TECHNICAL ASSISTANCE IN ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT

WATER QUALITY MANAGEMENT

30/10/2020 REPORT

IDENTIFICATION OF POLLUTION HOTSPOTS

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ABBREVIATIONS AND ACRONYMS

BOD	Biochemical Oxygen Demand
CFC	Chlorofluorocarbon
CH_4	Methane
Co	Cobalt
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
Cu	Copper
CWS	Coffee Washing Stations
DNAPL	Dense non-aqueous phase liquid
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry (South African)
EAC	East African Community
EC	Electrical Conductivity
EDCs	Endocrine Disrupting Chemicals
EDPRS-2	Economic Development Poverty Reduction Strategy - 2
EIA	Environmental Impact Assessment
EIP	Early Implementation Project
EUCL	Energy Utility Corporation Ltd
FONERWA	National Fund for Environment
GHG	Green House Gases
GIS	Geographical Information System
GoR	Government of Rwanda
ha	Hectare
IWRM	Integrated Water Resources Management
K	Potassium
LNAPL	Light non-aqueous phase liquid
LVB	Lake Victoria Basin
LVEMP	Lake Victoria Environmental Management Project
M&E	Monitoring and Evaluation

MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MIGEPROF	Ministry of Family and Gender Promotion
MINAFFET	Ministry of Foreign Affairs and Cooperation
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINEACOM	Ministry of Trade, Industry and East African Community Affairs
MINECOFIN	Ministry of Finance and economic Planning
MINEDUC	Ministry of Education
MINEDUC	Ministry of Education
MINICOM	Ministry of Commerce
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MIS	Management Information System
MISWWTS **MoE**	Management Information System for Wastewater Treatment Systems Ministry of Environment
N	Nitrogen
N_2O	Nitrous oxide
NGO	Non-Governmental Organization
NH_4	Ammonia
NO_2	Nitrite
NO_3	Nitrate
NPS	Nonpoint Source
NWRMP	National Water Resources Master Plan
NWRS	National Water Resources Strategy
P	Phosphate
PCB	Polychlorinated biphenyls
PhACs	Pharmaceutically Active Compounds

PM	Particulate matter
PM_{10}	Particulate matter of 10 microns
$PM_{2.5}$	Particulate matter of 2.5 microns
POPs	Persistent Organic Pollutants
RDB	Rwanda Development Board
RECP	Resource Efficiency and Cleaner Production
REMA	Rwanda Environment Management Authority
RNRA	Rwanda Natural Resources Authority
RRECPC	Rwanda Resource Efficiency and Cleaner Production Centre
RWFA	Rwanda Water and Forestry Authority
SANS	South African National Standard
SAR	Sodium Adsorption Ratio
SCOP	Stockholm Convention on Persistent Organic Pollutants
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SWAT	Soil and Water Assessment Tool (river basin model)
TCE	Trichloroethylene
TN	Total Nitrogen
TP	Total Phosphorus
UNEP	United Nations Environment Program
USA	United States of America
USD	US Dollar
USEPA	US Environmental Protection Agency
USLE	Universal Soil Loss Equation
UST	Underground storage tanks
WASAC	Water and Sanitation Corporation
WHO	World Health Organisation
WWTW	Wastewater Treatment Works

GLOSSARY OF TERMS

This glossary is an alphabetical list of terms used in this report that are either unique or specialized, along with a simple and concise explanation of what each term means.

Alkalinity The sum of the anions of weak acids, plus hydroxyl, carbonate and bicarbonate ions in water.

Biochemical oxygen demand :(BOD) The amount of oxygen consumed by aerobic biological organisms (biota) in water, to break down organic material present in a given water sample at certain temperature over a specific time period. It is a measure of the portion of organic carbon that is relatively easily oxidized by micro-organisms. It is used as an indicator of dissolved organic carbon, often in conjunction with chemical oxygen demand (COD).

Catchment : The area of land that contributes water to a particular river. Includes the natural resources, people and land use activities on the area of land.

Chemical oxygen demand (COD) :A measure of the oxygen requirement of organic matter in water. It is used as an indicator of dissolved organic carbon, often in conjunction with biochemical oxygen demand (BOD).

Endocrine disrupting chemicals (EDC) :Chemicals that, at certain doses, can interfere with endocrine (or hormone) systems of humans and living organisms. These disruptions can cause cancerous tumours, birth defects, and other developmental disorders.

Erosion : The action of surface processes (water or wind) that remove earth materials from one location and transport it to another. Rainfall, and the resulting runoff from rainfall, produces soil erosion. The different forms of soil erosion are: splash, sheet, rill, and gully erosion. The impact of a falling raindrop creates splash erosion - once surface runoff occurs, loosened soil particles, termed sediment, will be transported. Sheet erosion is the transport of sediment by overland flow, with rill erosion occurring as concentrated flow paths. Gully erosion occurs as a certain threshold is reached and flow paths become deeper channels.

Eutrophication: The process whereby nutrients accumulate in a body of water to the extent that problems occur with macrophyte, algal and cyanobacterial growth.

Heavy metals A metallic element with atomic number greater than 20 (i.e. that of calcium). Many can be toxic.

Hydrocarbons: Organic compounds that are made of only hydrogen and carbon atoms. They are found in many places, including crude oil and natural gas.

Nonpoint sources :A source of pollution whose initial impact on a water resource occurs over a wide area or long river reach (such as un-channeled surface runoff from agricultural land or a dense settlement). Also referred to as Diffuse Sources.

Pathogen A bacterium, virus, or other microorganism that can cause disease.

Persistent Organic Pollutants (POPs) :Organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes.

Point sources :A source of pollution whose initial impact on a water resource is at a well-defined local point (such as a pipe or canal).

Polluter-pays principle :The principle that those responsible for environmental damage must pay the repair costs, both to the environment and to human health, and must also pay the costs of preventive measures to reduce or prevent further pollution and environmental damage.

Pollution Contamination caused by waste, harmful biochemical products derived from human activities, that may alter man's habitat and cause adverse effects on the environment like man's social wellbeing, animals, flora and fauna and the world he or she lives in.

Runoff That part of precipitation that does not evaporate and is not transpired, but flows through the ground or over the ground surface and returns to bodies of water.

Salinisation Increase in the amount of inorganic salts or dissolved solids in the water.

Sedimentation (Refer to Erosion above) Once loosened soil is picked up by either wind or water, it is termed "sediment". In terms of soil erosion, sediments collected by the flow of water may be transported by rolling or sliding along the floor of a river (bedload) or by suspension in the moving fluid (suspension) before being deposited. A catchment may be considered to be made up of a patchwork of sediment source zones (source of sediment) and sink zones (sediment deposition areas), with sediment spending most time in storage. Management of sedimentation therefore needs to be at the catchment scale in order to effectively manage the irregular pattern of sources and sinks throughout the catchment.

Soil moisture Water stored in or at the land surface and available for evapotranspiration.

Watershed A catchment boundary is called a watershed, which is usually on the highest point between 2 catchments e.g. on top of a ridge, hill or mountain. A watershed divides the pathways that water will follow/drain into the catchments on either side of it. A watershed is therefore referred to as the source area of catchments.

CHAPTER 1 INTRODUCTION

1.1 Introduction to the overall project

The Government of Rwanda is implementing a pilot project of Least Developed Countries Funds II (LCDF II) titled “Building resilience of communities living in degraded forests, savannahs and wetlands of Rwanda through an Ecosystem-based Adaptation (EbA) approach“. The project is funded by Global Environment Facility (GEF) through United Nations Environment Programme (UNEP) under climate change adaptation GEF focal area for total duration of four years. The main objective of the project is to increase capacity of Rwandan authorities and local communities to adapt to climate change by implementing Ecosystem based Adaptation (EbA) interventions in degraded forests, savannahs and wetlands ecosystems. The project is being implemented for restoration of Nyiramuhondi watershed in Ngororero District; Murago wetland and Lake Cyohoha North in Bugesera District; Kibare lakeshores in Kayonza District and Nyandungu wetland in Gasabo and Kicukiro Districts; and Lake Ruhondo in Musanze District

The consultancy entitled “Technical Assistance in Environmental Management Project” is among the key studies that will be carried out under LCDF II/REMA project. This study will collate current knowledge on status and health of wetland and catchment ecosystems in Rwanda with particular focus on Nile-Akagera upper, Nile-Nyabarongo lower and Nile-Nyabarongo upper catchments including Nyiramuhondi watershed

The specific tasks for this consultancy in Technical Assistance in Environmental Management are the following:

- Strategic Plan for Ecosystem Based Adaptation and Wetland Management which includes a status quo description, national wetland management plan, guidelines for wetland management, and technical support with implementation of the plan.;
- Water Quality Management which includes identification of pollution hotspots in Rwanda, develop water quality management guidelines, develop water quality management plan for Rwanda, a water quality modelling tool, and integrated urban pollution management plans for five urban areas.;
- Develop integrated catchment management for some catchments in Rwanda (Nile-Akagera upper, Nile-Nyabarongo lower and Nile-Nyabarongo upper including Nyiramuhondi watershed), and
- Capacity building and training.

The present document is part of Water Quality Management task and constitutes the Final Report of Identification of Pollution hotspots.

1.2 Introduction to the Water Quality Management task

There are five overarching objectives for the Water Quality Management task, namely to identify pollution hotspots and develop spatial pollution indices, to develop simple modelling tools, to develop guidelines for water quality management, to develop a water quality management plan for Rwanda, and to develop an Integrated Pollution Management/ Plans for Nile-Nyabarongo upper, Nile-Nyabarongo lower, Nile-Mukungwa as well as Nile-Akagera upper catchments

This report presents the findings from the objective one on identification of pollution hotspots and development of spatial pollution indices. It considers the feedbacks and recommendations to the inception phase made by Rwanda Environment Management Authority (REMA) and the technical task force put in place to follow up this consultancy.

According to the term of reference for this objective, the consultant is required to review the existing programs, plans, projects and the legal framework for water pollution management in Rwanda, particularly as they affect wetland ecosystems. Through development and geo-referencing additional data sets and/or imagery as necessary, establish national data-layers representing indices of point-source and non-point-source pollution that impact key water quality indicators such as BOD, COD, DO, Nitrates, heavy metals etc. (recognizing that erosion issues are covered under the catchment planning). Indices should be based not only on the underlying generation of pollutants, but also on the extent to which measures / investments are already in place to manage them.

- For point sources, this should cover human waste and industrial waste, including indices related to e.g. size of urban settlements and type / capacity of sanitation facilities available; approximate numbers and types of industries and application of clean production / effluent treatment facilities.
- For non-point sources, this should include metrics related to land use practices, agrichemical application (based on local consumption and/or specific types of agricultural practices), rural population density, and types and maintenance of rural infrastructure (particularly roads).

1.3 Layout of the report

This report consist of the following chapters:

Chapter 1 introduces the overall Technical Assistance in Environmental Management project, the water quality management task, context of this report and the layout of the report.

Chapter 2 briefly describes the methodology that was followed to collate the information for the pollution indices sub-task and compilation of the report.

Chapter 3 provides an overview of institutions in Rwanda involved in water quality management, legislation that deals with water quality management, and an introduction to policies, strategies and plans relating to water quality management. It also introduces Rwandan water quality standards and guidelines.

Chapter 4 describes point and non-point sources of pollution in Rwanda.

Chapter 5 describes water quality concerns and indicators of pollution in Rwanda.

Chapter 6 describes the initial list of priority pollution sources and water quality constituents / concerns.

Chapter 7 draws conclusions that are applicable to the development of water quality management guidelines, a water quality management plan for Rwanda, and Integrated Pollution Management Plans for five for Nile-Nyabarongo upper, Nile-Nyabarongo lower, Nile-Mukungwa as well Nile-Akagera upper catchments

CHAPTER 2 METHODOLOGY

This report focuses on collating data and information on the status of water quality and water pollution in Rwanda and to develop spatial pollution indices. Where appropriate, consideration was given to water quantity in order to estimate possible pollutant loads. The project team have developed geo-referenced layers of suitable indices of point- and nonpoint sources of pollution. A wide range of water pollution indices were considered to portray the status of key water quality indicators such as sediment/turbidity, BOD, COD, dissolved oxygen, nutrients, and microbial status. Descriptions of fitness for use were based on national and regional (e.g.EAC) water quality guidelines and standards where such were available, and these are presented in this report. Where applicable, assessment of pollution indicators also considered air, soil and solid waste pollution and its impacts on surface water resources

2.1 Water quality management status quo

A high-level overview was undertaken of institutions involved in pollution management, legislation, policies and strategies, plans and programmes, as well as water and air pollution standards and guidelines. The objective was to map out the key players and the tools they use with respect to pollution management in Rwanda. The primary source of information was information published on the Internet by the respective ministries and their implementing agents. In this chapter a brief review was also undertaken of water and air quality standards and guidelines applicable to Rwanda and recommendations were made about the development (or adoption) of water quality guidelines that can be used to assess the fitness for use for different water user sectors. User sectors include for example, domestic water use, irrigation water use, industrial water use, etc. Although the examples given in this section refer mostly to the South African Water Quality Guidelines, reference is made to other guidelines developed by countries such as the USA, Canada, and Australia. The chapter is concluded with an overview of steps to develop a simple Water Quality Index that can be used to report water quality to the public.

2.2 Pollution sources

Sources of pollution were reviewed, and a distinction was made between point and nonpoint sources of pollution.

Based on the fact that point sources discharge their effluents to the well-known stream channels or surface water bodies through conduits such as outfall pipes, ditches or canals, indices for describing point sources were investigated and focused on domestic and industrial wastewater, and where data available included the type and capacity of wastewater treatment facilities, other sanitation facilities, numbers and types and industries and their effluent treatment facilities, types of storm water drainage systems, etc. The Ministry of Trade and Industry's guidelines to promote industrial parks and land use zoning, which include environmental and social interests, were also consulted in this task.

For nonpoint sources; the focus was put on sources of pollutants that may contribute to water quality issues such as air deposition, soil and solid waste pollutants as well as other activities associated with localized high activity areas, such as mines, intensive animal raising units, landfills, and industrial sites.

Where information was obtained about the location of different pollution sources, it was plotted on maps to indicate their distribution in Rwanda, as well as the concentration of different sources in certain areas. In some cases, where information on the location of non-point source was only available as maps published in reports rather than in digital format, such map were reproduced in this report.

The sources of information for this chapter were various studies undertaken in Rwanda into pollution area. Three studies are of particular relevance for the completion of this section:

- The first was an integrated study of wastewater treatment systems in Rwanda that was undertaken and completed in 2015 by ENGIN for REMA (ENGIN, 2015). The report refers to the development of a comprehensive management information system for wastewater treatment systems (MISWWTS). This information system contained data on wastewater treatment systems, their location, size of the works and wastewater treatment technologies used, etc.
- The second was a study being undertaken by NIRAS for the Ministry of Environment, "Results-based monitoring and evaluation system". The objective of the Water Pollution Baseline Study of the larger NIRAS study was to establish a reliable estimate of the current level of pollution of surface water bodies in the country together with a clear and reliable understanding of the principal sources of this, and to establish a baseline against which future monitoring can be conducted. The results of this study also informed the assessment of the pollution constituents and the impacts on water users and ecosystems.
- The third study was an investigation into the effluent quality discharged by industries in the Lake Victoria basin (Ministry of Trade and Industry, 2017).

Where required additional documents were consulted to complete information collected in the above studies

2.3 Pollution constituents

A wide range of pollutants were considered, and attempts were made to describe the situation in Rwanda even though it may not be a concern, or yet a concern. The pollutants included the ones specified in the TOR of the project (biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), Nitrates, heavy metals) as well as other pollutants. The collection of data and information for the pollution task consisted of internet searches, interviews with stakeholders with specialist knowledge of water pollution in Rwanda, and the review of existing monitoring data and similar projects. This includes stakeholders in government departments and well as consultants and NGOs. The team consulted with appropriate institutions and agencies (including WASAC, REMA, RWFA, etc.) for existing data, plans, policies, strategies and regulations. The team also worked with other consultants conducting water quality related studies for REMA, RWFA, and Ministry of Environment to build on existing work rather than duplicate it. A first step was to develop a stakeholder list in collaboration with the REMA and RWFA. The team w accessed reports available in the public domain as well as project reports held by stakeholders. A referral technique was used to identify new sources of data and information as the data collation activities progressed. Published information has been taken up in the project bibliography.

To assess the spatial situation with respect to different water quality constituents, water quality monitoring data were obtained from RWFA for the period 2011 – 2017, representing annual sampling surveys carried out in Oct – Nov 2011, Apr-May 2012, Oct – Nov 2012, Apr-May 2016, Sep 2016, and Apr-May 2017 respectively. These data sets represented monitoring that was undertaken on behalf of RWFA (or its legacy organisation). Use was made of bubble maps to visually display the spatial situation for different constituents. A bubble chart is used to visualize a data set in two to three dimensions. The first two dimensions are visualized as the X and Y coordinates of the sampling point, and the third as size of the bubble (concentration). The average concentration for each constituent, at each sampling point, was calculated for the whole data period, and these were then plotted as bubble on a map of Rwanda. The size of the bubble is an indication of the mean concentration, and for each bubble map a key if provided to indicate the concentration. The actual mean concentrations are provided in an Appendix to this report.

In order to assess the impacts of pollutants on the receiving environment, the observed pollutant concentrations were compared to the guidelines used in Rwanda (RNRA, 2012a, b, c) to ensure continuity in assessment criteria Table 2-1 below provides the list of constituents and target values used to assess the fitness for use as presented

Table 2-1: List of constituents and target values used to assess the fitness for use (MoE, 2017)

No	Constituent	Abbreviation	Target value	Units	Target type
1	Dissolved oxygen	DO	>68	% saturation	Lower limit
2	Hydrogen potential	pH	6.5 – 8.5	pH units	Range
3	Electrical Conductivity	EC	<1000	µS/cm	Upper limit
4	Dissolved inorganic nitrogen (Nitrite + nitrate)	DIN	<3	mg/l	Upper limit
5	Dissolved inorganic phosphorus	DIP	<5	mg/l	Upper limit
6	Temperature	T	<25	°C	Upper limit
7	Total dissolved solids	TDS	<500	mg/l	Upper limit
8	Total suspended solids	TSS	<30	mg/l	Upper limit
9	Turbidity	Turb	<150	NTU	Upper limit
10	Escherichia coli	E coli	<4	cfu/100ml	Upper limit

2.4 Identification of potential pollution hotspots

For the purpose of this report, pollution hotspots were defined as geographic areas where there is a high density of various pollution sources that could have a negative impact on the local population or the local environment. It was decided to exclude known individual point sources (for example problematic industrial dischargers, landfills, or wastewater treatment works discharges that do not meet effluent limits). The focus in this investigation was on the cumulative impacts in a specific geographic area. Problematic point sources have already been documented in a number of reports (MINICOM, 2017; ENGIN, 2015, MoE, 2017).

To identify pollution hotspots, a number of GIS overlays were used. These included coverages of urban areas, mining activities, industries, coffee washing stations, tea factories, as well as the location of the water quality monitoring networks useded by RWFA and the University of Rwanda. These coverages along with the information provided in the various reports consulted during the compilation of this report, were used to identify potential geographic hotspots.

As stipulated in the terms of reference for this task, sedimentation was mostly disregarded because it is such a pervasive problem throughout the country, and it has been investigated in great detail. See for example Karamage et al. (2016), which provided a very good overview of soil erosion in Rwanda and its relationship to crop production. Erosion and sedimentation is also dealt with in greater detail in the integrated catchment management plans developed for the Akagera Mugesera Catchment and the Nyabarongo Downstream Catchment as part of this project.

CHAPTER 3 REVIEW OF POLICIES AND REGULATIONS

3.1 Introduction

Rwanda is facing a multi-faceted water challenge, which, if not addressed effectively, has the potential to significantly limit the economic growth potential of the country, especially considering the deteriorating water quality in the country. The deterioration in water quality is a factor of growing concern. Importantly, deteriorating water quality is an economic and developmental issue, and should be addressed as such. Without a change in how water resources are managed, worsening resource water quality will continue to erode the socio-economic benefits from, and increase the costs associated with, the use of the country's water resources.

One focus of this project is to develop Water Quality Management Guidelines, and Plans for Rwanda that are relevant to addressing water quality deterioration and that are pragmatic, implementable and appropriate to the future institutional and governance landscape in Rwanda.

The objective of this assessment of pollution indices is to identify water pollution issues, sources of pollution, and water quality management challenges for Rwanda by providing a high-level overview of the water pollution situation, the institutions involved in pollution management, as well as the legislation, policies and strategies that have been developed to govern different aspects of development and environmental/pollution management in Rwanda. Further chapters of the report provide a review of a wide range of pollution issues, mostly related to surface water, the root causes of water quality deterioration in rivers and lakes, and geographical differences in water quality issues across Rwanda.

3.2 Institutions involved in pollution management

Table 3-1 below includes a list of the institutions which play a role in pollution management.

Table 3-1: Institutions which play a role in pollution management

Institutions		Roles and responsibilities
Ministries	Ministry of Environment	Ensure that environment and pollution control policies and strategies are passed by Cabinet and communicated to stakeholders. The Ministry of Environment also leads and actively participates in resource mobilisation; provides policy oversight to strategy implementation including enforcement of accountability and continued alignment to high level political interests.
	Ministry of Local government (MINALOC)	Establish, Develop and Facilitate the management of efficient and effective decentralized government systems capable of law enforcement and delivery of required services to the local communities.
	Ministry of Infrastructure (MININFRA)	Develop institutional and legal frameworks, national policies, strategies and master plans relating to water supply and sanitation.
	Ministry of Trade and Industry (MINICOM)	The Ministry of Trade and Industry has a vision to achieve accelerated and sustained economic growth led by a dynamic and competitive private sector.

		The mission is to facilitate Rwanda's economic transformation through enabling a competitive private sector integrated into regional and global markets, while ensuring a level playing field and the protection of consumers. The above mission will be achieved through accomplishing the following strategic objectives: ● To create a business environment conducive to growth and the protection of consumers. ● To increase the share of services and manufacturing in GDP ● To support private sector growth and job creation with a focus on SMEs. ● To promote trade integration into regional and global markets with a focus on improving Rwanda's trade balance.To build an effective human resource base and institutional capacity for delivery.
	Ministry of Agriculture and Animal Resources (MINAGRI)	MINAGRI is the ministry responsible for the development of agriculture and animal resources in Rwanda. The objective of agricultural development is to monitor and evaluate the implementation of programs related to crop production, and to formulate policies and strategies to support agriculture. With respect to animal resources the ministry develops and monitors policies, strategies, and guidelines to improve animal resources in the country. These policies, strategies, and guidelines deal, amongst other, with the One Cow per poor family program, promoting milk production and the dairy industry, improving animal production and meat consumption, promoting small stock such as sheep, goats, pigs and rabbits, beekeeping, and promoting aquaculture. The ministry with its implementing agencies play a pivotal role in managing pollution from agriculture.
	Ministry of Health (MoH)	The Ministry of Health provide and continually improves the health services of the Rwandan population through the provision of preventive, curative and rehabilitative health care thereby contributing to the reduction of poverty and enhancing the general well-being of the population. The ministry deals, amongst other, with outbreaks of waterborne diseases, and promoting sanitation practices to prevent the contamination of water with waterborne pathogens.
Regulatory Institutions	Rwanda Environment Management Authority (REMA)	REMA is mandated to facilitate coordination and oversight of the implementation of national environmental policy and the subsequent legislation. It develops regulations and ensure protection and conservation of the Environment and natural resources across the country. REMA has, amongst other, a department for Environmental Regulation and Pollution Control. This department is responsible for ensuring that environmental degradation is prevented, and remedial measures are proposed where degradation occurs. It also develops regulations, guidelines and procedures

		aimed at promoting better environmental sustainability of developmental activities. Its main functions are: ▪ Coordinating activities related to formulation and setting up of environmental regulations and standards; ▪ Coordinating enforcement activities including overall supervision of environmental auditing and inspection activities; ▪ Ensuring regulatory compliance and environmental management conditions are being adhered to and proposing appropriate enforcement action in cases of non-compliance; ▪ Preparing inspection and audit plans, methodology and procedures; ▪ Preparing procedures and safeguards for the prevention of accidents which may cause environmental degradation and evolving remedial measures where accidents occur. Coordinating the development of programs for prevention and control of pollutants including hazardous substances and wastes.
	Rwanda Utilities Regulatory Agency (RURA)	In relation with pollution management, RURA mainly intervenes in water and sanitation sector with mandate to regulate the provision of water services in a way that promotes fair competition, sustainable and efficient use of water resources and to ensure that water service providers offer a good quality of service in regards to drinking water. The authority has also to ensure that the sanitation sub-sector is effectively promoted through regulation of sanitation services. Sanitation regulation consists of establishing regulatory tools necessary for the sound regulation of sanitation services in Rwanda, licensing sanitation service provision, monitor compliance by licensees with license terms and conditions through audits and inspections conducted to sanitation service providers and analyze reports from sanitation service providers
	Rwanda Standards Board(RSB))	Provision of standards based solutions for Consumer Protection and Trade promotion for socio-economic growth in a safe and stable environment. Set standards for, amongst other, drinking water, domestic wastewater discharges, industrial wastewater discharges, limits for irrigation water supply, and for livestock watering.

	Rwanda Water Resources Board (RWB)	Rwanda Water Board is in charge of water resources management in Rwanda Rwanda Water Resources Board (RWB) has the following responsibilities: 1° to implement national policies, laws and strategies related to water resources; 2° to advise the Government on matters related to water resources; 3° to establish strategies aimed at knowledge based on research on water resources knowledge, forecasting on water availability, quality and demand; 4° to establish strategies related to the protection of catchments and coordinate the implementation of erosion control plans; 5° to establish floods management strategies; 6° to establish water storage infrastructure; 7° to establish water resources allocation plans; 8° to establish water resources quality and quantity preservation strategies; 9° to control and enforce water resources use efficiency; 10° to examine the preparation of roads, bridges, dams and settlements designs in order to ensure flood mitigation and water storage standards; 11° to monitor the implementation of flood mitigation measures and water storage during the implementation of roads, bridges and settlements' plans;
	Rwanda Investigation Bureau (RIB)	The 2018 reforms in the criminal investigation arrangements in Rwanda lead to the formation of RIB under which the Environment Protection Unit (EPU) has the overall mission to meet the investigation and prosecution obligations as stipulated in the 2005 Organic Law determining the modalities of protection, conservation and promotion of environment in Rwanda.
	Rwanda Agricultural Board (RAB)	The Rwanda Agriculture Board is an autonomous body that has the general mission of championing the agriculture sector development into a knowledge based; technology driven and market oriented industry, using modern methods in crop, animal, fisheries, forestry and soil and water management in food, fibre and fuel wood production and processing. Through its Department of Land Husbandry, Irrigation & Mechanization, best irrigation management practices can be promoted to protect receiving rivers and lakes, and through its Department of Animal Resources good livestock management practices can be promoted to minimize the impact on water resources.
	Rwanda Biomedical Centre (RBC)	The Rwanda Biomedical Centre (RBC) was to establish a Centre of Excellence to ensure quality health service delivery, education and research. The Centre has developed standard operating procedure (SOPs) for water borne diseases such as cholera, dysentery, typhoid fever, etc.

		These SOP's describe amongst other, procedures for the detection and confirmation of outbreaks, outbreak investigation procedures, and strategies for controlling water borne disease outbreaks.
	National Agricultural Export Development Board (NAEB)	NAEB falls under the Ministry of Agriculture and Animal Resources and is a merger of the Rwanda Tea Development Authority, Rwanda Coffee Development Authority and Rwanda Horticulture Development Authority. Its purpose includes identification of suitable locations to establish factories for processing agricultural and livestock products for export, to set quality standards for agriculture and livestock export commodities and make sure they are complied with, and to promote increased investment in industry and infrastructure meant for adding value to agricultural and livestock products for export. As such, NAEB has an influence on pollution from agricultural processing plants.
Management/Service Institutions	Water and Sanitation Corporation (WASAC)	The Water and Sanitation Corporation (WASAC) is the entity setup to manage the water and sanitation services in Rwanda. It does this by providing quality, reliable and affordable water and sewerage services through continuous innovations and detailed care to the needs of Rwanda's population. With respect to pollution, WASAC often have to treat water contaminated with high sediments, organic matter, and algae, to drinking water standards. It is also responsible for compliance to domestic wastewater standards at WWTWs.
	Rwanda Development Board (RDB)	Support enforcement of regulations and laws by incorporating them into Investment regulation and monitoring instruments including incentives and information packages. RDB also evaluate project proposal and decide if an EIA is required or not. In case an EIA is required, RDB will assess the document and issue EIA certificate.
	Local Government Authorities	Plan, mobilise resources, supervise and monitor the implementation of pollution management programme, projects and activities in line with the overall GoR policies, laws and strategies related to pollution management.
	Rwanda Resource Efficient and Cleaner Production Centre (RRECPC)	The RRECPC was established to promote resource efficiency and cleaner production in Rwandan industries. The vision of the RRECPC is to become a Centre of excellence and merit for Resource Efficient and Cleaner Production Technologies and sustainable development of enterprises in Rwanda. Its mission is to promote resource efficient and cleaner production practices for production efficiency, environmental performance and human development of Rwandan enterprises. The overall objective of the RRECPC is to improve resource productivity and environmental performance of businesses and other organizations; thereby contributing to a sustainable industrial development and sustainable consumption and production for Rwanda's transitional economy. This contributes to strategic goals and outcomes of the EDPRS 2.

	Water User Organisations(WUOs)	Water Users Organisation in irrigation (WUOs) is an association formed by all water users of a defined irrigation scheme. It is endowed with a legal personality in view of the management, enhancement and sustainability of the water resource and irrigation scheme. The Ministry of Agriculture and Animal Resources, is responsible for regulation, monitoring and evaluating the performance of all Irrigation WUAs.
	Water Management Committees (WMCs)	Water management committees that will operate and maintain the water facilities at a district level, and help with monitoring, especially in rural areas not served by WASAC. Sometimes also referred to as District hydrographic committees.
	Catchment Committees	Since catchment boundaries are not identical to administrative, catchment committees bring together physical representatives of key stakeholders from multiple districts in the same catchment, either in full or partly. The Catchment office will be hosted in the catchment area and will liaise with all stakeholders that rely on the same catchment. In relation to pollution control, the Catchment Committee shall have the following responsibilities among others: 1°identify the issues and priorities to be addressed by the catchment management plan; 2° Provide information on water bodies at risk of depletion, flooding or water quality degradation; 3° Monitor the implementation of the water quality management plan; 4° Settle disputes among water users at the initial stage; 5° Monitor the compliance of water use permit on ground and advise accordingly;
	Non-Governmental Organizations (NGOs)	Supplement the public-sector efforts in water resource management and development. Empower communities and Water user groups with skills, knowledge and information in IWRM. Enhance advocacy and accountability in water service delivery and watershed protection.

3.3 Legislation related to pollution management

Table 3-2 below includes a summary of the relevant legislation related to pollution management.

Table 3-2: Summary of relevant pollution management legislation

Legislation	# and date	Relevance to pollution
The National Constitution	2003 (Amended in 2015)	The constitution of Rwanda guarantees the right to a clean environment for every citizen and other people living in Rwanda, and imposes on the state and population, the responsibility for keeping the environment clean and pollution-free. Article 23 states that everyone has the right to live in a clean and healthy environment. while Article 53 of the amended Constitution states that everyone has the duty to protect, safeguard and promote the environment, that the State should ensure that the protection of the environment, and do so by means of a law that determines the modalities for the protecting, conserving and promoting the environment.
Law determining the use and management of water resources in Rwanda	Law N°49/2018 of 13/08/2018	This Law determines the use and management of water resources in Rwanda. It defines 'water' as a good belonging to the state public domain, recognizing the right to water for all. The Water Law provides a clear framework for the principles of integrated water resources management, including the prevention of pollution, and the principle of "user pays" and "polluter pays. It also provide that polluting water bodies by dumping, spilling or depositing chemicals of any nature above tolerable limit for human health or aquatic life, commits an offence (art.37) and set penalties for the defaulters
Law on environment	Law No 48/2018 of 13/08/2018	This Law determines modalities for protecting, conserving and promoting the environment. The law on environment gives effect to the National Environment and Climate Change Policy, which sets out how to transform into a nation that has a clean and healthy environment, resilient to climate variability and change that supports a high quality of life for its society. It defines the responsibilities of citizen and state and set principles for exploiting natural resources such as land, water, forests and air as well as protecting biodiversity, among others. The law requires all project developers whose projects may have harmful effects on the environment to carry out environmental impact assessment (EIA) before launching them. Articles 17, 18, 19 and 20 provide guidance on conservation and protection of built environment, focusing on the management of liquid and solid wastes, management of hazardous and toxic wastes and the management of electronic wastes. Article 42, 43, and 45 provide for prohibited acts, including prohibited acts in wetlands and protected areas, prohibited emission of noise, prohibited acts in protection of biodiversity and prohibitions related to chemicals and wastes At last the law provides for administrative sanctions for all defaulters (from art.46 to art.60)

Law relating to the prohibition of manufacturing, importation, use and sale of plastic carry bags and single-use plastic items	Law N° 17/2019 of 10/08/2019	This Law prohibits the manufacturing, importation, use and sale of plastic carry bags and single-use plastic items. The law is expected to check the increasing habit of unnecessary consumption and disposal of single use plastic items which becomes a burden to the environment.
Law governing the preservation of air quality and prevention of air pollution in Rwanda	No. 18/2016 of 18/05/2016	This Law applies to all measures aimed at the preservation of air quality as well as all elements or activities likely to affect air quality or pollute the atmosphere. The law sets, amongst other, air quality standards, and describes compliance with minimum air quality standards, emission limits, specific tolerance limit of pollutants from industries, inspection of air pollutants from the transport sector, air pollutants from construction works, air pollutants from the storage of objects, air pollutants from waste incineration, and air pollutants from other sources. The law also makes provision for administrative sanctions.
Ministerial Order establishing the list of projects that must undergo environmental impact assessment, instructions, requirements and procedures to conduct environmental impact assessment	No 001/2019 of 15/04/2019	This Order establishes: 1° the list of projects that must undergo an environmental impact assessment before they obtain authorisation for their implementation; 2° instructions, requirements and procedures for conducting environmental impact assessment.
Ministerial Order **Determining the list of Water Pollutants**	No. 004/16.01 of 24/05/2013	This order defines a water pollutant and then provides a list of: ▪ Physico-chemical pollutants; ▪ Organoleptic Pollutants & Organic Pollutants; ▪ Radionuclides; and ▪ Biological Pollutants.

Ministerial Order Establishing Modalities of Inspecting Companies or Activities that Pollute the Environment	N° 006/2008 of 15/08/2008	This ministerial order describes the modalities of inspecting companies or activities that pollute the environment. It describes, amongst other, the responsibilities of inspectors, search and seizure of pollution products, analysis of suspected products, and decisions that REMA can take.
The Code of Criminal Procedure	No. 30/2013 of 24/5/2013	The Code of Criminal Procedure currently in force has been enacted in 2013. It governs the procedures by which authorities investigate, prosecute, and adjudicate crimes which includes environment offences.

3.4 Policies related to pollution management

Table 3-3 below includes a summary of the relevant policies related to pollution management.

Table 3-3: Summary of relevant pollution management policies

Policies	Date	Relevance to pollution
National Environment and Climate Change	2018	The National Environment and Climate Change Policy provides strategic direction and responses to the emerging issues and critical challenges in environmental management and climate change adaptation and mitigation. The policy goal is for "Rwanda to have a clean and healthy environment resilient to climate variability and change that supports a high quality of life for its society." It sets up two key principles related to pollution management: ● *Polluter Pays Principle* according to which those responsible for environmental damage must be held liable for the repair caused to both the physical and human environments. They must also be held responsible for the costs of preventive measures to reduce or prevent further pollution and environmental damage. ● *The Pollution Prevention Principle* which anticipates problems and prevents negative impacts on the environment and people's environmental rights Key policy statement related to pollution management include: ● Prevent and promote integrated pollution control and waste management

		● Promote the circular economy to advance sustainable consumption and production patterns: ● Promote green technologies and procurement: and ● Promote sustainable management of wetlands.
National Water Resources Management Policy	December 2011	The overall goal pursued in this water policy is to manage and develop the water resources of Rwanda in an integrated and sustainable manner, so as to secure and provide water of adequate quantity and quality for all social and economic needs of the present and future generations, and ensure full participation of all stakeholders in decisions affecting water resources management. For this purpose, the Government shall: ▪ Monitor and assess water resources to understand the water balance and to support water accounting, identify the spatial and temporal occurrence and distribution in the country; ▪ Formulate a water resources management strategy addressing, inter alia, watershed protection and provides mechanisms for the designation of special conservation and or protection zones; ▪ Promote water conservation techniques and technologies, including rainwater harvesting, water recycling and other appropriate technologies.
National Water Supply Policy	December, 2016	The vision of water supply policy is to ensure sustainable, equitable, reliable and affordable access to safe drinking water for all Rwandans, as a contribution to improving public health and socio-economic development. The mission of water supply sector is to Plan, build and operate water and sanitation services in a sustainable, efficient and equitable manner. Core instruments, capacities and administrative processes will be established/revised to ensure effective sector programme management and water sector programme steering Policy objectives:

		1. Raise rural water supply coverage to 100 per cent by fast tracking implementation of a strategic investment programme 2. Ensure affordable rural water supply services and sustainable functionality of rural water supply infrastructure 3. Ensure safe, reliable and affordable urban water supply services for all (100 per cent service coverage by 2018) while striving for full cost recovery. 4. Ensure safe, affordable and reliable water supply services for schools, health facilities and other public places 5. Strengthen the sector's institutional and capacity
National Sanitation Policy		The vision of National Sanitation Policy is to ensure sustainable, equitable and affordable access to safe sanitation and waste management services for all Rwandans, as a contribution to poverty reduction, public health, economic development and environmental protection while the mission is to promote, plan, build and operate services in a sustainable, efficient and equitable manner. Core instruments, capacities and administrative processes will be established to ensure effective sector programme management and sanitation sector programme steering Objectives: 1. Raise and sustain household sanitation coverage to 100 per cent by 2020, and promote hygiene behaviour change 2. Implement improved sanitation for schools, health facilities and other public institutions and locations 3. Develop safe, well-regulated and affordable off site sanitation services (sewerage and sludge collection, treatment and reuse/disposal) for densely populated areas. 6. Enhance storm water management in urban areas to mitigate impacts on properties, infrastructure, human health and the environment5. Implement integrated solid waste management in ways that are protective to human health and the environment. Ensure safe management of e-waste, industrial wastes, nuclear waste and health care waste

Mining Policy	13 January 2010	Covers wider aspects of regulation, institutional and investment framework for the mining industry, value addition and capacity building strategies as well as providing a clear plan of action to support the sub sector's growth. This policy targets to improve the mining sector knowledge, skills and use of best use of best practices.
Electronic Waste Policy **(Draft)**	Not yet adopted in Sept 2017	E-waste (Electronic waste) refers to discarded office and household electronic and electrical equipment and components destined for reuse, resale, salvage, recycling or disposal. It includes computers, entertainment electronic devices, mobile phones, television sets, refrigerators, etc. It is some of the fastest growing waste in the world, but it is much more hazardous. It is also a resource and its valuable components can be recycled and re-used. Rwanda has developed a draft E-Waste Management Policy and Bill, that intends to: ● Promote sustainable E-waste management processes and systems; ● Develop Small and Medium-sized Enterprises (SMEs) and create jobs by ● Promote investment in E-waste management; ● Protects the environment from E-waste pollution and hazardous materials by ○ establishing an adequate E-waste legal and regulatory framework; and ○ Develops a skilled workforce in E-Waste management (MINECOFIN, 2015).
Sustainable Development Goals (SDGs)	2016	Goal 3: Good Health and Well-Being. Ensuring healthy lives and promoting the well-being for all at all ages is essential to sustainable development. Increasing access to clean water and sanitation, reducing or eradicating wide range of diseases (water borne diseases-malaria etc.) Goal 6: Ensure access to water and sanitation for all. Poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families in Rwanda. Goal 14: Conserve and sustainably use the oceans, seas and marine resources. Our rainwater, drinking water, weather, climate, coastlines, much of our food, and even the oxygen in the air we

		breathe, are all ultimately provided and regulated by the sea. Air and water pollution management is essential to conserving this water resource. Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss. Polluted air can damage trees directly in the dry form or indirectly through its effects on the chemistry of water and soils and by making trees more vulnerable to other biological and environmental stressors. Acid rain weakens trees by damaging their leaves, limiting the nutrients available to them, or exposing them to toxic substances slowly released from the soil. Acid rain that flows into streams, lakes, and marshes also has serious ecological effects. In watersheds where soils do not have a buffering capacity, acid rain releases aluminium, which is highly toxic to many species of aquatic organisms, from soils into lakes and streams. Air pollution management is essential in sustainable management of Rwandan forests and combating the impacts. Goal 16: Promote just, peaceful and inclusive societies. Water pollutants in Rwanda are mainly from resultant human activities, thus by having inclusive institutions that promote inclusive participation at all times on environmental protection, then together improved conditions for life can be reached.
Vision 2020	Adopted in 2000	Vision 2020 recognizes sustainable environmental and climate change management as a cross-cutting pivotal area to the realization of national aspirations. It recognizes that the major problem in the field of environmental protection in Rwanda is the imbalance between the population and the natural resources. This leads to alarming degradation observed through massive deforestation, the depletion of biodiversity, erosion and landslides, pollution of waterways and the degradation of fragile ecosystems.
Vision 2050	Under development	Rwanda has made good progress on implementing Vision 2020, however in order to incorporate recent international agreements and development goals, it was required to develop a new Vision for Rwanda, the Vision 2050. This Vision 2050 will consider the lessons learned from Vision 2020 and is centred on ensuring high standards of living for all Rwandans, food security, protection of the Rwandan family, and improved access to affordable services in health, education, finance, housing, energy, infrastructure, amongst others. One of the main goals of the Vision 2050 is to work towards reaching an upper middle income by 2035 and high income by 2050. Currently, there is a national consultative

		process about the draft Vision 2050 report which is in draft format and still a confidential document yet to be made available to the public. Therefore, this section is to be updated once the Vision 2050 is made available.
National Forestry Policy	2018	The National Forestry Policy defines the government's medium to long-term intentions for the development and management of the national forest resources in the following seven policy statements: 1. The capacity of forest institutions and actors will be enhanced to match the requirements for Sustainable Forest Management (SFM); 2. Ensure Sustainable Forest Management through the establishment and implementation of integrated forest management plans at all levels; 3. Private sector will be encouraged to increase their investment in forestry sector; 4. Appropriate regulatory instruments will be developed and implemented to ensure sustainable and efficient biomass supply; 5. Biodiversity and ecosystems services and values will be enhanced in accordance with national and international agenda; 6. Active participation of stakeholders in Sustainable Forest Management to ensure ownership and proper benefit sharing; 7. The adoption of Agroforestry and Trees Outside Forest (TOFo) techniques will be enhanced to contribute to overall forest resources and agriculture productivity.
National Environmental Health policy	2008	The National Environmental Health Policy recognises that inadequate and unsanitary facilities for excreta disposal, poor management of liquid and solid wastes, and inadequate practices of handwashing with soap that leads to contamination of food and water in both rural and urban areas are contributing factors to environmental health related diseases. The policy focuses on the reduction of infant, child and adult morbidity and mortality rates by reducing and eliminating health risks associated with environmental hazards, which are the direct causes and spread of diseases and conditions related to environmental health through the following specific objectives: 1. Promoting a legal and regulatory framework that supports voluntary compliance and facilitates policy implementation by the various actors.

		2.Formulating an institutional framework that enables efficient coordination and collaboration of the various sectors and partners who have environmental health responsibilities. 3. Creating community awareness about factors that contribute to a poor environmental health situation, their prevention and means of promoting health. 4.Strengthening the capacity of environmental health personnel and community health workers so that they are efficient agents and catalysts in bringing about the desired change. 5.Promoting those practices, which ensure a healthy environment at household and community levels, whilst ensuring active participation of the population. 6.Ensure provision, sale, offer and exposure for sale food and water which is safe for human consumption.
Urbanisation and Human Settlements Policy	2015	This policy provides opportunities for alleviating pressure on rural land and biodiversity resources because increased urbanization raises challenges of utility supplies (water, energy, and housing) as well as waste disposal.
Industrial policy and Investment code	April 2011	Environmental compliance advisory (especially relating to Environmental Impact Assessment), has been included among the services provided by the RDB, which is an opportunity to promote sustainable Environment and Natural Resources management.
The National Biodiversity Policy	September 2011	The national biodiversity policy has been developed in Rwanda and seeks to address the following issues: improved management of protected areas, conservation of biodiversity outside protected areas, access to genetic resources and benefits sharing, agro-biodiversity, bio-prospecting and biodiversity business, and biodiversity knowledge management including research and indigenous knowledge.
National Industrial Policy	April 2011	The policy recognises that economic activities are intrinsically linked with the physical environment. The National Industrial Policy will enforce the implementation of Rwanda's environmental laws and policies, such as the requirement for industry relocation from marshland areas.

3.5 Strategies and plans related to pollution management

Table 3-4 below includes a summary of the relevant strategies and plans related to pollution management.

Table 3-4: Summary of relevant pollution management strategies and plans

Strategy	Date	Relevance to pollution
National Strategy for Transformation (NST1)	2017-2024	The National Strategy for Transformation (NST1) which is also the Seven Year Government Programme (7 YRGM) is an implementation instrument for the remainder of Vision 2020 and for the first years of the journey under vision 2050. This strategy is expected to lay the foundation for decades of sustained growth and transformation that will accelerate the move towards achieving high standards of living for all Rwandans. It is provided that during the seven years of implementation, the strategy will put emphasis on strengthening monitoring and evaluation.
Rwanda National Water Resources Master Plan	May 2014	The Rwanda NWRS Master Plan is the development of a Master Plan for sustainable water resources development, utilization and management in the country. The Masterplan shall be a blueprint for a process of sustainable water, land and related resources development and management with the aim to maximize economic and social welfare in an equitable manner while safeguarding the environment.
Water And Sanitation Sector Strategic Plan 2013/14 - 2017/18	June 2013	One of the central objectives of this water and sanitation services strategic plan that is relevant to pollution management is the environment and water resources protection, climate change and disaster management. It stipulates that the following: ▪ Water supply and sanitation services will be developed in close coordination with water resources management, based on an integrated approach. ▪ Water use should be rational and sustainable and shall abide with environmental regulations and safeguards. ▪ Waste disposal shall be planned and managed with a view to minimize environmental impact and ensure the protection of water resources.
Integrated development plan (IDP)	2012	Through the IDP, the GoR encourages adoption of holistic and cross-sectoral approaches in planning and development – integrating settlement, agriculture, infrastructure development, environmental protection and good governance.

3.6 Water quality standards and guidelines

The main purpose of water quality management is to either maintain an existing satisfactory water quality condition, or to change an unsatisfactory or polluted condition into a satisfactory condition. In most cases the satisfactory condition can be defined as "sustainable development which meets our own needs without endangering the ability of future generations to satisfy their needs". Although the definition of sustainable use is straightforward and easy to understand, translating this into measurable water quality management objectives is more difficult.

The status of water quality in a particular catchment can only be expressed in terms of fitness for use. This implies that there is a user or multiple users within a catchment, and that it is known how these user sectors (e.g. domestic, agricultural, industrial, cultural, etc.) is affected by changes in water quality. For a specific user sector, water quality can be 'ideal' or 'unacceptable' or something between these two extremes. Water quality guidelines and water quality standards provide guidance on interpreting water quality data for a particular user sector.

Water quality standards are generally rules establishing, for regulatory purposes, which specifies the limit of some unnatural alteration in water quality that is permitted or accepted as being compatible with some particular intended use or uses of water. In the case of wastewater discharge standards, it specifies a permissible concentration, which is legally enforceable, for waste that is discharged to the environment, in order to protect the long-term sustainable use of the receiving water body. In the case of a standard for potable water quality, it specifies a permissible concentration that is legally enforceable, for constituents in the water in order to protect the long-term health of consumers of drinking water, or protect household appliances against long-term damage.

Water quality guidelines, on the other hand are not legally enforceable, and it describes the effects of a change in water quality on domestic and industrial water users, agricultural crops, livestock, or aquatic organisms. Guidelines are generally expressed as a range of values, where each range is associated with a description of the fitness for use, and where the total range extends from the most ideal for a particular use, to the point of being totally unacceptable for that particular use. Guidelines also provide the necessary information for water users and water managers to assess water quality in general, as well as to evaluate the acceptability of land-use developments on water quality.

Water quality guidelines are used as the scientific basis for the development of water quality management objectives, to interpret data obtained from water quality monitoring, assess the effect of human activities on water quality, assess the effect of accidental spills, and to assess and evaluate management performance.

In this section, the Rwandan water quality standards for potable water, and for effluents discharges are presented, as well as water guidelines for irrigation water use and for livestock watering. These standards and guidelines have been developed by the Rwanda Standards Board and have been aligned with East Africa Standards.

1.1.1 Potable water standards

Rwanda Standard RS 435, as revised in 2011, specifies the limits for water that is treated to drinking water standards. The standard makes a distinction between drinking water supplied to consumers, and containerised or bottled drinking water. The standard specifies the physical, chemical, inorganic quality, organic quality, and microbiological limits that potable water need to comply with. The standard recognises that not all consumers receive treated potable water via a tap and specifies bacteriological limits for treated water entering a distribution system, or untreated water entering a distribution system, or water in a distribution system, unpiped supplies, and emergency supplies of water.

The standard has been aligned with other African and international standards and is probably appropriate for Rwanda as a member of the EAC. Enforcement and monitoring compliance to the standard will contribute to protecting the health of consumers, especially vulnerable individuals such as infants, the elderly, and sick, immunocompromised individuals.

Potable water standard should not be used to assess the fitness for use of raw water (river or lake water) because the standard sets the limits for water that has been treated to potable standards.

1.1.2 Water quality tolerance limits (guidelines) for particular water uses

1.1.2.1 Irrigation standards

Rwanda Standard RS 188 (2013) specifies the tolerance limits for water intended for irrigation purposes. The guideline specifies ranges for irrigation water that is ideal and would pose no problem for the crops being irrigated, upper limits which would be regarded as unacceptable for irrigation and severe problems can be expected, and the range between these extremes where increasing problems can be expected as the water quality deteriorate from the ideal to the unacceptable upper limits. RS 188 also recommends maximum concentrations of trace elements in irrigation water. Consideration can be given to describing the potential impacts on the major crops being irrigated in Rwanda, of increasing constituents' concentrations. Different crops have different tolerances for increasingly poorer irrigation water quality. This information would enable water resources managers to make informed decisions about possible changes in crop types should irrigation water quality deteriorate to such a point.

1.1.2.2 Livestock watering

Rwanda Standard RS 190 of 2013 specifies the characteristics, requirements and test methods for water to be used for livestock watering. RS 190 also provides guidance on the daily water consumption recommended for certain types of livestock. The guidelines are aligned with international water quality standards for raising and watering livestock.

1.1.3 Effluent standards

Rwanda Standard RS 110 of 2017 (Revised) provides the limits for the discharge of treated domestic wastewater effluent into the environment as well as the test methods that should be employed for the individual constituents.

A draft standard for the safe disposal of tannery effluent (DRS 363: 2017) has been published by the Rwanda Standards Board for public comment. This standard will probably become available in the near future.

Rwanda Standard RS 109 of 2009 specifies the limits for the discharge of treated industrial wastewater effluent into the environment as well as the test methods that should be employed for the individual constituents.

According to the EAC website, the EAC Secretariat is working to harmonise effluent discharge standards, strengthen the capacity of EAC Partner States in enforcement of pollution control laws and establish pollution monitoring system in the EAC, and urges Partner States to allocate more resources for the implementation of conventions to which they are party such as Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, and the Stockholm Convention on Persistent Organic Pollutants.

At an EAC regional RECP meeting organized held in Nairobi in July 2016 for harmonizing GIS mapping report, all EAC countries represented by Directors of National cleaner production centres and RECP Experts agreed to apply regional EAC standards in order to harmonize limits used to assess industrial pollution levels (Niyonzima, 2017). The EAC standards "East African Industrial and Municipal Effluents Standards" was published in January 2016 (EAC Gazette, 2016), and were based on the following criteria:

- The minimum values of National Environmental Authorities (NEMAs) pollution limits in milligrams per litre for the three countries (KENYA, UGANDA and TANZANIA) were consider for the minimum pollution load requirements for BOD, COD, TN & TP and a green colour code was assigned to effluents that meets were below this limit.
- The maximum values of National Environmental Authorities (NEMAs) pollution limits in milligrams per litre for the three above countries were considered for the medium pollution load requirements for BOD, COD, TN & TP. Effluents with concentrations between the minimum value and maximum value were assigned a blue colour.
- All pollution intensities in milligrams per litre greater than the medium pollution intensities were assigned a red colour.

Table 3-5: Regional EAC standards used to assess industrial wastewater effluents (MINICOM, 2017).

Minimum pollution load (Green)	Medium pollution load (Blue)	High pollution load (Red)
BOD < 30 mg/l	BOD between 31 – 250 mg/l	BOD > 500 mg/l
COD < 60 mg/l	COD between 61 – 500 mg/l	COD > 500 mg/l
TN < 10 mg/l	TN between 10 – 20 mg/l	TN > 20 mg/l
NO_3 < 5 mg/l	NO_3 between 5 – 10 mg/l	NO_3 > 10 mg/l
TP < 5 mg/l	TP between 5 – 10 mg/l	TP >10 mg/l

1.1.4 Air quality standards

The Rwanda air quality law was promulgated in May 2016 (Table 3-2) and it is supported by the Rwanda Standards Board who has developed emission standards and air quality specifications that are applicable for Rwanda and aligned with East African Community standards. These include:

- RS EAS 750 Air quality – emissions to the air by cement factories – guidelines. This Rwanda Standard published in 2011 is identical to the first edition 2010 Regional Standard EAS 750/2010 Air quality - Emissions to the air by cement factories - Guidelines.
- RS EAS 751 Air quality – specifications. This Rwanda Standard published in 2011 is identical to the first edition 2010 of Regional Standard EAS 751/2010 Air quality - Specification.
- RS EAS 752 Air Quality – Tolerance limits of emission discharges to the air by factories. This Rwanda Standard published in 2011 is identical to the first edition 2010 of regional Standard EAS 752/2010 Air quality – Tolerance limits of emission discharged to the air by factories.

The Air Quality Law applies to all measures aimed at the preservation of air quality as well as all elements or activities likely to affect air quality or pollute the atmosphere. Specific reference is made emissions from industries, vehicular transport, construction works, storage of objects that may interfere with air quality, waste incineration, and other sources. The law places an obligation on the authority responsible for regulating air quality to set, amongst other, air quality standards, and describes compliance with minimum air quality standards, emission limits, specific tolerance limit of pollutants from industries, inspection of air pollutants from the transport sector, air pollutants from construction works, air pollutants from the storage of objects, air pollutants from waste incineration, and air pollutants from other sources. Rwanda Standards published three standards, a guideline for emissions from cement factories, limits on emissions from factories, and general guidelines and limits on ambient air quality that are affected by emissions, and limits on emissions. The Standard gives two types of limits, namely “guidelines” and “limit levels”. The limit levels are defined as binding and shall be used for regulatory purposes. Limit levels are usually measurable in shorter periods averaging. On the other hand, the “guidelines” are based on studies that indicate safe levels averaged over relatively longer periods and mostly, they are derived from WHO Guidelines.

The Air Quality Law mandates REMA to establish ambient air quality standards, establish occupational air quality standards for various sources of air pollution, establish quality standards for emissions from different sources contributing to air pollution; establish specific quality standards for industries; determine stack heights of chimneys for air emissions; or prescribe any matter in relation with or affecting air emission quality standards. The three RS air quality standards appears to address most of these requirements but not the stack height specifications.

It is unclear why cement factories were specifically targeted with a separate standard. However, RS EAS 750 only provides guidelines and it is assumed that the minimum emission limits specified in RS EAS 751 would legally apply to those factories.

The law also mandates the authority to institute air quality monitoring. In July 2017 it was reported that REMA was working with other partners to implement an air pollution monitoring project which would include installation of facilities that measure the amount and composition of air pollutants in various locations in the country. It was also stated that REMA partnered with the police to introduce a mandatory car emission control check through the Motor Vehicle Inspection Centre. All vehicles undergoing technical control must take an emissions test.

What might be lacking is ways of dealing with cumulative impacts and the effect of local climatic conditions on ambient air quality. It is conceivable that the cumulative impacts of air pollution sources, all meeting their respective emission standards, may result in ambient air quality limits being exceeded due to localised climatic conditions. For example, Henniger (2013) described a temporary phenomenon for the air pollution indicators that is visible during clear and calm weather situations, e.g. the distinctive relief caused an accumulation within small valleys called "Marais" during the night time. It is therefore advisable that consideration be given to developing more stringent site-specific limits for the City of Kigali once monitoring data becomes available indicating exceedances despite good control over point sources.

1.1.5 Relevance

Standards and guidelines provides water resources managers with the tools to contextualise, and make sense of observed pollution data. Standards are legally enforceable instruments, while Guidelines are instruments designed to assess fitness for use.

- Standards - An assessment of compliance can be made by comparing observed effluent data to the effluent standards. If the observed effluent data falls below the limits set for a specific constituent, then the effluent is in compliance with the standard. If the observed effluent data exceeds the limits set in the standard, then the effluent is non-compliant and remedial action needs to be taken. The Rwandan standards have been aligned with EAC standards and these are appropriate for the managing pollution in the region.
- Guidelines - An assessment of the fitness for use can be made by comparing river or lake data to water quality guidelines for a specific use. If the observed river or lake quality data falls within the guidelines for a specific constituent and use (e.g. irrigation water use), then the water is ideally suited for that purpose and no problems are expected. If the observed river or lake data exceeds the limits set in the guidelines, then the water would be less suited for the intended use. As the quality becomes poorer and move away from the guideline limits, more problems can be expected until the water eventually becomes unacceptable for a specific use.

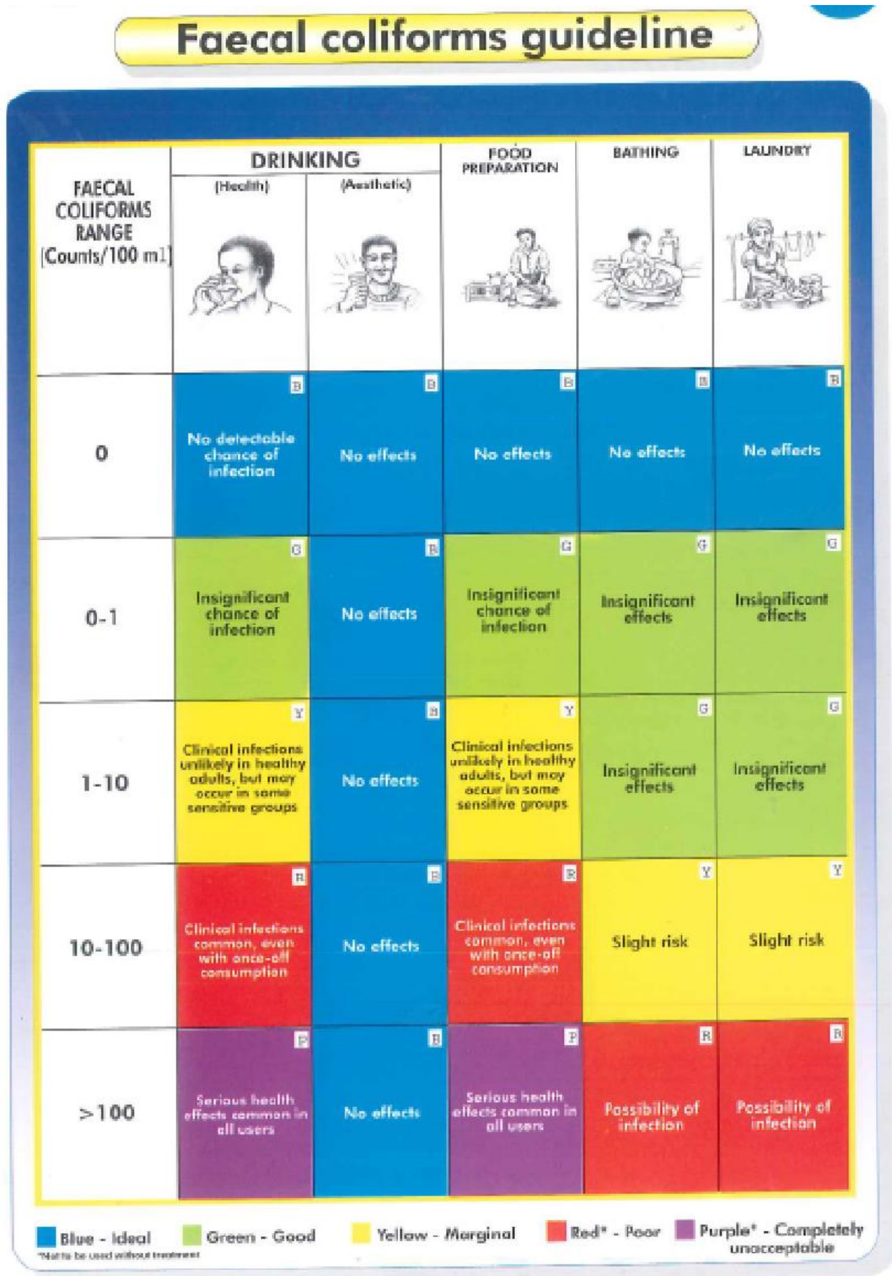
Rwanda can consider the development of country specific guidelines for specified uses which describes the impacts of deteriorating water quality on a specific user sector. In general, guidelines address a wider range of water quality constituents than would be addressed in water quality standards.

For example, South Africa has developed water quality guidelines for the following water uses (DWAF, 1996a-g): Domestic water use, Recreational water use, Industrial water use, Agricultural water use: Irrigation, Agricultural use: Livestock Watering, Agricultural water use: Aquaculture, and Aquatic Ecosystems.

The constituents considered for example for the Domestic water use guidelines were Algae, Aluminium, Ammonia, Arsenic, Asbestos, Atrazine, Cadmium, Calcium, Chloride, Chromium(VI), Colour, Copper, Corrosion, Dissolved Organic Carbon, Fluoride, Indicator Organisms (Heterotrophic Bacteria, Total Coliforms, Faecal Coliforms, Coliphages, Enteric Viruses, Protozoan Parasites), Iron, Lead, Magnesium, Manganese, Mercury, Nitrate, Odour, pH, Phenols, Potassium, Radioactivity, Selenium, Settleable Matter, Sodium, Sulphate, Trihalomethanes, Total Dissolved Solids, Total Hardness, Turbidity, Vanadium, and Zinc.

The South African water quality guidelines for domestic water supply (Water Research Commission, 1998) gives guidance on the ideal quality, and the possible consequences of progressively poorer quality water used for domestic purposes. Figure 3-1 shows an extract from the guideline document and shows an example of the guideline for Faecal coliforms. In this case the consequences are described for drinking water (health and aesthetic considerations), food preparation, bathing, and laundry. Please note, the aforementioned example is designed to assess the fitness of water for domestic purposes. Water that is treated for drinking water purposes, have to comply with South African drinking water standards (SANS 241) which is similar to the Rwanda Standard RS 435 for potable water. Figure 3-2 shows an extract from the Irrigation Water Guidelines (DWAF, 1996), specifically for the Sodium Adsorption Ratio (SAR). In this example it describes the possible consequences of irrigation water with increasing SAR values, on the soils being irrigated.

Countries such as the USA, Canada, and Australia have developed similar water quality guidelines for different water uses and these are available in the public domain. As an interim measure, Rwanda can consider identifying and adopting appropriate water quality guidelines from elsewhere to assess fitness for use until such time as the country has developed or customised guidelines for its own use.



Faecal coliforms guideline

FAECAL COLIFORMS RANGE (Counts/100 ml)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
0	B No detectable chance of infection	B No effects	B No effects	B No effects	B No effects
0-1	G Insignificant chance of infection	B No effects	G Insignificant chance of infection	G Insignificant effects	G Insignificant effects
1-10	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	B No effects	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	G Insignificant effects	G Insignificant effects
10-100	R Clinical infections common, even with once-off consumption	B No effects	R Clinical infections common, even with once-off consumption	Y Slight risk	Y Slight risk
>100	P Serious health effects common in all users	B No effects	P Serious health effects common in all users	R Possibility of infection	R Possibility of infection

Blue - Ideal Green - Good Yellow - Marginal Red* - Poor Purple* - Completely unacceptable

*Not to be used without treatment

Figure 3-1: Example of the South African Faecal coliform guideline for domestic water supply (WRC, 1998).

Table 2 : Effects of the SAR on Soil Physical Conditions

SAR Range	Infiltration Rate	Hydraulic Conductivity and Hardsetting
Target Water Quality Range • 1.5	***Should ensure an adequate infiltration rate for soils sensitive to the formation of infiltration rate-reducing surface seals under conditions of rainfall during the irrigation season or irrigation with water having an EC < 20 mS/m***	**No significant reduction in hydraulic conductivity below inherent soil hydraulic conductivity expected in this SAR range for any soil; no hardsetting above inherent hardsetting expected in any soil in this SAR range**
1.5 - 3.0	Infiltration problems likely to occur in soils sensitive to the formation of infiltration rate-reducing surface seals under conditions of rainfall during the irrigation season or irrigation with water having an EC < 20 mS/m; no problem is expected with irrigation waters having on EC > 90 mS/m and slight to moderate problems at ECs in the range of 20 - 90 mS/m	No significant reduction in hydraulic conductivity below inherent soil hydraulic conductivity expected in this SAR range for any soil; no hardsetting above inherent hardsetting expected in any soil in this SAR range
3.0 - 6.0	Infiltration problems likely to occur in soils sensitive to the formation of infiltration rate-reducing surface seals when irrigated with water having an EC < 25 mS/m; no problem is expected with irrigation waters having an EC > 130 mS/m and slight to moderate problems at ECs in the range of 25 - 130 mS/m	Hydraulic conductivity reduction likely to occur in soils sensitive to hydraulic conductivity reduction. A low EC in the soil solution may cause hydraulic conductivity to be irreversibly reduced by up to 25 % for sensitive soils; Hardsetting increasingly likely to occur in sensitive soils at ECs < 6O mSg/m for SAR = 3 and < 120 mS/m for SAR = 6
6.0 - 12.0	Infiltration problems likely to occur in soils sensitive to the formation of infiltration rate-reducing surface seals when irrigated with water having an EC < 35 mS/m; no problem is expected with irrigation waters having an EC > 200 mS/m and slight to moderate problems at ECs in the range of 35 - 200 mS/m	Hydraulic conductivity reduction likely to occur in soils sensitive to hydraulic conductivity reduction. A low EC in the soil solution may cause hydraulic conductivity to be irreversibly reduced by > 25 % for sensitive soils and < 25 % in less sensitive soils, depending on the particle size distribution of the soil and the type of clay mineral present in the clay size fraction. Tolerant soils will show little or no effect Small and reversible changes in hydraulics occur in sensitive soils when EC is in the range of 100 - 200 mS/m; Hardsetting likely to occur in sensitive soils at ECs < 120 mS/m for SAR = 6 and < 240 mS/m for SAR = 12

Figure 3-2: Example of the South African guideline for assessing irrigation water supply, for the sodium adsorption ratio of the water (DWAF, 1996).

Water quality index

A Water Quality Index (WQI) is a means by which water quality data is summarized for reporting to the public in a simple and a consistent manner. A WQI improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status, and evaluates water quality trends. These indices assess the appropriateness of the quality of the water for a variety of uses. The development process of a water quality index is generally done in four steps (Boyacioglu, 2007):

- Parameter selection - selecting the set of water quality variables of concern,
- Developing sub-indices - transformation of the different units and dimensions of water quality variables to a common scale,
- Assignment of weights - weighting of the water quality variables based on their relative importance to overall water quality, and

- Aggregation of sub-indices to produce an overall index - formulation of overall water quality index.

Ministry of Environment (2017a) described the development of a Water Quality Index based on the GEMS/Water quality index. The GEMS/Water Global Drinking Water Quality Index (GEMS Water, 2007) is based on the water quality index (WQI) endorsed by the Canadian Council of Ministers of the Environment. The index allows measurements of the frequency and extent to which parameters exceed their respective guidelines at each monitoring station. Therefore, the index reflects the quality of water for domestic purposes for both health and acceptability, as set by the World Health Organisation. The index is determined on an annual basis resulting in an overall rating for each sampling station per year. This allows both spatial and temporal assessment of global water quality to be undertaken.

Ministry of Environment (2017a) proposed to calculate a proximity-to-target (PTT) score for each determinant at single monitoring sites as the difference between the temporal average (for the reporting period) of the determinant concentration and the target divided by the range between the minimum or maximum of the measured determinant concentration (for exceedance and non-exceedance targets, respectively) and the target. The PTT scores are scaled to the range between 0 and 100, where 100 indicates that the target is met, and decreasing scores indicate an increasing distance from the target.

Furthermore, the water quality at sampling sites is then ranked using the Water Quality Index (WQI). The water quality index (WQI) at site level is computed as the arithmetic mean of the site-level PTT scores for the selected determinants. The WQI scale is then divided into different water quality categories, ranging from very bad to excellent. The team proposed further that for the spatial aggregation at the basin level and country level, the water bodies be divided into stretches of homogenous quality (between consecutive monitoring stations), and finally, the proportion of the stretches with good quality compared to all water bodies assessed.

It is recommended that the Government of Rwanda appoint a research organisation such as the University of Rwanda to evaluate a number of water quality indexes and to use the knowledge gained to develop a simple water quality index that is appropriate for Rwanda. Such a Water Quality Index should then be used to summarise and report the status of water quality in Rwanda to the general public.

CHAPTER 2 SOURCES OF POLLUTION

❖ Introduction

This chapter provides an overview of point and nonpoint sources of pollution in Rwanda.

The Law on Environment (No 48/2018 of 13/08/2018) defines **pollution** as the contamination caused by waste, harmful biochemical products derived from human activities that may alter man's habitat and cause adverse effects on the environment like man's social wellbeing, animals, flora and fauna and the world he or she lives in.

The Ministerial Order N°004/16.01 defined a **pollutant** as any substance that may contaminate a water body which is directly or indirectly discharged into such a water body and produces harmful effects to aquatic life.

Sources of pollution are generally divided into two categories, namely point sources and nonpoint sources:

- A **point sources** of pollution is one whose initial impact on a water resource is at a well-defined local point (such as a pipe or canal). The US EPA describes point sources of pollution as any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.
- **Nonpoint sources** (also called diffuse sources) of pollution whose initial impact on a water resource occurs over a wide area or long river reach (such as un-channelled surface runoff from agricultural land or stormwater and dry-weather runoff from a dense settlement). The US EPA describes nonpoint source pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and ground waters.

2.1 Point sources

The following were deemed to be key point sources with respect to pollution in Rwanda:

- Industrial point sources
- Wastewater treatment works
- Mining wastewater
- Coffee washing stations
- Solid waste dumps
- Air pollution point sources

2.1.1 Industrial point sources

Effluent discharges from industries can have a significant impact on receiving water bodies. These can include high concentrations of BOD/COD, nutrients, heavy metals, suspended solids, oils and grease, bacterial pathogens, etc

Ministry of Environment (2017) undertook a survey of pollution sources which included, amongst other, industrial sources. Their survey covered the entire country, and focussed on a sample of 517 major groups of water users which coffee washing stations, factories and industries, hydropower plants, irrigation schemes, mining companies and water treatment plants. These categories were considered because they were using huge amounts of water and they often discharged their wastewater directly into receiving water bodies. The industrial sectors, the pollutants associated with the sector, and examples of sector industries in Rwanda is presented in Table 4-1.

Table 4-1: Pollutants associated with different industrial sectors (modified from Ministry of Natural Resources, 2017)

Sector	Examples in Rwanda[1]	Pollutants associated with the industrial sector
Food and beverages	Inyange, Urwibutso, Nyabisindu dairy, Azam, BRALIRWA Ltd, Skol Ltd, SORWATOM, Tea Factories, Coffee washing stations, Fruits and Crops Initiatives, (FCI), CAFERWA, AKANOZE COTRA COPRA,	Microbes (E-coli, coliforms, BOD/COD, suspended solids
Chemicals	Sulfo Rwanda Industries, Mironko plastic industries, Ameki Color, paints industry	COD, organic chemicals, heavy metals, suspended solids, and cyanide
Mining	Rutongo Mines Ltd, Eurotrade International Ltd, Gatumba Mining Concessions Ltd, Natural Resources Development Ltd, numerous artisanal mines	Suspended solids, metals, acid, salts and mercury
Textile and leather	UTEXRWA, Kigali Leather	BOD, suspended solids, sulphates and Chromium
Pulp and paper	Trust Industries Ltd	pH, BOD/COD, suspended solids, chlorinated organic compounds
Petrochemicals and refineries		BOD, COD, Mineral oils, phenols and chromium
Iron and steel	SteelRwa	BOD, COD, oil, metals, acids, phenols and cyanide

[1] Some of the industries provided in the above list may have wastewater treatment plants to treat their wastewater. However, there is irregular audit/monitoring of compliance with guidelines for effluent discharges

Roofing	TOLIRWA, SAFINTRA, PETROCOM	Fe, Heavy metals, BOD/COD
Microelectronics		COD and organic
Hospitals and pharmaceutical industries	Butare hospital/CHUB, King Faycal hospital, Kanyinya hospital	pH, BOD, Heavy metals, partially metabolised pharmaceuticals
Learning institutions, hotels & lodges, and prisons	University of Rwanda, Serena Hotel, Umubano Hotel, Relax Resort Kiyovu, Gikondo prison, Mpanga prison	pH, BOD, cooking oils, TN, TP, microorganisms

Ministry of Environment (2017) reported on a countrywide survey of some 88 factories and industries producing different items. They found that some of the industries treat their wastewater by using alternative means not mentioned in the questionnaire that was used in the survey. In general, more than 30 % of the industries did not treat their wastewater due to insufficient capacity to treat their wastes, or treatment not being required. They concluded that, depending on the complexity of processes occurring at some specific industrial sites, special attention needed to be taken into account during the monitoring of on-site wastewater treatment facilities as well as for any wastewater monitoring plan.

The Rwanda Industrial Master Plan listed a number of companies that generated organic pollution in the city of Kigali (Table 4-2).

Table 4-2: Industries in Kigali that generate organic pollutants

1. Nyabugogo Slaughterhouses: Commercial Infrastructure Results in strongly polluted waters. Large quantities of a strong organic pollution. Easily biodegradable pollution flowing in the River Mpazi and directly in the Nyabugogo River without going through the marsh. Transmission of parasitic diseases
2. Kabuye Sugar Works: Sugar Producing Factory Sugar cane waste, cellulose matter, sugar molasses and alcohol. Organic pollution of the Nyabugogo being able to bring the eutrophication. Obstruction of the banks and canals by the solid losses.
3. Ovibar: Factory making wine from banana. Produces residual liquid waste full of organic pollutants. Sickening odour; contamination of the soil and water through organic pollutants. From the factory, the polluted water flows openly through residential areas, which is a health hazard.
4. Sulfo Rwanda industries and Sakirwa (Only soap making): Manufactures soaps, beauty oils and mineral water. Residual water filled with oils, greases and emulsified fats. Sickening odour, contamination of the soil and water by oils. From the factory, the polluted water flows openly through residential areas, which is a health hazard.

5. Bralirwa: Manufactures alcoholic drinks and soft drinks. Residual water filled with toxic waste. Organic pollution (alcohols, yeasts) and chemicals (soda ash). Sickening odour, contamination of the soil and water by organic pollutants and chemicals. The residual organic wastes have high levels of BOD cause a high risk of reducing oxygen in the water and environment with negative impact on the living organisms. The residual waste-water flows openly before falling into a ravine.
6. Tolirwa and Uprotur: Factory manufactures galvanised iron sheets and heavy metal sheets. Heavy metal waste with a poisonous effect to the population which uses the water of Nyarugenge by the heavy metals and chrome salt.
7. Rwanda Association of Battery Manufacturers: Manufacture of batteries. Residual water containing a variety of chemical products (heavy metals). Contamination of the ground and waters by various chemical pollutants. Population contamination by polluted waters.
8. Ameki Color: Manufacture of paints. Residual water full of oils and chemical residues. Contamination of the soils and water by the oils and chemical pollutants, affecting the population indirectly.
9. Utexrwa: Manufacture of fabrics (textiles). Residual water filled with dyes and chemical pollutants coming from laundering of used cloths as hydrogen peroxide and sodium silicate as well as a multitude of dyes. Contamination of the soil and waters of Kagugu by the remainder of residues of the dyes and chemical pollutants. (Utexrwa has access to an installation of pre-treatment_ check the working order thereof)
10. Nyanza Landfill: The Nyanza Landfill has closed down and was replaced with Nduba Landfill. However, there are still concerns about leaching of pollutants from the site into underground waters via breakdown of wastes from domestic, hospital, industrial, sludge from septic pits, engine oil, etc. Risks of contamination of the source of River Nyacyonga, ground waters of the Kagarama sector and of various streams.

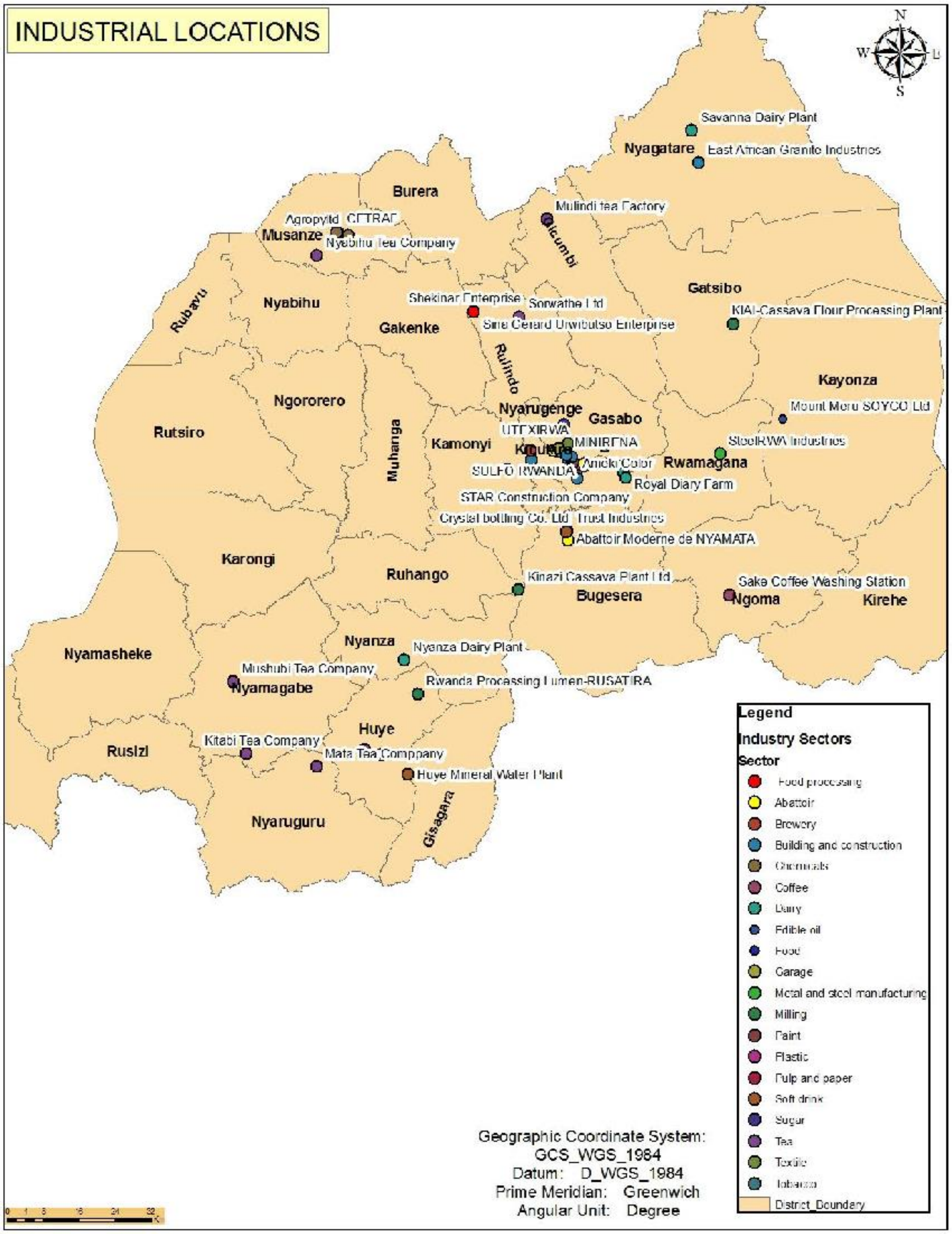


Figure 4-1: Map showing the distribution of industries in Rwanda (Ministry of Trade and Industry, 2016 a & b, Ministry of Trade and Industry, 2017)

The Ministry of Trade and Industry (2016, a & b, 2017) undertooksampling and analysis of industrial effluent from local industries in the Lake Victoria Basin to establish the levels of industrial pollution, in order to promote cleaner production technologies. It was concluded that the pollution levels from sampled industries were very high (MINICOM, 2016a). Of the 28 industries sampled during Phase 1 of the survey, 7 industries exceeded the effluent standards for nitrates, and 13 industries exceeded the phosphate standard.

However, for Chemical Oxygen Demand (COD), 21 out of 28 industries exceeded the COD standard. For Biochemical Oxygen Demand (BOD), 25 of the 28 industries exceeded the BOD standard. A similar pattern emerged during the second phase sampling (MINICOM,2016b) when 22 of the 24 exceeded the RBS COD standard, and 20 of the 24 industries exceeded the BOD standard. During the last sampling conducted in 2017 after implementing Cleaner Production Technologies in eight industries indicated that, comparing the level of pollution before and after Cleaner Production Technologies, 5 of the 8 industries showed the increasing level of nitrates, 2 of the 8 showed the increasing level of Phosphates while has decreased at one industry. The BOD levels have increased in 6 of the 8 industries and decreased in the other 2, and finally the level of COD increased at the all most Industries. Figure 4-2 to Figure 4-5 displays the BOD, COD, nitrate and ortho-phosphate concentrations in industrial effluents, classified using the EAC effluent standards (Table 3-5, Ministry of Trade and Industry, 2017).

High organic loads exceeded the effluent standards were common amongst the industries investigated during the first phase of the survey. It was strongly recommended that industries should implement industrial wastewater monitoring, industrial wastewater treatment plant should be undertaken to treat wastewater to effluent standards, and Cleaner Production Technologies should be promoted and implemented reduce water use, and reduce pollution loads from industries.

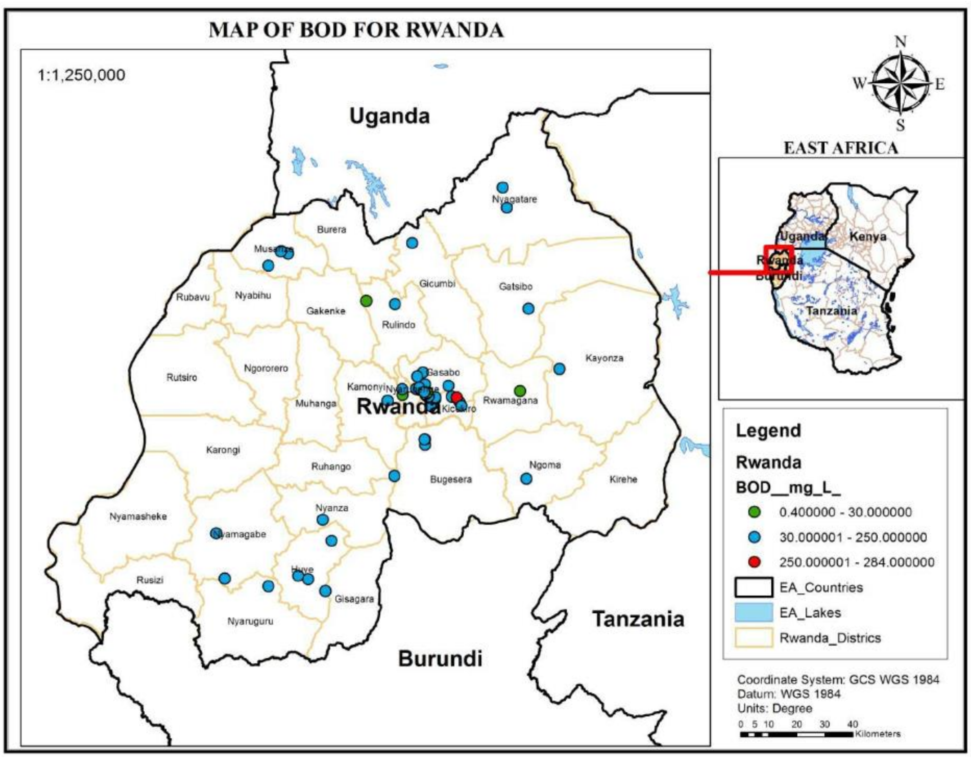


Figure 4-2: Map showing the BOD concentrations in industrial effluents, classified USING THE EAC effluent standards (Ministry of Trade and Industry, 2017)

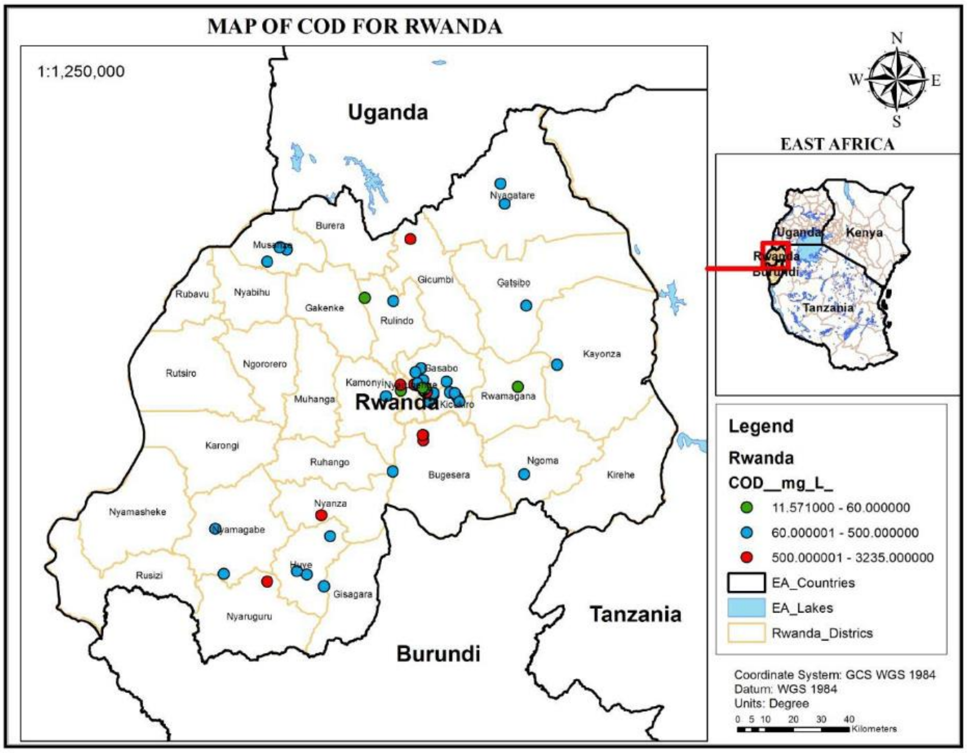


Figure 4-3: Map showing the COD concentrations in industrial effluents, classified using the EAC effluent standards (Ministry of Trade and Industry, 2017)

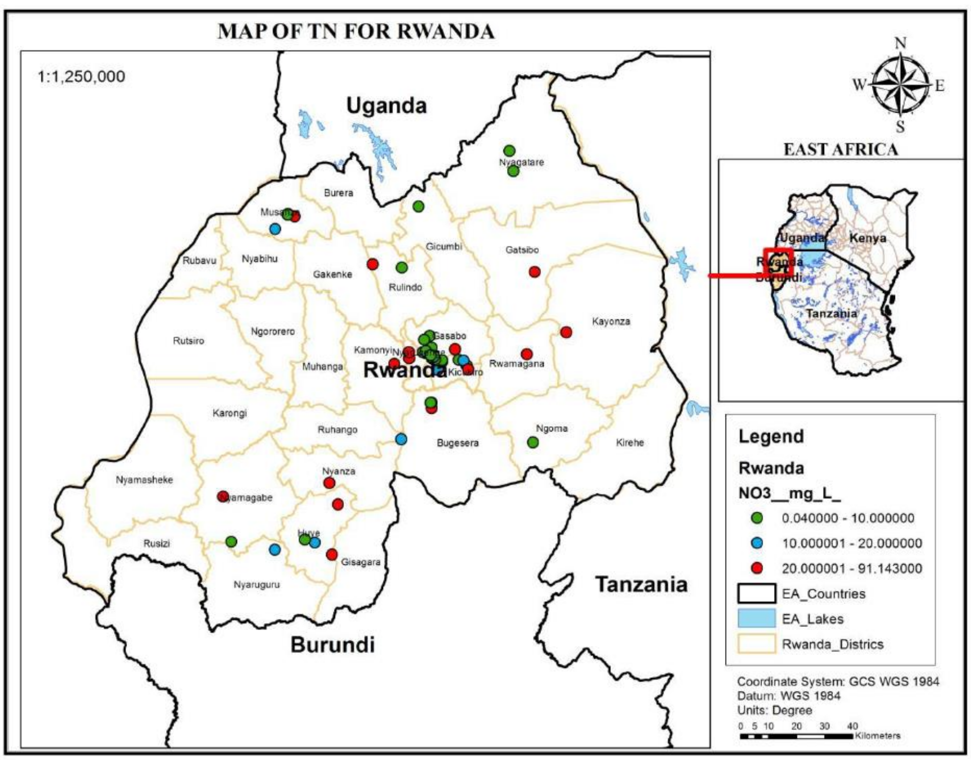


Figure 4-4: Map showing the Nitrate concentrations in industrial effluents, classified USING THE EAC effluent standards (Ministry of Trade and Industry, 2017)

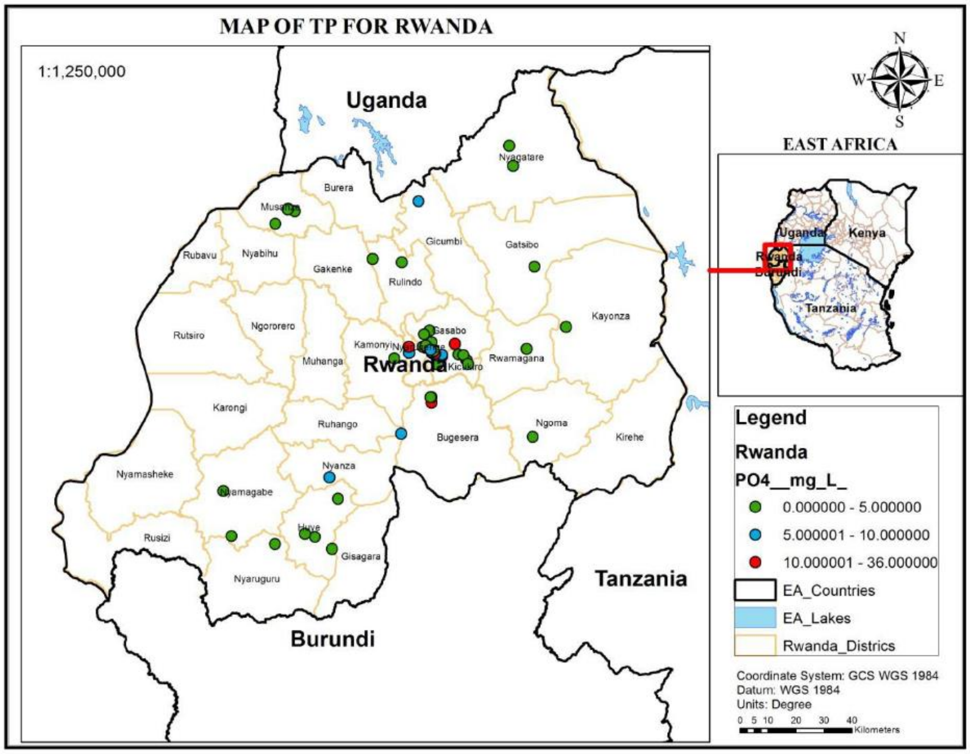


Figure 4-5: Map showing the ortho-phosphate concentrations in industrial effluents, classified USING THE EAC effluent standards (Ministry of Trade and Industry, 2017)

Relevance

The pollution impacts of the industrial sector varied widely between different sectors. However, based on the 2016 and 2017 surveys undertaken for the Resource Efficient and Cleaner Production Project of the Ministry of Trade and Industry, high organic loads characterised by high BOD and COD concentrations that exceed effluent standards, appears to be a common pollution concern amongst many industries.

The recommendation by many authors is supported that industries should internalise the cost of industrial wastewater treatment (application of the "polluter pays" principle) by treating their wastes on-site to meet Rwandan industrial effluent standards. This is particularly important to reduce the impact of high organic wastewater on receiving streams and rivers.

The implementation of cleaner production technologies, such as those recommended by the Rwanda Resource Efficient and Cleaner Production Centre (RRECPC) (MINICOM, 2017), is strongly supported in order to prevent generation of wastewater, and to curtail harmful emissions from industrial sites, and to enhance the efficient use of resources. The vision of the RRECPC is to become a Centre of Excellence for resource efficient and cleaner production technologies and sustainable development of industries in Rwanda. The overall objective of the centre is to improve resource productivity and environmental performance of businesses and other organisations. The centre's promotion of resource efficiency and cleaner production in SMEs is one way to address industrial pollution within Rwanda and to support the sustainable development and the implementation of EDPRS 2 green economy component of "high environmental standards and sustainable green innovation in the industrial and private sector" (Ministry of Trade and Industry, 2017). These initiatives are strongly supported.

2.1.2 Wastewater Treatment Works (WWTW)

Wastewater treatment works (WWTWs) that discharge treated effluent into surface water streams are important point sources of pollution if they don't meet effluent standards. However, if there is a high density of WWTWs, all meeting effluent standards, their cumulative impacts might also be significant. Domestic WWTWs are regarded as important sources of nutrients, organic matter, suspended solids, human pathogens, and depending on the demographics, a source of partially metabolised pharmaceuticals and endocrine disrupting chemicals.

Situation in Rwanda

ENGIN (2016) undertook a comprehensive survey of wastewater treatment systems in Rwanda for the Rwanda Environment Management Authority. As part of the study a comprehensive management information system for wastewater treatment systems (MISWWTS) were developed. According to the study there are about 161 wastewater treatment systems in Rwanda (Figure 4-6) with most of the systems concentrated in Kigali City (some 119 of the 161 WWTWs). However, these tend to be small, often on-site, treatment systems designed to treat the wastewater of a hospital, hotel, resort, training institution, office complex, etc. The study also sampled the final effluent from some of the WWTWs and found that, of the thirteen treatment works sampled, five exhibited no environmental or public health problems, four posed no environmental problems but required chlorination of the final effluent, three posed a serious health risk and urgent interventions were recommended, and one had an odour problem.

The distribution of WWTWs by province and by district are displayed in Figure 4-6 and Figure 4-7.

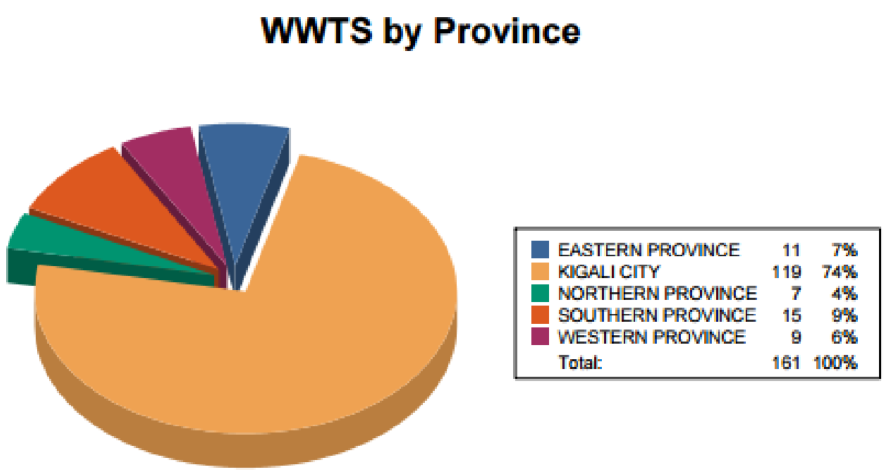
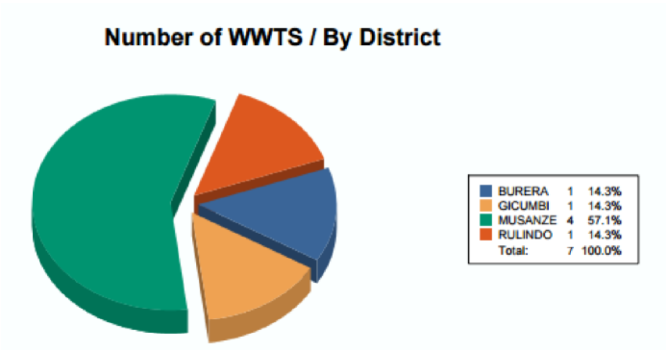
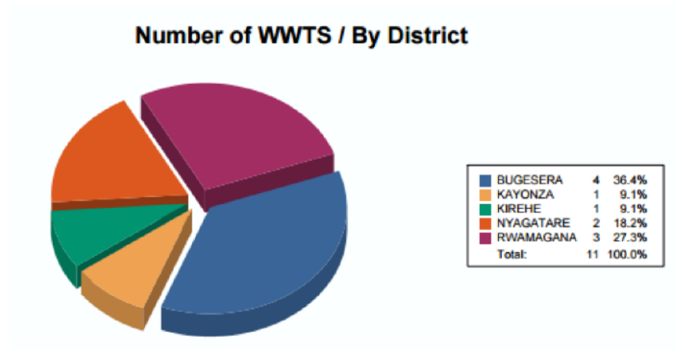


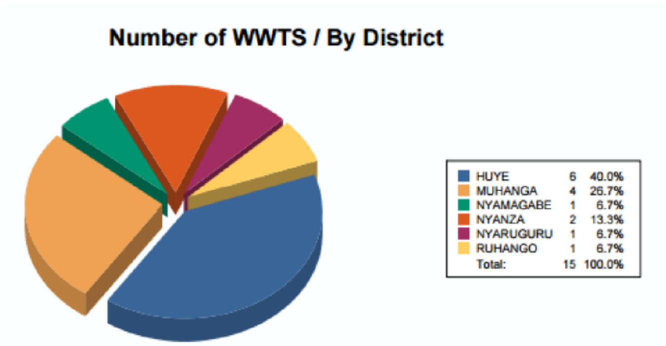
Figure 4-6: Distribution of WWTS by province ENGIN (2016)

Northern province	Eastern province

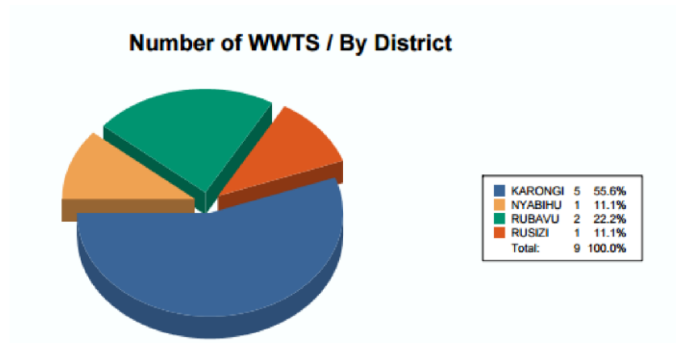




Southern province



Western province



Kigali City

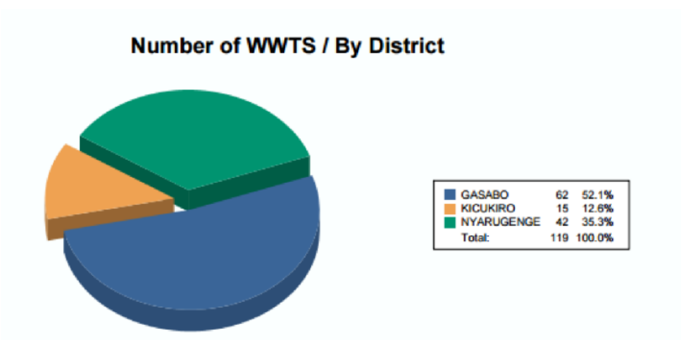


Figure 4-7: The distribution of WWTWs by province and district (ENGIN, 2016).

Relevance

There is a great need to develop centralised WWTWs for industrial parks, designed to treat predominantly industrial wastewater, and for all the major urban centres in Rwanda to treat domestic wastewater. Although small WWTWs adequately treat the wastewater from hotels, hospitals, etc., it is grey water and sludge discharged from dense urban areas that have a significant impact on urban streams, wetlands, and receiving rivers. Collecting and treating the domestic wastewater will have a significant positive impact on improving the health of urban communities in Rwanda. This is especially important in the light of increasing urbanisation trends observed all over Africa and the need to safeguard the health of those urban communities, and the aquatic ecosystems affected by growing urban centres.

Industries not located in industrial parks should be required to treat their wastewater to EAC standards as discussed previously, and to employ cleaner production technologies to minimise the waste they produce.

2.1.3 Wastewater from Mining

Mines can be significant source of pollution and pollutants such as heavy metals, suspended solids, salinity, sulphates, and acidification are associated with mining activities.

Situation in Rwanda

The impacts of mining on water quality is a major concern. There are some 102 mines registered with the Mining Authority (2015 count) (Figure 4-8). Currently the key minerals being mined in Rwanda include cassiterite (a tin ore); colombo-tantalite (commonly called coltan1 - an ore that is the source of niobium and tantalum); wolfram (a tungsten ore); and Gold mined from Gicumbi and Nyamasheke districts. Other key minerals include ambrigonite, beryl and semi-precious stones such as tourmaline, topaz, corundum, chiastorite, amethyst, sapphires, opal, agate and flint. Construction materials which can be used in their primary state or processed include amphibolites, granites and quartzites, volcanic rocks, dolomites, clay, kaolin, sand and gravel (Ministry of Forestry and Mines, 2010).

Mining in Rwanda dates back to private companies who mined cassiterite and wolframite in the 1930s, and coltan in more recent times. Nationalisation of the mining sector in 1973 coupled with mismanagement, resulted in the collapse of the sector in the 1980s-1990s. Privatisation of government mines in 1997 has seen a recovery in the mining sector and increased foreign investment in exploration and mining in the 2006-2009 period; key players in the industry are private sector and small-scale/artisanal miners. Groups of devoted artisanal miners (<10 to 200 members) organized by a "sub-contractor" mine over large concession areas. Mineralisation (Sn, W and Ta) can be in-situ (i.e. found in hard rock) or of alluvial/eluvial nature (i.e. occurring as poorly consolidated material). The majority of the mining operations are small scale operations or artisanal mines.

The Mining Policy of 2010 (Ministry of Forestry and Mines, 2010) set out a policy which sought to comprehensively cover all aspects of the regulation, institutional and investment framework for the mining industry, as well as provide plans of action to support the sector's growth. The policy found that mining had a large impact on Rwanda's economy, and that there was significant potential for the future growth. The policy also found that there were many constraints faced by the mining industry throughout the value chain, which would impede the industry from realising this potential.

Haidula, Ellmies, and Kayumba (2011) undertook environmental monitoring of small-scale mining areas in Rwanda to assess the impacts of such mining activities on the receiving environment. A total of 19 water samples and 16 samples of solid materials (stream sediments, soil, tailings) were collected and analysed for major, minor and trace elements. The study concluded that of issues of major concern were concentrations of arsenic in soils and stream sediments downstream of the mines in Masoro/Rutongo (near Kigali), Rutsiro (Western Province), Gifurwe (Northern Province) and Rwinkwavu (Eastern Province). At these sites, arsenic- and partly lead-rich tailings material was released in large quantities from processing plants and tailings dumps. The highest arsenic concentration, at 533 mg/kg, was detected in the soils of a farm downstream of Gifurwe tailings dam, exceeding international guideline values by many times. As an immediate response, the study recommended that the downstream farmland in the river course should be declared as a contaminated site and prevented from any other land use until measures have been taken to rectify the situation. Except at Rwinkwavu, the river water downstream of the mine sites was of relatively good, partly excellent quality. This could be attributed to high rainfall and thus dilution rather than proper environmental management. At Rwinkwavu, arsenic contamination in the huge reservoirs downstream of the mining area slightly exceeded EAC standards for drinking water. It was recommended that the contamination must be monitored closely. The study expressed concerns that the wide use of contaminated water for irrigation and human consumption could cause bio-accumulation of arsenic.

Relevance

The mining industry is one of the industries that are expected to grow in future. The Mining Policy set out its objectives as increasing productivity by establishing 3 industrial mines by 2020, increasing investment to 500 million by 2020, creating more employment opportunities and higher paying jobs (50,000 employees by 2015 in the sector), increasing exports to $240million per year by 2020, reduced imports to $10million per year fall in construction material imports, increasing tax revenue by $30million per year by 2020, reducing environmental impacts by allowing no artisanal treatment in rivers, and ensure greater macro-economic stability. The growth in the mining industry is a concern with respect to pollution, especially if this is not undertaken in an environmentally unsustainable manner but focused on short term gains. The envisaged reduction in environmental impacts in the Mining Policy is a positive statement but it should be followed up with actions to ensure that the impacts of the many small mining operations are mitigated. The impacts of the many small mining operations are more difficult to control than the impacts from large mines that can afford to implement pollution control measures.

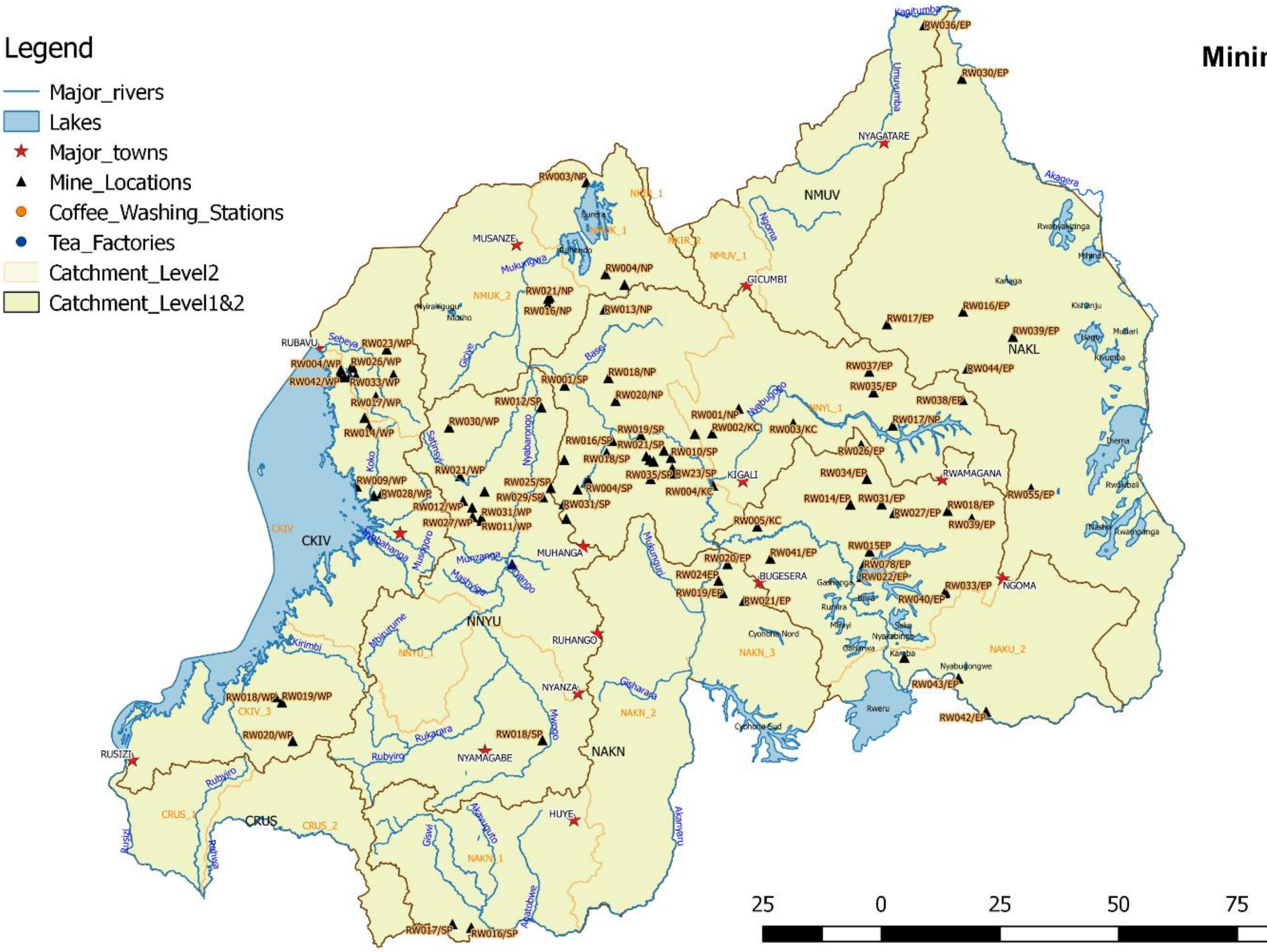


Figure 4-8: Distribution of mines in Rwanda

2.1.4 Coffee washing stations

Coffee plays a major role in the economy of Rwanda, contributing significantly to foreign exchange earnings and to the monetisation of the rural economy. According to the National Agricultural Export Development Board, about 400,000 small holder farm families produce it and depend on it for their livelihoods. Coffee was introduced by Germans in early 1900s, it is dominated by mainly 'bourbon' type of Arabica coffees. Production ranges from 267, 000 to 420,000 bags per year (16 000 MT to 21000MT). The total area in coffee is currently 42,000 hectares grown and it is grown in most provinces in the country at an altitude less than 1900 m. However, concerns have been expressed about the impacts of coffee washing stations on receiving water streams.

Situation in Rwanda

Coffee washing stations (CWS) contribute significantly to the organic loads in receiving rivers and streams (Figure 4-9). The traditional wet-milling process begins when the pulp is removed from freshly harvested coffee cherry. The cherry is poured into a funnel that leads to a depulper, where the outer skin, or pulp is removed. This leaves the seeds, or coffee beans, covered in sticky, gelatinous mucilage. The mucilage is then removed from the bean through a fermentation process that can last anywhere from 12 to 36 hours or more depending on local conditions and practices. One traditional method of depulping involves running a continuous stream of water through the depulper as it is operating. Then following fermentation, the coffee is washed to remove the mucilage, a process that can require large volumes of water. The wastewater from the wet milling process is one of the leading contaminants of local water sources in coffee-growing communities. The mucilage is high in sugars and pectin. The sugars and pectin in the water ferment into acetic acid which are released into local receiving streams, where they can only be broken down by oxygen in the water. The amount of oxygen needed to break down the organic pollutants in the coffee washing wastewater, commonly measured as the biochemical oxygen demand (BOD), often exceed the rate at which oxygen is replaced in the receiving stream. This results in anaerobic conditions developing which threatens aquatic life and creates favourable conditions for the production of bacteria harmful to human health.

Kazoora (2011) found that, in comparison to other African countries, Rwanda's CWS are inefficient in water use. It was estimated that a CWS that has the capacity to process 625 tons of cherries during a coffee season (to produce 125 tons of parchment coffee), operating at 4% capacity, would need 400m^3 of water per day if there was no water recirculation and 113m^3 if there was full recirculation. It was also found that many have difficulties in waste water treatment. The guidelines for the optimal operation of CWS water in Rwanda was for processing 1 ton of dried coffee, 75m^3 is required if there is no water reuse and 25m^3 if there is full water reuse (Kazoora, 2011).

Coffee washing stations only operate during the production season that normally runs from 15 March to 30 June (USAID, undated).

Tea factories also produce wastewater that are rich in organic material (Figure 4-10) but these as well as dairies were dealt with under the impacts of industrial point sources.

Relevance

Kazoora (2011) recommended the AD-Coffee Waste System (AD-CWS) as a technology that can use waste generated by coffee processing to generate biogas and fertilizer. Biogas can be used at source to dry coffee beans, thereby saving on energy costs and fertilizer can be sold to generate additional income. The other saving is associated with reduced pollution into receiving streams and commitment costs of water treatment, loss of riverine biodiversity, etc.

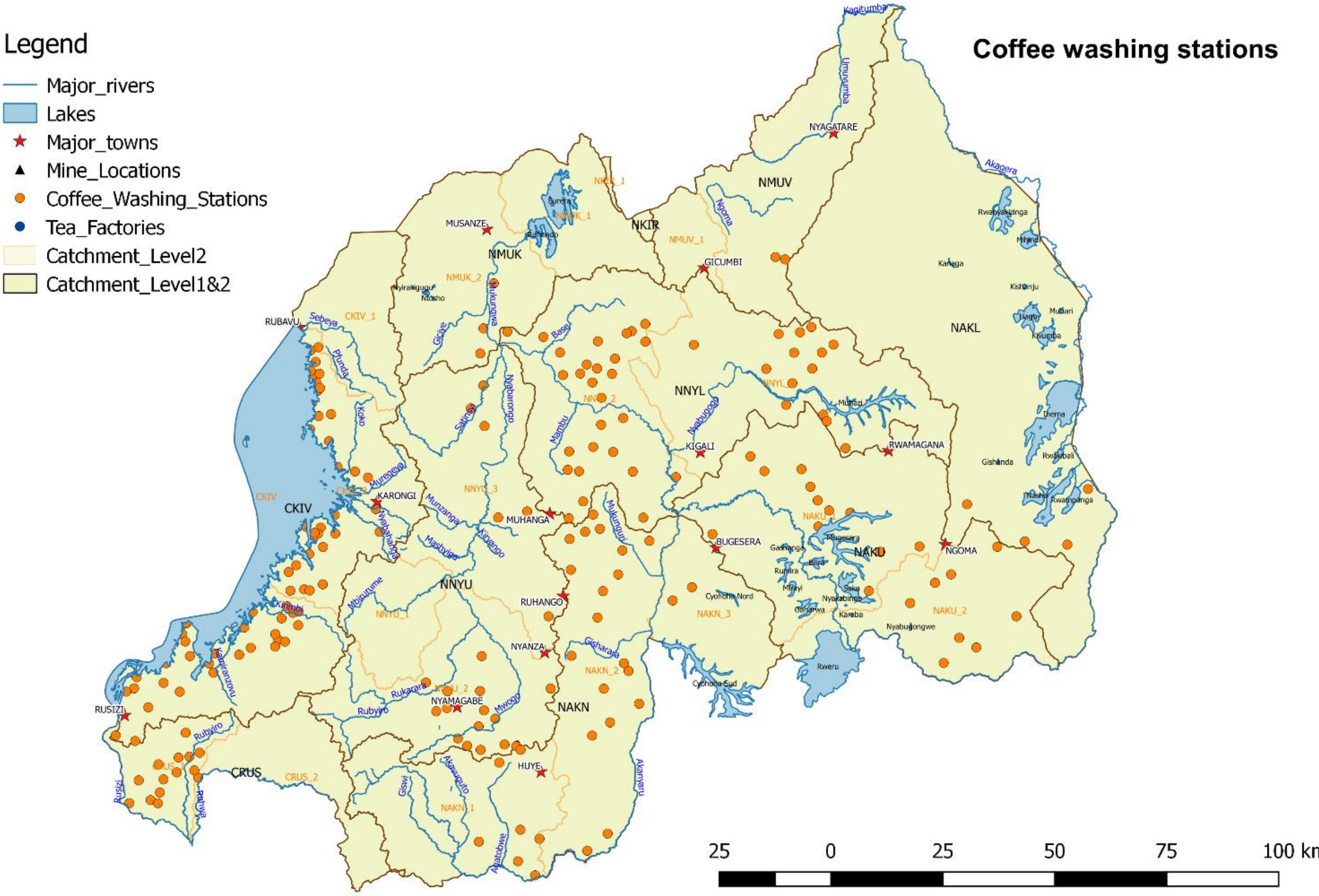


Figure 4-9: Distribution of Coffee Washing Stations in Rwanda

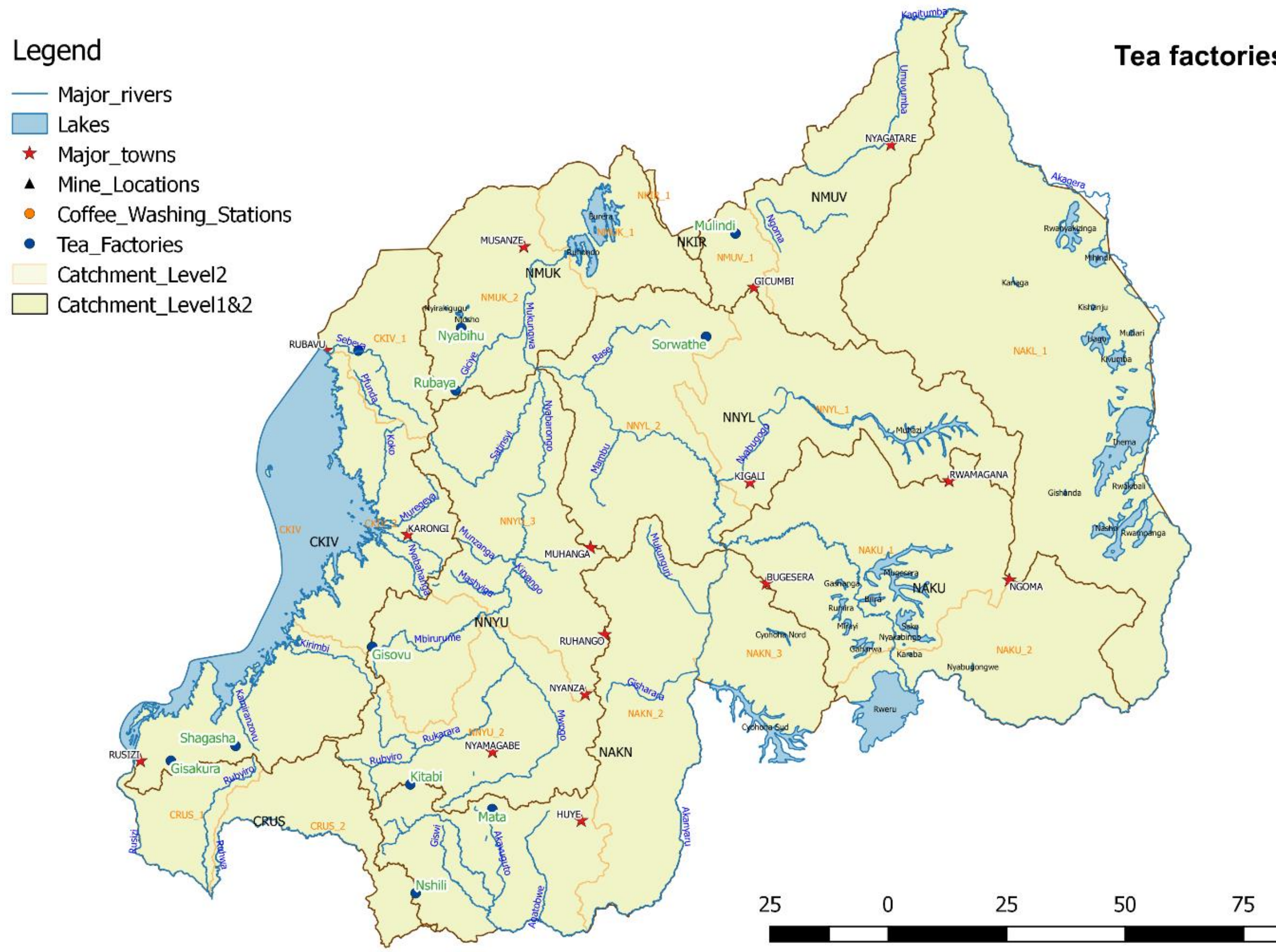


Figure 4-10: Distribution of tea factories in Rwanda

2.1.5 Aquaculture

Fish farms can have a major impact on water quality as the outflow from a pond can be high in BOD/COD, ammonium and nitrates from fish wastes and food residues.

Situation in Rwanda

All fish ponds in Rwanda are constructed as a flow through systems with an inlet and outlet and water flows through the pond at a rate that minimised the build-up of ammonium in the water, which is toxic to fish in high concentrations. There are future plans to developing cage culture fish farms in Rwandan lakes. The targeted lakes are Lake Kivu, Lake Burera, Lake Ruhondo and Lake Muhazi. The first three lakes are deep lakes and present less risk for water quality while Lake Muhazi is a shallow lake and concerns have been expressed about practicing fish farming on that lake.The total number of ponds and their total surface area per sector are as presented in in annex I

Relevance

The impacts of fish pond outflows on receiving streams and rivers need to be investigated to ensure aquaculture is practiced in a responsible manner in Rwanda.

2.1.6 Solid waste dumps

Solid waste dumps and landfills can also be regarded as point sources of pollution. Pollutants associated with landfills include organic wastes from decomposing organic wastes, heavy metals from corroding metallic objects and old batteries, waterborne pathogens from discarded diapers and sewage sludge, acidic waters, hydro-carbons and oils from used motor and cooking oils, etc. Landfills and solid waste dumps are also sources of atmospheric emissions that can be harmful to humans and animals near the dumps. These include methane gas, ammonia from household and discarded agricultural chemicals.

The leachate from unlined landfills is a highly concentrated "chemical soup," so concentrated that small amounts of leachate can pollute large amounts of groundwater and surface water rendering it unsuitable for use for domestic water supply. In addition to potential carcinogens and highly toxic chemicals, leachate contains a variety of conventional pollutants that render a leachate-contaminated groundwater unusable or highly undesirable due to tastes and odours.

Situation in Rwanda

The Water and Sanitation Regulation Unit conducted audits and inspections to solid waste disposal facilities throughout Rwanda (MINICOM, 2017). The audits and inspections were carried out in the four Districts of Eastern Province (Rwamagana, Kayonza, Ngoma & Nyagatare), two Districts of Northern Province (Gakenke & Musanze), two Districts of Western Province (Rubavu & Karongi) and five Districts of Southern Province (Kamonyi, Muhanga, Ruhango, Nyanza & Huye). In addition, Nduba dumpsite serving as waste disposal facility for the City of Kigali was also visited. The audit found that:

- The visited Districts were in the process of improving solid waste management by conducting studies or constructing modern landfills.
- The operation and management of landfills/waste disposal facilities fell under the responsibilities of Districts or City of Kigali. However, Musanze, Kamonyi and Nyagatare

Districts have delegated the management of their waste disposal facilities to private operators.

- The types of waste disposed off in landfills consist of solid waste from households, restaurants, hotels, markets, etc. No hazardous waste was recorded at the sites.
- The quantities of waste dumped in the sites were unknown due to lack of weighing machines/bridges at the dumpsites. The number of incoming trucks and quantity of waste was only recorded at Nduba dumpsite.
- Improved waste disposal facilities/landfills were only recorded in Kamonyi, Ruhango and Huye Districts. These facilities are well covered and various compartments / hangars well demarcated for waste sorting, drying, collection etc. The Districts of Nyanza, Kayonza and Nyagatare now have modern landfills and faecal sludge treatment plants through LV WATSAN Project.
- Upcountry, waste was disposed offfree of charge and salaries of employees are paid by Districts except for Rubavu and Musanze Districts where workers are paid by operators. Also, the hauling companies are paid by Districts from sanitation/hygiene taxes collected from commercial and market premises (5,000Frw/month for hygiene purposes).
- As for Nduba dumpsite, waste disposal fee varies from 3,000 to 5000Frw, depending on the size of the hauling trucks.
- With the exception of Ruhango, Rubavu and Musanze Districts, none of the workers at sites had even the most basic protective clothing as gloves, masks, boots and overcoats to avoid direct contact with waste.

It appears that very few landfills and solid waste dumps had any controls in place to collect contaminated stormwater runoff and other liquids that seep from the waste, and to dispose of it safely. At some sites sewage sludge was also disposed of.

The Office of the Auditor General undertook a Performance Audit of the management of solid and liquid waste (sewage) in the city of Kigali to assess whether the City manages solid and liquid waste in a manner that is friendly to the environment (Biraro, 2016). The findings related to pollution were:

- Failure to manage leachate from unsanitary landfill: City of Kigali did not put in place an appropriate management system for leachate to protect ground and surface water. In addition to this, no water facility has been provided as planned and the population in Gatunga cell is still using the water from this contaminated source. This situation increases the risk of diseases due to unsafe water.
- Inappropriate solid and liquid waste disposal: Solid waste disposed on the site are compacted and covered by soil at least once in two months instead of end of each working day. In two months, waste deposited at the site and left uncovered gets decomposed and attracts vermin and flies which eventually spread to the surrounding population. This also allows oxygen gas to penetrate in the solid waste and may cause combustion of the landfill as was the case in the former Nyanza dumping site. To reduce bad smell from the liquid waste, some chemicals are spread onto the liquid waste surface. The system of collection

in pits does not give a fair and sustainable solution as many pits are required to accommodate that liquid waste. At the time of the audit (April 2016), 3 pits were already full, and they were digging a fourth one. These pits are located on the top of the hill and if it rains heavily, they are likely to overflow and spread into the neighbourhood and contaminate water and crops. This leads to spread of disease to the neighbouring population.

- Failure to manage greenhouse gases emitted from the landfill: Failure to monitor gases emitted from the landfill can lead to adverse impacts if not fixed. The decomposition of the organic matter in anaerobic conditions generates methane gas which is a global warming gas and can cause combustion if not eliminated or reduced. The liquid waste (sewage) generates ammonia gas whose emissions to the atmosphere are an environmental concern, contributes to bad smell, the eutrophication of surface water, and nitrate contamination of groundwater. Ammonia emissions also contribute to the formation of fine particulates, which have a negative impact on animal and human health.
- Lack of sustainable management system for solid and liquid waste: As of June 2013, more than 300 tons of solid waste are collected every day and dumped to the unsanitary landfill located in Nduba Sector, Gasabo District. Nduba Landfill has not been developed to address the environmental and public health treats that caused the re-location from Nyanza dumpsite. The method of waste disposal at Nduba landfill is still the same as that used at the former Nyanza and hence pauses the same health risks. For the liquid waste (sewage), there is no system to receive and treat the sewage emptied from septic tanks from different parts of the City. They are deposited into pits at Nduba site and as of today they have become like small lakes (ponds) of sewage. Disposal methods used at Nduba still expose City of Kigali to environmental and health hazards.

It was finally concluded that the collection of solid waste from areas of generation to the landfill site is excellent in the City of Kigali and the latter is ranked among the cleanest cities of Africa. However, there is still a long way to go towards an environmental friendly and sustainable management of solid and liquid waste (Biraro, 2016).

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Relevance

Unlined and unprotected landfills and solid waste disposal facilities pose a water and air pollution risk to nearby communities and ecosystems. It is highly recommended that properly designed landfills be installed for major urban centres to ensure that waste is properly collected, transported and safely disposed off, recycled or reused. These designs should specifically focus on preventing or mitigating liquid and gaseous emissions from landfills. The Rwandan guidelines for the management of waste disposal sites (landfill) and regulations on solid waste collection and transportation should be enforced to ensure compliance with the said regulations and guidelines. Recycling and reuse should also be encouraged in the rural areas.

2.1.7 Air pollution sources

Air pollution can have an impact on human health and the health of terrestrial and aquatic ecosystems. A number of activities generate air pollution and are evident in Rwanda:

- Fuel combustion from stationary sources – include the burning of fossil fuel (coal or oil) for electricity and steam generation for industrial energy requirements (point source).
- Fuel combustion from mobile sources – emissions largely from the transport sector and pollutants include combustion products, diesel fumes, unburned fuel, and volatile lead species (nonpoint source).
- Industrial and chemical processes – emissions from industrial plants (point sources).
- Solid waste disposal – incineration of industrial, residential and hospital wastes. They contribute a wide range of heavy metals as well as a host of toxic chlorinated organics and alkali chlorides (point sources).
- Land surface disturbances – These include mining, quarrying, and construction activities, waste dumps, agricultural activities (burning of waste), and veld fires. Particulate matter is the primary pollutant (nonpoint sources).

All thermal processes produce carbon dioxide. Although it is not a pollutant *per se* it is contributing to global climate change. Primary air pollutants include sulphur and nitrogen oxides (SOx and NOx), particulate matter, carbon monoxide, and volatile organic compounds.

The environmental impacts of air pollution include:

- Acidic deposition
- Smog formation and visibility reduction
- Hazardous air pollutants
- Stratospheric ozone depletion
- Global climate change

Situation in Rwanda

Air pollution is a growing concern in urban areas in Rwanda. The major emission sources are the transport sector; manufacturing industries such as cement, and steel mills; quarrying activities that contribute dust to the air; domestic cooking; soil-blown dust, and waste combustion. Transportation and vehicles are the largest sources of air pollution, especially in Kigali City. The combustion of fossil fuels to power vehicles and engines — cars, trucks, buses, motorbikes, generators, and water craft has major adverse impacts on the environment and human health (REMA, 2015). Concerns rate to the contributions to greenhouse gasses and climate change due to the release of CO_2 and for respiratory ailments from the inhalation of small particulates and fumes.

Point sources of air pollution needs to comply with the RS/EAS air quality standards.

Refer to the more detailed discussion of air pollution in Chapter 5.

Relevance

Point sources of air pollution needs to be monitored and the Rwandan air quality standards needs to be enforced.

2.2 Nonpoint sources

Point sources are generally defined as discernible and confined sources of pollution that discharge from a single point of conveyance, such as a pipe, ditch, channel, tunnel of conduit. Nonpoint or diffuse sources of pollution represent those that are not included in the preceding definition (Pegram and Görgens, 2001). Nonpoint source of pollution of surface waters in Rwanda is largely caused by rainfall and the associated surface runoff, or groundwater discharge. Nonpoint pollution sources can be diffuse and intermittent, contribute to contamination of surface waters over a widespread area, such as stormwater wash-off and drainage from urban or agricultural areas. Different types of non-point sources cause different water quality effects, both in terms of the key constituents and the processes governing the production and delivery of contaminants. The character of non-point sources in a catchment indicates the particular water quality concerns that are likely to occur.

Water pollution from non-point sources are related to the climate, natural features and human activities on any land area (Pegram and Görgens, 2001). These characteristics work together in determining the production and delivery of pollutants from that area. Although land use is generally assumed to be the over-riding determinant of water quality impacts, there is generally more variation in loading within a land use category. Assessing pollutant loads from non-point source areas required the separation a catchment into areas with relatively homogeneous non-point source characteristics, based on the:

- Land use: natural, agricultural, human settlement, industrial etc.;
- Natural features: soils, topography, geology etc.; and
- Climate: rainfall, temperature, evaporation etc.

Climate and hydrology affect nonpoint pollution - Rainfall, surface runoff, interflow and groundwater discharge are the driving hydrological forces causing pollution impacts from a non-point source. **Rainfall depth and erosivity** affect the mobilisation of particulate contaminants, while its variability determines seasonal and “first-flush” effects. **Surface runoff** washes off and delivers particulate and dissolved contaminant, but can also dilute their concentrations as runoff increases. **Interflow and groundwater discharge** deliver dissolved contaminants, which have infiltrated and leached from the land, into the surface water environment. **Temperature** influences potential evaporation as well as affecting assimilation through biological die off and chemical reaction rates. Lastly, **Evapotranspiration** results in concentration of dissolved groundwater contaminants, thereby increasing the concentration of groundwater discharge.

Key nonpoint sources of pollution that were identified for Rwanda were agricultural runoff, runoff and drainage from urban areas, gravel roads and erosion, and diffuse air pollution sources.

2.2.1 Agricultural runoff

Agriculture is the predominant land use in most of rural Rwanda.

The following generic land use categories can contribute to nonpoint source pollution, particularly sediments, nutrients, and agrochemicals:

- Livestock grazing can contribute to sediment yield through removal of the natural vegetative cover (overgrazing), while nutrients and pathogens are associated with livestock faecal matter. These impacts are aggravated and significant bank destabilisation (habitat destruction) can occur where livestock are allowed direct access to wetlands and rivers.

- Croplands are often a major rural source of sediment, particularly if good land management practices are not adhered to. Wash-off of nutrients from fertilizers and of agrochemicals (pesticides and herbicides) can also have a significant impact, where these are applied. Croplands are particularly vulnerable during the preparation of plots for planting and harvesting when the soil is disturbed.
- Irrigation of crops can be a further source of nutrient (inorganic fertilizer), pesticides, and pathogens if manure is used as fertilizer.
- Confined animal facilities, such as livestock enclosures and chicken farms, can contribute significant nutrient, organic matter (BOD) and pathogen loads from faecal waste, especially during storm runoff. This is the main concentrated agricultural source, and may include dairies and piggeries.

Situation in Rwanda

Nonpoint sources of sediments

Agriculture is a major source of sediments in Rwanda. The Rwandan economy is primarily based on rudimentary agriculture where over 80% of the population is dependent on subsistence agriculture (Karamage et al., 2016). The rapid population increase caused a shortage of land resources, leading to a general decline in forest areas from 1960–2000. To cope with the demographic pressure, the government launched a large-scale national cropland conversion campaign that aimed to expand the irrigated cropland by 100,000 ha by 2020, among which 35,000 ha will be hillside irrigation, and 90% of the cropland is located on slopes of 5%–55% . With a hilly and mountainous relief, coupled with a fragile soil and a high average rainfall intensity of 1156 mm per annum that concentrates in the wet season, the lands of Rwanda are highly susceptible to soil erosion. According to a global assessment, Rwanda was among the 22 countries most seriously affected by soil degradation (Karamage et al., 2016). Previous studies suggested that severe soil erosion in Rwanda, like in other East African countries, could be associated with unsustainable agricultural land management increased by high population densities Karamaga et al. (2016) estimated that the mean soil erosion rate was 250 tons per hectare per year over the entire country, with a total soil loss rate of approximately 595 million tons per year. The mean soil erosion rate over cropland, which occupied 56% of the national land area, was estimated at 421 tons per hectare per year and was responsible for about 95% of the national soil loss. About 24% of the croplands in Rwanda had a soil erosion rate larger than 300 tons per hectare per year, indicating their unsuitability for cultivation. With a mean soil erosion rate of 1642 ton per hectare per year, these unsuitable croplands were responsible for 90% of the national soil loss. Most of the unsuitable croplands are distributed in the Congo Nile Ridge, Volcanic Range mountain areas in the west and the Buberuka highlands in the north, regions characterized by steep slopes (>30%) and strong rainfall. Refer to the section on sedimentation in the following chapter for further discussions on the topic.

Nonpoint sources of nutrients from fertiliser applications

Total arable land in Rwanda is reported at 2.3 million ha, but net cropped area in any season is only about 1 million ha (MINAGRI, 2013). Rwanda has approximately 1.5 million smallholder subsistence farmers, more than 80 percent of which cultivate less than 1 ha of land. The Crop Intensification Program (CIP), that begun in 2007, has promoted increased agricultural productivity of high-potential food crops by creating incentives for producers to adopt new production technologies, especially fertilizer, seed and irrigation. The program has emphasized improving the availability, access and use of fertilizers. Government embarked on the bulk procurement of fertilizers while developing a private led distribution system. There has been a resultant increase in fertilizer access and use, and productivity of major staples. This has been facilitated by government subsidies that made fertilizers affordable and advisory extension services that promoted fertilizer use. The use of fertilizers and improved seeds have led to a national productivity increase of three and five-fold for maize and wheat, respectively, and two-fold for rice and Irish potatoes, contributing to improved food security and increased rural incomes. (MINAGRI, 2013); Cantore, ibid).

Consequently, national fertilizer use has increased from 4kg/ha in 2006 (before the CIP was launched in 2007) to 30kg/ha in 2013, (MINAGRI 2013), while fertilizer availability increased from annual quantities of 8,000t/a to 35,000t/a. The nation target for 2017/18 is that fertilizer availability increases to 55,000t/a and fertilizer use increases to 45kg/ha. The Fertilizer Assessment Report (IFAD 2014) estimates that Rwanda must increase its consumption of fertilizer more than four-fold, to 144,000 t/a, to meet the agriculture sector growth targets.

Average application rates of 45kg/ha are still very low in comparison to commercial application rates in countries like South Africa where 300kg/ha of an N.P.K mix plus a nitrogen top-dressing of 150kg/ha for field crops and 1500kg/ha of an N.P.K mix plus a nitrogen top-dressing of 250kg/ha for high value crops such as potato are not uncommon.

The main types of fertilizers used in Rwanda are Urea (46%N), Di-ammonium Phosphate (DAP) (18% N and 46%P) and N.P.K formulations (mainly 17-17-17) (17%N; 17% P and 17%K). The Fertilizer Assessment report (IFAD 2014) showed that on average, over all crops, the ratio of fertilizer types is 40% DAP, 33% N.P.K (17:17:17) and 27% Urea. Therefore, a national use of say 55 000t/a of fertilizer will translate into 10 306t/a N; 13 205t/a P and 3 085t/a K.

Fertilizers applied to a field are not all taken up by the crop. Leachate losses, especially nitrogenous fertilizers which are highly soluble, are strongly influenced by when and how fertilizers are applied. Timing of application in relation to rainfall, season and crop growth is crucial. Greater uptake of fertilizers by crops results from split applications and the use of slow release compounds. The manner of application of the fertilizer also affects how much is lost, for example, incorporation produces less loss than broadcasting the fertilizer, but deep application may result in high leachate losses. Up to 96 percent of nitrate fertilizers, which are more mobile, may be lost if they are placed at a deeper depth leading to high percolation rates.

Relevance

Agriculture is major source of soil loss and sedimentation in Rwanda’s rivers.

In addition, agriculture can be a source of nutrient enrichment in Rwanda’s rivers, wetlands, and lakes. At the current rate of fertiliser application it may not be the major source. However, fertiliser can be exported adhered onto soil particles washed off agricultural lands and this may be a significant pathway for nutrients to enter receiving waterways.

2.2.2 Urban runoff

High levels of non-point sources of contamination, particularly organic material (BOD/COD), hydrocarbons, pathogens, and sediments are associated with formal urban areas and industrial activities with the urban boundaries. Their general character and impacts in Rwanda are similar to those other developing countries, and are as follows:

- Formal residential areas range from sparse small holdings on the outskirts of cities, through suburban and high density multi-stories apartments in the urban centre (informal settlements are dealt with below). They generally have some levels of waste management services (onsite sanitation, solid waste removal, and storm water drains). Residential areas cause increase storm runoff from impervious surfaces, with an associated wash-off of sediment, nutrients, pathogens, organic matter, litter, heavy metals, hydrocarbons and toxic substances. These impacts tend to increase with population density and are aggravated in areas where the waste management services are inappropriately used, overloaded or inadequately maintained. Increased streamflow and encroachment into the riparian zone causes habitat destruction.

- Commercial and light industrial areas are generally located near the urban core and have similar water quality impacts to formal residential areas. Storm runoff increases with impervious area and heavy metal loading tends to be higher, associated with greater pedestrian and vehicle traffic. Pathogen and sediment wash-off can be similar or even higher than in formal residential areas due to the higher density of people. Garages and workshops are often a source of significant hydrocarbon pollution because there is no used oil recycling in Rwanda.

- Heavier industrial areas, are located both within and on the edge of urban centres, and include the metal, food and beverage manufacturing, and agricultural product processing industries. They can be major contributors to atmospheric emissions, with high rates of deposition in the surrounding area. They are generally associated with increased storm runoff and wash-off of heavy metals, toxic organics and nutrients, depending upon the processes and management practices at the site. Other water quality impacts are similar to commercial areas.

- Roads within and between urban centres are a major non-point source of heavy metals and hydrocarbons. Sediment, nutrient, litter, pathogens and organic matter loads from these roads are comparable to commercial and industrial areas. Unpaved and gravel roads in urban areas can cause severe soil erosion, sediment wash-off, and dust pollution.

- Construction and urban development sites represent a significant source of sediment loads in urban areas; often an order of magnitude higher than other urban land uses. This also results in an increase in adsorbed contaminants, such as nutrients and heavy metals, particularly where the construction is in an area with high atmospheric deposition rates. Concrete wash water generally has a high pH due to the cement in the wash water.

- Quarrying activities in urban areas can be dealt with separately as a concentrated source, because the wash-off and groundwater discharge from active quarries and dumps often have very high concentrations of salts, and hydrocarbons from construction trucks. Furthermore, quarries can cause significant sediment in surface runoff and atmospheric contamination through wind erosion of dust particles.

- Waste disposal sites and landfills represent a major concentrated source associated with formal residential and industrial areas. These include solid waste landfills, sludge disposal sites and effluent irrigation fields, which may be associated with nutrient, organic matter, heavy metal, toxic substance and litter impacts in surface wash-off or discharge of leachate.

Situation in Rwanda

In most urban areas in Rwanda, the storm-water drainage systems which was designed to mitigate the impacts of flooding during heavy rainfall events, were found to be inadequate and not keeping pace with the rapidly growing urban population. Localised impacts have been erosion of unstable land and water courses, increased flooding, and threats to private and public infrastructure. When flooding was combined with poor liquid and solid waste collection in urban settlements, it was found that urban runoff carried high loads of pollutants such as hydrocarbons, heavy metals, bacteria, sediment, pesticides and fertilizers into streams or groundwater, threatening environmental and human health (REMA, 2015). Refer to the discussions in the next chapter on microbiological pollution, organic pollution and dissolved oxygen, and urban litter.

Relevance

Urban runoff, especially in areas with poor sanitation services, is a major concern and should be addressed through the development of integrated water quality improvement plans for key urban areas such the City of Kigali and Secondary Cities.

2.2.3 Gravel roads and erosion

Roads, and gravel roads can be a significant source of erosion and fine sediments. Erosion is a natural occurrence in the environment. However, when roads are constructed, they create an interference with the natural drainage systems and collect water, channel it through culverts, increasing its volume and velocity, resulting in accelerated erosion downstream of a bridge or culvert. One of the area's most prone to erosion and gully formation is along the side of roads, especially gravel roads. Roads also act as a source of oil pollution due to vehicle maintenance often conducted next to a road.

Situation in Rwanda

Most rural roads in Rwanda are unpaved gravel roads with the exception of the national roads that are paved. The total road network covers some 2,662 km of paved roads and 11,346 km unpaved roads, making a total of 14,008 km. Roads are classified into national (2,860 km), District (1,835 km) and gravel roads (3,563 km). All secondary roads are unpaved and become very difficult to travel across during the wet season. Truck movements during the rainy season become very difficult due to floods and mudslides, especially with the mountainous terrain of the country. All these contribute to the sediment loads to rivers.

Many roads in urban areas are also unpaved roads and the dust generated by vehicle traffic accumulate and are washed off as sediment during the first rain events. For example, in the City of Kigali there are 153 km of paved classified roads and 864 km on unpaved classified roads (MIDIMAR, 2015). Unrehabilitated road cuttings and embankments with a steep slope can be significant sources of sediment during rainfalls, especially on newly constructed roads, or newly graded roads.

Some of the negative impacts with regard to pollution include contamination of runoff from road with construction material such as sand / cement / silt from stacked excavated earth, and elevated air pollution and noise pollution in the project area during construction and maintenance (Huguette, 2017). Air pollution is due to generation of noxious gases emanating from asphalt plants, construction equipment, crushers etc., while noise pollution is due to operation of various types of construction equipment. It includes runoff from staked construction waste entering the water bodies and existing drainage systems causing clogging of drain outlets as well as the drains themselves.

Landslides pose a risk to roads and erosion damage to nearby rivers and streams. According to the National Risk Atlas of Rwanda, a total of 553 kilometres of paved national roads and 691 kilometres of unpaved national roads are exposed to landslides. These figures represent respectively forty-five percent and thirty-nine percent of total [classified] national paved and unpaved roads in the country. The total district roads exposed to landslides is 2,003 kilometres. This represents about seventy-four percent of the total length of the [classified] district roads in the country.

Relevance

The erosion impacts of construction, maintenance and operational activities on gravel roads can be mitigated by integrating land stability into the road designs to address the landslide risks, by planting grasses on embankments slopes with low landslide risks; by stone masonry construction on embankments' slopes with high risks; and tree planting along rehabilitated roads. In addition, the application of appropriate erosion-protection measures, in particular where it concerns works on slopes and in stream beddings. Furthermore, road and other works should not be executed under aggressive weather conditions (rains, strong winds) (Huguette. 2017).

2.2.4 Air pollution

The quality of surface water resources is often correlated with air quality in the surrounding area. Atmospheric contaminants may be from natural or human sources, and may be deposited onto land and water surfaces during dry periods or be washed out with rainfall. The latter is generally the main deposition mechanism, with the concentration of some chemicals in rainfall accounting for the majority of contamination in the associated runoff.

Wind erosion and fire are probably the two main natural sources in Rwanda, while emissions from vehicles, industries, energy production and domestic fuel burning comprise the major human sources. These human sources are generally concentrated around urban and industrial areas, and urban deposition is generally far greater than rural deposition. Atmospheric deposition is a significant contributor to non-point sources of heavy metals, nutrients, and sulphates, which can have a great impact on rainfall acidity.

Situation in Rwanda

Rwanda has one of the lowest emissions per capita in the world, estimated at 0.65 tonnes CO_2/person (including land use change), compared to a global average of 4.63 tonnes CO_2/person (Nsengimana et al., 2011). The majority of greenhouse gases emissions were CO_2 (87%) at 531 Gg, dominated by transport (52%) and industrial processes (28.5%). The aggregate emissions or total CO_2 equivalent, used for measuring global warming potential, amount to 5,010.4 Gg in 2005, dominated by agriculture (78%) and energy (18%). Nitrous oxide (N_2O) and methane (CH_4) are the most potent greenhouse gases, contributing 62% and 26% of aggregated emissions. Four key sources contribute 91% of aggregate emissions: N_2O from agricultural soils (57%); CH4 from enteric fermentation in domestic livestock (19%); CH4 from residential energy from fuel; and combustion (8%); CO_2 from road vehicles (5%) (Byamukama et al., 2010).

Aligned with its commitment to reduce air pollution, Rwanda became a member of the Climate and Clean Air Coalition during the COP22 held in Marrakech (Morocco) on November 2016.

Refer to the more complete discussion on air pollution in the next chapter (Section 4.2.4).

Relevance

The monitoring of air pollution should be strengthened, and point source areas of air pollution should be targeted for control and rehabilitation.

CHAPTER 3 WATER QUALITY CONCERNS AND INDICATORS

3.1 Introduction

Rwanda is experiencing a range of water pollution problems. In this section these are introduced and the situation in Rwanda is reviewed. Where information is available at Level 1 catchment scale, these are discussed.

3.2 Erosion and sedimentation

3.2.1 Description

Erosion is the action of surface processes (water or wind) that remove soil particles from one location and transport it to another. Rainfall, and the resulting runoff from rainfall, produces soil erosion. The different forms of soil erosion are: splash, sheet, rill, and gully erosion. Sedimentation refers to the erosion; wash-off and silt load carried by streams and rivers and typically reflects the natural geophysical and hydrological characteristics of the upstream catchment. Many Rwandan rivers carry naturally high suspended solids load, but it is aggravated by changes in land-use. Sediment loads have further increased through extensive agricultural activities and practices, construction activities, silviculture practices, over-grazing, destruction of the riparian vegetation, and the physical disturbance of land by industrial and urban developments.

The Rwanda State of the Environment and Outlook report (REMA, 2015) stated that sediment as a form of pollution, heavy rains, unsustainable agricultural practices, deforestation and steep slopes contribute to erosion and the consequent siltation of receiving water bodies (rivers, lakes, wetlands and reservoirs). The waters of the Bugesera and Gisaka lakes in which the Akagera River traverses turn brown during rainy seasons due to heavy siltation. Siltation in wetlands affects their ability to regulate water flow and filter physical and chemical pollutant.

High sediment loads are readily visible in Rwanda's readily visible in Rwanda's highly turbid and muddy streams and rivers, particularly during the rainy season. Total Suspended Solids were especially elevated in water samples taken from the Sebeya and Nyabarongo Rivers, which registered from 500 to 660 mg/L and 320 to 350 mg/L, respectively. Sediment concentrations vary considerably with run-off patterns. High levels of suspended sediment have led to considerable economic losses due to siltation of rivers, lakes and reservoirs that generate almost half of Rwanda's electricity.

Erosion control has been practiced in Rwanda formally since 1937 at INEAC research stations (Kabiligi, 1985), with the program being extended nationally in 1947. At this time ditches and planting trees and grass was obligatory for all land holders. After 1962 erosion control was abandoned but in 1966 several compulsory programs were revived (1966-1970; 1977-1981; 1982-1986). In 2005 the same approach was followed, with many bench terraces being constructed (Rushemuka et al., 2014) and with the Land husbandry, water harvesting and Hillside Irrigation (LWH) project and LVEMP II project these strategies have seen further progress. It is clear that over time, and as the population pressures on the land has grown, the shape of the landscape has changed significantly.

A key lesson learnt through these programs is the inherent link of soil conservation and erosion control with soil fertility management. This was learnt as perfectly adequate bench terraces were abandoned if built on strongly acidic, depleted and unproductive soils without adequate nutrient supply (Rushemuka et al., 2014).

Rwandan soils are naturally fragile, a physico-chemical alteration of basic schistose, quartzite, gneissic, granite and volcanic rocks (Twagiramungu, 2006). Soils therefore require high levels of investment in soil amendments.

Although erosion is considered to be a severe problem, analysis of the problem has seen limited attention due to the costly and laborious nature of collecting data over large areas. The magnitude and spatial pattern of soil erosion are unclear at the national scale (Karamage et al., 2016) meaning that modelling techniques have been used to make predictions. The Universal Soil Loss Equation (USLE) (Lufafa et al., 2003), Revised Universal Soil Loss Equation (RUSLE) (Karamage et al., 2016) and Soil and Water Assessment Tool (SWAT, uses Modified Universal Soil Loss Equation (MUSLE)) (Ndomba et al., 2010) have been used to model erosion at a National scale. Values for the national mean soil erosion rate have been provided as 250 t.ha-1.a-1, with a total soil loss rate of approximately 595 million tons per year using the Universal Soil Loss Equation (USLE) model (Karamage et al., 2016). In terms of estimations for the catchment the average soil erosion rate may be considered to be 438 t.ha-1.a-1, with cropland erosion being 699 t.ha-1.a-1 (Karamage et al., 2016). This is higher than the national mean soil erosion rate indicating that the area is a large contributor to national erosion.

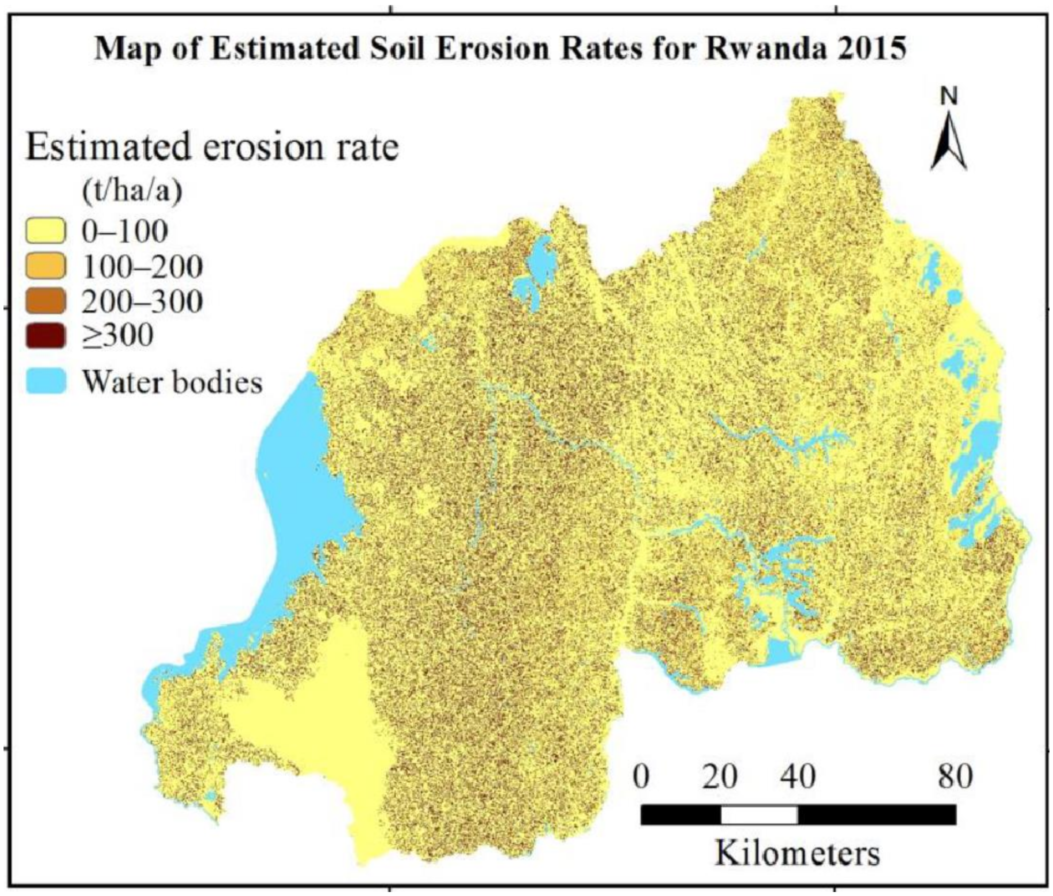

Figure 5-1: Map of estimated soil erosion rates for Rwanda 2015 (Karamage et al., 2016)

One problem facing water supply in Kigali is the high sediment load in river water, which is costly to remove. According to Electrogaz's Kimisagara water plant, annual suspended sediment levels averaged 250 mg/L and 134 mg/L for 2006 and 2007, respectively. Installation of a water sheet to filter sediments is planned to improve water quality.

Managing non-point pollution sources of sedimentation requires an integrated water catchment approach. Government policy restricting cultivation within 15m of riverbanks and 50m of lakeshores is a positive measure to protect water resources.

One source of sediments is landslides which exposes large areas of open soil that can be washed into rivers and streams during high rainfall events. The Rwanda slope susceptibility map (Figure 5-2) shows the spatial distribution of the susceptibility classes for the entire country (MIDIMAR. 2015). The western high lands are more prone to landslide while the eastern lowlands are of low susceptibility. Due to its hilly topography, Rwanda shows high susceptibility to landslide, 42% of the country's area is classified with moderate to very high susceptibility.

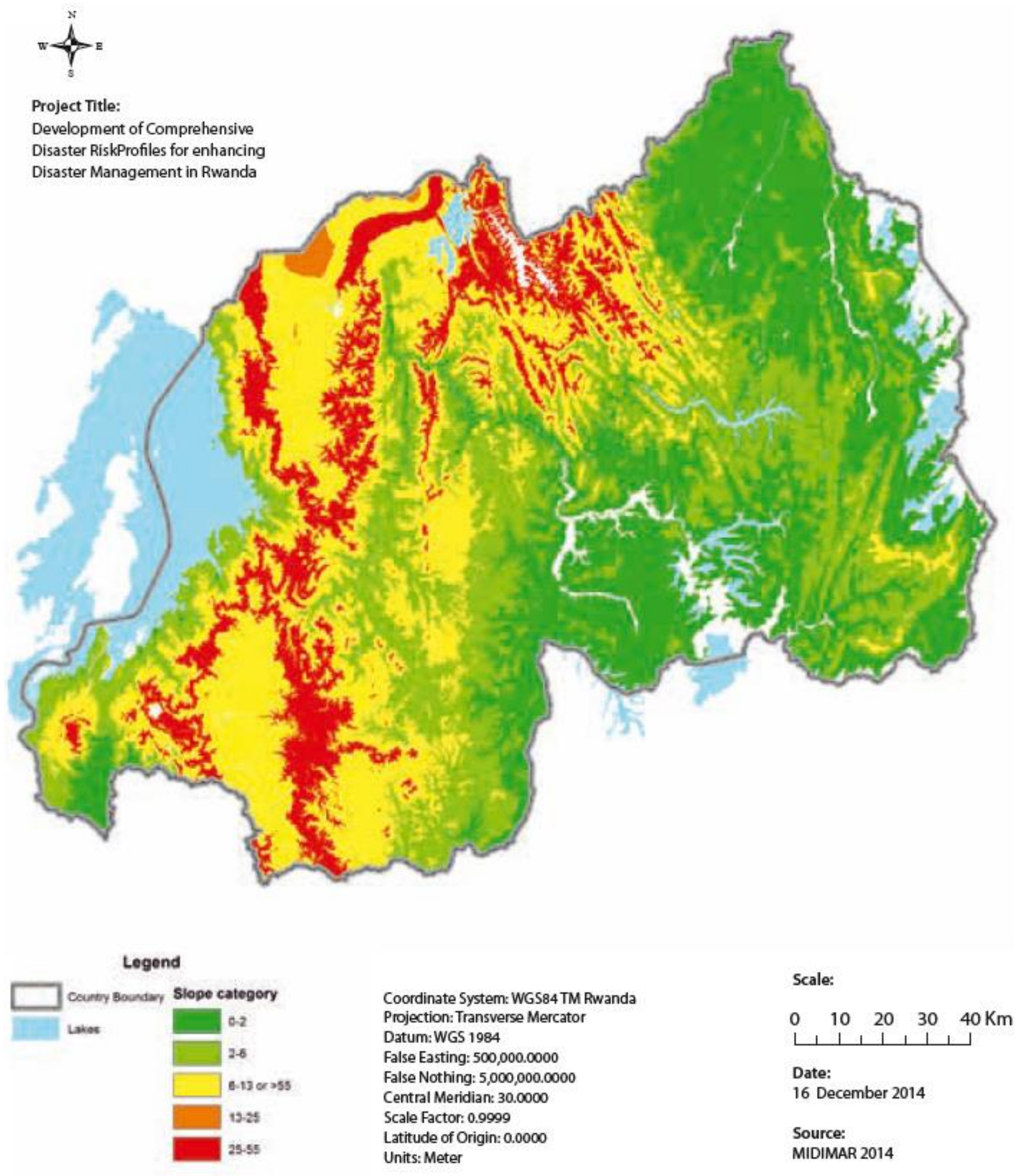

Figure 5-2: Slope susceptibility map of Rwanda (MIDIMAR, 2015)

The sedimentation issues are also unpacked in much greater detail in the Nyabarongo Downstream, and Akagera Upstream catchment management plans that are being developed as part of this project.

The Ministry of Environment (2017) stated that the increase in population while the cultivated land remains constant has led to extension of agriculture to steeply sloping land areas with shallow soils that require higher standards of management if their resources are to be conserved. Unfortunately, they were poorly utilized by farmers with limited capacity for their sustainable management and this has led to the loss of a large amount of soil from agricultural lands which end up causing the siltation of rivers. This is aggravated by unsustainable mining activities being carried out in most of the catchments. These also contribute to the siltation of rivers and this can be observed by the high turbidity of rivers even in the absence of rain which normally conveys soil from agricultural lands into water bodies.

3.2.2 Status

Ministry of Environment (2017) found that in the Congo basin, the Total Suspended Solids (TSS) varied between 0 to 1,343.3 mg/l. For most of the sites, the TSS values were below or slightly above the acceptable standards (30 mg/l). However, the TSS were highly elevated above the standards at the Koko River outlet (1,343.3 mg/l), Sebeya river outlet (990.3 mg/l) and Sebeya river after confluence with Bihongora river (282 mg/l). The authors felt that the presence of high values of the total suspended solids for Sebeya and Koko rivers could be attributed to the fact that two river catchments are affected by intensive mining activities. For Sebeya River, intensive unsustainable mining activities were practised from its source in Muhanda Sector of Ngororero District and Nyabirasi sector of Rutsiro District but also downstream in Kanama and Nyundo Sector of Rubavu District. For Koko River, which is located in Rustiro District, the same activities are occurred from its upstream reaches to its outflow. Although the two catchments were exploited for agricultural activities as well which are also susceptible to contribute to the accumulation of suspended solids in rivers, mining activities were the most likely major contributors due to the fact that the sampling was done in a period when there was no rain, which means that there was very limited or even no soil erosion coming from agricultural lands.

Ministry of Environment (2017) recorded values for the Total suspended solids (TSS) that were higher than the acceptable limit for most of the sites in the Nile basin. The highest values were found at the outlet of upper Nyabarongo catchment (2,631.7 mg/l), Nyabarongo river before its confluence with the Mukungwa river, and at the outlet of Giciye river (1,998 mg/l). Giciye river is a tributary of Mukungwa river. The authors stated that the accumulation of TSS in Nyabarongo river before the Mukungwa river confluence was mainly due to mining activities being carried out in the entire upstream part of the sampling site. Considering that the TSS concentration at the beginning of Nyabarongo river (after the confluence of Mwogo and Mbirurume rivers) was found to be relatively low (150 mg/l) compared to the one at the outlet of Upper Nyabarongo river (before receiving Mukungwa river), this was an indication that most of the activities contributing to the sedimentation of Nyabarongo river are happening in between the Districts of Muhanga and Ngororero. These findings appear to confirm the findings of historical water quality monitoring undertaken in 2011, 2012, and 2015/16 (RNRA, 2012a, b, c, and RNRA, 2016).

A review of the average turbidity's recorded by RWFA from 2011-2017 indicate that most of the rivers in Rwanda were very turbid and 22 of the 37 monitoring points exceeded the turbidity guideline value of 30 NTU (Figure 5-3).

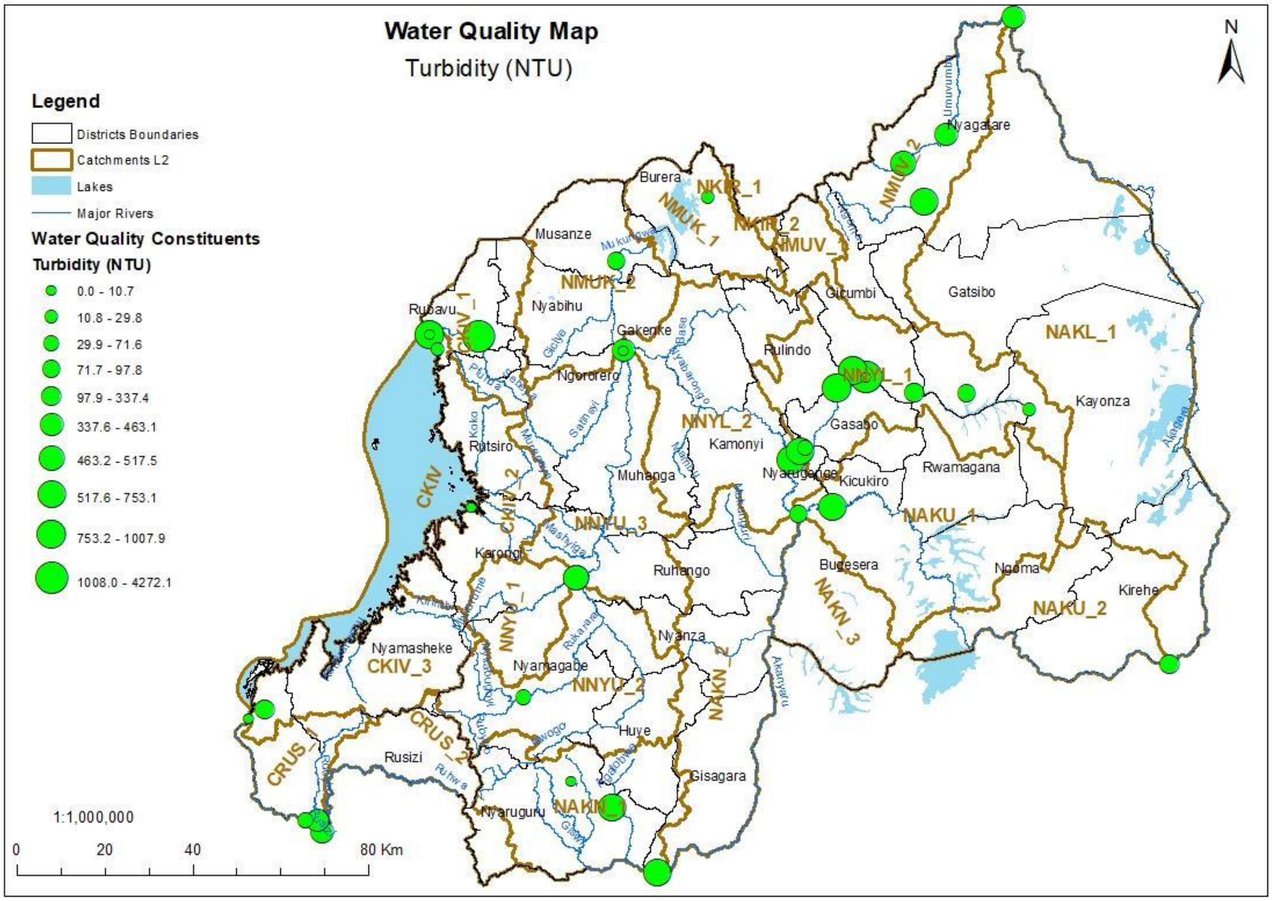

Figure 5-3: Bubble diagram of mean turbidity's (NTU) recorded in Rwanda between 2011 - 2017.

3.2.3 Potential impacts

High suspended sediment loads decrease light penetration into water thereby reducing primary productivity of the aquatic ecosystem, it affects the natural balance of predators and prey in biotic communities, it smothers habitats, pants and organisms, and change the viability of riverine vegetation. Additionally, high sediment loads deposited in lakes and reservoirs reduce their storage capacity over time. Excessive sediment concentrations also cause damage to hydropower plants where scour damage to turbine blades shorten the lifespan of turbines. High turbidity also interferes with cultural and recreational activities in rivers and lakes because it obscures underwater hazards.

The key water quality concern in Rwanda in terms of surface water quality is related to sedimentation/siltation of water bodies, mainly due to soil erosion (Ministry of Natural Resources, 2017). This is followed by microbiological contamination that is linked to poor sanitation. The issue of sedimentation is strongly linked to good land care and should be addressed in the water quality guidelines and plan for Rwanda.

3.3 Microbiological pollution and water-borne pathogens

3.3.1 Description

Microbial pollution is the presence of micro-organisms and parasites which cause diseases in humans, animals and plants. Most waterborne pathogens occur in human or animal faeces and enter waterways via various pathways. Micro-organism include protozoa (e.g. Giardia & Cryptosporidium), bacteria (e.g. E. coli), bacterial infections (e.g. Shigella), viruses (e.g. hepatitis) and helminths. Recreational and potable users of water rely on access to safe water. Theirs is a major concern in the national drive to provide reliable and safe sources of water to all. Groundwater contamination in urban areas, dense human settlements, and overloaded sewage systems are the major source of deteriorating microbiological water quality. Micro-organisms and parasites may enter the water system in partially-treated sewage effluents, seepage and run-off from inadequate sanitation and waste disposal.

The microbial content of water represents one of the primary determinants of fitness for use. Human settlements, inadequate sanitation and waste removal practices, stormwater wash-off and sewage spills are the major sources of deteriorating microbiological water quality in Rwanda.

The spread of diseases such as cryptosporidiosis, dysentery, cholera and typhoid are caused by the use of water that is contaminated by faecal matter. Pathogens derived from faecal matter can also affect fruit and vegetable crops through contaminated irrigation water.

The World Health Organization estimates that 94% of diarrhoea cases are preventable by increasing the availability of clean water, and improving sanitation and hygiene (WHO, 2007).

Surface and drinking water quality, in peri-urban and rural areas, could further be compromised by unskilled plant operators, old and inadequate infrastructure, and poor maintenance. Interruptions in the water supply and provision of poor quality water are common in these areas.

The State of the Environment report (REMA, 2015) stated that the impacts of untreated sewage and wastewater include the risks to humans of water-borne disease. The use of water that is likely to be contaminated (such as unprotected spring water) increases the risk of contracting disease. According to Rwanda’s 2010 DHS, the prevalence of diarrhoea is especially high among children age 12-23 months and 6-11 months (25 per cent and 22 per cent, respectively).

Pollution by domestic waste: Used domestic water which is 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, and so forth.

3.3.2 Status

Ministry of Environment(2017) found that the counts of E-coli at all the Congo basin sampling sites were found to be far above the acceptable standard of 4 cfu / 100 ml. These concentrations varied from 21.3 cfu / 100 ml at to 1,166.6 cfu /100 ml. The high concentrations of E-coli were attributed to poor sanitation practices in the entire area. However, there are some areas where the concentration of E-coli was found to be extremely high emphasising the need for special attention in terms of improving sanitation practices. Specific districts included the Koko catchment (Rutsiro District). Ruhwa catchment (Rusizi District but this catchment was shared with Burundi), Rubyiro catchment (Rusizi District), and the Sebeya catchment (Rubavu District). The authors felt that it was important to note is that in The Sebeya catchment two sites were monitored, one upstream after the confluence of Sebeya and Bihongora river in Kanama sector, and the other one at the outlet of Sebeya River to the lake Kivu. A very high increase in E-coli concentration was observed from the upstream site 53 cfu / 100 ml to the site at Sebeya outlet 223 cfu / 100 ml. It was concluded that this indicated that the areas contributing much to the accumulation of E-coli in Sebeya River were those between Mahoko Centre in Kanama as well as Nyundo and Rugerero areas. These areas have a large number of people living along the river and for most of the time having their toilets located very close to the river.

Ministry of Environment (2017) also found that the concentration of E-coli for all the monitored sites in the Nile basin were higher than the acceptable limit (4 cfu/100ml). The highest concentrations of E-coli were found at:

- Nyabarongo River(6,666.7 cfu/100ml), downstream of the confluence of the Mwogo and Mbirurume;
- Giciye River(4,133 cfu/100ml), upstream of the confluence with the Mukungwa River;
- Stream coming from the Gikondo industrial park (3,133.3 cfu/100ml), at the Kinamba bridge;
- Muvumba River (2,533.3 cfu/100ml), upstream of the confluence with Warufu River;
- Nyabugogo River (2,200 cfu/100ml), after flowing through the Kigali urban area; and
- Muvumba river (2,033 cfu/100ml), at the border with Uganda.

The authors concluded that it appears that lack of adequate sanitation was a very big issue in most parts of the basin and this being the case for both urban and rural areas. The best approach to deal with this concern in urban areas could be through improved wastewater treatment technology and management, whereas in rural areas the most appropriate approach could be through on-site sanitation systems coupled with education, sensitization and behaviour change campaigns on improved sanitation practices. Similar findings were made with monitoring undertaken in 2011, 2012, and 2015/16 (RNRA, 2012a, b, c, and RNRA, 2016).

A review of the average E coli counts recorded by RWFA from 2011-2017 indicate that all of the rivers in Rwanda recorded E coli counts greater than the guideline value of 4 cfu/100ml (Figure 5-4).

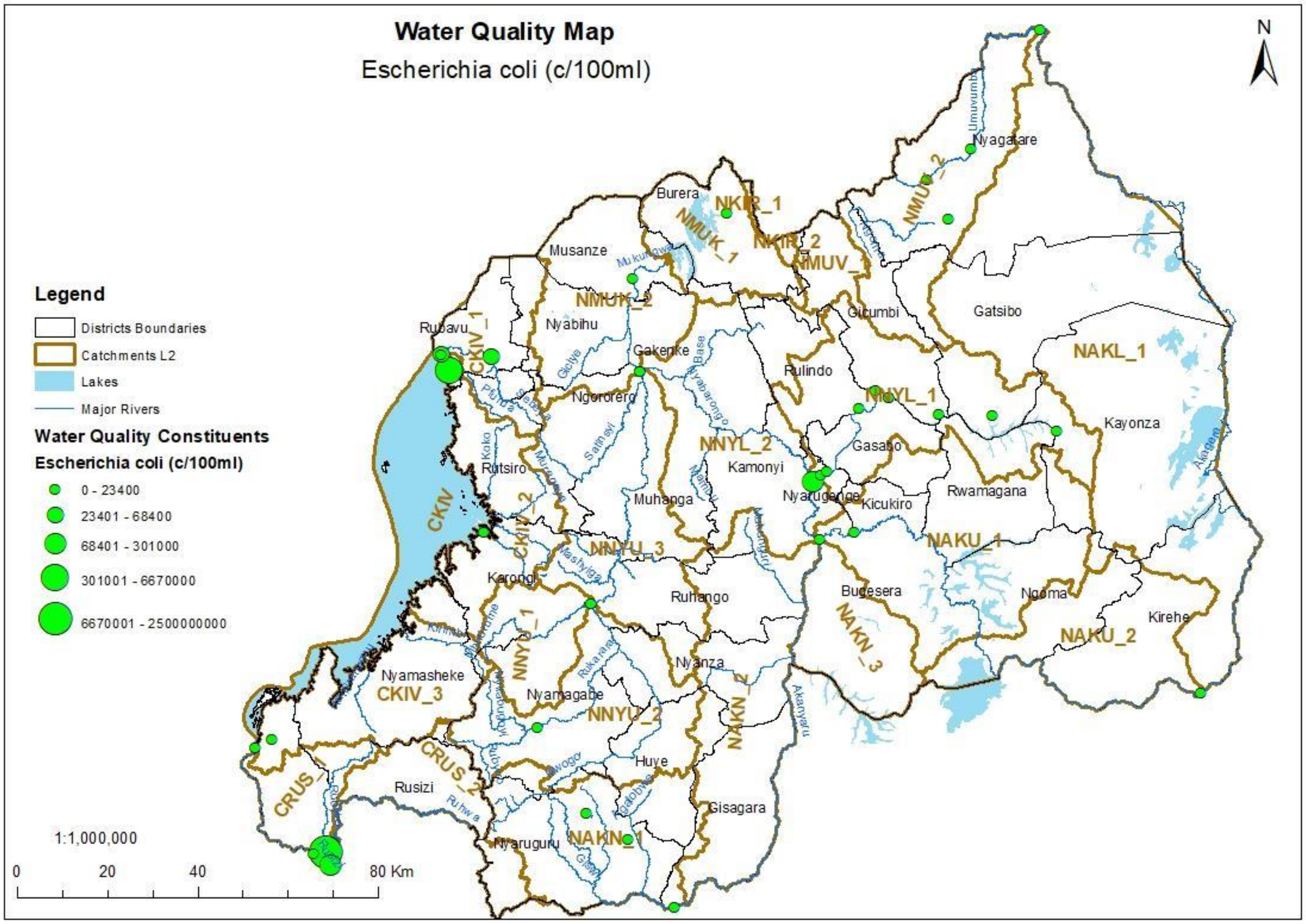

Figure 5-4: Bubble diagram of mean E coli counts (counts/100ml) recorded in Rwanda between 2011 - 2017.

3.3.3 Potential impacts

The high E coli counts in Rwandan rivers mean that the water poses a real health risk to users that take water directly from the river for drinking water and for other domestic uses. It also poses a health risk children swimming and playing in rivers and streams, and there is a risk of contracting diseases if vegetables are eaten raw if it was irrigated with river water high in pathogens.

The recommendations of Ministry of Environment (2017) are supported that in order to address the bacteriological pollution in urban areas should be through improved wastewater treatment technology and management or grey water discharges, whereas in rural areas the most appropriate approach could be through on-site sanitation systems coupled with education, sensitization and behaviour change campaigns on improved sanitation practices.

3.4 Salinization

3.4.1 Description

Salinity refers to the total dissolved inorganic compounds in the water and is measured as total dissolved solids (TDS). Salinization refers to the increase in the amount of salts or dissolved solids in the water, as well as the accumulation of salts in soils, to the detriment of cultivated crops. Another definition of salinization refers to the build-up of salts in a river system to such a level that it poses a threat to the ecological integrity of the river and interferes with the desirable uses of the water. Human activities that contribute to salinity include the discharge of municipal and industrial effluent; irrigation return water; urban storm-water runoff; surface mobilisation of pollutants from mining and industrial operations and seepage from waste disposal sites, mining and industrial operations. Effects of increased salinity include build-up of salts in irrigation soils and the resultant reduction in crop yields; increased scale formation and corrosion in domestic and industrial water conveyance systems, increased requirement for pre-treatment of selected industrial water uses, and changes in aquatic biota.

Salinity is a measure of the dissolved solids in the water and are measured as TDS (total dissolved solids) or as Electrical Conductivity (EC). The total dissolved solids concentration is a measure of the quantity of all compounds dissolved in water. The total dissolved salts concentration is a measure of the quantity of all dissolved compounds in water that carry an electrical charge. Electrical conductivity (EC) indicates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. The effects of the TDS are governed by the constituent inorganic salts and it affects the metabolism of organisms. Secondary effects include those on water chemistry, which in turn affect the fate and impact on the aquatic environment of other chemical constituents or contaminants.

In Rwanda salinization has not been identified as a major water quality problem in rivers due to the high level of dilution with low salinity water. However, there are specific hotspots where localised salinization could occur although the impacts are confined to the area where pollution occurs.

3.4.2 Status

Ministry of Natural Resources (2017) found that TDS concentrations in the Congo basin sampling sites varied from 9.9 to 525.3 mg/l. The highest concentration was observed at the CKIV1 site. When compared with other site values, it was observed that five sites were presenting TDS values varying between 450 and 525 mg/l. It was speculated that this could be an indication of increased water pollution activities induced by surface runoff or domestic and industrial wastewater dumping near the affected sampling sites which was located at Rubavu, Karongi and Rusizi towns.

The authors found that the sampling showed concentrations of TDS varying at all sites in the Nile basin from 13.3 to 292.3 mg/l. All recorded values were below the standard limit for surface water bodies (Figure 5-5).

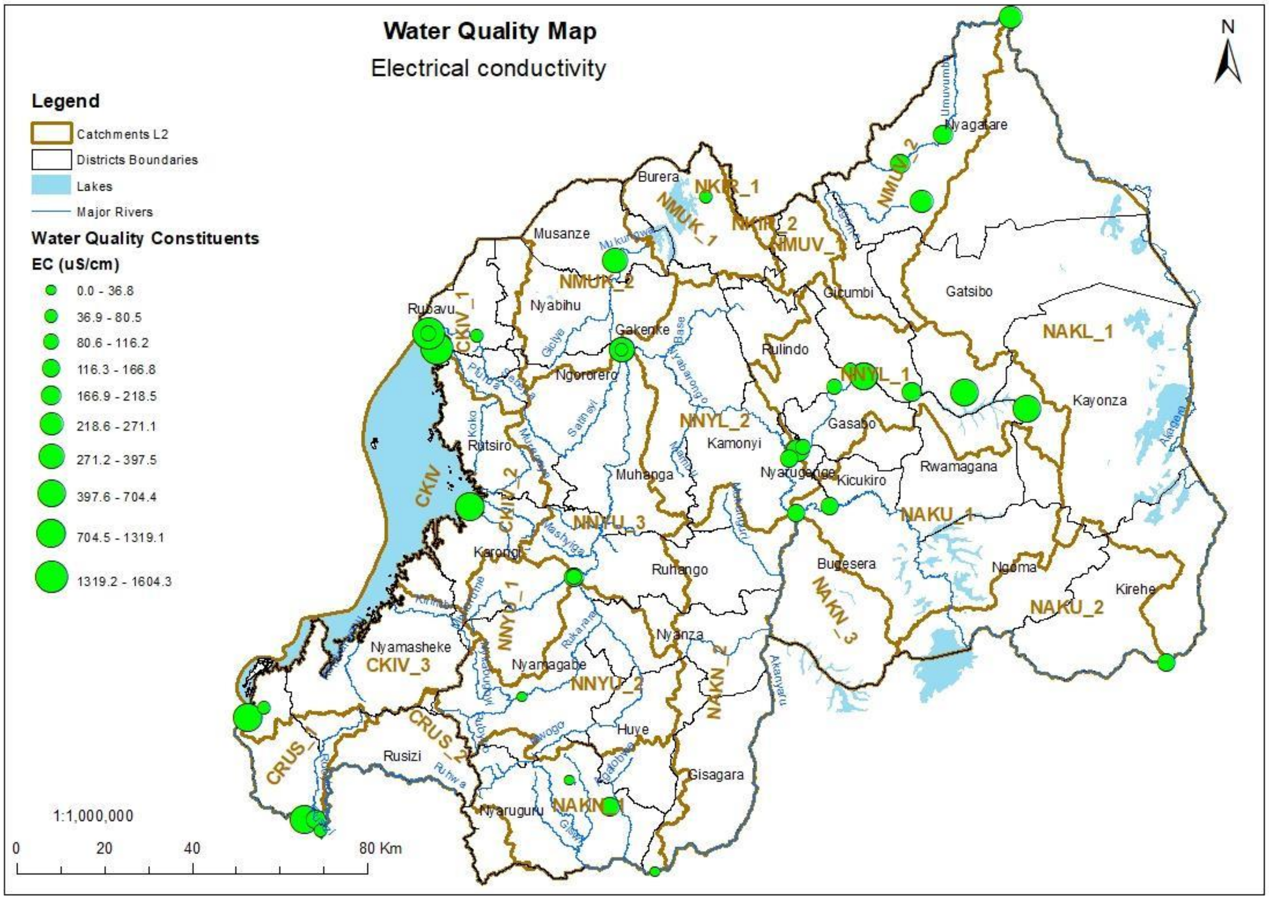

Figure 5-5: Bubble diagram of mean Electrical Conductivity (µS/cm) recorded at sampling points in Rwanda between 2011 - 2017.

A review of the average electrical conductivity, a measure of salinity, recorded by RWFA from 2011-2017 indicate that most of the rivers in Rwanda have low salinity and the guideline value of 1000 µS/cm was only exceeded at 5 of the 39 sampling points in Rwanda (Figure 5-5). This confirms the findings of historical water quality monitoring undertaken in 2011, 2012, and 2015/16 (RNRA, 2012a, b, c, and RNRA, 2016).

3.4.3 Potential impacts

With the exception of a few hotspots where industrial effluent discharges may increase salinity, salinization of rivers in Rwanda is not a major concern. However, the situation should be monitored in the light of the industrial expansion that is envisaged for Rwanda as part of the EDPRS 2.

3.5 Nutrient enrichment and eutrophication

3.5.1 Description

Nutrient enrichment refers to the accumulation of plant nutrients in rivers and dams in excess of natural requirements resulting in nutrient enrichment or eutrophication which may impact on the composition and functioning of the natural aquatic biota. The most essential nutrients required by plants are nitrogen and phosphorus in various forms (NO_2, NO_3, NH_4, PO_4). The direct impact is the excessive growth of algae and macrophyte (rooted and free-floating water plants) leading to impacts on the attractiveness for recreation and sporting activities; the presence of toxic metabolites in cyanobacteria; the presence of taste- and odour-causing compounds in treated drinking water, and difficulty in treating the water for potable and/or industrial use.

In Rwanda there are concerns of nutrient enrichment, eutrophication and nuisance algal growth in some of the lakes that serve as a source of domestic water for surrounding communities and towns. Nutrient enriched water also promotes the growth of invasive aquatic water plants such as water hyacinth (Refer to Section).

The State of the Environment Report (REMA, 2015) felt that improper fertilizer applications can increase nutrient loads and affect water quality. The report on the Impact of Fertilizer Use in Rwanda, found with respect to the Rweru-Mugesera Wetland Complex, that under the land consolidation programme, farmers based fertilizer application rates on uniform rates and national recommendations for fertilizing different crops such as maize, wheat and rice. The report recommended that it is best to establish the local soil's specific fertility needs and apply the right dose of fertilizer in consequence. Many farmers also preferred the ease of applying chemical fertilizers to the labour-intensive use of organic ones and the associated best practices for cropping. The report concludes that "the impact on the aquatic systems is clearly linked to the increasing use of mineral fertilizers and decreasing use of organic manure and good conservation practices by farmers". It notes that the Rweru-Mugesera lakes wetland complex suffers from pollution and habitat degradation due to the loss of soil fertility and runoff of mineral fertilizers through erosion and leaching (REMA, 2014).

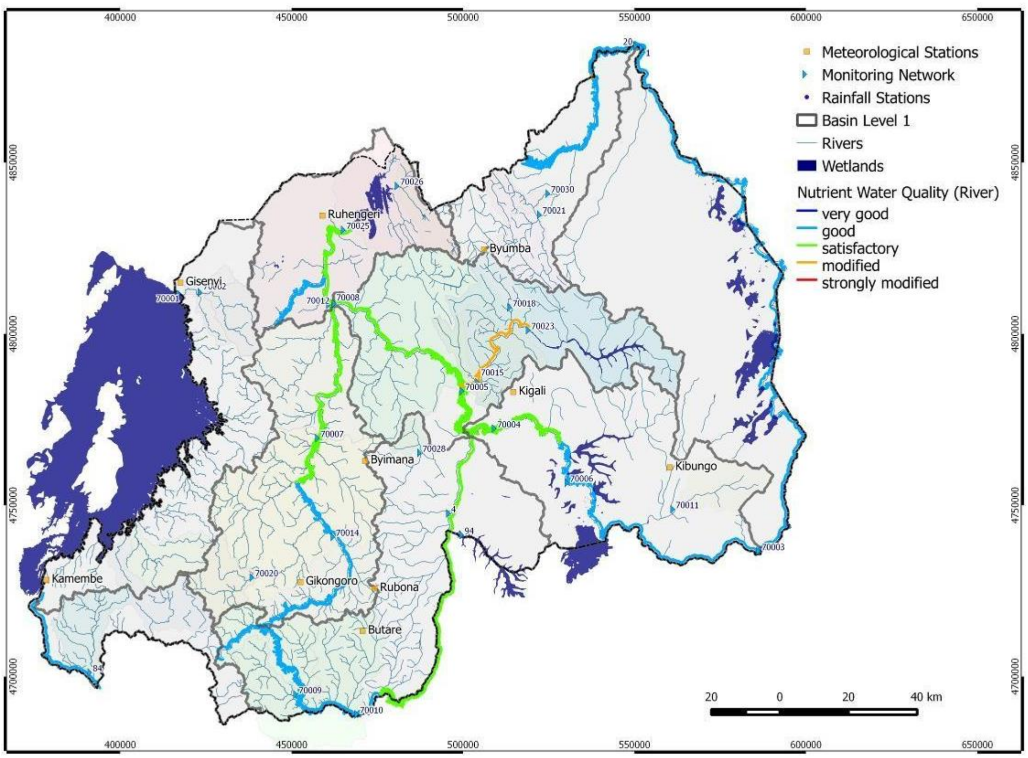

figure 5-6: National water quality map of nutrient concentration (nitrogen, phosphorus) as reported in the Rwanda water resources master plan.

The State of Environment and Outlook report (REMA, 2015) raised a concern that increasing pollution from agro-inputs, including ammonia, nitrate, phosphate and pesticide residues (through leaching and erosion) is affecting groundwater locally and the ability of ecosystems to naturally purify water.

3.5.2 Status

The investigation of the Ministry of Environment (2017) showed that values for the Dissolved Inorganic Nitrogen (DIN) in the Congo basin sites were all below the maximum acceptable standard limit of 3 mg/l. Recorded concentrations were varying between 0.5 and 2.2 mg/l. The highest values were found at Lake Kivu, on the Nyamasheke side with 2.2 mg/l and the at the outlet of Sebeya River with 2.1 mg/l respectively. Recorded values for the Total dissolved phosphorous (DIP) in the Congo basin sites were all below the maximum acceptable standard of 5 mg/l. Concentrations varied between 0.1 and 1.4 mg/l. The highest concentration was found at the outlet of Koko River (1.4 mg/l).

Ministry of Environment (2017) also found that in the Nile basin sampling points, all recorded values of Dissolved Inorganic Phosphorous (DIP) were below and well within the acceptable limit of 5 mg/l. The observed concentrations of the Dissolved Inorganic Nitrogen (DIN) for almost 50 % of the monitored sites in the Nile basin region was found to be higher than the acceptable limit of 3 mg/l. The highest values were found at Muvumba river (8.1 mg/l), before its confluence with Warufu river, and at Muvumba river after confluence with Warufu river (7.7 mg/l), as well as at the outlet of Mulindi river (7.7 mg/l) before it flows into Uganda. In 2012 the Total Phosphorus concentration was found to be high in three sites in the Nile basin (Nyabugogo after mining activities at Rusine centre, Nyabarongo at Nzove and Kadahokwa River) (RNRA, 2012c).

A review of the average total phosphorus and total nitrogen concentrations recorded by RWFA from 2011-2017 indicate that most of the rivers in Rwanda had high nutrient concentrations. Three of the 39 sampling points recorded nitrogen concentrations higher that the guideline value of 3 mg/l and none of the sampling points recorded phosphorus concentrations greater than the 5 mg/l guideline value (Figure 5-7 and Figure 5-8).

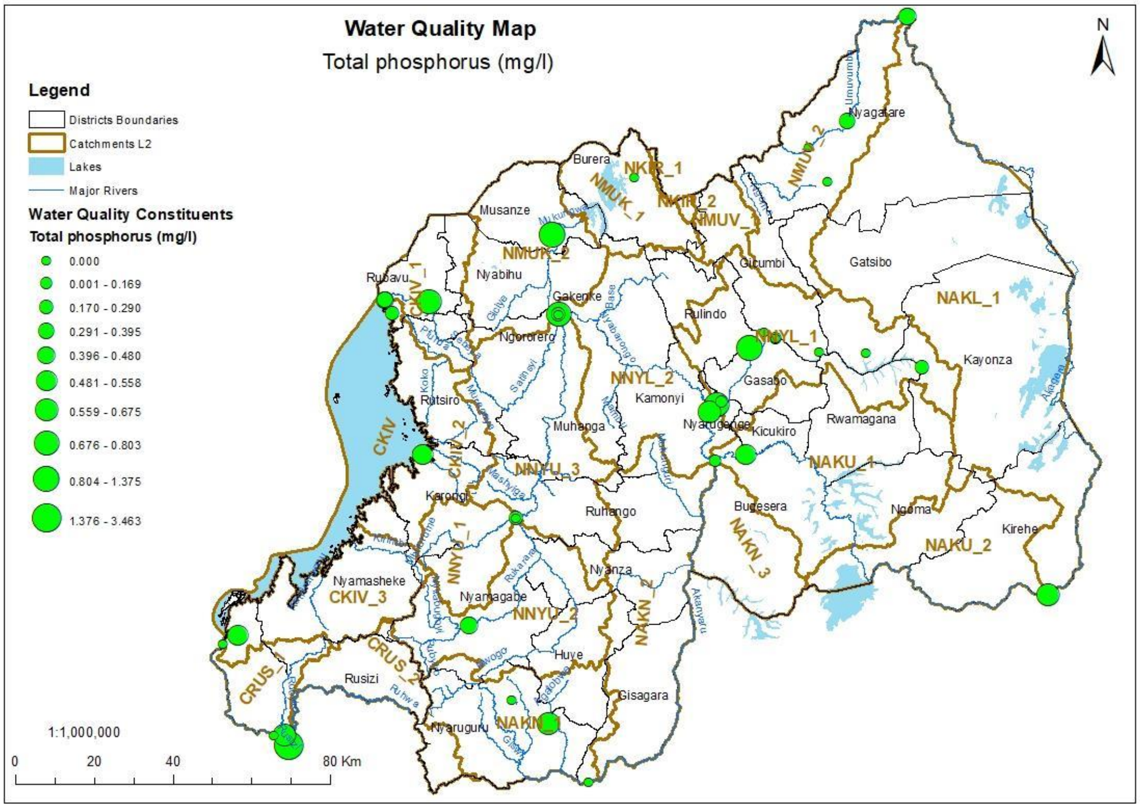

Figure 5-7: Bubble diagram of mean Total Phosphorus concentrations (mg/l) recorded at monitoring points in Rwanda between 2011 - 2017.

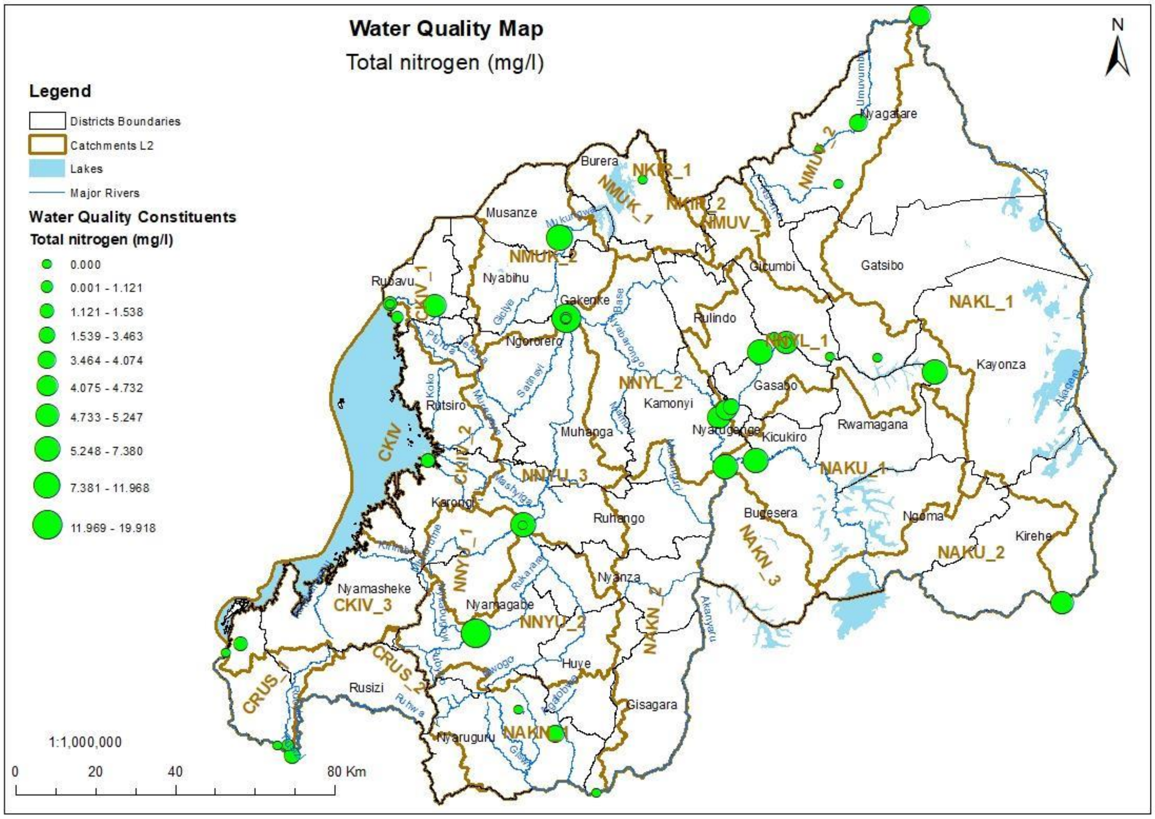

Figure 5-8: Bubble diagram of Total Nitrogen concentrations (mg/l) recorded at sampling points in Rwanda between 2011 - 2017.

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3.5.3 Potential impacts

Nutrient enrichment and eutrophication of rivers and lakes stimulate excessive growth of aquatic algae and plants. The problems associated with excessive eutrophication are numerous and they may be both long- and short-term. These include, amongst others:

- Increased occurrence and intensity of nuisance algal blooms;
- An increasing dominance of blue-green algae;
- Increased occurrence of toxic blue-green algae;
- Clogging of irrigation canals with filamentous algae;
- Increased occurrence of floating and rooted aquatic water plants (macrophytes);
- Increased occurrence of taste and odour problems in drinking water;
- Increased occurrence of deoxygenation in bottom waters with associated chemical effects (hydrogen sulphide and elevated levels of heavy metals);
- Increased fish and invertebrate mortality;
- Changes to ecological community structure and loss of biodiversity;

- Increased water treatment costs through filter clogging in water treatment works;
- Increased interference in recreation activities (boating, fishing, swimming);
- Increased occurrence of human health problems (gastroenteritis, skin complaints);
- Loss of property values
- Interference with irrigation and livestock agriculture (e.g. mortality of stock);
- Undesirable aesthetic conditions (e.g. turbidity, foam, discolouration, odours).

Although many of the phosphate concentrations measured in Rwanda were below the acceptable limit of 3mg/l, it was still high enough to induce eutrophication in lakes and reservoirs. The OECD total phosphate limits for eutrophic conditions in lakes are between 0.035 – 0.100 mg/l, and if the mean TP concentrations exceed 0.1 mg/l severe algal bloom problems can be expected (Ryding and Rast, 1989).

3.6 Acidity and Alkalinity

3.6.1 Description

The acidity or alkalinity of a water body is measured as pH which measure of the hydrogen ion activity in a water body. The pH of natural waters is determined largely by geological and atmospheric influences. Freshwater resources in Rwanda Africa are relatively well-buffered. However, human-induced acidification, from industrial effluents, and possibly mine drainage, can cause a lowering of the pH, leading to mobilisation of elements such as iron, sulphate, aluminium, cadmium, cobalt, copper, mercury, manganese, nickel, lead and zinc. This may affect the aquatic biota, as well as domestic, industrial and agricultural users (corrosion of metal equipment and appliances).

In Rwanda, acid mine drainage is not a concern yet. There may be localised impacts as a result of industrial effluent discharges, or seepage from solid waste dumps due to eroding batteries.

3.6.2 Status

The investigation that the Ministry of Environment (2017) undertook found that the pH values in the Congo basin sampling sites were within the acceptable range except for Lake Kivu at Rubavu where it was found to be 9.3 compared to the acceptable upper limit of 8.5. This was attributed to the discharge into the lake of wastewater from BRALIRWA which was likely the major contributing factor. The plant discharged alkaline wastewater containing sodium hydroxide used in the bottle washing process. This wastewater is usually discharged directly into the lake. The authors speculated that the other factor which may also contribute to elevated pH value is the soil composition of that region which is mainly composed of carbonate compounds which in aqueous solution gives the equilibrium bicarbonate and carbonate ions buffering the solution which contributes to raising the pH value.

The pH values recorded in the Nile basin region were found to be within the acceptable range for all the sites monitored except for four sites where the upper guideline limit of 8.5 pH units were exceeded (Figure 5-9). In 2012 there was one site in Bugesera District (Cyohoha South Lake) with the pH value higher than the standard . The high value for pH was attributed to the nature of the soil which had calcium and magnesium carbonate in its structure therefore playing a key role in these high pH values recorded (RNRA, 2012b,c). Elevated pH values can also be attributed to high algal concentrations in lake water.

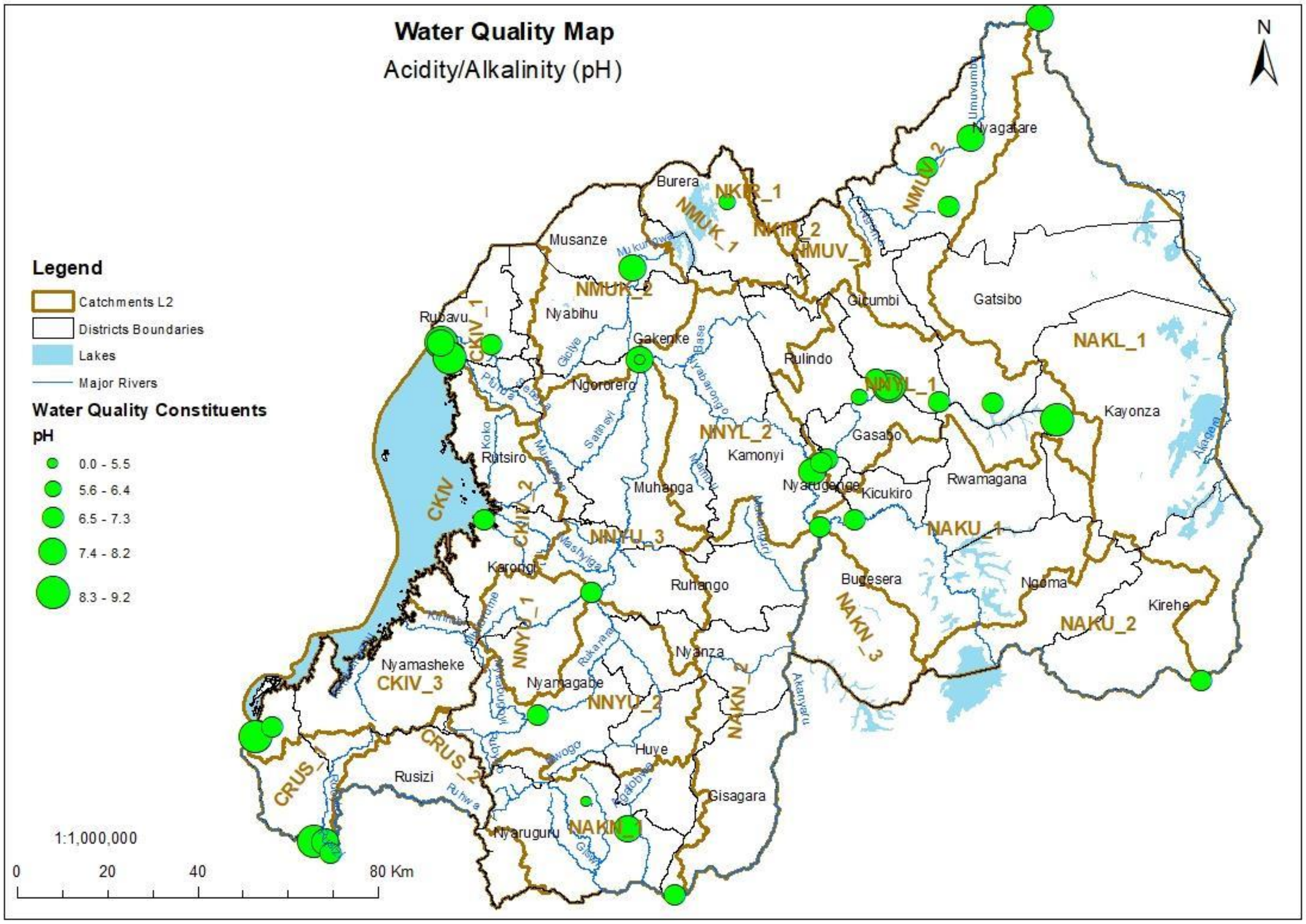

Figure 5-9: Bubble diagram of pH value (pH units) recorded at sampling points in Rwanda between 2011 – 2017.

3.6.3 Potential impacts

With the exception of localised sites, acidity or alkalinity does not appear to be major concern in Rwanda. A monitoring strategy should be followed to monitor pH levels in the country and to manage sites where acidic or alkaline discharges affect the fitness for use of the water.

3.7 Solid waste and litter

3.7.1 Description

Urban stormwater runoff can be polluted by, inter alia, nutrients, low pH (acidity), micro-organisms, toxic organics, heavy metals, litter/debris, oils, surfactants and increased water temperature. While the impact of litter may appear to be mainly visual and of aesthetic importance, litter can have serious impacts on the aquatic ecosystem of urban streams and rivers.

This section is focused on concerns associated with solid waste or litter in urban and peri-urban streams and rivers. Solid waste refers to litter (other terms used include trash / rubbish / garbage / refuse / floating matter) that enter the stormwater drainage system and that are deposited into urban streams and rivers. This includes solid waste that has deposited directly into the river or tributaries. One definition of litter is "all improperly discarded waste material, including, but not limited to, convenience food, beverage, and other product packages or containers constructed of steel, aluminium, glass, paper, plastic, and other natural and synthetic materials, thrown or deposited on the lands and waters".

Solid waste has a number of impacts on water quality:

- Aesthetic impacts – The presence of large amounts solid waste detracts from the aesthetic appeal of the river and affects the economic value of waterfront properties.
- Impacts on dissolved oxygen – The decomposition of biodegradable solid waste (garden refuse, food wastes, dead animals, faecal matter, etc.) can have a significant localised impact on oxygen depletion in the river. This affects the dissolved oxygen content of the water and in turn, aquatic organisms that are sensitive to low dissolved oxygen concentrations. Dissolved oxygen also affects the solubility of trace metals and nutrients and low concentrations promote the release of metals and nutrients from the sediments.
- Bacteriological impacts – Solid waste can threaten the health of contact (e.g. kids playing in the river, baptisms) and limited contact users. Of particular concern are bacteria and viruses associated with disposable nappies, medical wastes, animal carcasses, and human and domestic pet wastes. Ingestion of river water when playing in urban rivers can expose children to water borne diseases such as diarrhoea, gastroenteritis, cholera, salmonellosis, dysentery, and eye, ear, nose and skin infections.
- Safety of users – Lacerations caused by broken glass or sharp metal fragments can expose the bloodstream of recreational users to microbes that can cause waterborne diseases such as hepatitis, and typhoid fever.
- Impeding flow and bank destabilisation – The accumulation of floating solid waste, dumping of building rubble, or dumping of large objects such as car bodies, broken furniture, tyres, and shopping trollies can redirect stream-flow and destabilise the river channel.
- Entanglement of wildlife and aquatic organisms – Entanglement can occur if wildlife, livestock or aquatic organisms are ensnared by debris in the river. It can occur accidentally and lead to wounds and infections, or loss of limbs in wildlife and farm animals. It can also cause strangulation or suffocation, or impair the ability of to swim resulting in drowning or difficulty in movement which may affect the ability to find food or escape from predators.
- Ingestion by organisms – Ingestion of floating or deposited rubbish can lead to starvation or malnutrition if the intestinal tract is blocked or digestion of food is impaired. Ingestion of sharp objects can also cause damage of the mouth, digestive tract or stomach lining causing infection and pain in the animal. Rubbish that settle at the bottom of the river such as glass, cigarettes, rubber, and construction debris, are a problem for bottom-feeders and -dwellers.
- Hydrocarbon pollution – Hydrocarbon pollution from dumped oil cans or automotive parts can kill microscopic organisms in the river.

- Trace metals – Trace metals from rusting batteries or electronic equipment can be toxic to aquatic organisms.
- Nutrient enrichment – the decomposition of organic solid waste and release of nutrients in this process would contribute to nutrient load in the river. However, when compared to other nutrient loads from sources such as treated and untreated wastewater and agricultural runoff or seepage, decomposing organic solid waste would probably represent a minor source.

3.7.2 Status

As in many other countries, the presence and magnitude of solid waste in water courses are not monitored actively in Rwanda. Although Rwanda has a reputation for being the cleanest country in the region, many district environmental officers have raised concerns about solid waste and litter in urban water bodies. This was strongly linked to the lack of solid waste removal services in many areas, especially in informal settlements and slums located in urban areas. Concerns have also been expressed about poor operations at landfills (refer Section 4.1.5).

3.7.3 Relevance

The impacts of solid waste are listed above. Solid waste and litter will be addressed, amongst other, in the Integrated Pollution Management Plans that will be developed for five urban areas as part of this project.

3.8 Dissolved oxygen, BOD/COD and organic pollution

3.8.1 Description

Organic pollution refers to the discharge of organic or bio-degradable material to surface water that consumes oxygen when they decay, leading to low dissolved oxygen concentrations in the water. Elevated concentrations of organic matter from decomposing plant matter can occur naturally in water but can be aggravated by poor waste disposal practices. The decomposition of biogenic litter (vegetation, cellulose-based paper) in urban streams can contribute to low oxygen concentrations in urban streams. Organic matter can be measured as the COD (chemical oxygen demand) or BOD (biochemical oxygen demand) of the water. Low dissolved oxygen concentrations are detrimental to aquatic organisms and it affects the solubility of metals. Metals adhered onto bottom sediment particles in streams, lakes and reservoirs can dissociate under low or anoxic conditions, dissolving back into the water where it can affect aquatic biota.

Most aquatic organisms are dependent on the maintenance of adequate dissolved oxygen concentrations in the water for its survival and functioning. Dissolved oxygen concentrations fluctuate diurnally, depending on the relative rates of respiration and photosynthesis of aquatic plants. Factors causing an increase in DO include atmospheric re-aeration, increasing atmospheric pressure, decreasing temperature and salinity, and photosynthesis by plants. Factors causing a decrease in DO include increasing temperature and salinity, respiration of aquatic organisms, decomposition of organic material by microorganisms, chemical breakdown of pollutants, re-suspension of anoxic sediments, and release of anoxic bottom water.

The focus of this section is on oxygen demand that reduces the DO in water, specifically the decomposition of organic material and the chemical breakdown of pollutants.

The presence of oxidisable organic matter, either of natural origin (detritus) or originating in waste discharges, can lead to reduction in the concentration of dissolved oxygen in surface waters. Oxygen depletion may be due the aerobic decomposition of organic waste by microorganisms or the breakdown of chemicals. The potential for organic wastes to deplete oxygen is commonly measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD). BOD is a common measure of organic pollution. COD is a measure of the oxidation of reduced chemical species in water, i.e. the "reducing capacity" of an effluent. The impact of dissolved oxygen depletion on aquatic organisms depends on the frequency, timing and duration of such depletion. Continuous exposure to concentrations of less than 80 % of saturation is most harmful to aquatic organisms, and is likely to have acute effects, whilst repeated exposure to reduced concentrations may lead to physiological and behavioural stress effects. Occasional short-lived depletion of oxygen is less important. In all cases, if the rate of change in dissolved oxygen concentration is rapid, adverse effects on biota will be increased significantly. The extent to which any organism is affected by a decrease in dissolved oxygen is determined by its dependence on water as a medium. Most fish are 100% aquatic and are thus very dependent on dissolved oxygen for respiration and are very sensitive to low concentrations. The oxygen requirements of fish and other aquatic organisms vary with type of species (particularly warm- or cold-water species), with life stages (eggs, larvae, nymphs, adults) and with different life processes (feeding, growth, reproduction) and size. Cold water-adapted species are especially sensitive to depletion of dissolved oxygen. If possible, many species will avoid anoxic or oxygen-depleted zones. A few species, such as lungfish and some catfish, can, however, survive out of water for some time.

Certain aquatic invertebrates respire with gills or by direct cuticular exchange, and are thus subject to the same stresses as fish. Other insects are able to utilize atmospheric oxygen (e.g. many hemipterans and coleopterans carry air bubbles under their wings or under special mats of hairs) and are thus less affected by reduced dissolved oxygen concentrations.

The main sources of organic enrichment of rivers include domestic sewage, food-processing plants, breweries and vegetable canning, animal feedlots, abattoirs and cattle grazing. Of these, enrichment by organic matter from sewage and sewage effluents is probably the most common and extensively documented type of pollution in rivers. Most organic material in sewage is not directly toxic to aquatic organisms but it leads to a decrease in dissolved oxygen concentrations. Other impacts include an increase in turbidity and the concentration of suspended solids, an increase in nutrient concentrations, and possibly bacterial contamination of the receiving water body.

3.8.2 Status

Ministry of Environment (2017) found higher DO values at all monitored sites in the Congo basin. DO varied from 83.2 to 111.2 %. These values exceeded the standard limit which is good for the aquatic life and also for the self-purification process of these water streams. Dissolved oxygen is essential to all forms of aquatic life, including those organisms responsible for the self-purification processes in natural waters. The oxygen content of natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure. Oxygen is needed because it is required for the metabolism of aerobic organisms, influences inorganic chemical reactions, maintains several grades of water like taste, degree of asepsis and consumed from decomposition of organic matter.

Ministry of Environment (2017) found that DO percentages at the Nile basin sites varied from 5.1 % at Akanyaru river, Busoro bridge, to 110 % at Muhazi lake, Rwesero. They concluded that the lower percentage of dissolved oxygen in water bodies was mainly due to accumulation of suspended solids which limited the aeration of water bodies but also due to the presence of organic matters that consume a lot of dissolved oxygen when it decomposes (Figure 5-10, Figure 5-11 and Figure 5-12). In 2012, high COD/BOD concentrations were attributed to water pollution mainly due to the surrounding human activity occurring near the sites. This may have been due to the dumping of wastewater coming from household, industrial or agricultural activity in the surrounding area (RNRA, 2012a, b, c).

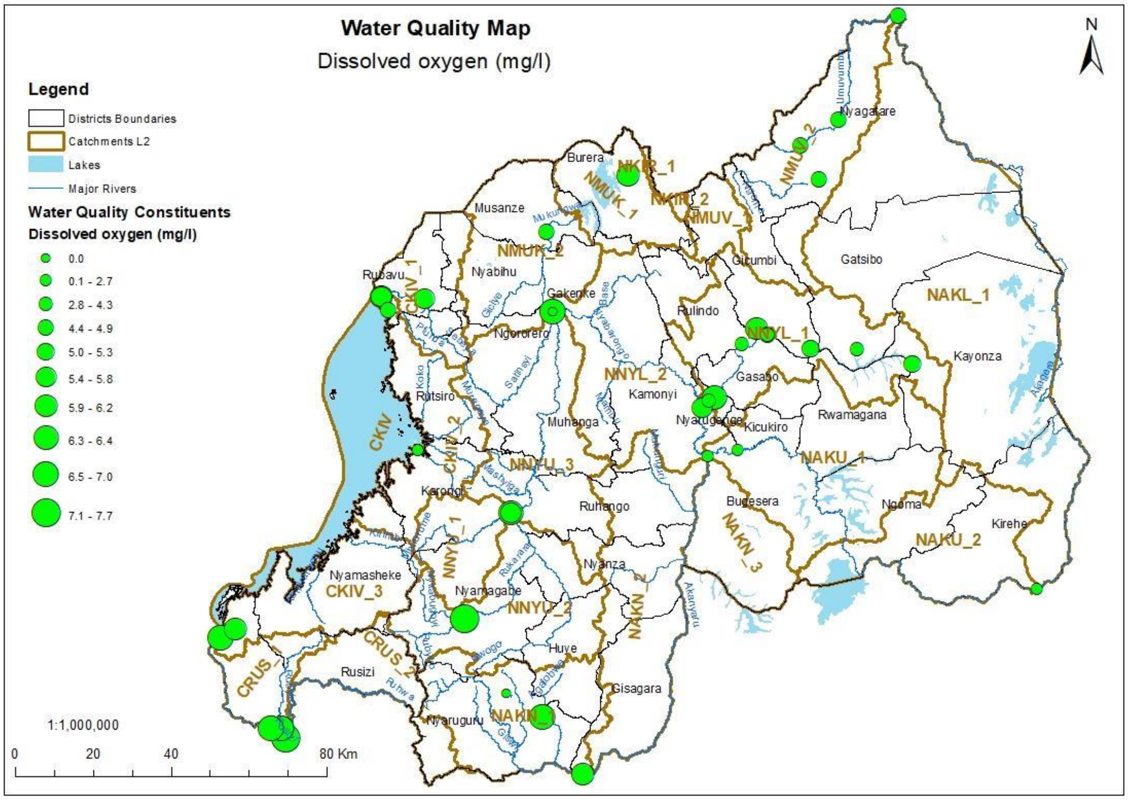

Figure 5-10: Bubble diagram of Dissolved Oxygen concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

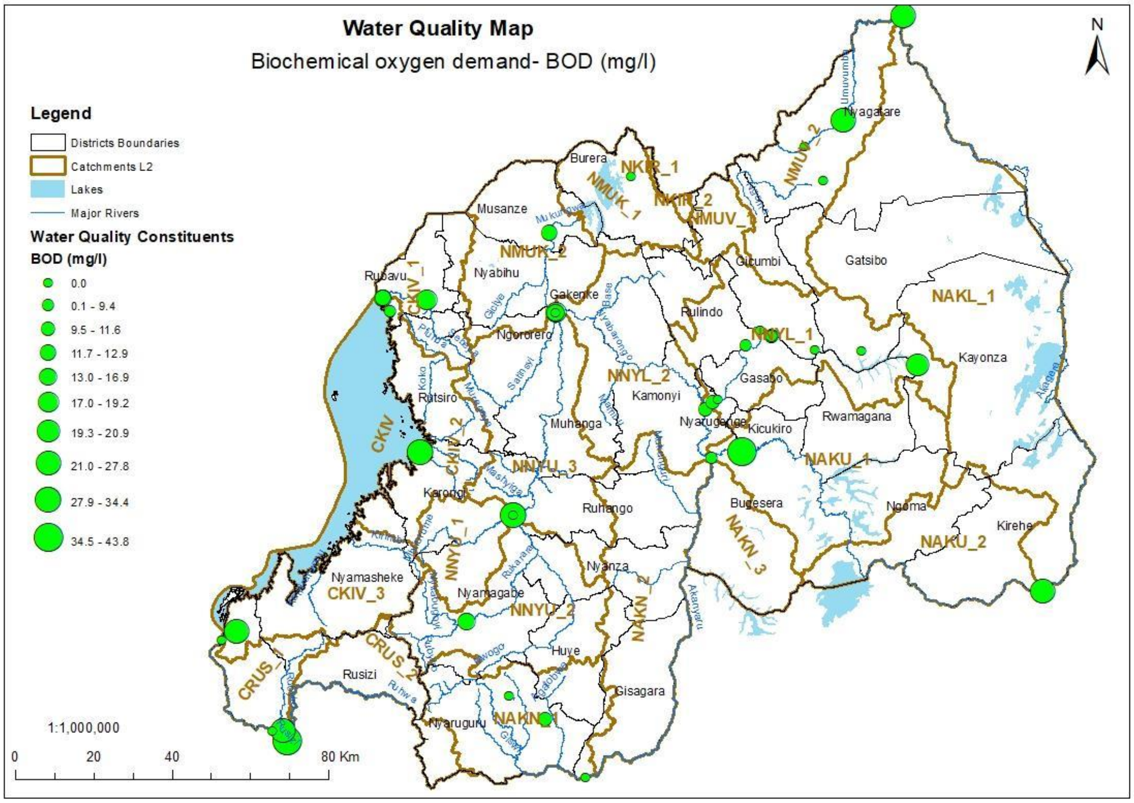

Figure 5-11: Bubble diagram of Biochemical Oxygen Demand concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

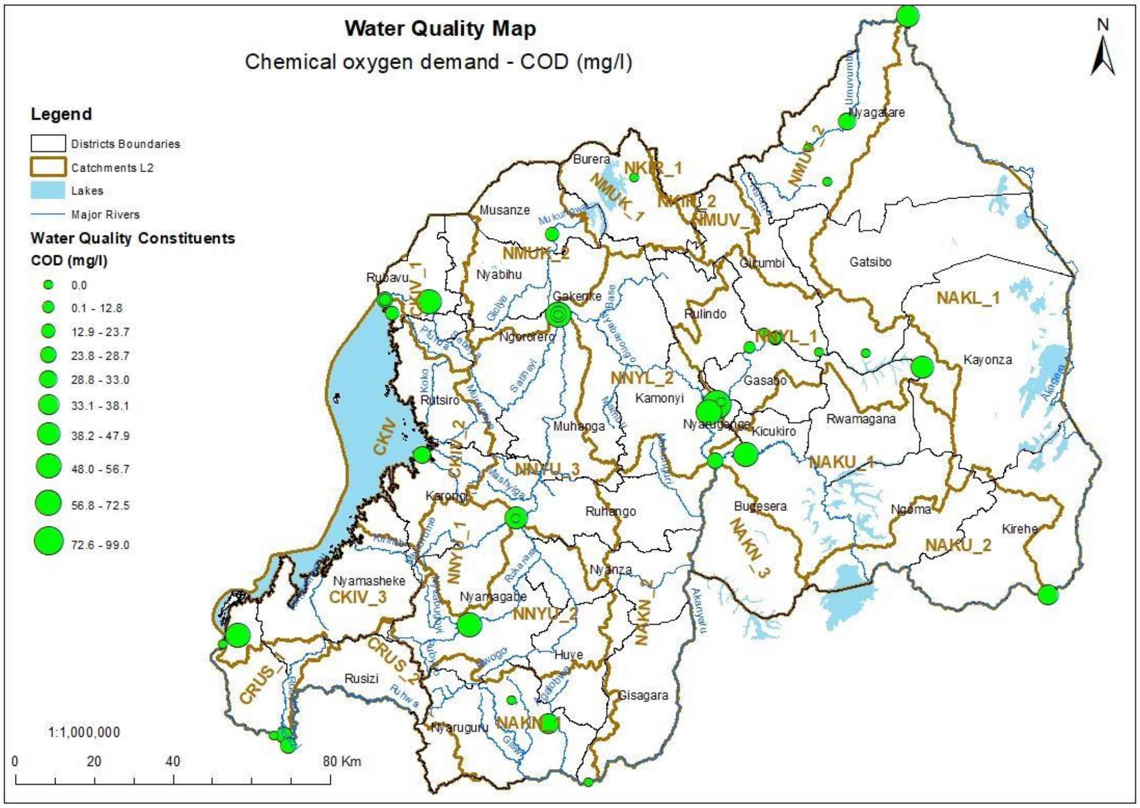

Figure 5-12: Bubble diagram of Chemical Oxygen Demand concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

A review of the average dissolved oxygen concentrations recorded by RWFA from 2011-2017 indicate that many of the rivers in Rwanda had DO concentrations below the lower limit of 6 mg/l (or 68% saturation). Of the 39 sampling points, DO concentrations less than 6 mg/l were recorded at 25 points.

3.8.3 Potential impacts

Maintaining high DO concentrations in rivers and lakes is essential to protect aquatic ecosystems. The impacts on ecosystems and other goods and services provided by healthy rivers and lakes are described above. Pollution controls should be implemented to protect receiving water bodies in Rwanda because many communities depend on the aquatic ecosystem services that these water bodies provide.

3.9 Agrochemicals and toxic substances

3.9.1 Description

This concern refers to the pesticides and herbicides residues in surface waters that are harmful to aquatic ecosystems and/or users of the water. It includes pesticides or their residues such as chlorpyriphos, endosulfan, atrazine, deltamethrin, DDT & penconazole. These compounds can have chronic or acute impacts on aquatic biota and/or it can cause respiratory diseases in humans and animals. Sources include spray drift of pesticides/herbicides into surface water courses, the wash off of pesticides into surface and groundwater during rainfall events or irrigation of crops, or accidental spillages at storage facilities or during loading operations. In many cases pesticides adhere onto soil or organic particles and are washed off along with these particles.

Agrochemicals and biocides, also known as pesticides, are chemicals that kill living organisms and are used in the control of pests (Griffen et al, 2011). The most commonly used biocides are herbicides, fungicides and insecticides. Rwanda is a user of pesticides in agriculture, suggesting that the potential for non-point source environmental contamination is moderate to high. The type of pesticide and usage pattern is variable across the country and is dependent on climatic conditions and crop types. Pesticide use also occurs as vector control in public health, commercial pest control, domestic use, and in selected industrial or food-processing technologies. However, the infrastructure to monitor and control pesticide use is also poorly developed. Data on pesticides in water sources in Rwanda are sparse.

The factors determining runoff and leaching of biocides include the physiochemical properties (e.g. water solubility, soil mobility and pesticide persistence) of the pesticide and soil properties (e.g. texture, organic matter content, depth of the soil horizon, erosion potential, pH and microbial content). Of primary concern, however, is the persistence and accumulation of pesticides in food chains, and the role of certain pesticides in causing reproductive failure and endocrine system abnormalities in species not intended as their target. Control of pesticide use is therefore paramount.

3.9.2 Status per Level 1 catchment

Not assessed but concerns have been expressed about the potential impacts of irresponsible use of agrochemicals on aquatic ecosystems.

3.9.3 Relevance

Farmers should be educated about the impacts of pesticides and herbicides on aquatic ecosystems and human health and the responsible application of these agrochemicals on their crops to protect receiving waters should be emphasised.

3.10 Heavy metals

3.10.1 Description

Metals include sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), titanium (Ti), iron (Fe) and aluminium (Al). Trace metals are defined, in geological terms, as those occurring at 1000ppm or less in the earth's crust. Trace metals can be divided into two groups: (i) those like cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn)] that occur naturally in trace amounts in most waters (and most of which are plant nutrients) and (ii) those like cadmium (Cd), lead (Pb) and mercury (Hg) that do not usually occur in measurable amounts in natural waters, are potentially toxic in low concentrations, and have become widely distributed as a result of human activities.

The main sources of trace metals in water bodies are geological weathering, the atmosphere, industrial effluents, leaching from solid waste dumps, agricultural runoff, and drainage from mining activities (from both direct discharge and leaching from the spoils of operational and abandoned mines). Many trace metals are employed in, and result from, industrial activities.

The overall ecological consequence of trace metal contamination of aquatic ecosystems is a reduction in species richness and diversity and a change in species composition. The selective elimination of less tolerant species, with the resultant reduction in competition and predation, may result in an increase in the abundance of more tolerant aquatic species. The degree of change is related to the concentration of the metal(s) and the type (chronic, acute, constant, intermittent) and timing (in relation to season and thus flow rate) of exposure.

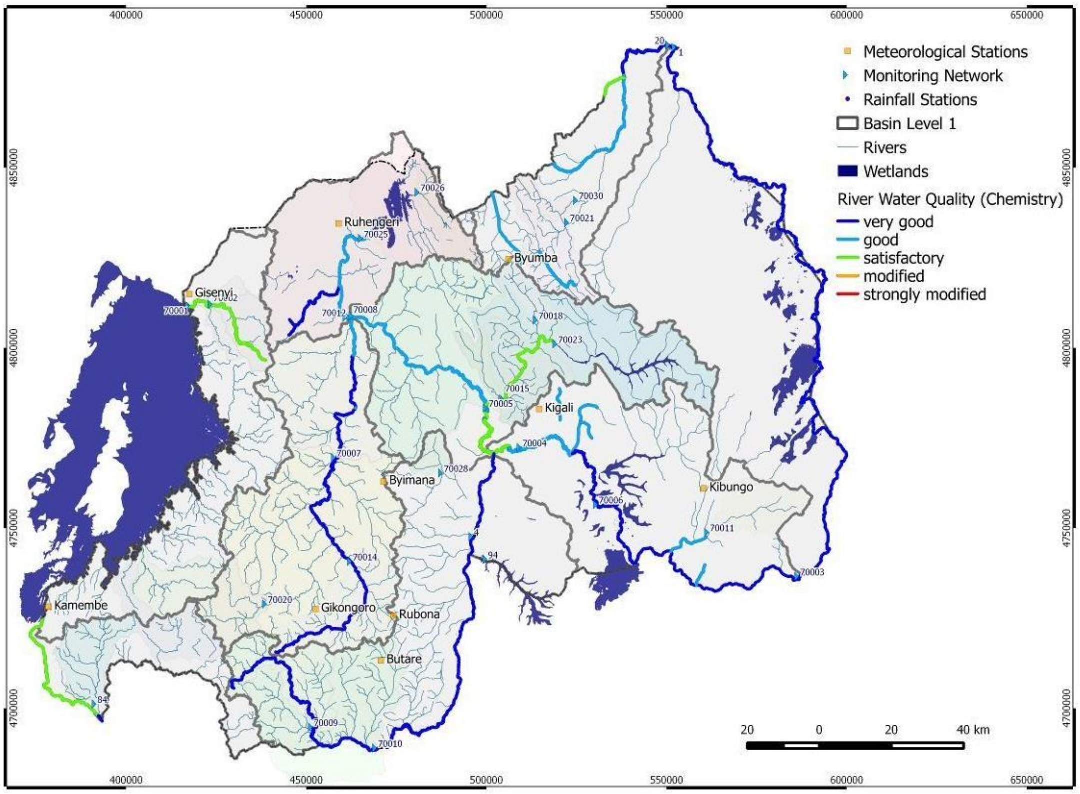

figure 5-13: National water quality map chemical quality (major ions, metals Zn and Cu as reported in the national water resources master plan for Rwanda.

3.10.2 Status

Some rivers and lakes are affected by elevated metal concentrations, often associated with industrial activities in their catchments (figure 5-13Figure 5-16). No guidelines have been set for these metals. Some of the metal concentrations exceed the upper limits of the United Nations Economic Commission for Europe (UNECE, 1994) guidelines for aquatic ecosystems. All 5 samples analysed for lead exceeded the upper guideline of 0.082 mg/l Pb, all 9 samples for cadmium exceeded the upper guideline of 0.0039 mg/l Cd, and 20 of the 25 sampling points recorded Zinc concentrations greater than the upper guideline value of 0.120 mg/l Zn. These guidelines are quite strict, and it is recommended that Rwanda adopt aquatic ecosystem guidelines that might be more appropriate.

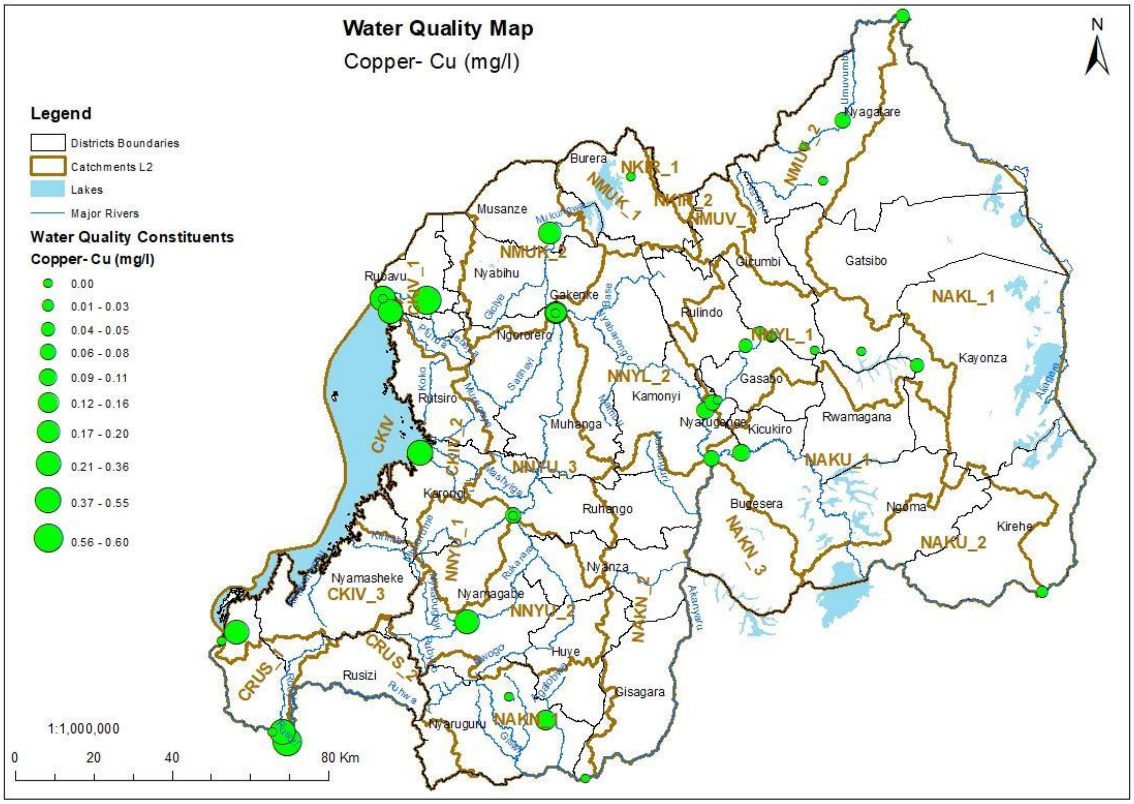

Figure 5-14: Bubble diagram of Copper concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

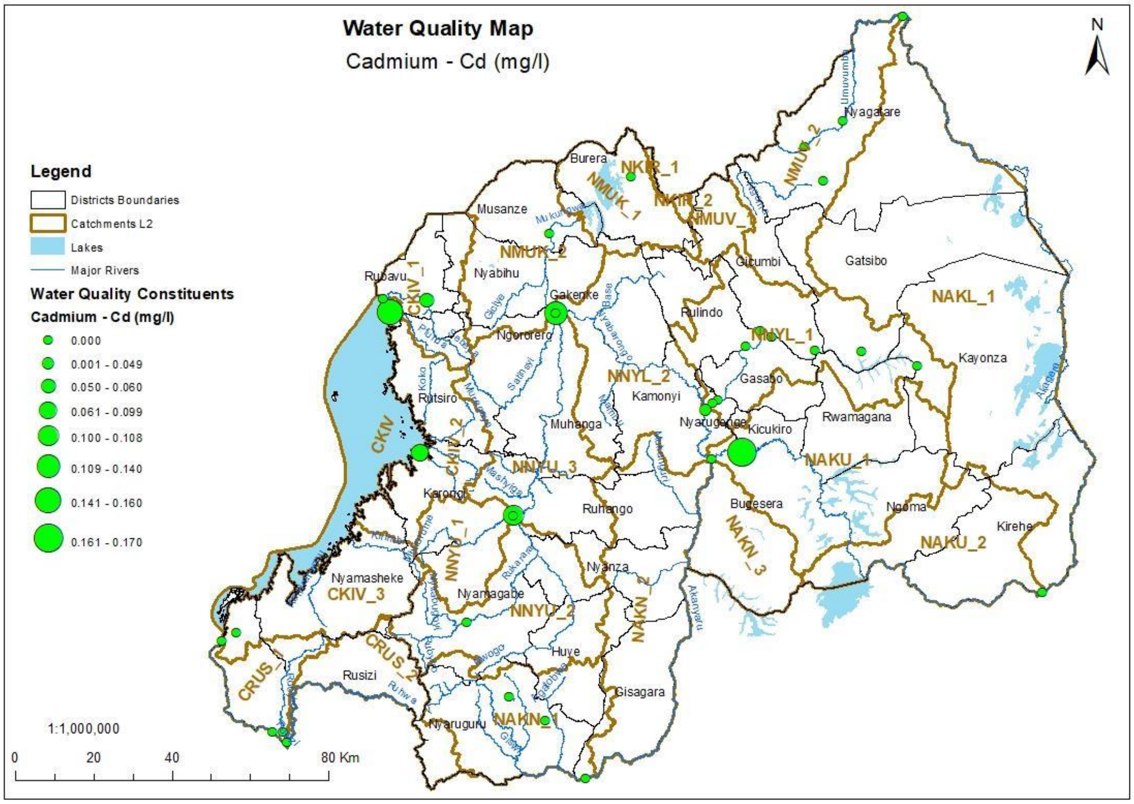

Figure 5-15: Bubble diagram of Cadmium concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

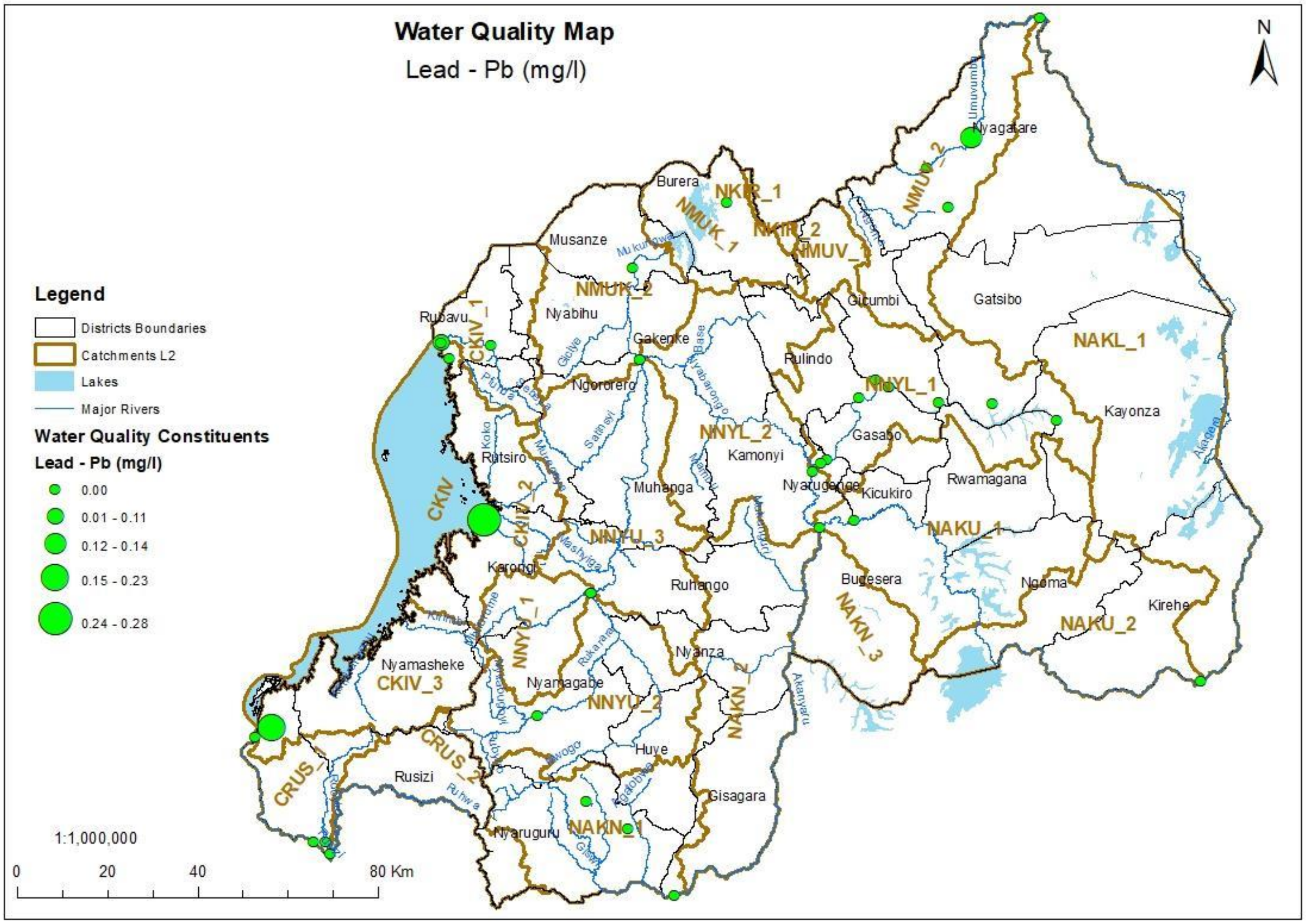

Figure 5-16: Bubble diagram of Lead concentrations (mg/l) recorded at sampling points in Rwanda between 2011 – 2017.

3.10.3 Possible impacts

The impacts of elevated metal concentrations on aquatic ecosystems are described above. Elevated metals generally originate from industrial activities and can be controlled by enforcement of the Organic Law and monitoring of industrial discharges.

3.11 Invasive aquatic plants

3.11.1 Description

Invasive aquatic plants are introduced plants that have adapted to living in, on, or next to water, and that can grow either submerged or partially submerged in water. Their presence may harm native ecosystems or commercial, agricultural, or recreational activities dependent on these ecosystems. They may even harm human health.

Originally from South America, the water hyacinth (*Eichhornia crassipes*) is one of the worst aquatic weeds in the world. It’s beautiful, large purple and violet flowers make it a popular ornamental plant for ponds. It is now found in more than 50 countries on five continents. Water hyacinth is a very fast-growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limiting boat traffic, swimming and fishing. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.

The water hyacinth Eichhornia crassipes which was introduced as an ornamental plant, has invaded lakes in Rwanda from Muhazi to Rweru from the River Nyabarongo, and even reached Lake Victoria through Akagera River (REMA, 2009). The water hyacinth has invaded several lakes in the Akagera complex. Lake Mihindi has now been completely covered by this plant. The water hyacinth is a major biodiversity problem in the inland water ecosystem of the Lake Victoria Basin.

The Revised and Updated National Biodiversity Strategy and Action Plan of Rwanda (UNEP/GEF, 2014) identified water hyacinth, Eichhornia crassipes, as a serious problem. It stated that this exotic and invading aquatic plant species is in competition with local plant species, and is responsible for worsening the overall water evaporation of the aquatic ecosystems. Lakes and rivers in hydrological system have been invaded by water hyacinth due to unwanted introduction. Due to water hyacinth introduction, some water bodies such as Mihindi are under serious threats, while Kishanju has been completely disappeared. This has as consequence: loss of all biodiversity and serious decreasing of fishery production.

Invasive plant species, particularly the water hyacinth, are a growing concern. This aquatic weed grows rapidly to from thick mats on water surfaces, reducing dissolved oxygen levels, which consequently impair water quality as well as affect fish stocks. UNEP observed the presence of water hyacinth in relatively limited quantities of two to three metre bands along lakeshores and wetlands inside the Akagera National Park, such as in Lake Hago. Water hyacinth, however, was not detected during inspections of water bodies in other parts of the country. A programme to remove hyacinth infestation has recently been implemented; however, it remains to be seen if this will translate into long-term control.

3.11.2 Status

Seburanga et al. (?) reported water hyacinth infestations in Lake Bulera and Mukungwa floodplain.

Nzohabonimana (2014) reported that over the past few decades, lakes such as Kivu, Cyohoha, Ruhondo, Burera, Mugesera and Rweru have become overrun with water hyacinth, which forms thick, floating mats that cover large surfaces and affect aquatic life by sucking oxygen out of the water. The Rwandan government has now launched a campaign to remove the plant from its lakes as part of a five-year initiative dubbed "Supporting Ecosystem Rehabilitation and Protection for Pro-poor Green Growth Program" (SERPG) that aims to preserve the country's natural resources and boost its green economy.

Severe infestations have been reported in Lake Cyohoha.

WASAC has raised concerns about the presence of water hyacinth mats in Lake Mugesera and it interfering water abstractions for potable water treatment. REMA has also reported that for decades, invasive aquatic species-particularly water hyacinth has threatened the existence of Lake Rweru and its ecosystem. They continue to describe manual removal techniques to control infestations in the lake.

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3.11.3 Potential impacts

The floating mats of water hyacinth block the intake structures of water treatment works and the water beneath the mats are often coloured black due to the high organic content from decomposing dead plants. The water is also low in oxygen which can further interfere with the water treatment process.

An aquatic weed management strategy should be developed for Rwanda. Consideration should be given to chemical control measures where severe infestations are experienced.

3.12 Hydrocarbon pollution

3.12.1 Description

Petroleum and petroleum-derived products are complex mixtures, mainly of hydrocarbons (compounds of only carbon and hydrogen) plus some other compounds of sulphur, nitrogen and oxygen, and a few additives. The hydrocarbons range from the very volatile C4 up to the heavy end C45+. The more common petroleum products include petrol, naphtha and solvents, aviation gasoline, jet fuels, paraffin, diesel fuel, fuel oils and lubricating oils.

Surface water concerns about hydrocarbon pollution are about wash off from road surfaces and parking lots, especially during the early season rains, and dumping of used oil into stormwater drains.

Petroleum and petroleum-derived products are divided into Light Non-Aqueous Phase Liquids (LNAPLs) and Dense Non-Aqueous Phase Liquids (DNAPLs). LNAPLs are those organic compounds which do not dissolve in water and which will float on groundwater, most commonly petrol-derived products and degreasers. DNAPLs are those organic compounds which do not dissolve in water and sink to lower levels, such as chloroform, liquid chlorofluorocarbons (CFC), trichloroethylene (TCE), creosote and polychlorinated biphenyls (PCB) (Weaver et al. 2007).

These products are ubiquitous in our lives, and can be spilled into the environment in a variety of ways: overturned fuel tankers, automobile and truck crashes, spillage at the fuel pump, leakage from storage tanks, discarding sump oil; to mention only a few. Leakage from underground storage tanks (USTs) is probably the source that has the greatest impact on groundwater.

The serious health risk posed by hydrocarbon contaminated land or water systems to human health and the environment is widely recognised. The carcinogenic properties of the halogenated hydrocarbons are well documented. Awareness of this reality has led to international efforts to remediate many of these contaminated sites, either as a response to the health risks or to control the detrimental effects on the environment. For decades, efforts have been directed toward the evaluation of cost effective methods to rehabilitate hydrocarbon contaminated soil and groundwater. Over the years, many clean-up methods have been developed and applied. However, the remediation of hydrocarbon-contaminated land is extremely difficult and costly due to their varying physical properties and complex mixture of chemical compounds. Hydrocarbon degradation in the natural environment depends on several factors such as pH, chemical composition, and physical properties of the contaminated soil and/or water, among others.

3.12.2 Status

Hydrocarbon pollution is not routinely monitored in Rwanda. However, many district environmental officers have commented on the irresponsible dumping of used motor oil by garages and workshops, often onto the soil, into stormwater drains, or nearby streams and wetlands. This appears to be problem wherever workshops are located.

3.12.3 Potential impact

Water contaminated with oil and fuel can cause serious disruptions in water treatment works, coating surfaces and contaminating sand filters. Efforts should be made to introduce a used oil recycling programme in Rwanda to minimise the impacts of hydrocarbon pollution on water bodies in the country. Monitoring surveys should be undertaken to determine the extent and severity of hydrocarbon pollution in Rwandan water bodies.

3.13 Emerging pollutants

3.13.1 Description

3.13.1.1 Endocrine disrupting chemicals

There has been a great deal of interest and, in some cases, concern, regarding human health effects associated with pharmaceuticals, hormones, and other organic waste water contaminants. Chemicals that interfere with the endocrine systems of humans and wildlife are termed endocrine disrupting chemicals (EDCs). Chemicals that elicit a pharmaceutical response in humans are termed pharmaceutically active compounds (PhACs). EDCs and PhACs are not mutually exclusive classifications, as some, but not all, PhACs are also EDCs.

An EDC has been defined as "an exogenous substance or mixture that alters the function(s) of the endocrine systems and consequently causes adverse health effects in an intact organism, or its progeny or (sub) populations". From reports in literature, a wide range of chemicals has been found or suspected to be capable of disrupting the endocrine systems. The list of EDCs includes:

- pesticides (e.g. DDT, vinclozolin, TBT, atrazine),
- persistent organochlorines and organohalogens (e.g. PCBs, dioxins, furans, brominated fire retardants),
- alkyl phenols (e.g. nonylphenol and octylphenol),
- heavy metals (e.g. cadmium, lead, mercury),
- phytoestrogens (e.g. isoflavoids, lignans, β-sitosterol), and
- synthetic and natural hormones (e.g. β-estradiol, ethynylestradiol).

Pharmaceuticals and personal care products (PhAC and PCPs) include a large number of chemical contaminants that can originate from human usage and excretion, veterinary applications of a variety of products, such as prescription/non-prescription medications, and fungicides and disinfectants used for industrial, domestic, agricultural and livestock practices. PhACs, PCPs and their metabolites are continually introduced into the aquatic environment and are prevalent at detectable concentrations that can affect water quality and potentially impact drinking water supplies, and consequently ecosystems and human health respectively.

3.13.1.2 Persistent organic pollutants (POPs)

Persistent Organic Pollutants (POPs) are highly stable, toxic, hydrophobic and lipophilic compounds, with the ability to accumulate in biological tissues. Many POPs can be lethal in high concentrations, but their greatest detrimental effects lie in their chronic toxicity, leading to dermal effects, liver and kidney disease, defects of the immune-, reproductive-, nervous-, and endocrine systems and even cancer. Because of their lipophilic nature, these pollutants tend to accumulate in matrices rich in organic matter, such as soil, sediment and biota, and can bio-accumulate in food chains. Global concerns about POPs lead to the United Nations Environment Programme (UNEP) initiating the Stockholm Convention on Persistent Organic Pollutants (SCPOPs) in May 1995. The convention is an international, legally binding treaty initially focussing on the reduction and elimination of the twelve most harmful POPs. These POPs included certain chlorinated pesticides (Aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene), two groups of industrial chemicals – hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB), and unintentional combustion by-products known as polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). Later more chemicals were added to the list.

3.13.1.3 Nanoparticles

Nanomaterials or nanoparticles are defined as objects with one, two, or three external dimensions in the size range of 1-100 nanometres (nm). Examples of nanotechnology applications include the development of highly accurate and sensitive medical diagnostic devices, new ways of disease therapy, and the monitoring and remediation of basic water supplies.

Nanoparticles are commonly used in personal care products, food storage containers, cleaning supplies, bandages, clothing, and washing machines. Nanoparticles are likely to enter surface waters during the production, usage, and disposal of nanoparticle containing products. Estimates of nanoparticle concentrations in some natural surface waters are in the ng/L - µg/L range (parts per trillion to parts per billion), but the concentrations may increase with greater production and use of nanoparticle-containing.

3.13.2 Overview of emerging pollutants in Rwanda

Rwanda is a signatory of the Stockholm Convention on POPs that was signed on May 22, 2001 and ratified as approved by the Presidential Order n° 78/01 of 8 July 2002. In compliance with article 7 of the Stockholm Convention on POPs, Rwanda developed a national plan of implementation of the Convention, with the intension to comply with the convention and submit the national plan to the Conference of the Parties at least in two years following the effective date of the Stockholm Convention (June 2006) (MINITERE, 2006).

As is the case in many developing countries, research is required to get a better understanding of the severity and extent of emerging pollutants in Rwanda before strategies can be developed for its management.

3.13.3 Status

There is currently very little data to assess the overall situation with respect to emerging pollutants in Rwanda.

3.13.4 Potential impacts

It is recommended that Rwanda adopt a precautionary approach to emerging pollutants, that is prevent the discharge of such pollutants where possible until there is sufficient information available to determine whether such pollutants are present in Rwandan rivers, wetlands, and lakes, and in what quantities.

3.14 Air pollution

3.14.1 Description

Air or atmospheric pollution, as defined in The Organic Law (Organic Law 04/2005, 2005), is a "voluntary or accidental contamination of the atmosphere and the surrounding air, gas, smoke, any particles or substances that may endanger biodiversity, human health and their security or disrupt agricultural activities, disrupt installations or the nature of tourist sites and mountains". The effects of air pollution on human health are linked to respiratory disorders and diseases such as asthma, reduced lung function, lung cancer, cardiovascular disease and stress related symptoms.

Outdoor air pollution is in the form of diverse and widespread sources of emissions and natural phenomena. The primary man-made sources of outdoor air pollution arise from transportation, industry, combustion fuels, industrial processes, and use of pesticides. More specifically, the pollutants include suspended particulate matter, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), hydrocarbons and ozone due to population growth, urbanisation, industrialisation, and increased use of motor vehicles (Rugigana et al, 2016). Emissions from motor vehicles specifically are identified as a major source of air pollution growing as a result of population growth and associated urbanisation.

According to Rugigana et al (2016), the natural phenomena that contribute to air pollution include volcanic eruptions (which happen occasionally), forest fires, production of materials that have a biological origin (e.g. pollen including mould spores), and organic material from plants and animals, evaporation of volatile organic compounds, and wind erosion of soil due to wind storms that spread dust clouds (Nsengimana et al, 2011).

Indoor air pollution is largely from the use of wood and charcoal for cooking. Rugigana et al (2016) notes that over 85% of Rwandans depend on wood for domestic energy because alternative energy sources are often unreliable and unaffordable. This results in extensive deforestation as a consequence. This is not limited to rural areas as 60% of people in urban areas use fuel wood, charcoals and kerosene for cooking (CARE, 2010 and REMA, 2009, in Rugigana et al, 2016). Other biomass that is burned indoors for fuel is animal dung and agricultural residues. Open or traditional cooking stoves in poorly ventilated kitchens exacerbates the pollutants. Other indoor pollutants include cigarette smoke, construction materials and methods, materials for furniture and fittings as well as paints and solvents (Rugigana et al, 2016).

Per capita emissions in Rwanda are estimated at 0.65 tonnes CO_2/person (including land use change) compared to a global average of 4.63 tonnes CO_2/person (Byamukama et al, 2010). The majority of greenhouse gas (GHG) emissions in Rwanda are CO_2 (87%) at 531 gigagrams (Gg), dominated by transport

(52%) and industrial processes (28.5%) (Byamukama et al, 2010). Rugigana et al (2016) acknowledges the close connection between climate and air quality. For example, ozone and particulate pollution are strongly influenced by shifts in the weather (e.g. heat waves or droughts). Declining air quality is therefore considered to be exacerbated by climate change in the future if emission reduction measures are not implemented (IPCC, 2007, in Rugigana et al, 2016).

Particulate Matter (PM) is often an indicator of air quality. The WHO (2013) defines PM as a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. With regards to the health effects of PM, commonly used indicators refer to the mass concentration of particles with a diameter of less than 10 µm (PM_{10}) and of particles with a diameter of less than 2.5 µm ($PM_{2.5}$). $PM_{2.5}$, often called fine PM, also comprises ultrafine particles having a diameter of less than 0.1 µm. In most locations in Europe, $PM_{2.5}$ constitutes 50–70% of PM_{10}. PM between 0.1 µm and 1 µm in diameter can remain in the atmosphere for days or weeks and thus be subject to long-range transboundary transport in the air.

PM_{10} and $PM_{2.5}$ include inhalable particles that are small enough to penetrate the thoracic region of the respiratory system. The health effects of inhalable PM are well documented. They are due to exposure over both the short term (hours, days) and long term (months, years) and include respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions; as well as mortality from cardiovascular and respiratory diseases and from lung cancer (WHO, 2013).

The WHO air quality guideline values for ambient air pollution (annual average) are 10 µg/m^3 for $PM_{2.5}$ and 20 µg/m^3 for PM_{10} (WHO, 2013). The mean annual concentration of fine suspended particles of less than 2.5 micron in diameter is a common measure of air pollution. WHO has modelled air quality for $PM_{2.5}$ and the data available indicates that the annual mean concentrations of $PM_{2.5}$ in Rwanda are 42.8 µg/m^3 and specifically 50.6 µg/m^3 in urban areas (WHO, 2014). This is four to five times the accepted guideline of 10 µg/m^3. The WHO interactive map indicates that most of Rwanda falls within the range of 36-39 µg/m^3, with limited areas being below this (in the range of 26 – 35, or 16-25), mostly in the area of Lake Kivu to the west, Nyungwe Forest National Park and Akagera National Park, including a small area below the standards (WHO, 2016).

Rwanda has one of the lowest emissions per capita in the world, estimated at 0.65 tonnes CO_2/person (including land use change), compared to a global average of 4.63 tonnes CO_2/person (Nsengimana et al., 2011). The majority of greenhouse gases (GHG) emissions were CO_2 (87%) at 531 Gg, dominated by transport (52%) and industrial processes (28.5%).

The aggregate emissions or total CO_2 equivalent, used for measuring global warming potential, amount to 5,010.4 Gg in 2005, dominated by agriculture (78%) and energy (18%). Nitrous oxide (N_2O) and methane (CH_4) are the most potent greenhouse gases, contributing 62% and 26% of aggregated emissions. Four key sources contribute 91% of aggregate emissions: N_2O from agricultural soils (57%); CH4 from enteric fermentation in domestic livestock (19%); CH4 from residential energy from fuel; and combustion (8%); CO_2 from road vehicles (5%) (Byamukama et al., 2010).

Aligned with its commitment to reduce air pollution, Rwanda became a member of the Climate and Clean Air Coalition during the COP22 held in Marrakech (Morocco) on November 2016.

The Rwanda Air Quality and Climate Change Monitoring Project by FONERWA (Rwanda's Green Fund) partnering with Ministry of Environment, Ministry of Education (MINEDUC), Massachusetts Institute of Technology (MIT) and University of Rwanda, was recently initiated in April 2017 (RONERWA, 2017). It is reported that eight air pollution monitoring stations will be installed in different areas of the country with the intention to increase the coverage progressively over time. The project will involve the collection and processing of climate change and air quality data which will provide useful data to inform decisions in this field in the future as data in this area is currently lacking.

3.14.2 Status

The WHO (2016) has modelled ambient air pollution in the form of $PM_{2.5}$ for Rwanda. Lake Kivu is mapped as slightly lower than the country average with areas falling within the annual average range of 16-25 and 26-35 µg/m^3. However, this is still almost two to threefold the guideline value of 10 µg/m^3. The reason that it is lower than the rest of the country is most likely due to the lack of development associated with the lake itself.

Air quality is monitored by the Rwanda Climate Observatory Project, located on the summit of Mt. Mugogo, a 2.5 km peak in the Virunga mountain range. DeWitt et al (2016) describe the measurements that are undertaken which include black carbon aerosol concentration, ozone and carbon monoxide gas concentration, and solar intensity. It has been found that black carbon levels close to those in major US cities were found in this rural region, likely from local and transported biomass burning (DeWitt et al, 2016). Major sources of air pollution include agricultural burning, cook fires, charcoal making, kerosene lightning, brick kilns, and older diesel generators/vehicles. CO and O_3 measurements were used in conjunction with BC aerosol data and HYSPLIT back trajectories were also used to help discriminate between periods of heavy burning and periods of pollution transport from Kigali, Kampala, and other large East African cities, which may have more black carbon contribution from diesel vehicles and generators.

NNYU Upper Nyabarongo

The WHO (2016) has modelled ambient air pollution in the form of $PM_{2.5}$ for Rwanda. The area that corresponds with the Nyungwe Forest National Park is slightly lower than the country average at an annual average range of 26-35 µg/m^3 but is still almost threefold the guideline value of 10 µg/m^3. The reason that it is lower than the rest of the country is most likely due to lack of development associated with the National Park.

NMUK Mukungwa

Namugize (2011) considered the environmental baseline in the Nyabihu District to inform a study relating to geothermal energy prospecting. Whilst no air quality data is available for the district, the author was of the opinion that there are existing concentrations of volcanic gases in the atmosphere due to the proximity of two active volcanoes, Nyiragongo and Nyamuragira, in the DRC. Furthermore, Namugize (2011) noted that soil emission measurements of CO_2 and H_2S were carried out by the Federal Institute for Geosciences and Natural Resources (BGR) in 2008 and found values ranging from 0 to 236.7 mg CO^2 m^{-2}day^{-1} and 0.01 mg H_2S m^{-2}day^{-1} (Jolie et al., 2009, in Namugize, 2011). This suggests that there are existing levels of natural gas emissions.

NNYL Lower Nyabarongo

There are a number of studies that focus on urban air pollution in Kigali as the capital. Henninger (2009) found that in February 2008 daily mean PM_{10} levels from sunrise till sunset reached 1,013 µg/m^3, which was significantly higher than the WHO recommended levels for short time exposure to PM_{10} of 50 µg/m^3

for a 24 hour mean. With night time levels even higher due to climatic influences. Such levels appear to be increasing in areas with high rates of traffic due to the exhaust of the vehicles and the stirring up of dust from the ground, but also in residential areas from burning wood for cooking etc.

Henninger (2013) analysed the PM_{10} particles in a further study and found that airborne particles from anthropogenic sources dominate nearly two-thirds of the aerosols of the urban atmosphere. The most dominating anthropogenic airborne particles were diesel exhaust particulates (29%; due to the high density of aged vehicles using diesel engines), fly-ash (25%; traditional sort of cooking) and kerosene (13%; surrogate fuel due to the decreasing stock of wood). Only 12% of pollen and other organic aerosols could be determined within the atmosphere and dust by a geogenic source contributed 21%.

NAKL Lower Akagera

The WHO (2016) has modelled ambient air pollution in the form of $PM_{2.5}$ for Rwanda. The annual average for Lower Akagera is mostly above the guideline value of 10 $\mu g/m^3$ as a range of 36-69 $\mu g/m^3$ (the same as most of the country), with the eastern extent slightly lower between 16-25 and 26-35 $\mu g/m^3$ and a small area indicated as below the guideline value. This is most likely due to the lack of development associated with the Akagera National Park.

3.14.3 Potential impacts

Monitoring of air pollution in Rwanda should be strengthened and management of sources that exceed EAC guidelines and standards should be instituted.

CHAPTER 4 IDENTIFICATION OF POLLUTION HOTSPOTS

4.1 Introduction

For the purpose of this report, potential pollution hotspots were defined as areas where there is a high density of pollution sources that could have a negative impact on the local population or the local environment.

4.2 Potential pollution hotspots and motivation

A number of potential pollution hotspots have been identified where there was known to be a high density of pollution sources. The most obvious hotspot was the City of Kigali where there is a mosaic of industries, high rise areas, urban areas, informal settlements, urban agriculture, transport network, network of stormwater drains and canals, etc. Collectively the area generates high air and water pollution loads. Other parts of the country were examined using GIS overlays to identify known or potential hotspot areas. These are presented in Figure 6-1 and Table 6-1.

For this report, known individual point sources (for example problematic industrial dischargers, landfills, or wastewater treatment works discharges that do not meet effluent limits) were not identified as hotspots because their existence has already been documented in a number of reports (see for instance Ministry of Trade and Industry, 2017, ENGIN, 2015, and the Ministry of Environment, 2017). These sources are known and can be controlled by means of existing pollution management instruments. In this section the focus was on cumulative impacts in a specific geographic area.

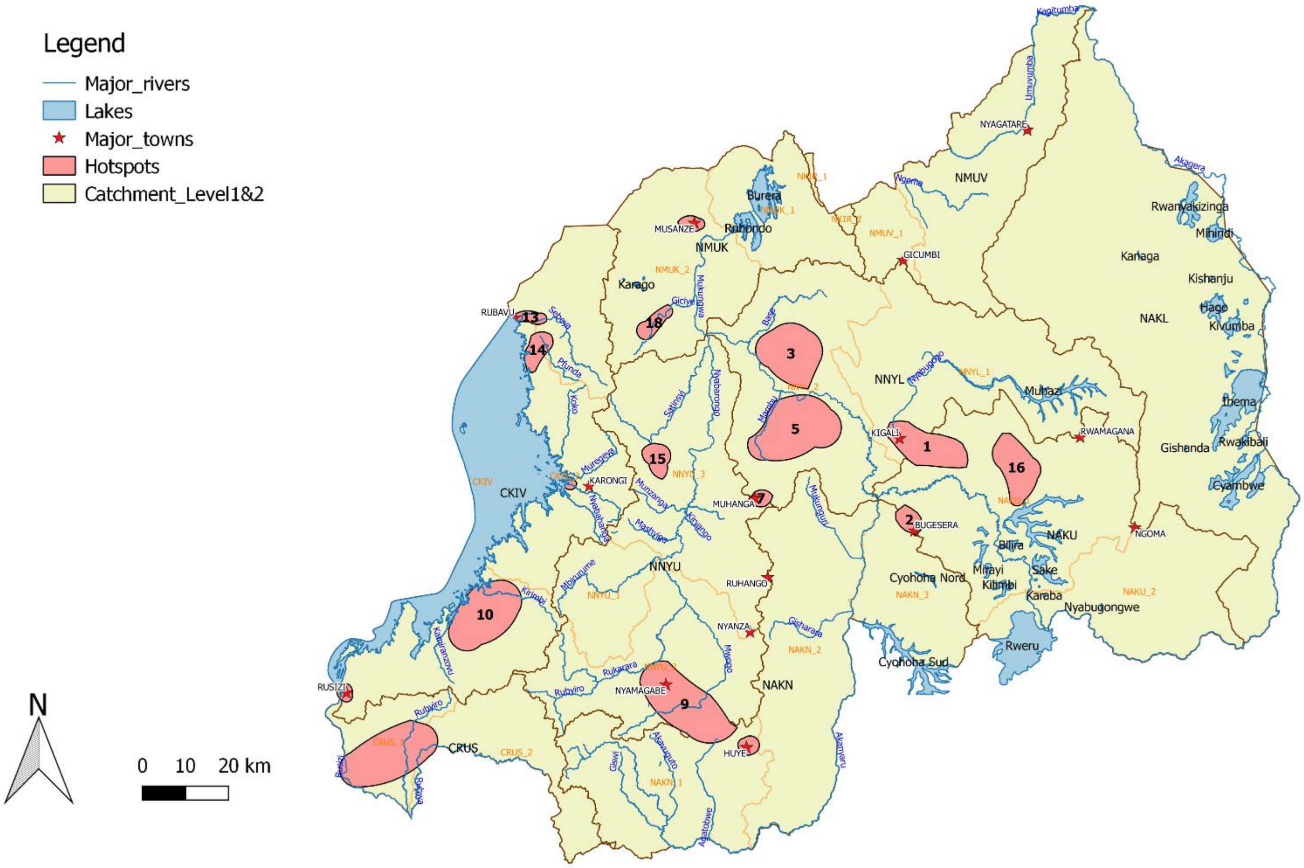

Figure 6-1: Map of Rwanda showing the location of the draft list of pollution hotspots.

Table 6-1: Draft list of pollution hotspots in Rwanda.

No	District/Urban area	Catchment	Motivation
1	Kigali / Gasabo & Kicukiro	NNYL1	The City of Kigali probably has the highest concentration of urban pollution sources that include industries with limited or no wastewater treatment, stormwater runoff contaminated with grey water and sewage discharges, high concentration of garages and vehicle workshops, and high atmospheric pollution emissions from vehicles, industries and cooking stoves. Integrated Pollution Management Plans are being being developed for Kigali (Gasabo and Kicukiro districts) as part of the current project.
2	Bugesera / Bugesera	NAKN 3	Bugesera is growing rapidly as a result of industries and the new airport being established there. It is not yet regarded as a

			significant pollution hotspot, but air emissions and wastewater discharges should be monitored to track its impacts on the environment and communities in the area.
3	Gakenke	NNYL 2	Potential hotspot - There is a high concentration of mining activities and coffee washing stations in this area. Its impacts on the Base River and the Nyabarongo is unknown because no monitoring is done in the area. It is recommended that a survey be undertaken in area to confirm whether this is a hotspot area.
4	Musanze / Musanze	NMUK 2	Musanze is an important urban area with a high concentration of pollution sources. These include concerns about wastewater discharges from industries, garages and workshops, an abattoir, informal settlements, grey water discharges, informal settlements, etc. It also has a high concentration of vehicles and is a transport hub for the region. An Integrated Pollution Management Plan is being developed for Musanze as part of the current project.
5	Kamonyi	NNYL 2	Potential hotspot - There is a high concentration of mining activities and coffee washing stations in this area. Its impacts on the Mambu River and the Nyabarongo is unknown because no monitoring conducted at the outflows into the Nyabarongo. It is recommended that a survey be undertaken in area to confirm whether this is a hotspot area.
6	Karongi / Karongi	CKIV 2	There is a concern about the potential impacts of urban runoff from Karongi on water quality in Lake Kivu. The urban area probably suffer from the same pollution problems as other urban areas in Rwanda and it is located on an important lake. It is recommended that an Integrated Urban Management Plan be developed for Karongi.
7	Muhanga / Muhanga	NNYU 3 & NNYL 2	Muhanga is an important urban area with a fair concentration of pollution sources. These include concerns about wastewater discharges from some industries & hospital, garages and workshops, an abattoir, informal settlements, grey water discharges, informal settlements, etc. It also has a high concentration of vehicles (air pollution emissions) and is situated on an important transport route. An Integrated Pollution Management Plan is being developed for Muhanga as part of the current project.
8	Huye / Huye	NAKN 1	Huye is an important urban area with a moderate concentration of pollution sources. These include concerns about wastewater discharges from some industries, the university

			and prison, garages and workshops, an abattoir, informal settlements, grey water discharges, informal settlements, etc. It also has a high concentration of vehicles and is situated on an important transport route. An Integrated Pollution Management Plan is being developed for Huye as part of the current project.
9	Huye & Nyamagabe	NNYU 2	Potential hotspot – There are a large number of coffee washing stations that may have impacts on the Mwogo and the Rukarara rivers during the coffee harvesting season. It is recommended that the status of this hot spot be determined by means of an investigation.
10	Nyamasheke	CKIV 3	Potential hotspot - There are a number of coffee washing stations in the smaller catchments that drain towards Lake Kivu. These may impact on the rivers and water in the lake during the coffee harvesting and processing season. It is recommended that a survey be undertaken of the Lake Kivu catchment during the height of the coffee harvesting season to determine the extent of impacts on the rivers and the water quality in the lake.
11	Cyangugu / Rusizi	CKIV 3	Concerns have been expressed about the impacts of urban runoff from Cyangugu on water quality in Lake Kivu. The urban area probably suffer from the same pollution problems as other urban areas in Rwanda and it is located on an important lake. It is recommended that an Integrated Urban Management Plan be developed for Cyangugu.
12	Rusizi	CRUS 1	Potential hotspot - There is fair distribution of coffee washing stations that may have an impact on the Rubyiro River during the coffee harvesting season. It is recommended that the water quality data records in the lower reaches of the Rubyiro River be reviewed to determine if there are significant impacts on the Rusizi River.
13	Gisenyi & Rubavu / Rubavu	CKIV 1	Concerns have been expressed about the impacts of urban runoff from Gisenyi/Rubavu on water quality in Lake Kivu, as well as agro-processing plants on the lower reaches of the Sebeya River. It is recommended that an Integrated Urban Management Plan be developed for Gisenyi and the lower Sebeya River. The urban areas probably suffer from the same pollution problems as other urban areas in Rwanda and it is located on an important lake.
14	Rutsiro	CKIV 2 & CKIV 1	Potential hotspot - A high concentration of mining activities in the Pfunda River may have an impact. It is recommended

			that a review of water resources in the area be undertaken to confirm the status of this area.
15	Ngororero	NNYU 3	Potential hotspot - There is a concentration of mining activities in the upper reaches of the Satinsyi River which may impact on the quality in the Nyabarongo River. It is recommended that a survey of water quality in the river be undertaken to confirm its status and impact on the Nyabarongo.
16	Rwamagana	NAKU 1	Potential hotspot – There are a number of mines and coffee processing plants that may impact on water quality in Lake Mugesera and eventually the Nyabarongo River. It is recommended that a survey of water quality in the area be undertaken to confirm its status and impact on Lake Mugesera.
17	Nyagatare / Nyagatare	NMUV 2	Potential hotspot – Nyagatare may suffer from the same urban pollution problems experienced in other urban areas of Rwanda. However, there appears to be fewer industries (dairy and granite industries) associated with Nyagatare. It is recommended that the need for an Integrated Pollution Management Plan for the urban area of Nyagatare and surrounds be investigated.
18	Nyabihu / Giciye River	NMUK 2	The Giciye River has a high impact on the Mukungwa River and mining activities in its catchment have been identified as having a major impact on suspended sediment load.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main objectives of this sub-task on identification of pollution hotspots was to collate data and information on status of water quality and pollution in Rwanda and develop spatial pollution indices. The assessment used various methodologies including critical review of institutions, legislation, policies, strategies, standards and guidelines regarding water quality and pollution in Rwanda, desk review of reports and different studies on water quality and pollution, field surveys and consultations with key stakeholders.

This report provides good baseline for the development of a water quality management guideline and, water quality management plan in Rwanda and for integrated catchment management plans for key four specific catchment areas. Based on the findings of the assessment, the following conclusion are drown:

7.1.1. Institutional and legislative overview

Rwanda had an extensive range of laws, policies, strategies and master plans that could be used to manage pollution in the country. There are also a number of ministries and their agencies that have the mandate of managing different types of pollution. However, the fact that responsibilities are dispersed over a number of ministries and authorities makes it difficult to coordinate pollution management actions as each organisation has their own priorities and funding streams. The inter-ministerial committee envisaged in the Water Law and the Water Resources Master Plan provides a forum for such coordination, but it may not be responsive enough to dealing with short term pollution incidents. There is a need for local action and involvement of communities. The catchment committees or similar structures can provide a mechanism for mobilising local actions. There is need for clarity on roles and responsibilities for water pollution management, and for alignment of pollution management policies and strategies between role players have been taken forward in the development of a water quality management plan for Rwanda, as well as in the integrated management plans for four specific catchment areas.

7.1.2. Point and non-point sources

Point sources that were reviewed in this study included industrial sources, wastewater treatment works, mining wastewater, coffee washing stations, aquaculture, solid waste dumps, and sources of air pollution. On the other hand, the non-point sources that were considered included agricultural runoff, runoff from urban areas, gravel roads and erosion, and air pollution. Air pollution was discussed under point sources (e.g. industrial smoke stacks) and non-point sources (e.g. vehicle emissions).

Each source was described, and the types of pollutants associated with the source were identified. The status and relevance of the source within the context of Rwanda was also described.

In general, the impacts of point sources tended to be localised and unless there was a large concentration of pollution sources in a particular area, for example in a specific urban area, where the cumulative impacts would extend to a specific area or sub-catchment. The biggest impacts of pollution were associated with non-point sources, particularly the impacts associated with agricultural sources (suspended sediments, nutrients, and possibly agrochemicals). Urban areas also contributed to water pollution (e.g. grey water disposal), solid waste (e.g. dumping of solid waste in water courses), and air pollution (e.g. factories and vehicle emissions). Depending on the persistence of the urban pollutants, their impacts could extend well beyond the urban edge.

7.1.3. Pollution concerns

A comprehensive list of pollution issues were discussed. These included erosion and sedimentation, microbial pollution and water-borne diseases, salinization, nutrient enrichment and eutrophication, acidity and alkalinity, sold waste and litter, dissolved oxygen and organic pollutants, agrochemicals and toxic substances, heavy metals, invasive aquatic weeds, hydrocarbon pollution, emerging pollutants, and air pollution issues. Each pollution issue was described, its status in Rwanda was reviewed, and the potential impacts on the environment was discussed. The links between the pollutants and their sources were also discussed to link up with the previous chapter of the report.

The water quality monitoring data collected in Rwanda since 2012 were also analysed and the average concentrations were mapped to show the spatial distribution of concentrations. These were prepared as GIS coverages.

It was clear from the various reports that the priority pollutants or water quality concerns were, in order of importance, sediments, microbial pollution, BOD/COD and organic pollutants that affect dissolved oxygen in water bodies, nutrient enrichment, and solid waste. These finding were aligned with the National Water Resources Master Plan that concluded that the main water pollution issues were:

- High E. coli and coliform bacteria loads (and others that have not been measured) from untreated sewage;
- High organic loads, high biochemical oxygen demands (BOD) and chemical oxygen demands resulting in low concentrations of dissolved oxygen; and
- Very high sediment loads and turbidity.

Strategies to manage the pollutants were addressed in the Water Quality Management Plan for Rwanda, as well as the Integrated Urban Pollution Management Plans for five urban areas in Rwanda that was compiled as part of this project.

7.1.4. Pollution hotspots

The distribution of pollution sources and pollutant concentrations were used to identify 18 potentially hotspot pollution areas where there was a large concentration of pollution sources and elevated pollution concentrations.

5.2 Recommendations

Each of the pollution issues identified in this report required a different approach to manage their impacts. These were unpacked in the guidelines and management plans developed as part of the project. Management interventions would require close cooperation between various government institutions who have control of landuse activities under their jurisdiction.

Recommendations are divided in the following sections:

- Polices, regulations and institutional framework
- Sources of pollution, and
- Water quality concerns and indicators.

7. 2.1. Policies, Regulations and institutional framework

Policies, regulations and institutions on water quality management in Rwanda were found existing and effective. However, there is a need of improvement in some areas. Rwanda can consider the development of country specific guidelines for specified uses which describes the impacts of deteriorating water quality on a specific user sector: Domestic water use, Recreational water use, Industrial water use, Agricultural water use: Irrigation, Agricultural use: Livestock Watering, Agricultural water use: Aquaculture, and Aquatic Ecosystems.. In addition, it was recommended to the Government of Rwanda to appoint a research organisation such as the University of Rwanda to evaluate a number of water quality indexes and to use the knowledge gained to develop a simple water quality index that is appropriate for Rwanda. Such a Water Quality Index should then be used to summarise and report the status of water quality in Rwanda to the general public.

7.2.2. Sources of pollution

Point pollution sources such Industries, wastewater treatment works, mining wastewater, coffee washing stations as well as solid waste dumps were found to be the abundant sources of pollution in Rwanda that need particular attention. Therefore, high organic loads characterised by high BOD and COD concentrations that exceed effluent standards, appears to be a common pollution concern amongst many industries. It is recommended to the Government of Rwanda:

- to implement cleaner production technologies which prevent generation of wastewater, to curtail harmful emissions from industrial sites and enhance the enhance the efficient use of resources.
- to develop centralised WWTWs for industrial parks, designed to treat predominantly industrial wastewater, put in place a strategy for all the major urban centres in Rwanda to treat domestic wastewater and request industries not located in industrial parks to treat their wastewater in accordance with applicable standards employ cleaner production technologies to minimise the waste they produce
- Enforce Rwandan guidelines for the management of waste disposal sites (landfill) and regulations on solid waste collection and transportation to ensure compliance. Recycling and reuse should also be encouraged in the rural areas.
- The impacts of the many small mining operations are more difficult to control than the impacts from large mines that can afford to implement pollution control measures- In order to reduce the water-related impacts of small-scale mines, there is need to develop tools to guide on best practice guidelines for small scale mining
- AD-Coffee Waste System (AD-CWS) as a technology that can use waste generated by coffee processing to generate biogas and fertilizer. Biogas can be used at source to dry coffee beans, thereby saving on energy costs and fertilizer can be sold to generate additional income. The other saving is associated with reduced pollution into receiving streams and commitment costs of water treatment, loss of riverine biodiversity

On the other hand, agricultural runoff, runoff and drainage from urban areas, gravel roads and erosion as well as diffuse air sources were found as key non-point sources of pollution in Rwanda.

- The erosion impacts of construction, maintenance and operational activities on gravel roads can be mitigated by integrating land stability into the road designs to address the landslide risks, by planting grasses on embankments slopes with low landslide risks; by stone masonry construction on embankments' slopes with high risks; and tree planting along rehabilitated roads. In addition, the application of appropriate erosion-protection measures, in particular where it concerns works on slopes and in stream beddings. Furthermore, road and other works should not be executed under aggressive weather conditions (rains, strong winds

7.2. 3. Water quality concerns and indicators

Sedimentation of water bodies mainly due to soil erosion and microbiological contamination that is linked to poor sanitation were found to be key concern of surface water quality. On the other hand, microbiological contamination and agro-chemical pollution were particular sources of groundwater contamination. In order to improve or protect the quality of surface water and the underlying aquifers, control of probable sources of pollution such as faecal coliforms/nutrients from pit latrines should be considered. It was therefore recommended:

- to implement water quality management and pollution control guidelines and water quality management plan for Rwanda addressing key water quality issues.
- improve wastewater treatment technologies and management or grey water discharge in urban areas, whereas in rural areas on site sanitation systems are encouraged, coupled with education, sensitization and behaviour change campaigns on improved sanitation practices.
- develop a comprehensive programme for farmers' education about the impacts of pesticides and herbicides on aquatic ecosystems and human health and the responsible application of these agrochemicals on their crops to protect receiving waters should be emphasised.
- .implement the aquatic weed/water hyacinth management strategy; and
- introduce a used oil recycling programme/project in Rwanda to minimise the impacts of hydrocarbon pollution on water bodies in the country, coupled with the monitoring surveys to determine the extent and severity of hydrocarbon pollution in Rwandan water bodies; and to apply a precautionary approach to emerging pollutants, that is prevent the discharge of such pollutants where possible until there is sufficient information available to determine whether such pollutants are present in Rwandan rivers, wetlands, and lakes, and in what quantities

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Annex I: Number of ponds and their total surface area per sector in Rwanda

Sector	Total # of ponds	Total area (ha)
Base	12	75.3
Bumbogo	3	10.9
Bushoki	7	35.2
Cyeru	14	70.8
Cyinzuzi	7	34.0
Fumbwe	80	279.2
Gacaca	8	32.8
Gacurabwenge	3	6.5
Gahini	2	9.0
Gakenke	8	37.2
Gashenyi	2	5.7
Gashora	14	48.6
Gikomero	10	48.6
Gitovu	3	6.1
Janja	4	34.4
Kabacuzi	5	12.1
Karembo	43	108.5
Kayumbu	10	45.3
Kigabiro	0	60.7
Kinoni	10	40.5
Kinyinya	20	37.2
Kisaro	2	1.6
Mbogo	10	56.7
Mugesera	3	7.3
Muhazi	3	7.3
Mukarange	25	46.9
Muko	5	35.6
Munyiginya	6	25.1
Murambi	8	12.9
Musambira	8	24.3
Musenyi	6	14.6
Musha	16	62.3
Mushishiro	14	34.0
Ndera	25	97.1
Nemba	3	7.7
Ngoma	29	222.2
Nyamabuye	25	121.4
Nyamata	5	21.4

Nzige	0	161.9
Remera	3	14.6
Rubaya	9	34.0
Rugalika	4	32.4
Rukara	6	25.1
Rukomo	14	30.4
Rukozo	18	76.9
Runda	6	8.1
Rurenge	12	72.8
Rusororo	48	191.4
Rutare	6	54.2
Rutunga	1	4.9
Rwasave	100	
Rwaza	10	21.9
Shyogwe	9	21.9
Tumba	8	40.5