district

and of the plot of the Social Security of Rwanda in Kacyiru and the Intercontinental Hotel of Kigali.

The situation doesn't encourage a better conservation of the quality of water resources.

Little study exist on the characteristic physico-chemical and bacteriological of the worn-out waters produced in the urban centres, especially in Kigali, what doesn't permit an aprecier the polluting contributions validly (COD, BOD₅, matters in suspension, petroleum products, greases, phosphor, nutrient, faecal Coliforms and other pathogenic germs,...) of these sewage's toward the different aquatic ecosystems. However, the survey done in 1991 by the SGI-Engineers Conseils (General Society for the industry) as well as the visits done in the districts of Kigali and in some other cities as Gisenyi, Ruhengeri and Butare, let conclude to elevated levels of pollution in number of hydrosystems of which in particular the non arranged sources, the rivers and the lakes fig: in appendixes.

The Central Prison of Kigali comes in head with 9200 mg/L of COD and 840 mg/L of BOD₅, the Plot of Social Security (COD: 1.124 mg/L; BOD₅: 405 mg/L), the hospital (CHUK). The strong rates of organic matters of the waste waters non treated from the Central Prison of Kigali deserve that one especially worries some.

The Nyabugogo river receives most rain waters of the city of Kigali and a part of waste waters, and the Kivu lake is the place of dismissal of the biggest part of waters coming from the West regions of the country.

Of the point of microbiological view, the sources are contaminated strongly by bacteria of faecal origin (faecal coliforms) coming from the latrines implanted in the concessions situated on the hills not respecting the perimeters of security in relation to the sources of catchment. It constitutes serious threats for the populations who don't have any other alternatives anymore that to get a stock in these waters of sources as waters of drink.

b) Industrial and small-scale pollution.

Most industries in Rwanda are constituted of agro-industrial units that all as much that they are, their pollution in the aquatic ecosystems, has know, the rivers, lakes or wetlands. These industrial waste waters, for most loaded of organic and/or inorganic chemical pollutants, solid matters in suspension constitute serious threats for the biologic diversity of the water plans (rivers, lakes, wetlands) and for the health of the populations consumers of this water.

The pollutants of industrial origin are:

- The sewage of the Sugar Works Factory of Kabuye are also of important sources of pollution for the Nyabugogo river and probably also for the Nyabarongo. The main pollutants are the garbage of the cane, the cellulosic matter and the alcohol. Others small factories increasing the pollution of waters of Nyabugogo river.
- The factory of *UTEXRWA*, a textile industry situated in the city of Kigali, is an important source of pollution of the Nyabugogo river. The waste waters rich in products of scalding of cloths use, as the caustic sodium carbonate, the peroxide of hydrogen and the silicate of sodium, as well as a multitude of dyes yesterday known for their carcinogenic character among the mammals, are poured in river without any previous treatment.

- The *SODEPARAL*, a factory of tannery treating leathers and skins, that produce of the garbage very toxic non bills, which loss is at the state raw discharges in the rivers. The main pollutants of the factory are the compounds of the arsenic, the DDT and a range of benzenedichloride.
- A certain number of painting producers exists of which there are the *AMEKI COLOR*, *SIRWA COLOR*, *RWANDA PAINTS*, *SIGMA COLOR* that are contributed to the pollution of waters and soils in the city of Kigali and even farther in the country, today don't exist anymore.
- The *TOLIRWA*, iron factory of the sheet metal and use various categories of paintings and other chemicals that are driven in the rivers.
 - *BRALIRWA*: this industrial unit of restaurant is situated near the Kivu lake and polluted the lake without previous treatment. The garbage toxic non treated, mainly the caustic sodium carbonate, come from the washing of the bottles. The polluting matters of BRALIRWA coming from the brewer's yeast, the alcool and organic matter of solid waste. These matters have a biochemical demand in oxygen elevated, what can contribute to reduce the rate of oxygen dissolved immediate in the vicinity of their dismissal places, and the living organisms as fish wind to flee or to die, reducing the productivity of the lake thus.
 - *The mining industries*: The extraction of the tin and the Wolfram in some regions of the country, shortcoming the mud's that result from this type of activity, cause the erosion of soil and landslides. The lost earth is driven in water, increasing the speeds of sedimentation of the lakes, rivers and the turbidity of water thus with chemical components (minerals) dangerous for the human consumption and for the aquatic life.

The information collected from the Direction of the industry, 70% of the industries are localised in the city of Kigali, that most industrial units are not endowed with devices of treatment of their garbage and that the industrial sewage of Kigali are driven in the Nyabugogo river.

To the look of everything that precedes, an immediate action considered in the domain of the sewage would be a survey to value to the national level the management of the domestic and industrial waste waters, to characterise them of the point of physico-chemical and bacteriological view (since no reliable qualitative nor quantitative data exists on the waste waters) as actualising the data exists and to value the polluting loads that every type of sewage brings in the different aquatic ecosystems that receive it, what would permit to classify the sources of pollution by order of importance and finally to identify the actions important to overcome the pollution of water due to the liquid garbage.

Other sources of contamination of water are used oils of the cars or trucks of which management is very little respectful of the environment. No survey exists on resources of contamination in the country. According to the investigations on the land, a part of these waste oils is poured on the ways under pretext to fight against the uprisings of dusts in dry season, the rest would be buried in soil or in the canalisation of pluvial waters.

However the negative impact of these hydrocarbons products on the human and the living organisms are felt. They contain aromatic fractions that, when they enter in the living organism are going to set on the fundamental biologic molecules (DNA, RNA and proteins) to the level of which they can provoke important disruptions: they can lead cancerous tumours or can provoke genetic mutations. They are capable to reduce the halieutical productivity of the surface waters because of the reduction of the rates of oxygen exchanges between the

atmosphere and the aquatic environment by the protective layer that they form to air-water interface.

The main parameters generally used for the assessment of the polluting loads of origins servant industrial are:

- Faecal and total Coliforms
- Biochemical demand in oxygen (BOD₅) and chemical demand in oxygen (COD)
- Suspensions matters
- Waste oils and greases
- Phosphorus
- Nitrogen: nitrogen ammoniac (NH₃ and – NH₄⁺), nitrite and nitrate (NO₂⁻ NO₃⁻), and total nitrogen
- pH.

In term of comparison of organic contributions pollutes, the UTEXRWA appears, according to the studies of SGI Engineer Conseils (1991) data are in appendices, as being the polluting biggest industrial unit, toward of TOLIRWA, BRALIRWA and SIGMA COLOR. It is to note, in spite of the existence of a purification station that waters used of UTEXRWA remain very loaded with 278 mg/L of BOD₅ and 2000 mg O₂/L of COD to the entry against 105 mg/L of BOD₅ and 863 mgO₂/L of COD to the exit. It poses the real problem of the functionality of the purification facilities of which is endowed some industrial units.

3.2.3. The strong garbage

The strong garbage pose a real problem as for their management in the urban centres, in particular in the city of Kigali.

According to done investigations, the middle quantity of garbage produced could be valued to 0,55kg/habitant/day, so the total quantity of domestic strong garbage generated would rise to about 665.914 tons in 2001.

The collection of these garbage was assured by the service of cleanings that only collected hardly 60% of the quantities generate in the city, and threw them to the wild discharge of Nyanza, and this without a particular contribution of the households. If the recycling as fertilising in gardening constitutes one of elimination of a certain quantity but negligible of the domestic strong garbage, the weak rate of collection by the service of hygiene and purification drives the populations to opt for very damaging solutions of fortune to the environment, in particular to resources of water (dismissal in the streets and in the collectors of pluvial waters). This management little orthodox of the small garbage to drag the pollution of soils and the sources as well as the waters of surface.

However, thanks to an awareness of the populations and thanks to the process of decentralisation the management of the garbage comes back in progress, more and more to the districts of the city, has the exception of the districts of farming type, the financial contribution of the populations partially supports the loads of the operations.

In the case of individual of Nyamirambo, the management of the strong garbage makes on a communal basis, and a centre of sorting, retraining and valorisation is there operational. This change of behaviour, if it maintained himself/itself, has term he/it could drive has a purification of this locality and has a better protection of resources therefore in water in the city.

Another case observes, was the one of the city of Gisenyi. Indeed, the NGO ACAPE, in partnership with the province of Gisenyi, assures the collection of the domestic garbage in the city and this against a moderate financial contribution on behalf of the population and enterprises and services of the place.

In general in many localities, the sorting don't make the basis, so that finds special garbage (biomedical garbage, plastic garbage) miscellanies to the domestic garbage that are thrown in the environment without treatment or in the valleys, of such convenient being damaging for the environment and in particular for the quality of resources in water and the health of the populations.

However, it is shown through the literature that very little of these products of synthesis used in agriculture, in particular the pesticides organic chlorides, deteriorated after their use; a good part infiltrates in soil or it is laundry by the pluvial waters that drag them in the plans of water where they can be kept in the sediments during several years. In these conditions there is to fear a contamination of the sources of the surface water being in the immediate surroundings of the phytosanitary products and their effects on the health of the populations riparian and same on the one of the wild fauna drinking of these waters. Because the pesticides are for most carcinogenic compounds and mutagenic.

In these conditions, it's important to value their rates in the aquatic systems, what would permit to follow their possible impacts on the environment in view of the measures and correction of case of studies.

3.2.4. The Pesticides and chemical manure

The pesticides

Pesticides are chemical compounds toxic to certain living organisms, from bacteria and fungi up to higher plants and even mammals. Most pesticides are compounds which do not occur naturally in the environment and, therefore, detectable concentrations indicate pollution. There are approximately many different pesticides currently available. The most widely used are insecticides (for extermination of insects), herbicides (for extermination of weeds and other undesirable plants) and fungicides (for preventing fungal diseases).

The mode of action of a pesticide is determined by its chemical structure. These structures are similar for the related compounds which comprise separate classes of pesticides such as the organochlorine pesticides, organophosphorus pesticides, the carbamate pesticides, the triazine herbicides and chlorphenolic acids.

The monitoring of pesticides presents considerable difficulties, particularly for groundwaters and surface waters. There is a wide range of pesticides in common agricultural use, and many of them break down into toxic products. Screening of water samples for all compounds is very expensive; therefore, a preliminary survey of local pesticide use needs to be carried out to reduce the number of target compounds in each specific assessment programme.

Environmental levels of organochlorine pesticides tend to be higher than other pesticides because of their widespread and prolonged use, combined with their great chemical stability. Exemple: DDT and its metabolites (DDD, DDE) are still high in many environments, especially in arid areas.

The data are collected by the division protection of plants. Indeed, Rwanda is an importing country of products phytosanitary. During the agricultural country 1999-2000, it imported 126 tons of fungicides, 32 tons of insecticides for the cultures of coffee. Uses of pesticides are observed in the low funds on the cultures of tomatoes (endosulfan). Another worrying situation, are pesticides expired in stock has the division protection of the plants and at the populations of which pose problem of elimination.

The chemical manure's

The chemical manure's of NPK type of commercial formula 17-17-17 are use for the fertilisation of soils. The strong rates of washing of soils due to their weak content in organic matter and to the strong slopes of the lands are going to provoke strong rates of accumulation of nourishing elements as the phosphor and nitrogen in the waters of surface and even in the sources. This enrichment of the surface waters is probably has the origin of the proliferation of the floating aquatic plants, as the hyacinth of water (*Eichkornia crassipes*) that prevents the navigation on the plans of water. Another less negligible negative consequence of the invasion of the water plans by the plants, it is the reduction has term of productivity of these waters has their impoverishment in dissolved oxygen, because this one will have been entirely consumes by the invading plants to the detriment of the halieutical resources.

CHAPTER 4: QUALITY AND QUALITY ASSESSMENT

Water quality criteria, standards and the related legislation are used as the main administrative means to manage water quality in order to achieve user requirements. The most common national requirement is for drinking water of suitable quality; however, the number and specification of variables standardised have a technical and economic implication on the country. It is, therefore, not practical to standardise all variables at once. Hence, it is necessary to prioritise the variables based on their impact on the water resources and key uses of the water resources, domestic and fishing or sustenance of aquatic life.

In addition, industries such as detergent manufacture, paints, Electro-plating, food canning, fish processing, fertilizer and pesticide manufacturing, sulfuric acid plants, fluoride mining, contribute to various types of pollutants including heat, nutrients, heavy metals, acids, and detergents.

The principal reason for monitoring water quality has been, traditionally, the need to verify whether the observed water quality is suitable for intended uses. However, monitoring has also evolved to determine trends in the quality of the aquatic environment and how the environment is affected by the release of contaminants, by other human activities, and/or by waste treatment operations

4.1. BASIS OF SELECTION OF VARIABLES

Water for drinking and fisheries is accorded top priority. Therefore, the variables to be standardised in order to protect the water resources and enhance environmental health are mentioned below:

Temperature (°C): Temperature should be less than 25°C for trout farming areas and below 35°C for other regions. As temperature rises, dissolved oxygen decreases. Higher temperatures increase the solubility of many chemical compounds and may influence the effect of pollutants on aquatic life and also affect palatability of drinking water. Heated effluents cause stratification and lowering of dissolved oxygen. Fish have upper and lower limits for optimal growth. Therefore, changes in temperature regimes alter the distribution and species composition of aquatic communities.

Suspended Solids: it is recommended that water should have less than 30 mg/l whether the suspended solid has or as no oxygen demand. Suspended solids blanket spawning grounds, river bed, plant life and benthic organisms. They restrict fish vision and affect gill action. Water transparency is reduced with resultant decrease in primary production.

Biochemical Oxygen Demand (5-day at 20 °C): BOD is not a pollutant itself, but is a measure of organic pollution. Waters with BOD levels less than 4 mg/l are deemed clean while those with BOD more than 10 are considered polluted. High BOD concentrations may limit water use for public consumption, fisheries and irrigation.

Floating materials: Foam, oils and greases should be absent as they reduce light transmission thus, reducing photosynthesis rate and consequently reducing the rate of re-aeration and dissolved oxygen content of the receiving water body. Floating materials are an aesthetic nuisance.

Heavy metals: heavy metal concentration should be less than 0.1 mg/l in combination. They adversely affect fish gills and cause asphyxiation. Heavy metal salts are lethal to fish at very low concentrations especially in soft water. Mercury in particular affects the rate of photosynthesis. At only 1 ppb radioactive carbon can be inhibited by 50%. Organo- mercury fungicides have been shown to halt uptake of carbon at 50ppb. Heavy metals are essential to organisms in trace amounts. At high levels they accumulate in sediments and in aquatic organisms, and are further concentrated in the food chain (biomagnification), hence, they may reach lethal levels.

Lead (Pb): less than 0.1 mg/l: Lead is a toxic material that accumulates in the skeletal structure of man and animals. Pb in blood lowers mental performance, causing damage to children.

Mercury (Hg): less than 0.005 mg/l: Mercury from industrial effluents is transformed into methyl mercury which accumulates in fish and presents serious hazard to aquatic life and to humans whose diet is rich in fish.

Silver (Ag): less than 0.05 mg/l: Silver, like mercury, accumulates in body tissues and is also toxic to aquatic life.

Chromium (Cr): total Chromium should be less than 0.5 mg/l while hexavalent Chromium should be less than 0.05 mg/l. The hexavalent form is more toxic than the trivalent form. Chromium is lethal to fish at very low concentrations.

Zinc (Zn): Less than 0.5 mg/l: Zinc is relatively non-toxic to man but is acutely and chronically toxic to aquatic organisms, particularly fish. It is widely used in industry and affects the aesthetic quality of drinking water.

Nickel (Ni): Less than 0.3 mg/l: Any appreciable amount of nickel ions will hinder self purification of a river and it is toxic to some plants at concentrations as low as 0.5 mg/l.

Copper (Cu): Less than 1.0 mg/l. High concentrations of copper restrict water use for drinking due to taste problems. Very large doses may result in liver damage and at concentrations above 1.0 mg/l it may be toxic to aquatic organisms.

Arsenic (As): Less than 0.5 mg/l: Arsenic may be acutely or chronically toxic to man.

Cyanides (CN): Less than 0.1 mg/l: Cyanide renders tissues incapable of oxygen exchange. Levels more than 0.2 mg/l are known to be lethal to fish.

Sulphide - Hydrogen sulphide (S): Less than 0.1 mg/l: Hydrogen sulphide is lethal to fish at slightly higher concentrations than those of cyanides.

Free Ammonia (NH₃): Less than 0.2 mg/l: The lethal concentration for a variety of fish species is in the range 0.2 to 2.0 mg/l NH₃.

Phenolic compounds (Phenol): Less than 0.001 mg/l: Phenolic substances are toxic to fish and other aquatic organisms and taint flesh of fish at sub-lethal concentrations. Phenolic substances, if released into water for public supply, will be detected through the characteristic taste of chlorinated phenols even with concentration as low as 0.002 mg/l.

Nitrates (N): Less than 10 mg/l: Nitrates cause eutrophication of fresh waters and methaemoglobinaemia ("blue baby syndrome") in infants.

Phosphates (P): Phosphates enrich fresh water environment with plant nutrients resulting in rapid algae growth which affect municipal, industrial and recreational uses.

4.2. CHEMICAL AND BACTERIOLOGICAL QUALITY OF DRINKING WATER AND SURFACE WATER IN RWANDA

4.2.1. Urban water quality, data collected by the laboratories of Electrogaz

According to the technical staff of the stations of water treatment and follow-up, the Electrogaz follows the quality of waters provided to the populations of the urban centres and control a certain number of physico-chemical and bacteriological quality indicators, and this since the source until to the subscriber then passing by the stations of treatment and the networks of distribution.

The commentaries ensuing of the data of the factory of Kimisagara can be summarised like follows:

- the results of analysis of the raw water of 2003 (waters of the Yanze river, waters of boring of Nyabarongo and waters of the Mugesera lake) are globally similar to 2002. in spite some variations observed to the level of some parameters, remarkable during the seasons of rains.
- The results of analyses bacteriological of the raw water (mixture of the three sources of provision) watch that is very polluted;
- the treated water, exempt micro-organisms is good to the consumption, because respect the recommendations of the WHO concerning quality of the drinking water;
- Physico-chemical parameters of water treated remain unaltered and respect the recommendations of the WHO concerning quality of the drinking water;
- Some elements of the treated water, whose contents the lead and the cadmium; if the rate of cadmium varied slightly, the one of lead has more that quintuple of November 2003 with the risk of exhibition of the consumers to the saturnism, as passing from 9 to 49,5 µg/L as neighbouring the value limits admissible (50µg/L) by the WHO. The rates of lead always more elevated in the treated water than in the raw water let believe to a contamination by the conducts of water of Electrogaz. The actions of renewal of the conducts of the network must be brought.
- The distributed water is globally of good quality physico-chemically and bacteriological, from the exit of factory to all network.
- the water of Kinyinya and Rwampara are very charged in iron and especially in manganese;

- The concentration of lead in Rwampara water doesn't fulfil the recommendations of the WHO
- the water of the industrial park and Mumena, sites of the Rwampara network, is often coloured and turbid with a strong concentration of iron.
- The bacteriological analyses done on the waters of these sources treated to chlorine never reveal the presence of indicators germs of pollution.

4.2.2. Commentaries on the drinking water quality provided by Electrogaz

Electrogaz provide 70% of drinking water in urban and 46% in rural (middle rate of 52% to the national level: data of the Ministry of MINITERE, 2001), in the cities, water provide by Electrogaz is sometimes contaminated. Because of the diversion and the weak chlorine concentration in water.

Indeed, during the stops and inopportune discounts of the electric current, the deposits (biofilms) glues to the partitions of the conducts can be pulled and can be put in suspension, what is going to drag an over consumption of chlorine for the deterioration by oxidisation of these biofilms.

To serve the quality water, the Electrogaz must consider the following measures:

- To assure to the stations of drinking water treatment an energising autonomy while endowing them with electric group
- To reinforce the decontamination Electrogaz must install on the network the stations relay of chlorinating in order to bring back the rate of chlorine to the level required.

Otherwise, elimination difficulties of the iron and the manganese contribute to change the water quality distributed. These mineral elements oxidise during the distribution and also contribute to proliferation of the specific germs as ferrobacteries and gallionela that participate to corrosion. In these conditions, a particular follow-up of the treatment imposes to have in the network a water containing more of 0,3 iron mg/l and 0, 05 mg/L of Mn.

About the processing plant of Karengé which pumps the raw water of the Mugesera lake, this raw water, according to the data of the quality control of the laboratory, would be charged little in mineral matter but very rich in organic matter, with a lot of algae coloured water in green, and this strong organic matter would make rougher the treatment of water. In fact, this coloration in green is probably the sign of an eutrophisation of the lake. It will be necessary, to look for clarify in order to take the urgent measures to avoid the death of the lake. Considering this strong organic matters, the station of Electrogaz uses the $KMnO_4$ and calcium hypochlorite to oxidise the organic matters, iron Manganese and alumina surfate like coagulant permit to destabilise the colloidal particles and to make flocculation the oxidised matters.

A deep analysis of this treatment path has make the observations below:

- it would be superfluous to use the calcium hypochlorite and the $KMnO_4$, because permanganate has a oxidising power stronger than the calcium hypochlorite;
- calcium hypochlorite used at the prechloration treatment generates the formation product especially organochlored of big molecular weights (humic acidic and fomic). Is recommended to suppress the prechloration and to make efficient the treatment of water by the $KMnO_4$, and the calcium hypochlorite (to destroy the organic matter and the rest of algae) and the aluminium surfate($Al(SO_4)_3$).

4.2.3. Rural water quality data collected

From 1993 to 2004, the program of follow-up of the quality of the drinking water in Rwanda, was carried by the Direction of Water and Purification in the MINITERE, by the laboratory Control of water quality, of numerous campaigns of samplings and measures carrying on 806 points of water left in the different provinces except Kigali Urban (the data are in attachment of this report Excel data).

Three categories of parameters (organoleptics, physico-chemical and bacteriological) permit to follow the tendencies, advantages and risks for the health of the populations, and to inform the inventors of projects on the types of water capture, treat and transport.

Waters produced from the sources and boring have the acceptable physico-chemical and bacteriological qualities according to the norms of quality of the drinking water in Rwanda:

1. In most cases, the values of pH of the waters of the sources and the underground waters are located between 4,0 and 6,0 and these waters are aggressive. These weak values of pH justify by the geological nature of the country, that is dominated by acidic soil. The few extreme values of the too acidic type (pH between 3,0 and 4,0) feels observed in regions of the West Centre and West South of the country, in particular in the localities of Tumba, Mbazi, Tare, Rushashi, Nyabikenke, Ramba, Gaseke and Giciye that will be able to be classified critical area must be neutralised to avoid the inherent negative effects due to the aggressiveness.
2. The waters of the sources in their major part are mineralised little with a lower conductivity 500 $\mu\text{S}/\text{cm}$. An exceptional case is observed only in the former township of Kigombe in the Province of Ruhengeri where the conductivity is superior to 1000 $\mu\text{S}/\text{cm}$.
3. Nitrogen salts (NH_4 , NO_2), coming from the deterioration of the plant or animal organic matter, or produced by oxidation of the organic nitrogen, of the chemical manures from the domestic or industrial sewages, are beyond the norms in isolated cases:
 - Three Districts where the rates of ammonium are extensively superior to the norm of 2,5 mg/L (Karangazi in the Province of Umutara:285 mg/L, Nyabisindu in the Province of Butare:700 mg/L, Kigombe in the Province of Ruhengeri: 750 mg/L).
 - Five townships with contents of nitrites beyond the admitted norm: (1 mg/L): Birenga (1,750 mg/L), Giciye (1,667 mg/L), Gituza (1,714 mg/L), Muyira (2,5 mg/L), Satinsyi (1,200 mg/L). The potential risk of methemoglobinemia at the infants of less than six months are expected. The nitrates contents of the order of 20 mg/L.
4. The Phosphate contents doesn't appear elevated (12,68 mg/L) against 5 mg/L for Nyagatare to the North East of the country.
5. The iron and the manganese contents are acceptable, zinc contents don't seem representative to pull a conclusion to the national level. It is necessary to note that no data exists on the metals traces as cadmium, mercury, copper, etc., on the waters sources in rural environment.

About the bacteriological qualities of water, the research of faecal coliforms by the laboratory of quality control of the MINITERE have revealed a frequent contamination of the sources by the faecal matters. Otherwise, a survey achieved in 2000, with the support of the UNICEF, indicate that 35% of the available sources are contaminated by excrement faeces.

This contamination of faecal origin of water would be due to the works of hygiene and purification constructed upstream of the sources by infiltration of waste water in the tablecloths, but it could be also come from a hygiene lack on behalf of the populations, as for example, the weakness of protective measures the bad storage of water, the bad maintenance of the drawing material, the failing to the level of the bodily hygiene, etc.

In the country, the investigation on the knowledge, attitudes and convenient achieved in 1995 indicated that 72% of the sources of water are without protection against the pollution and 79% of the material of drawing and storage are dirty.

4.2.4. Water quality in the households.

According to the investigation achieved in 1996, only 5% of the population consume the boiled water, only 5% of the women nursing wash the hands after toilet and before giving the breast to the baby. The drinking water, even exempt of pathogenic micro-organisms to the point of public provision of water, is contaminated in the households due to unhygienic conditions of storage.

It is in this case PSI (An American NGO) makes the commercial promotion of a disinfectant names "SurEau" to guarantee the bacteriological quality of water consumed. This disinfectant is locally produced by SULFO RWANDA INDUSTRIES. The product doesn't have any follow-up on behalf of the public services in relation with use by the population, possibility of the negatives effects on the health of the water consumers treated by this disinfectant (possibility of production of carcinogenic products as the halo methane for example for waters charged in organic matters), because this disinfectant is recommended for all marks of water (water of boundary-mark fountain, raw waters of rivers or lakes, etc....).

4.2.5. The quality of surface waters in Rwanda

The water of Rwanda are divided in two basins: the Nile Basin and Congo Basin.

According to studies done in 2001 on samples of water appropriated in about thirty different points of each of the basins by professor RULINDA J.B. of the faculty of the Sciences and the Technology of the National university of Rwanda, the results show that most rivers and lakes study are polluted.. not only the chemical composition of waters reflects the nature of soils crossed, but it is also influenced by the anthropics activities in the immediate surroundings of the water plans. So in the water of the Basin of Congo the Kivu lake close to Gisenyi or Cyanguu are the more polluted (O_2 dissolved: 0,30 mg/L; NO_2^- : 0,23 mg/L; PO_4 : 4,96 mg/L), while in the Basin of the Nile, the Muvumba river is the more polluted (NO_2^- : 0,308 mg/L; PO_4 : 1,275mg/L).

The values of alkalinity, acidity, pH and free CO_2 in these rivers remain globally compatible with the requirements of the water norms for the protection of the aquatic life, the irrigation and the production of drinking water. The pH evolves between 6.4 (Mwogo and Ruvubu) and 8.4 (Mukungwa). The waters of the basin of the Nile are generally troubled with content in suspension matters or solids (SM) of 1 mg/l (Mukungwa) to 367 mg/l (Muvumba II), the turbidity varies from 7 NTU (Mukungwa) in 461 NTU (Muvumba II) and the color is of 47 Hazens (Mukungwa) in 1240 Hazens (Muvumba - Ngoma). In the analyzed rivers, these results show that the waters of this basin of the Nile are mineralized weakly. The coefficient of

soil permeability (C.S.P) calculated for the studied rivers, is generally lower or equal to 60%, value considered like maximal limit for the agricultural uses. Only the Mukungwa rivers, Kabogobogos and Ruvubus - Akageras in Rusumo have values of C.S.P superior to 60%. This coefficient that makes intervene the influences of Na, Ca, Mg and K, diminution when the concentrations increases of Ca and Mg.

The comparison of ten under-basins of that the Nile Basin of Rwanda divided in ten under-basins (see chapter 7 fig 7.3) consists (B, C, D, E, F, H, I, J and K) in main parameters (Ca^{2+} , Mg^{2+} , SO_4^{2-} , K^+ , Na^+ , and Cl^-) watch that these waters of basins (B, D, and E) are magnesium, those of (B and D) being mixed (Ca-SO_4^{2-}) sulphated-magnesium and those of calcite (E). The waters of the under- basins (H, F and I), are mixed (calico, magnesium and sulphated) to character sulphate-magnesium in (H), calcite-sulphated in (I) and quite mixed in(F). In relation to the composition in potassium, sodium and chloride, the waters of the under basins (B, D and E) are sodic to characters potassic for (B and D) and to character sodic for (E). The under basin (J and G) contain waters chlorinated to character sodic. The waters of the under-basins (C, F, H and I, are mixed [Na K-Cl] to sodic character chlorinated in (C and F) and to mixed character [Cl-Na-K] in (H and I).

Globally in the Rwanda Nile Basin, waters coming from the Northwest and the south of Rwanda arrive to Rusumo being mixed [Ca-Mg-SO_4^{2-} -K Na-Cl] and of Rusumo in Kagitumba, they become more and more magésiennes and sodiques.

4.3. THE MAIN REASONS OF THE DETERIORATION OF WATER RESOURCES

The specific reasons of each of the sources of pollution are difficult has surround with rigor and precision, notably because of the complexity and the multiplicity of the fluxes. But a general portrait of the reasons says "primary" that are common has the set of the pollution's can be raised enough easily. Thus, in any order not taking into account their relative importance, the list summarised of the main reasons would be:

1. the geomorphology of the mountainous soils and damage and the development may be anarchical of the urban and rural agglomerations expressing themselves, in answer a demographic growth always growing, by a concentration of the population in the urban centres. Since the pollution is joined directly to the human activities, it is also in these urban centres that one recovers the problems of most important pollution. The sickening waste waters coming from the penitentiary centres of detention, of the hotels, of hospitals, of the walks publics, etc. The crumbling and slips of lands taste persons responsible have some considerations of the silting up of the plans of water and the strong loads of the surface waters in matters in suspension.
2. the non raising of a security perimeter all around of the sources and their non planning explain the rates of chemical and bacteriological pollution record in spring waters and underground. The analyses have watch that the waters of the sources arranged are of better quality has those of the sources non arranged. In spite of the organic law for the environment forbidding the activities of 10m before the rivers and 50 m before the lakes

3. the erosion of soils is also the origin of the deterioration of the water quality: colourful and water of matters in suspension; what would justify a strategy multisectoriel putting in play a collaboration between the different ministries.
4. the lack of alternative solution research has the use of synthesis pesticides. The produced pyrèthrine has Ruhengeri could be exploited in replacement of the chemical substances of synthesis, in view progressively to promote a biologic and lasting agriculture.
5. the weak responsibility of the citizens. This weak responsibility is the reason of the non respect of the environmental legislative and regulation. In other words, among some actors, as very literate as non literate, has observed an ignorance of the ominous consequences of their activities on the environment. It is probably the fact of the non availability and the non popularisation of the legislative and regulation texts. Sometimes the lack of integration or setting in application of the mechanism of management of the pollution of the environment in their process of scheduling can simply be a matter for the ecological incivism. Although it is remarkable in all sectors, this weak responsibility is especially considerable in the domestic sector for the pollution of sanitary type (faecal matters and garbage).
6. The difficult socio-economic conditions and poverty. In the absence of affordable alternative solutions to the economic plan, the citizens, even sensitise the best to the legal setting and the ominous consequences of the pollution and that don't want to deliver themselves some acts deliberate incivisme, can be forced to opt for polluting solutions. It is especially the case in the domain of the industrial sector, where good number of old facilities would require environmental investments so important that they would compromise competitiveness and even the survival of the enterprise. This interrelationship between poverty and pollution is a very known phenomenon and underline extensively as being a major constraint in number of studies and documents of support to the lasting development in the developing countries.
7. the knowledge limited of the best techniques of management and control of the pollution, that it is among the peasants, the city-dwellers, the entrepreneurs, the industries, or other generators of pollution. This reason is a little a corollary of the difficult socio-economic conditions, since the level of education ensues some, but also of the weak level of responsibility. However that may be, this limited knowledge is sometimes the reason of bad choice of management that doesn't smell justifiable by economic reasons.
8. The lack of bodily hygiene and food hygiene.

4.4. THE MAIN CONSEQUENCES OF SOURCES OF POLLUTION

The main sources of pollution's (domestic, commercial, industrial, small-scale and agricultural activities) affect air, water and soils, and their effects appear on the health of the populations has shortcoming the bronchi-pulmonary affections (pollutants of air), of the illnesses of water origin (bacteriological pollution of water) and the cases of poisonings by the products of synthesis as the pesticides and insecticides.

CHAPTER 5: IMPACTS OF THE AQUATIC POLLUTANTS

5.1. THE IMPACTS OF THE POLLUTANTS OF PLANS OF WATER (SEDIMENTATION OF RIVERS AND LAKES).

1. The important erosion of soils and the banks of the water plans, the crumbling of earth from the flanks of the hills and the clearing of the earth due to the mining extractions, observed in the country, caused the sedimentation of the beds of the lakes and rivers, reducing the capacity of storage and the out-flow of water, and of other starter caused the destruction of the soil cover initially assured by the development of some practices culturally on zones of strong slopes. The lake Cyohoha Nord has the East of Rwanda would have been dried continuation notably has the erosion coming from the banks and the pouring basins that nourished it in water.

2. The proliferation of the floating plants as the hyacinth of water (*Eichkornia crassipes*) consequent has the nitrogenous and phosphorated pollution, night not only has the aquatic life of the water plans but has the navigation also on these plans, decreasing their landscape value thus and affecting the tourist appeal of these water plans notably.

3. The worn-out waters domestic and industrial are the main sources of pollution of the water plans (Lake Kivu and Koko river has Gisenyi, Nyabugogo river, Muvumba, etc.).

4. The bacteriological pollution of faecal origin is generalised in these aquatic ecosystems.

5.2. THE IMPACTS OF TOXIC SUBSTANCES IN AQUATIC SYSTEM

No study on toxicology of the pesticides and insecticides. If some investigations had been led on the land, it would probably have been possible to record cases of poisonings or uneasiness that of the populations having the habit to manipulate these products of synthesis would have known as the pesticides; because he/it is known in most our African countries that the peasants, in spite of the formations that are given them by the agents of farming development on the use of the plant-care products, don't take still the necessary protective measures at the time of the manipulation of the products et/all of the pulverisation of the plants.

The effects on the health of these synthesis products are, of part the literature, characterise relatively yesterday and can be summarise as follows:

1. the somatic effects, that alter the physiology of the individuals: it is about a change of the vegetative functions, as the nervous conduction, the breathing or the functions detoxifiantes.

2. the germinal effects, that alter the reproductive functions or the progeny: these effects can consist in the barrenness or the induction of genetic mutations (or chromosomal), these capable to drag the illnesses or the congenital malformations (effects tératogènes).

3. the carcinogenic effects, that provoke the anarchical proliferation of cells differentiated, or "cancer".

5.3. IMPACTS OF THE AGRICULTURAL POLLUTION IN RWANDA

The population increases, the agricultural activities are intensified to satisfy the demand, and the parcels cultivate lost by erosion the organic matter and the mineral salts of soil. To increase these nutrients lost by erosion and washing, some quantities of mineral chemical manure are applied. This increase of the application of the chemical manure also increases their level in water.

In addition to the chemical manure, the application of the pesticides and insecticides also increase, dragging a concentration raised of pollutants in water. In more the application of manure and insecticides, some animal garbage are drag in waters, constituent especially a danger for the zones has stagnant waters as the arranged sources, the ponds piscicultural and the restraints of water.

One can also note the loss of fertility by soils because of the excessive use of Pesticides and insecticides. Indeed the residues of these synthesis products that infiltrate in soils kill the micro-organisms that normally is there to mineralise the matter of soil and to free the nourishing elements for the plants. So soils become impoverished and have term, become unfit has the culture.

Let's note, according to the investigations done in the setting of this work that the quantities of chemical manure's (NPK) used in Rwanda grow of year in year. However, it is generally admitted that the rate of nitrogen washing is of 5 has 30%, and the one of the phosphor of 0,5 has 5%, it means that a quantity important of manure is drained toward the plans of water. the main potential consequence of this washing phenomenon is the eutrophication of the water plans, characterised by a proliferation natural of aquatic plants and by line reduction of the dissolved oxygen. This small eutrophication to drive has term has the death of most living organisms in the plan of water, with important consequences in term of organic load and silting up. This phenomenon of eutrophication of waters sometimes makes difficult the treatment of some waters of surface because loaded of colloidal matters as the substances humics.

5.4. THE IMPACTS ON THE HUMAN HEALTH

The majority of the illnesses affecting the populations is of water origin: 52% of the deaths record in Rwanda are due to the bound illnesses has the bad quality of water. The physico-chemical and bacteriological measures done of 1999 have 2001 by the Laboratory of the quality of the water of the DEA (Direction of water and purification), and the analyses of follow-up tracks by the Laboratory of Control of Electrogaz ant reveal chemical and bacteriological contamination of some sources. The works of the Professor J. B. Rulinda (2001) have shown the chemical contamination of most waters of surface, whereas a fringe of the population prefers the water of the lakes and rivers have the one of the sources either arranged well stocked by Electrogaz.

The pretexts often evoke by these populations, it is that their forebears would always have drunk this water without having known epidemic ever, or because the arranged source is far from their concessions. This contamination of the waters of the sources has for consequence the proliferation of multiple illnesses of water origin as the cholera (diarrhoea, vomiting), the cramps of illnesses of water origin as the cholera (diarrhoea, vomiting), the cramps of the

stomach, the fevers typhoid and paratyphoid, the gastro-enteritis, the salmonellas, the parasites, the leptospirose, the amibiase, the schistosomiase, etc.

The affections of origin hydro-faecal are the most numerous among the illnesses caused by the consumption of bad quality water.

To these affections could be added the methemoglobinemy (inaptitude of blood has transport the oxygen) at the infants, due to the strong rates of nitrite record in most waters of human consumption.

CHAPTER 6: RESOURCES FOR MONITORING AND TECHNICAL CAPACITY OF LABORATORIES .

6.1. Objective of the chapter:

- a. To identify the laboratories capacities on the physical, chemical and bacteriological keys parameters analysis of water quality;
- b. To identify the existing facilities and equipment capable to permit to analyse of the keys parameters of water quality;
- c. To identify the staffing capacities (human resources of monitoring) in the country in relation to the follow-up of the quality of water resources (strengths and weaknesses of the present technical infrastructure);
- d. To identify the complementary facilities necessary to the follow-up of the water quality like sampling stations and communications
- e. To identify the training aim provide the technical follow-up of the water quality;
- f. To identify of the existing laboratories network on data processing and dissemination.

6.2. List of laboratories identified, staffing and laboratory facility

In the appendices, the list of national laboratories number of their activities in "water quality analyses" or working exclusively regular in the quality of water resources or having the material and human capacities permitting to follow the quality of water.

The visits done in structures of research or analyses in some big cities of the country (Kigali and Butare) permitted to identify some laboratories types in ministerial technical directions, in the faculties of the national university and in public corporations or semi-public.

Subject to all omission, the laboratories having kept the attention of the work team present themselves as follows:

In Kigali city:

1. The laboratory of the quality of the water of the department of water in the ministry of MINITERE : It takes care of the follow-up of the physical, chemical and bacteriological analyses of distribution of drinking water in rural area. It is directed by a specialist in physical chemistry bachelor degree, assist by four technicians laboratory of A2 level (2 biochemists, 1 math physicist and 1 humanist in pedagogy); it is nearly entirely team by

the UNICEF and from this year the laboratory is transferred to the National University in the department of science and technology.

2. The laboratory of quality control of Rwanda Bureau of Standards (RBS). It controlling the quality and the methodologies of analyses and delivering the accreditation or licences. An institution has particular statute, the laboratory of RBS makes part surely of the national technical capacities concerning control and follow-up the standards of the water quality in Rwanda. Staff of the laboratory is in processes of setting.
3. The laboratories of water quality control of the company Electrogaz.
Existing to the level of the processing plants of the water treatment of company as has Kimisagara and Karengye for example; these laboratories control and follow the physico-chemical and bacteriological quality of waters in the networks of distribution nourishing the urban centres, and propose the methods of dosages of the reagents during the treatment.
Staff management: chef of all laboratories and each laboratory staffed by technicians graduated in chemistry and biochemistry, assist by technicians of A2 level according to the size of the factory and the laboratory. The laboratory of the factory of Kimisagara in Kigali-town have a numbers of materials and human resources for monitoring.
4. The laboratory of hygiene of the water at the health Ministry. It is directing by a technician A1 in sanitary genius. The laboratory create in 1991, the Laboratory has benefited of a financial support of the WHO in equipment that allows him to search for the coliforms and some other indicators of physical, chemical pollution, so much in the sources of water that in the waters of surface.

In Butare city:

5. The laboratory of the faculty of sciences and the technology of the National University of Rwanda. It takes care of research on the chemical quality of resources in water and differents research of students on surface water and groundwater.
It is directing by a Professor in chemistry assist by other Professors, Assistant lecturer in analytical and physical chemistry and a number of technicians laboratory.
6. The laboratory of the hygiene of water and food commodities of the Project of National University of Rwanda and the University of Liege (Belgium). It has two sections:
 - the microbiological and physical-chemical laboratory. It is managing by a technician graduated in Biology bachelor degree, assist by some technicians in microbiology and physico-chemistry A2 level.
 - The laboratory analyses on food and water “watering”, water of piscatory and drinking water as mineral waters and source of water managed.
7. The laboratory of the Project PASI (intercollegiate Agricultural and Social Project) in the faculty of agronomy of the National university of Rwanda. It takes care of research in agro-forestry in view of the survey of impact of the trees on the fertility of soil and the

fertilising elements. It is directed by a teacher researcher in biochemistry and microbiology, assist by technicians A1 and A2 level.

In summary of this inventory on the material and human resources monitoring of different laboratories in concerning of water quality analyses has permits to make the reports below:

- a. the existing of national structures laboratories working in the water quality assessment;
- b. the existing some material and human resources for the follow-up of the water quality;
- c. the existing some capacities and facilities in the laboratories but not to follow up all indicators of quality keys parameters of which the residues of pesticides, BOD₅, COD and heavy metals;
- d. the existing of the expertise and capacities of the laboratories but the data are disparate and diversified;
- e. the relations of collaborations or networks doesn't exist between different level; ministerial department in charge of quality of resources in water, laboratories of the university and other stakeholders (NGO, private sector);
- f. no geo-reference of sampling sites and stations;
- g. no common system on methods for collecting database of quality of resources in water in Rwanda. For example the data on the surface waters are observe by the laboratory of the university for education profile, drinking water by the Electrogaz, analyses data by the laboratory of the department in charge of water management of the ministry and private sector (BRALIRWA, SHELL, ARC, EXPERCO, COFORWA, and National or international Red Croix;.
- h. no co-ordination and publishing of reports addressed to the government authority.

6.3. CAPACITY LEVEL LOCAL COMMUNITIES , NGOs INVOLVED IN WATER QUALITY

6.3.1. Involved communities or NGOs in water quality management programs.

In Rwanda there are no many NGOs involved in water quality. Some NGO are operating in water sources management , water-catchment, methodologies approaches participator to the hearth management of water and environmental quality of water.

In all programs the population is implied since the national level until the basis level of the community, but only one NGO "COFORWA" have a good experience from 1971 in water resources management and water quality assessment (data analyses: bacteriological and physico-chemical). The COFIRWA covering a number of district in many Province of Rwanda (Gitarama, Ruhengeri, Gikongoro and Kibuye). Others NGOs are Rwanda Red Croix (CRR), international Red Croix (CICR) and Internationals NGOs for refugees (ARC. American refugees committee).

- Some consultant offices in water sources management and water-catchment. EXPERCO (Butare Province), SHELL (Kigali Rural Province), ARC (Kibuye, Byumba, Mutara and Cyangugu Provinces), SOGEAR (Butare and Gikongoro Povince) are involved in services

of water for catchment and water supply for the people. For any project the services must have a number of water quality analyses data and methods of treatment bacteriological and physico-chemical.

6.3.2. Level of awareness on the importance of water quality management in Nile basin between stakeholders.

Considering the importance of the source of the Nile river in Rwanda, taking account of enormous natural resources that is in the basin, was created a national Forum of the Civil society on the Nile in Rwanda (FSCN) has for mission to mobilise some efforts for the promotion of a good management rational of waters and resources of the Nile basin in Rwanda. The objective is to sensitise the Rwandan population on the importance of the basin of the Nile and the good management rational of his/her/its resources, to sensitise the authorities on the problem of the Nile basin, protection of the environment and to make understand that the Rwanda Nile Basin river is a township resource of state of Nile Basin.

The national forum composed by national organisations working in the community development, promotion and protection of the environment.

NGOs are:

ISUKU, “ Association for preservation of hygiene and the environment ”, **INADEC**, **SERUKA**, **CCS-Gitarama**, **ARAMET**, **ARDI**, **ARECO-RwandaNziza**, **Women Network**, Association of Journalist for promoting of the environment, **ARFEM** and **AGAPE-Gisenyi**.

Chapter 7. CURRENT MONITORING STATIONS

7.1. HYDROLOGICAL SAMPLINGS STATIONS IN RWANDA.

The map are providing by Nile DST software (Georgia Water Resources Institute (GWRI), FAO, Nile Basin water resources and databases from the department of water resources management of Ministry of water (MINITERE).

In the map are 17 stations hydrologic discharges in yellow and 31 stations hydrologic GaugeHeight in red.

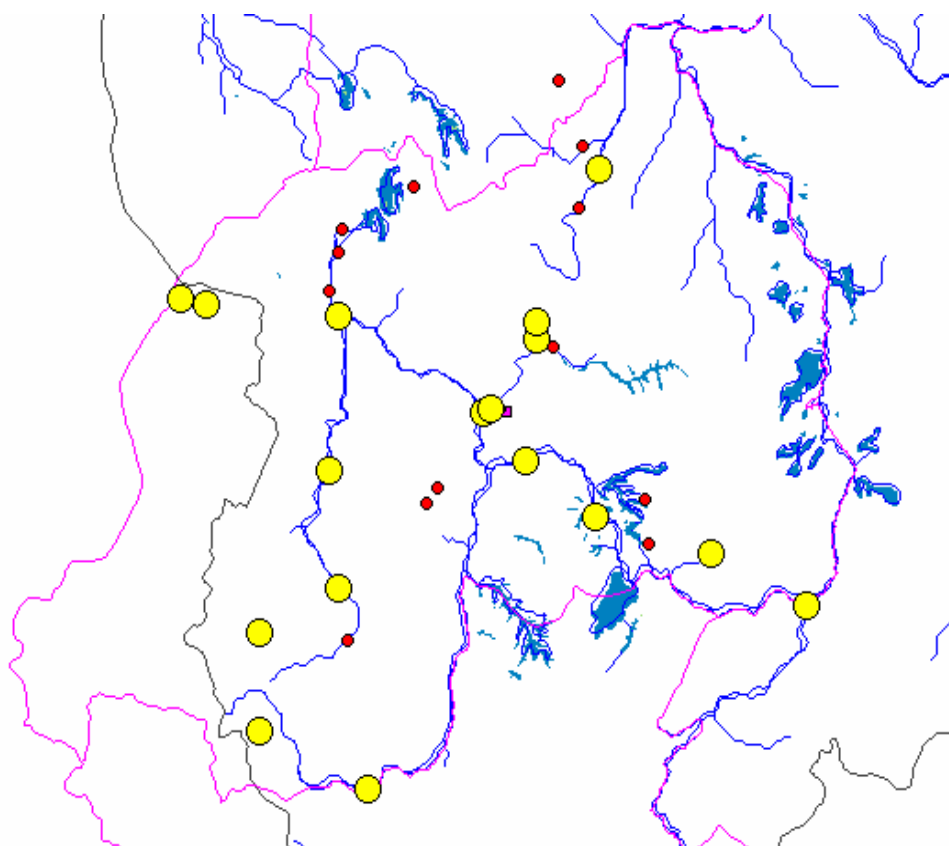


Fig 7.1 : Hydrologic stations in Rwanda.

Now are two monitored stations, after 1994 genocide from 13 Stations hydrologic remains operational to the national level.

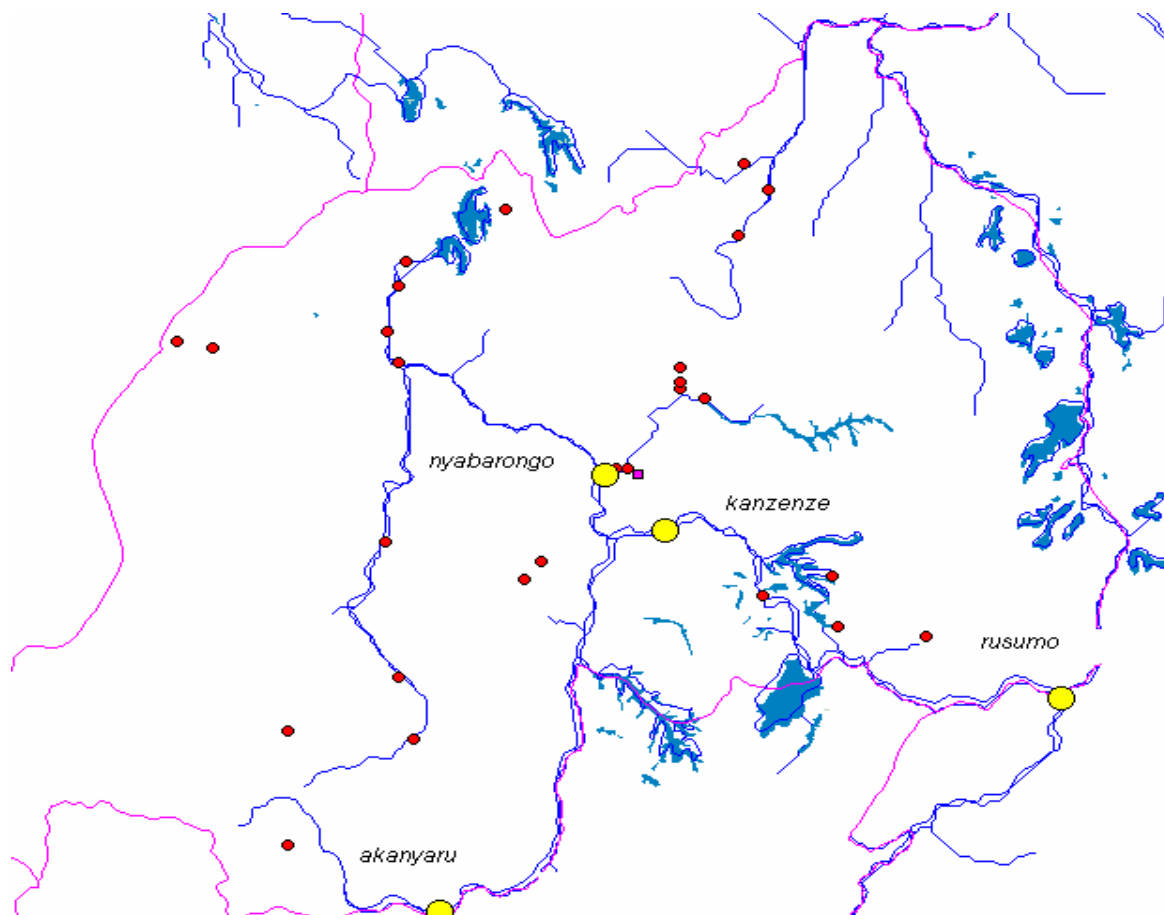


Fig 7.2 : Two hydrologic stations monitored by FOA project (Nyabarongo and Rusumo)

7.2. Example of monitored data quality of Rwanda Nile basin rivers

The data of physico-chemical and chemical analysis of the main rivers of the Nile Basin in Rwanda are in table (see table appendix). The map showing the course of Rwanda Nile basin rivers from the source, the crossed of the country to the exit to Uganda.

The measures have been done in mid-August and end of September 2000. the fourteen sites of sampling consist of the main rivers of Nile basin of Rwanda, that are: **Mwogo, Rukarara, Mbirume, Nyabarongo, Mukungwa, Nyabugogo, Base, Agatobwe, Migina, Akanyaru, Kabogobogo, Ruvubu, Akagera, Ngoma, Muvumba I, Muvumba II and Kagitumba.**

Before the confluence of two rivers, three samples have been appropriated, it means two before the meeting of the rivers at the rate of one by river and the third after mixture.

The main raised physico-chemical and chemical keys parameters are: the pH, the dissolved oxygen, the salinity, the conductivity, the acidity, the alkalinity, the colour, matters in suspension, the turbidity, free carbonic anhydride, the total toughness, the calico toughness, the main mineral elements of the surface waters (Ca^{2+} , Mg^{2+} , SO_4^{2-} , K^+ , Na^+ and Cl^-), and the trace elements (F^- , PO_3^{3-} , Cu^{2+} , Cr^{6+} , Mn and Fe).

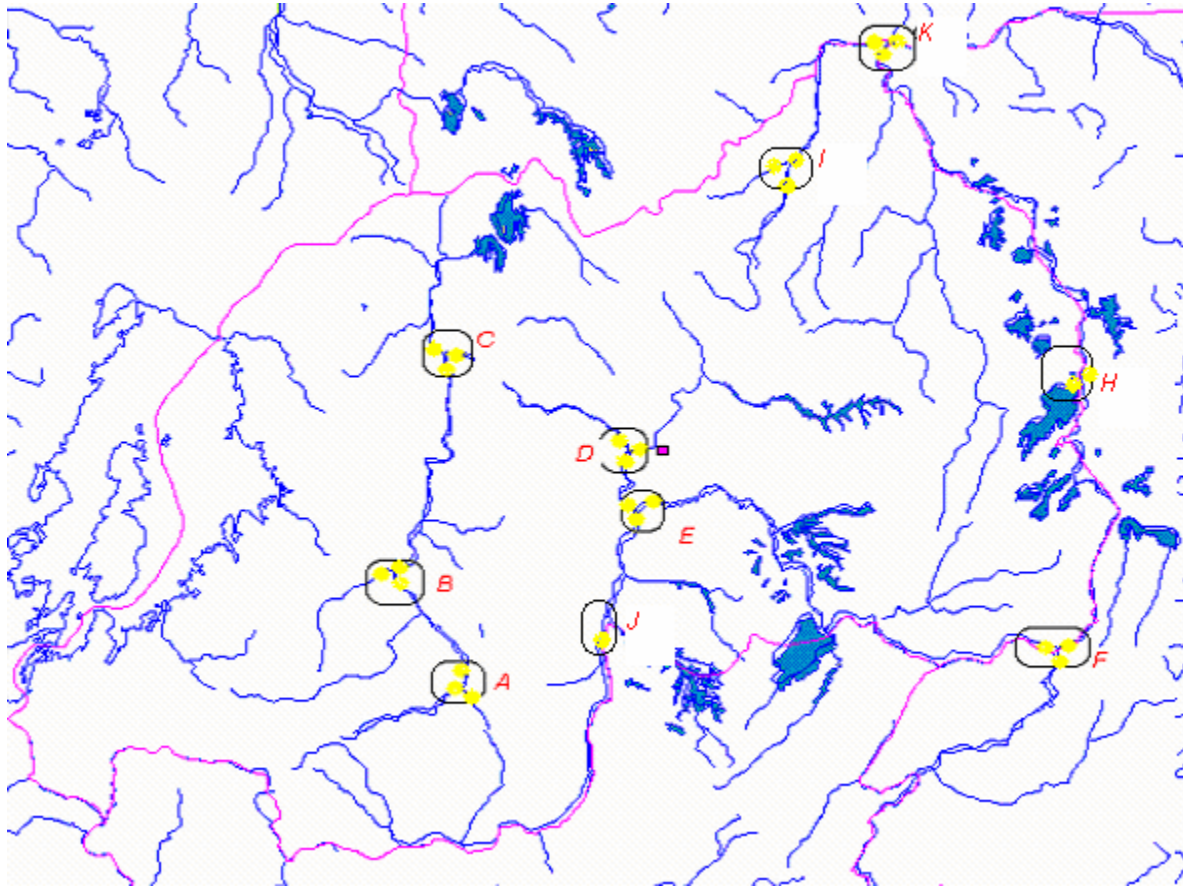


Fig 7.3 : Geo-location of sampling sites of Rwanda Nile rivers basin.

A): Mwogo, Rukarara, Mwogo+Rukarara, B): Mbirume, Nyabarongo, Mbirume+Nyabarongo
 C): Mukungwa, Nyabarongo, Mukungwa+Nyabarongo, D): Nyabarongo, Nyabugogo, Nyabarongo+Nyabugogo
 E): Nyabarongo, Akanyaru, Nyabarongo+Akanyaru, F): Akagera, Ruvubu, Akagera, Ruvubu,
 H):Akagera basin, I): Ngoma, Muvumba, Ngoma+Muvumba, J) Akanyaru, K) :Kagitumba.

7.3. Proposed geographical regular selecting hydrological and quality sampling stations

Integrating hydrological and water quality monitoring: No meaningful interpretation of analytical results for the assessment of water quality is possible without the corresponding hydrometric data base. Consequently, all aquatic environment monitoring should take into account the hydrological characteristics of the water bodies, which should be determined by preliminary inventories and surveys. All field observations and samples should be associated with the relevant hydrological measurements for different types of water bodies.

The combined evaluation of water quantity and quality data sets should also take into account spatial and temporal variabilities. The hydrological features of water bodies follow their own variability patterns which may be quite separate from natural and/or man-made water quality fluctuations. In practical terms, however, they tend to be rather closely inter-linked

According to the situation, there are two stations discharges **Nyabarongo (A)** (confluent Nyabarongo and Nyabugogo) and **Rusumo (B)** (confluent Akagera and Ruvubu) are in working position, this stations can be taken as quality selecting sampling stations and two others stations discharges **Kanzenze (C)** (confluent of (Nyabarongo and Akanyaru), the **Ngaru (D)** stations confluent of Mukungwa+Nyabarongo rivers) and the **Akanyaru (E)** station.

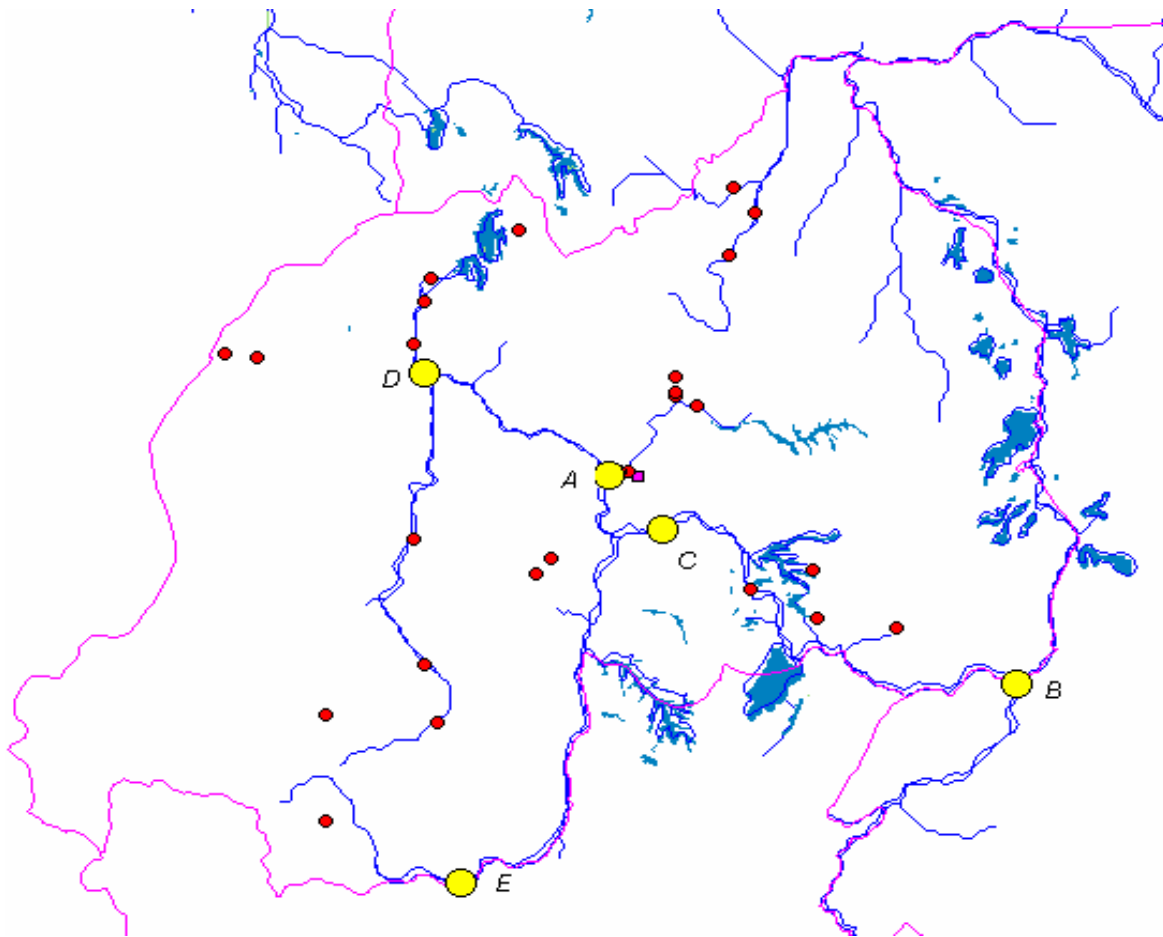


Fig : Proposed of Selecting sampling stations on Rwanda rivers

CHAPTER 8 : RESEARCH STUDIES INTO WATER POLLUTION

Three higher education institutions: NUR, KHI and KIST are involved in physico-chemistry and microbiology research in water pollution. Available results are in appendices. The existing database on pollutants was done in 1991 after that no data available. The constant office: SGI INGENIEURS has make some analyses on waste water from domestic users, industrial , hospital waste, hotels treatment, some stations of treatment and central prison of Kigali. Available data on BOD₅, COD and suspended matters.

CHAPTER 9: NATIONAL RESPONSES TO WATER POLLUTION PROBLEM

The roles and responsibility of each of the governmental intervening parties in the setting in work of the management of the water quality is summarize as follows:

1. to plan, puts in work and do the follow-up of the actions of struggle against the pollution of the clean water has all levels
2. to share the information and the data descended of the follow-up of the projects and programs with the other concerns, via the cells environments and the direction in charge of water.
3. to plan and in work the inter sectorial actions of struggle against the pollution of water, in coordination with the sectors imply;
4. to plan and puts in work the internal plan of struggle against the pollution of water
5. to present the results of the set of the actions of struggle against the pollution in the NILETEAP project
6. has the help of the network of cells environmental, collect, compile and diffuse the set of the data of follow-up, the resulting and the assessments of efficiency
7. to look after the respect of the norms of quality of the drinking water and dismissal of the residuary waters in the policies, plane, programs and sectored projects

9.1. ASSESSMENT OF ACHIEVED ACTIONS

9.1.1. Assessment of the actions has done

In the setting of the preparation of this national water quality monitoring, the need of an inventory of the actions of struggle against the pollution of water was done, thanks to the different visits led by the different actors in the different ministerial departments, the NGOs, the partners to the development, the local collectivities. It is evident from these meetings that a lot of projects or actions are led in the country in the domain of water, in particular in the domain of the provision of the populations in drinking water, since today it is one of the most Rwandans

preoccupations, that means how to have water in quantity and perennial way, even though the problem of water quality preoccupies them somewhat and that a certain number of persons responsible of projects includes in their specifications.

The majority of the projects is piloted by the Ministry of Water (MINITERE) by the Direction of water and Purification. The Ministry in charge of Health (MINISANTE) is also in charge of several projects and programs, notably those dregs have the management of the biomedical garbage, and the purification of basis (latrines and strong garbage). The Ministry of agriculture (MINAGRI) is as promoter of some projects and important programs concerning struggle against the pollution, mainly with regard to the management of the pesticides and the chemical manure's.

Finally, most other ministries are imply closely or from afar in a certain number of projects and programs.

The number of actions and the multiplicity of the actors imply demonstrate clearly that the lasting development constitutes a challenge that the state Rwandan exerts has raise. The adherence has some projects and programs of international nature also demonstrate the worry of collaboration interstate that the country wants to maintain in general in the domain of the environment and in particular in the one of struggle against the pollution of water.

For an optimization of the actions in the domain of water and purification, coordination of the actions imposes itself. It will find its solution in the setting up of the legislative and regulation setting. The adoption of the organic law regarding the environment and the creation of the Rwanda Environmental Management Authority (REMA) would probably put end has this scattering of the means.

Otherwise, of the meetings with different partners of the development of Rwanda (WHO, GTZ, Physicians Without Borders,) permitted to put in evidence their preoccupations about the coordination of the actions in the domain of the quality of resources in water also in the country. The need to coordinate all programs and all demands of the Rwandan government closely concerning resources in water becomes crucial for several among them. They underline the need of an institutional analysis so that the role and the responsibilities of each of the actors concerning water in Rwanda are more clear. The same preoccupations are expressed strongly in a certain number of reports having punished of the forums or seminaries organize to the national level in the domain of water and purification.

The new organization of the local communities has shortcoming in progress the process of decentralization in Rwanda should be able to facilitate the implementation devised of the projects between the different ministerial departments.

9.1.2. Identification of the needs

The needs of Rwanda concerning struggle against the pollution of waters are even numerous and vary. They enough clearly emerge the diagnosis of the situation and the assessment of the actions achieved or in progress that were previously present in this document.

- **The needs of legislative and regulation in water quality monitoring**

The needs legislative and regulation can summarised up as follows:

;

- finalization of the law draft structural code of purification and its adoption;

- adoption of the texts of setting in concrete application of the laws and regulations, in particular principle of pollutant payer (development, implemented work and of the incentives measures and coercive that must underlie this principle);
- Development and publishing of the national norms of quality of water and the residuary waters;
- Setting up of a legislative setting and the texts of application to control the illicit import of dangerous products for the environment;
- Backing of the means of control of the respect of the norms (capacities of measure and analysis);
- Creation of a system that permits to reward the effort agreed for the reduction of the pollution, even though the norms don't smell like attacks has 100%, this in order to encourage the gradual improvement;
- Education and sensitisation on the legislative and regulation setting, including the popularisation of the texts, in order to limit the failure to respect of the laws and regulations of has it the ignorance; in general coercive measures feels efficient little when the contravening don't consist well of the reasons that made of their acts an offense

▪ **The needs on the plans institutional and organisational**

The institutional and organisational needs, particularly important in term of span, can sum up as follows:

- setting up of the Rwanda Environmental Management Authority (REMA) would facilitate and accelerated the adoption of the different texts of law or decrees again in projects in the domain of the management of the environment.
- reinforcement of the inter sectorial coordination between the projects to avoid the duplications and to encourage the synergy between the actions;
- Exploitation of the synergy between the projects, to improve the global output of it,;
- reinforcement of the capacities of the laboratories of measure of the pollution of water and their impacts by the technical equipment, the formation of the staffs of the laboratories and the setting in network of these.
- establishing a network for data collection and dissemination

▪ **The needs in terms of information, education and communication**

The main needs in term of information, education and communication are the next one:

- setting up of a global strategic setting of environmental communication;
- adaptation of the shape and the content of the messages according to the publics targets;
- diffusion of positive messages, axes on the profits of the actions concerning quality of water;
- sensitisation and formation on the knowledge and the understanding of the pollution phenomena, as well as on the possible solutions. This need expresses itself all levels, but in particular to the levels of intervening parties as the NGO, the vectors of information (media) and the actors imply in the scheduling and the implementation of the projects and corrective programs.

9.2. CHALLENGES AND STAKES

The diagnosis achieves previously and the assessment of the actions permitted to raise a set of needs that remains to satisfy in the domains of provision in drinking water and struggle against the pollution of water in progress. To satisfy these needs, the actors concern having to raise many challenges, raised by inherent constraints to the institutional and socioeconomic context.

One of these main challenges is certainly the difficult socioeconomic context and the poverty of a large left of the population, aggravated by the war and the genocide of 1994. In this context, the scheduling of every action should take carefully in account the socioeconomic consequences. The research of alternatives polluting hands but economically accessible will constitute a permanent stake in the implementation of the sectorial actions that will ensue of this strategy. The use of a progressive gait could prove to be time ray to manage this constraint.

Another major challenge is of institutional nature. The sectorial decentralization of the actions of struggle against the pollution of water is very desirable because it is inherent to the lasting development principle. However, she/it leads the hour present certain time forced operational. Indeed, in spite of the good will of the ministries has work together and has interact (to see resolutions of the National Seminary on the launching of the initiative Africa 2000, organize jointly by the Ministry of the Public Works & the Ministry of the Change, in collaboration with the World organization of the Change, Kigali of the 16 to November 17, 1998, having succeeded has required her of a consensus inter Ministerial permitting to concentrate the efforts and the means instead of dispersing them), the "budgetary property" of the projects and programs or, in other words, the assignment of the budgets of a project or a program

Give has a particular ministry, brought line unavoidable competition and especially, a reflex of conservation. This small reflex to limit the sharing of the stains with other ministries or agencies that would have resources more suitable or more available to make gone line of work. However, the assignment of the budgets is inescapable in a mind of healthy management. It is therefore about a major challenge has raise that the one to continue has promote the decentralization of the actions of struggle against the pollution all in dec1oisonnant the sectors, in order to assure an optimal use of resources.

In this setting, the committees of development decentralized to the provincial level, as they are structures with representatives of different ministries, would help has raise this challenge of institutional nature, and this in relation with REMA.

Finally, the level of involvement and the engagement of the pollution generators towards struggle against the pollution of water constitute a third challenge of size. This engagement will necessarily be function of their perception of the problems and their consequences, as well as of their receptiveness facing the messages received, of or the crucial importance of the content and the fashions of diffusion of the messages. It is about a very important stake, because the success of the actions of struggle against the pollution of water rests largely on the engagement of the generators.

Above all, the adoption of the parent act on the environment Tests a priority of or will ensue the norms of quality of the environment that the generators of pollution will be called has respect.

9.3. ACTIONS ON WATER QUALITY MONITORING IN RWANDA

The global objective concerning quality of water, *"it is to improve the setting of the life of the Rwandan population while reducing the polluting loads whatever they are, in resources in water until has a compatible level with the requirements of the legislative and regulation" device.*

- To improve in a continuous way the global efficiency of the actions concerning struggle against the deterioration of the quality of resources in water.

It will be about making so that all action that is led or goes in progress in the sense of the improvement of the quality of resources in water.

- To put the necessary mechanisms in place to assure a better coordination, a better consistency and a synergy of the actions.

It will be about instituting procedures accepted to custom and that permit to lead in a concerted manner the various actions having to converge toward the same objectives.

- To develop and to set in motion the approaches, the methods and the tools required to achieve a follow-up more rigorous and continuous of the actions, axis on the verification of the attack of their objectives. This strategic axis imposes a rigorous follow-up of the actions in relation to the objectives thanks to the backing of the means (approaches, methods and tools)

- To put in work of the solutions adapted to the local context.

The adaptation of the solutions to the local context is so much fundamental for the efficiency that for the social acceptability of these solutions, considering the geographical and socioeconomic diversity of Rwanda.

- To create a climate of collaboration while encouraging the dialogue, while setting in motion a positive communication, and as distributing the profits pulls successful actions.

It means that one could not reach this global strategic objective without the enthusiastic involvement of all actors and partners. For that to make, it is primordial to create a climate of collaboration and exchanges between different actors, has know those imply in scheduling and the realization of the actions as well as the recipients of the actions.

Actions must be done in future (short term)

- Reinforcement of the capacities of coordination of the actions concerning quality of waters.
- Reinforcement of the capacities of follow-up of the actions, of measure of the results and feedback,
- Organisation decentralised of the coordination and the follow-up
- Use of a gradual approach in the application of the legislative and regulation setting.
- Promotion of a dialogue and partnerships between REMA and the different actors
- promotion of the value economic of the protective actions of resources in water
- Promotion of the social mobilisation for the improvement of the quality of water

CHAPTER 10 – ACTIONS BY NTEAP ON NILE WATER QUALITY MONITORING

10.1. SUGGESTION OF ACTIONS BY THE NTEAP ON WATER QUALITY MONITORING.

From the diagnostic survey and the analyses made of the situation, has the management of the quality of resources relatively in water of the Nile Basin in Rwanda some actions or projects must put in program has short and middle terms are identify like supports to the approaches of solutions below recommended facing the problems of deterioration of resources in water.

The actions must be done in future are:

- The objectives of the water quality assessment and monitoring must be defined first and the programme
- Inventory, capitalisation and storage of all studies done to Rwanda, concerning struggle against the pollution of Nile Basin water resources.
- Building capacities of analyses; staffing, laboratories: (some existing data are little exploitable, personal not qualified, under-equipped laboratories and requirement to put the laboratories in the network).
- Developing a methodologies and methods standardised guideline (existence of big disparities between the results of the laboratories for samplings sites of investigating).
- Monitoring of the quality of the aquatic environment must be coupled with the appropriate hydrological monitoring
- Establishment of the cartography or geo-mapping of sampling sites or stations of the quality of resources in water in Rwanda (requires to know the different qualities of water and their geographical distribution in view of the different possible uses.
- Establishment of a continuous coordination follow-up on the quality of resources in water, design of monitoring network and selection variables.
- To put in place a program of education and awareness to the national and community level on water pollution.
- Dissemination of the information by media and by incitement of local community in the management of quality of water resources.
- To invite the country to participate on the program of GEMS/Water for monitoring technology.
- All data should be given to decision makers, not merely as a list of variables and their concentrations, but interpreted and assessed by experts with relevant recommendations for management action .
- Establishing the Nile Basin Network for baseline reports.

10.2. THE NEEDS FOR IMPLEMENTING ACTIONS:

- To put in place the office coordinator on water quality information and database exchange and reports on Nile Basin rivers of Rwanda.
- To organise regular training on capacities building

- To help and to look after the respect of norms of water quality.
- To put in place the hydrological sampling stations on hydrological measurement and quality.
- To put in place some equipment and software for data analysis (computer, software, laboratories equipment and network installation).

RECOMMANDATION

- Key issues on effective policies and institution : a legislative framework providing the necessary resource use rights and deter resources degradation and how could such a framework be effectively implemented
- To adopt the national strategy concerning management of quality of water resources.
- Transboundary water policy and institution: how can water quality environmental concern and social concern including hearth and nutrition best be integrated into Transboundary river basin agreements
- Finalised the draft project of legislative text and regulations concerning quality of water, sanitation and water pollutants.
- To elaborate a national policy concerning environmental communication.
- To reinforce the national capacities of analysis of water, control and follow-up of the quality of the resources in water.
- To study and to adopt the proposal of actions or projects concerning quality of resources concerning improvement of the quality of the resources in water search for the sources of financing then for the implementation.

CONCLUSION

The management concerning quality of water presents a lot of assets for implementation, of which notably will affirmed of the ministries having a composing quality of water in their attributes, to decentralise the actions to the local level toward the recipients and also to unite strengths in view of an optimization of the use of the means and attack of the common objectives. It not only supposes the acceptance of each to take a part of the present prerogatives that is devolved to him concerning struggle for the preservation and improvement quality of resources in water, but each must as work so that is assured in the sector of the water quality a better coordination of the actions by an unique national structure.

As much the decentralisation of the setting in work of the actions is a requires inescapable, as much the coordination of the operations is extremely important, because it aims has increase the efficiency of the actions has assure the consistency and the convergence of the common objectives, while eliminating the duplications and search for the affects positive synergic of it.

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APPENDICE 1:**DATABASE ON NATIONAL LABORATORIES, EQUIPMENT, EXPERTS AND SKILLS****Equipment of water quality laboratory of the Direction of Water and Sanitation in Ministry of Lands, Environment, Forest, Water and Mines (MINITERE)**

This laboratory has transferred to National University of Rwanda under control of department of science from January 2005

<u>Analytical equipment</u>	Quantity
Spectrophotometer DR2000	1
Smart Colorimeter	1
pHmeter HACH	3
Digital Titration	5
Chlorimeter HACH	1
Conductimeter HACH	1
Oxymeter HACH	1
Reactor of COD HACH	2
BODmeter Track HACH	1
Autoclave	2
Sterilizer	2
Incubator	3
Distiller	1
Etuve memert	1
Refrigerator	3
Kits DelAgua	8
Bain-marie	1
Microscope	1
Filtration ramp of 6 posts	1
Digesdahl	1

Staff of the laboratory:

Physico-chemist specialist	1
Biochemist	2
Math-physician	1
Pedagogue	1

Equipment of water quality laboratory of Division public hygiene of the Ministry of Health MINISANTE.

<u>Analytical equipment</u>	Quantity
Spectrophotometer DR2000	2
Kits DELAGUA	4
pH-meters	2
Conductimeter	2
Emergency Eye Wash	3
Distiller	1
Sterilizer pressure	1
Bain-Marie	1
Incubator	1
Microscope	1
Digital Titration	1
Mixer Thermolyne	2
Minutia	1
Refrigerator + ColiMug	2
Pbl International	1
Isotherm box	1
Water filter	1
Lens	1
Compteur de colonies	1

Staff of the laboratory

Technician in health genius	3
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Equipment of water quality laboratory of National University of Rwanda.

<u>Analytical equipment</u>	Quantity
<u>PHYSICO-CHEMICAL</u>	
Spectrophotometer CECIL CE 2041	1
Spectroquant NOVA 30	1
pH-meter pH 325-A-SET-1 WTW	1
pH-meter pH 538-A-SET-1 WTW	1
Reflectometer	1
Centrifuge JOUAN	1

Centrifuge de recuperation	1
Centrifuge	1
Balance KERN	1
Balance	1
Balance de precisin	1
Polarimeter EUROMEX PO 400	1
Magnetic agitator LABINCO	1
Bain-Marie GFL	1
Bain-Marie simple Bioblock-Polystat 33	1
Evaporator rotator RE 100 BIBBY	1
PARNAS & WARGNER	1
Turbidimeter NTU 1100	1
Oven NABERTHERM	1
Desiccate	1
Pycnometer BRAND	1

MICROBIOLOGY

Oven (four Pasteur)	1
Balance of precision	1
Autoclave OMEGA 10L	1
Autoclave big capacity	1
Incubator JOUAN	1
Fridge OCEAN	1
Fridge HOT POINT	1
Microscope HUND	1
Bain-Marie GIFL	1
Stomacher IUL	1
Agitate LABINGO	1
Membrane GELMAN filtration	1
Distillate	1
GASPAK	1
Lampe UV SBS	1
STYEBOILER	1
Etuve	1
Extractor SOXHLET	1
Oven NABERTHERM	1
Desiccate	1
Turbidimeter NTU 1100	1
Pycnometre BRAND	2

Staff of the laboratory

Chef of the laboratory
Two technicians in chemistry and in biology

Equipment of ELECTROGAZ

<u>Analytical equipment</u>	Quantity
Spectrophotometer HACH 2000	1
Spectrophotometer DR HACH 2010	1
Balance SARTORIUS	1
pH-meter Sensor 1	1
pH-meter Sensor 2	1
Conductimeter	1
Sensor 5	1
Turbidimeter 2100P	1
Colorimeter	1
Oven	1
Distillate	1
Electrical plate	1
Agitator magnetic	1
Floculateur	1
Bain-Marie	1
Incubator Memmert	1
Sterilizer	1
Autoclave	1
Burette automatic	1
Ramp filtrate	1
Hotter	1
<u>Staff of the laboratory</u>	
Chef of the laboratory	1
Chemist	1
Biologist	

APPENDICE 2

Table 1 : Results of physico-chemical and chemical analysis of the main rivers of the Nile Basin in Rwanda

These measures have been done in mid-August and end of September 2000. the fourteen sites of sampling consist of the main rivers of the basin of the Nile to Rwanda, that are: Mwogo, Rukarara, Mbirume, Nyabarongo, Mukungwa, Nyabugogo, Base, Agatobwe, Migina, Akanyaru, Kabogobogo, Ruvubu, Akagera, Ngoma, Muvumba I, Muvumba II and Kagitumba.

Before the confluence of two rivers, three samples have been appropriated, it means two before the meeting of these rivers at the rate of one by river and the third after mixture.

Site	Nom de la rivière	T°C	pH	D.O mg/l	Salinity mg/l	Cond. µS/cm	Acid. mg/l	Alkal. mg/l		Colour Hazen	S.M mg/l	Turbidity FTU
								TA	TAC			
I.	A. MWOGO	19.8	6.41	0.74	0.030	70.5	30	0	24	246	20	46
	B. RUKARARA	20.7	6.56	7.90	0.010	36	12	0	10	299	43	59
	C. MWOG + RUKARARA	20.4	6.53	5.56	0.015	56	22	0	16	262	31	48
II.	A. MWOGO	23.3	7.05	7.73	0.010	54	18	0	14	309	42	58
	B. MBIRUME	24.9	7.30	7.74	0.020	67	20	0	14	730	120	142
	C. NYABARONGO	24.7	7.22	7.50	0.020	66	18	0	16	720	108	123
III.	A. NYABARONGO	20	6.95	9.06	0.010	48	48	0	35	1130	252	273
	B. MUKUNGWA	19.8	8.43	9.41	0.130	290	0	10	135	47	1	7
	C. NYABAR + MUKUNG	20.3	8.22	9.24	0.090	219	4	8	130	224	79	91
IV.	A. NYABARONGO	22.6	8.10	7.90	0.070	176	44	0	110	429	18	200
	B. NYABUGOGO	22.4	6.80	3.36	0.050	141	32	0	55	385	4	41
	C. NYABAR + NYABUGO	22.8	8.00	7.48	0.068	173	40	0	100	453	106	109
V.	A. NYABARONGO	22.4	7.95	7.50	0.080	186	70	0	120	225	14	210
	B. AKANYARU	21.7	6.59	5.55	0.010	45	22	0	45	344	46	101
	C. NYABAR + AKANYAR	22.2	7.58	7.65	0.050	135	28	0	115	211	113	180
VI.	A. AKAGERA	23.3	7.29	4.55	0.090	214	10	0	38	344	45	76
	B. RUVUBU	24	6.40	7.15	0.010	57	4	0	16	146	11	31
	C. AKAG + RUVU	23.3	7.17	5.75	0.060	149	14	0	28	342	42	73
VII.	A. AKAGERA	24.2	7.05	4.80	0.050	133	8	0	28	164	11	39
VIII.	A. NGOMA	20.0	6.71	7.28	0.050	133	8	0	8	930	223	373
	B. MUVUMBA	19.9	6.85	7.96	0.060	156	10	0	8	1050	367	461
	C. MUV + NGOM	19.9	6.83	7.70	0.060	154	8	0	8	1240	129	209
IX.	A. KAGITUMBA	22.5	7.07	7.38	0.050	127	4	0	10	172	15	48
X.	A. AKANYARU	19.7	6.87	9.03	0.003	17.4	4	0	6	372	37	40
	B. AGATOBWE	19.8	7.41	8.90	0.010	50	4	0	8	96	7	17
	C. AKANY + AGAT	20.3	7.06	8.50	0.006	36	14	0	6	240	16	38
XI.	A. KABOGOBOGO	23.2	7.06	7.80	0.070	172	10	0	6	154	11	36
XII.	A. AKANYARU	24.1	6.77	7.84	0.010	48	2	0	4	820	170	362
XIII.	A. MIGINA	20.8	6.92	8.45	0.030	98	4	0	10	70	6	10
XIV.	A. BASE	21.3	6.95	7.52	0.010	53	22	0	30	312	25	65

Site	Name of Nile rivers in Rwanda	Total hardness mg/l	Calcite hardness mg/l	CO ₂ mg/l	Ca ²⁺ mg/l	Mg ²⁺ mg/l	Cl ⁻ mg/l	F ⁻ mg/l	NO ₂ ⁻ mg/l	I ₂ µ/l	N-NH ₃ mg/l	SO ₄ ²⁻ mg/l	PO ₄ ³⁻ mg/l
I.	A. MWOGO	20	15	15	6	1.45	10	0.00	0.077	<0.20	0.18	5	0.425
	B. RUKARARA	8	5	7	2	0.87	2	0.00	0.120	<0.20	0.14	11	0.475
	C. MWOGO + RUKARARA	12	10	10	4	0.58	6	0.00	0.115	<0.20	0.15	7.5	0.600
II.	A. MWOGO	20	15	3	6	1.45	2	0.00	0.080	<0.20	0.14	5	0.450
	B. MBIRUME	12	5	5	2	2.03	6	0.00	0.147	<0.20	0.31	17.5	0.825
	C. NYABARONGO	16	15	4	6	0.29	6	0.00	0.127	<0.20	0.17	10	0.800
III.	A. NYABARONGO	20	16	10	6.4	1.16	9	0.00	0.088	<0.20	0.14	20	0.800
	B. MUKUNGWA	92	32	0	12.8	17.4	3	0.57	0.032	<0.20	0.08	5	0.170
	C. NYABARO + MUKUNGWA	72	32	3	12.8	11.6	9	0.40	0.058	<0.20	0.07	15	0.350
IV.	A. NYABARONGO	52	28	1	11.2	6.96	9	0.95	0.037	<0.20	0.09	28	0.600
	B. NYABUGOGO	44	32	19	12.8	3.48	18	1.85	0.183	7.619	1.70	19	0.500
	C. NYABUG + NYABARO	48	16	2	6.4	9.28	6	1.52	0.059	2.510	0.60	26	0.550
V.	A. NYABARONGO	60	16	3	6.76	12.76	9	0.23	0.045	<0.20	0.10	20	0.610
	B. AKANYARU	24	16	25	6.76	2.32	12	0.27	0.057	<0.20	0.07	17	0.330
	C. NYABAR + AKANYA	44	16	5	6.76	8.12	12	0.26	0.047	<0.20	0.08	18	0.420
VI.	A. AKAGERA	32	16	5	6.76	4.64	6	0.42	0.093	<0.20	0.55	20	0.600
	B. RUVUBU	24	16	12	6.76	3.32	2	0.27	0.073	<0.20	0.11	22.5	0.400
	C. AKAGERA + RUVUB	26	16	6	6.76	2.90	10	0.30	0.088	<0.20	0.52	20	0.725
VII.	A. AKAGERA	50	8	7	3.2	12.18	2	0.75	0.075	<0.20	0.08	12.5	0.45
VIII.	A. NGOMA	36	28	4	11.2	2.32	12	0.71	0.205	<0.20	1.42	27.5	1.175
	B. MUVUMBA	72	28	3	11.2	12.76	12	0.89	0.308	<0.20	1.56	22.5	1.275
	C. MUVUMB + NGOMA	56	24	3	9.6	9.28	12	0.76	0.228	<0.20	1.51	23	1.075
IX.	A. KAGITUMBA	40	24	3	9.6	4.64	12	0.78	0.080	<0.20	0.12	18	0.675
X.	A. AKANYARU	14	7.5	3	3	1.88	15	0.07	0.035	<0.20	0.16	17.5	0.825
	B. AGATOBWE	16	9	1	3.6	2.03	25	0.00	0.025	<0.20	0.00	17.5	0.500
	C. AKANY + AGAT	14	7.5	2	3	1.88	20	0.03	0.039	<0.20	0.06	17	0.450
XI.	A. KABOGOBOGO	22	20	3	8	0.58	25	0.00	0.035	<0.20	0.00	32.5	0.150
XII.	A. AKANYARU	14	7.5	2	3	1.88	10	0.02	0.137	<0.20	1.21	37.5	0.620
XIII.	A. MIGINA	18	14.5	3	5.8	1.02	25	0.00	0.025	<0.20	0.00	20	0.250
XIV.	A. BASE	24	24	7	9.6	0	6	0.17	0.069	<0.20	0.20	29	0.280

ite	Nom de la rivière	Cu ²⁺ mg/l	Mn mg/l	Cr ⁶⁺ µ/l	Fe mg/l	Na mg/l	K mg/l	C.P.S % Na
I.	A. MWOGO	0.150	0.175	0.275	0.900	4.74	1.52	45.66
	B. RUKARARA	0.300	0.325	0.275	0.875	3.34	1.12	60.84
	C. MWOGO + RUKARARA	0.200	0.250	0.300	0.900	3.36	1.15	49.61
II.	A. MWOGO	0.220	0.175	0.225	0.900	3.46	0.85	36.65
	B. MBIRUME	0.060	0.325	0.275	0.950	4.26	1.11	57.13
	C. NYABARONGO	0.240	0.150	0.275	0.910	3.87	0.97	43.48
III.	A. NYABARONGO	0.200	0.140	0.100	1.700	4.44	1.23	42.86
	B. MUKUNGWA	0.275	0.180	0.090	0.740	105.3	19.50	80.51
	C. NYABAR + MUKUNGWA	0.214	0.140	0.100	1.550	14.50	16.68	56.10
IV.	A. NYABARONGO	0.202	0.140	0.110	1.420	7.09	4.53	39.02
	B. NYABUGOGO	1.300	0.080	0.120	2.440	14.20	3.03	51.42
	C. NYABUG + NYABARONGO	0.275	0.100	0.110	2.000	10.94	9.20	56.22
V.	A. NYABARONGO	0.025	0.070	0.120	1.740	13.20	12.81	57.13
	B. AKANYARU	0.006	0.140	0.100	2.130	4.32	1.14	37.55
	C. NYAB ARONGO + AKANYARU	0.009	0.090	0.120	2.020	8.70	9.31	54.76
VI.	A. AKAGERA	0.020	0.125	0.275	0.780	9.85	6.76	59.30
	B. RUVUBU	0.050	0.050	0.250	1.490	12.68	10.94	72.23
	C. AKAG ERA + RUVUBU	0.030	0.150	0.325	0.090	11.90	10.85	70.19
VII.	A. AKAGERA	0.025	0.150	0.550	0.660	7.800	7.24	49.44
VIII.	A. NGOMA	0.100	1.02	0.700	1.430	8.60	5.77	51.52
	B. MUVUMBA	0.105	0.135	0.750	1.950	15.20	4.59	45.23
	C. MUV UMB + NGOMA	0.101	1.075	0.700	1.890	10.32	4.69	44.29
IX.	A. KAGITUMBA	0.101	0.175	0.250	1.540	9.02	2.81	45.37
X.	A. AKANYARU	0.090	0.175	0.300	1.000	2.73	1.15	44.29
	B. AGATOBWE	0.025	0.150	0.250	0.825	6.34	1.45	58.05
	C. AKANYAR + AGATOBWE	0.050	0.175	0.275	0.900	3.13	1.23	47.19
XI.	A. KABOGOBOGO	0.050	0.100	0.275	0.525	13.50	1.26	72.88
XII.	A. AKANYARU	0.060	0.425	0.500	3.370	2.56	1.38	44.67
XIII.	A. MIGINA	0.050	0.050	0.275	0.600	5.12	0.93	47.01
XIV.	A. BASE	0.475	0.130	0.130	2.300	1.650	0.50	18.30

C.P.S: Coefficient of Soil Permeability

APPENDICE 3

Table 2 : Quality control of pretreatment water by ELECTROGAZ

Paramètres de la qualité	Kimisagara	Kadahokwa	Muhazi	Rwasaburo	Nyamabuye	Cyunyu	Karengye	Shyogwe	Nyabarongo	Kanyabusage	Mpanga	Gihira	Mutobo	Gihuma	Gisuma
Coliformes Totaux /100ml	1497,83	194,50				166,50									
Couleur APHA	726,67				15,00		393,92								
Turbidité cm			50,00		50,00			18,60	5,71	50,00		1,25			
Turbidité FTU	124,783	195,81				188,58	42,83	434,93	8,73				0,00		18,80
PH	7,63	6,46	8,21	5,00	4,95	6,98	7,53	6,46	7,59	6,64	5,98	6,79	6,85	6,43	6,79
Chlore Résiduel mg/l	0,00			0,00		0,00				0,00					0,08
TA °F	0,00	0,00	0,00		0,00	0,00	0,00	0,00		0,00	0,00	0,00	0,00	0,00	0,00
TAC °F	1,26	0,97	145,25	0,63	0,83	1,41	7,51	17,11		1,73	2,30	2,84	8,98	2,72	0,92
TCa °F	2,00	1,10	155,08		0,81	0,24	4,38	5,20			0,20	1,75	1,05	1,36	1,37
TMg °F	1,00	1,20	48,83		0,76	0,30		2,08							
TH °F	3,00	2,60	203,75	20,00	1,56	0,55	9,50	7,28		2,33	0,35	3,97	4,20	4,79	2,98
Matière en suspension mg/l	81,38						22,75								
Matière organique mg/l	3,74	2,66			0,00	4,75	14,83	2,94				13,70			1,00
CO ₂ libre mg/l	4,79				25,79			17,28		3,78					0,20
Oxygène dissous mg/l	5,48														
Silicates	59,35														
Azote ammoniacal mg/l	0,56						0,36			0,89		0,50			
Chlorures Cl ⁻ mg/l	7,40						20,18								0,00
Nitrites NO ₂ ⁻ mg/l	0,00	0,01					0,18			0,00		0,03	0,00	0,01	
Nitrates NO ₃ ⁻ mg/l	2,36	1,60					0,98			22,92		22,83			0,48
Cyanure CN ⁻ mg/l	0,00											0,00			
Bromure Br ⁻ mg/l	0,22														
Iodure I ⁻ mg/l	0,40														
Fluorure F ⁻ mg/l	0,11														
Sulfate SO ₄ ²⁻ mg/l	14,58						0,00			28,83					
Phosphate PO ₄ ³⁻ mg/l	0,12						0,43			0,82		20,00			0,50
Ammonium NH ₄ ⁺ mg/l	0,80								0,81						0,18
Calcium Ca ²⁺ mg/l	20,00						42,92	51,96					8,30		10,76
Magnésium Mg ²⁺ mg/l	10,00					0,30	44,00	20,79				2,30	33,75		20,17
Manganèse Mn ²⁺ mg/l	0,36			0,00			0,25	1,00	0,39			0,70			0,21
Fer Fe ³⁺ mg/l	2,35	0,18					1,07	1,16	1,57	0,00		2,66			0,40
Cuivre Cu ²⁺ mg/l	0,02						0,058								
Zinc Zn ²⁺ mg/l	0,03														
Baryum Ba ²⁺ mg/l	2,50	3,80													
Chrome Cr ²⁺ mg/l	0,02														
Plomb Pb ²⁺ µg/l	34,38														
Cadmium Cd ²⁺ µg/l	7,45														

Aluminium Al ³⁺ mg/l	0,00														
Température °C	22,18			20,20		22,64				23,27			17,1	17,18	
Conductivité µS/cm	69,13			149,82						221,16				318,75	
Total solide dissous mg/l	34,48														
Salinité	0,00														

Table 3 : Quality control on water treated

Paramètres de la qualité	Kimisagara	Kadahokwa	Muhazi	Rwasaburo	Nyamabuye	Cyunyu	Karengé	Shyogwe	Nyabarongo	Kanyabusage	Mpanga	Gihira	Mutobo	Gihuma	Gisuma
Coliformes totaux /100ml	0,00	0,00													
Couleur APHA	4,78				15,00		0,08								
Turbidité cm			50,00		50,00			50,00	50,00	50,00		50,00			
Turbidité FTU	0,86	5,00				5,00	0,67	5,23			0,80	9,69	0,00		5,45
PH	7,78	6,65	7,93	6,12	6,29	6,92	6,94	7,16	7,75	7,50	6,47	6,88	6,99	7,00	7,28
Chlore Résiduel mg/l	0,74	1,18	1,02	0,75	1,18	0,75	1,53	1,02	1,42	1,42	0,60	2,23	0,95	0,56	0,83
TA °F	0,00	0,00	0,00		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TAC °F	4,60	1,13	136,67	0,71	1,87	1,00	0,00	19,94	1,75	1,75	2,43	1,83	9,23	2,92	2,28
TCa °F	7,47	3,69	152,75		1,16	0,43	5,17	7,62			0,20	7,67	1,05	2,00	3,49
TMg °F	1,80	2,20	48,33		1,09	0,32		2,88							
TH °F	9,31	5,42	204,42	30,00	2,25	0,74	11,50	10,21	2,08	2,08	0,40	9,65	4,20	9,64	6,96
Matière en Suspension mg/l	0,17						0,08								
Matière Organique mg/l	0,86	1,14			0,00	1,40	1,18	0,60				1,45			0,40
CO ₂ libre mg/l	4,39				6,44			5,52	3,83	3,83					0,10
Oxygène dissous mg/l	5,52														
Silicates	42,91														
Azote ammoniacal mg/l	0,02						0,04		0,74	0,74					
Chlorures Cl ⁻ mg/l	4,42						26,47		1,50	1,50					
Nitrites NO ₂ ⁻ mg/l	0,00	0,00					0,06		0,00	0,00		0,00			0,12
Nitrates NO ₃ ⁻ mg/l	2,85	1,35					0,98		22,73	22,73		2,67			0,85
Cyanure CN ⁻ mg/l	0,00								23,00	23,00		0,00			
Bromure Br ⁻ mg/l	0,93														
Iodure I ⁻ mg/l	1,43														
Fluorure F ⁻ mg/l	0,37														
Sulfate SO ₄ ²⁻ mg/l	58,29						75,00		27,92	27,92					
Phosphate PO ₄ ³⁻ mg/l	0,10						0,13		0,78	0,78		0,00			0,50
Ammonium NH ₄ ⁺ mg/l	0,02											0,00			0,10
Calcium Ca ²⁺ mg/l	73,00						51,67	76,24					8,30		35,00
Magnésium Mg ²⁺ mg/l	18,00					0,31	53,91	30,98				2,40	33,75		31,82
Manganèse Mn ²⁺ mg/l	0,01				0,00		0,07	0,10				0,17			3,20
Fer Fe ³⁺ mg/l	0,05	0,01					0,04	0,32	0,02	0,00		0,08			0,05
Cuivre Cu ²⁺ mg/l	0,01						0,00								
Zinc Zn ²⁺ mg/l	0,02														
Baryum Ba ²⁺ mg/l	1,46	3,00													

Chrome Cr ²⁺ mg/l	0,01													
Plomb Pb ²⁺ µg/l	48,00													
Cadmium Cd ²⁺ µg/l	10,59													
Aluminium Al ³⁺ mg/l	0,01													
Température °C	22,38	17,80				20,83						18,85	17,50	
Conductivité µS/cm	218,44											202,00	319,00	
Total Solide dissous mg/l	108,44													
Salinité	0,10													

APPENDICE 4:

Table 3 : Data base on pollutants domestic waste water – Kigali April 1991

N°	Sampling station	BOD ₅ (mg/L)	COD (mg/L)	SM (mg/L)
1	Hospital CHK input waste to treatment station	155	220	10
2	Hospital CHK output waste from treatment	11	56	0,5
3	Hotel Diplomat	105	122	0,1
4	Treatment station Caisse Social du Rwanda input	408	1124	15
5	Treatment station Caisse Social du Rwanda output	31	203	0,8
6	Hotel des Milles Collines (mini station)	101	515	3,5
7	Central Prison of Kigali	840	9200	370

Table 4 : data base on organic pollutants industry waste water – Kigali April 1991

N°	Sampling station	BOD ₅ (mg/L)	COD (mg/L)	SM (mg/L)
1	TOLIRWA	600	1.406	800
2	UTEXIRWA treatment station input	278	2000	8
3	UTEXIRWA treatment station output	105	863	0,1
4	SULFO INDUSTRY	54	80	1,5
5	SIRWA color	70	385	1
6	BRALIRWA	25	699	0,1

Information data from. : SGI INGENIEURS – CONSEILS April 1991

APPENDICE 6 : Team of the baseline study

Name	Organisation	Post
Dr Joseph Mukasa Ahorukomeye	NTEAP	Consultant, chef of the team
Dr Habimana Jean Bosco		Consultant
KABALISA Vincent de Paul	MINITERE	Chef of division of water management
BIRORI Mardochee	MINITERE	Chef of laboratory
NKONGORI John	ELECTROGAZ	Staff of laboratory