# A STUDY OF ENVIRONMENTAL IMPACTS OF ABATTOIRS ON WATER BODIES

## A Case of Nyabugogo Abattoir Facility in Kigali City, Rwanda

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**Masters (Integrated Water Resources Management) Dissertation**

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**By**

**Umubyeyi Naila**

**A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Masters in Integrated Water Resources Management of the University of Dar es Salaam**

**University of Dar es Salaam**

**July, 2008**

## CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the University of Dar es Salaam a dissertation entitled: ***A Study of Environmental Impacts of Abattoirs on Water bodies,*** in partial fulfillment of the requirements for the degree of Masters in Integrated Water Resources Management of the University of Dar es Salaam.

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(Supervisor)

**Date: ……………………………..**

# DECLARATION

# AND

# COPYRIGHT

I, **Umubyeyi Naila**, declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

**Signature: …………………………………………**

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# DEDICATION

*To my mother and my father,*

*You have always been behind all my achievements.*

## ABSTRACT

Abattoirs are known to pollute the environment from their processes. Nyabugogo Abattoir, the biggest in Kigali city, Rwanda, discharges its untreated effluent in Mpazi River. This research aimed at studying environmental impacts caused by the abattoir on its receiving water body and its users. It quantified the amount of water used and wastewater generated, identified and characterized the impacts, determined their significance and proposed mitigation measures. The overall water used and wastewater generated were estimated at 50 $m^3$ and 43$m^3$ per day respectively. The qualities of the effluent and the river water were studied. The samples were collected weekly, preserved and analyzed in each case using Standard Methods. The parameters studied for river water upstream and downstream were as follows: pH 7.62, 7.83; COD 67.50, 971.33 mg/l; BOD 38.17, 325.50 mg/l; DO 0.237, 0.026 mg/l; TSS 67.5, 848 mg/l; nitrates 7.33, 21.35 mg/l and phosphates 18.62, 27.68 mg/l. Except for pH, the other parameters were not meeting the WHO and EHSG standards of effluent. This resulted into anoxic conditions of the river. Also, data was collected for impacts of the abattoir on the people living in its vicinity using questionnaires; 80% complained about bad odors from the plant and 40% about skin diseases caused by using River water. Nyabugogo Abattoir generates large quantities of highly concentrated effluent which adversely impacts the environment.  Blood collection and dry cleaning should be adopted in order to reduce the effluent concentration and volume. A subsurface flow constructed wetland was proposed for Nyabugogo Abattoir effluent treatment.

# TABLE OF CONTENTS

## LIST OF FIGURES

# LIST OF TABLES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| AS | Activated Sludge |
| ATP | Applied Training Project |
| BOD | Biochemical Oxygen Demand |
| CHUK | Centre Hospitalier Universitaire de Kigali |
| CIA | Central Intelligence Agency |
| CGIS | Center for Geographic Information System |
| COD | Chemical Oxygen Demand |
| CP | Cleaner Production |
| CSTR | Complete Mix Stirred Tank Reactor |
| CW | Constructed Wetland |
| DO | Dissolved Oxygen |
| D/S | Downstream |
| EHSG | Environmental, Health and Safety Guidelines |
| EIA | Environmental Impact Assessment |
| ELECTROGAZ | Rwandan company for producing, transporting and distributing water, electricity and gas |
| EPA | Environmental Protection Agency |
| FWS | Free Water Surface Wetlands |
| HSSF | Horizontal Subsurface Flow Wetlands |
| IPPC | Integrated Pollution Prevention and Control |

| | |
|---|---|
| ISRA | Investigative Survey Research Approach |
| KCC | Kigali City Council |
| mg/l | milligrams per liter |
| MINALOC | Ministry of Local Government |
| MININFRA | Ministry of Infrastructure |
| MINITERE | Ministry of Lands, Human Resettlement and Environmental Protection |
| MLA | Meat and Livestock in Australia |
| MRC | Meat Research Corporation |
| NBI | Nile Basin Initiative |
| ND | Not Detected |
| REMA | Rwanda Environmental Management Authority |
| TSS | Total Suspended Solids |
| U/S | Upstream |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNR | Université Nationale du Rwanda |
| WHO | World Health Organization |
| WQM | Water Quality Management |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Water is the most popular and the most important liquid for all living things in the earth (Tsuno, 2006). We all cannot survive if water of suitable quality is depleted. It is regarded as being polluted when it is unfit for its intended use (Turk, 1980).

Growing demands for water and increased pollution loads threaten the quality of many lakes, rivers, estuaries and groundwater bodies around the world and pose serious threats to public health, agricultural and industrial production, ecological functions, and biodiversity (World Bank, 2003).

As the world is becoming more and more urbanized, mostly in developing countries, the issue of urban environmental sustainability is becoming critical and the associated environmental impacts are occurring at an unprecedented rate (Marsalek *et al.*, 2006).Statistics indicate that, out of the current world population of about 6.5 billion people, more than 54% live in urban areas, whereas 35 years ago the urbanized population represented only 37% of the total (Judith, 2006). By the year 2025, it is estimated that an extra 2 billion people will have been added to the urban population, bringing it to 5 billion or over 60% of the total (Judith, 2006).

With the advent of increasing population and industrialization, the range of requirements for water has increased, together with greater demand for higher water quality (Turdukulov, 2003). In parallel with water uses for a variety of human activities (drinking and personal hygiene, fishing, agriculture, industries, transport, recreation and other activities) since ancient times, water has been considered as the most suitable medium to clean, disperse, transport and dispose wastes.

Increasing disposal of wastes in the water bodies means a great potential for environmental damage, and emphasize the need to monitor, protect and manage water resources. However, water quality should also be preserved from the view points of living environment for biota and the ecosystem. Impact of water pollution on these means direct and indirect adverse effects on human beings through the food chain and disturbances in the ecosystem.

Rwanda, like any other country of the world, is embarking on the actions to protect, preserve and improve the quality of the environment. However, concern for the environmental management in most cases occurs late after the quality has been lowered.

Water resources management in Rwanda is challenged by rapid population growth and scale of urbanization, particularly in the domain of delivery of water and sanitation services, not forgetting environmental protection.

Large volumes of domestic and industrial waste water are produced in Kigali city, estimated at 37,572 $m^3$ per day (Umuhoza, 2007). This is due to rapid population growth that occurred after the 1994 genocide, where rural-urban migration was high. That rapid population growth comes along with the need to increase food production in order to satisfy the demand.

Nyabugogo abattoir is one of the meat processing plants in Kigali city and the largest in Rwanda. It is located in a densely populated area and the effluent is discharged in Mpazi River, untreated. Mpazi River is a tributary to Nyabugogo River, which itself is a tributary to Nyabarongo River, one of the two largest rivers in Rwanda along with Akanyaru; both making the Kagera River, the biggest influent of Lake Victoria (Tate *et al.*, 2003). Nyabarongo River is the source of approximately 22% of the total volume of raw water sources in Kigali city (MININFRA, 2006).

This study will emphasize on identifying environmental impacts caused by Nyabugogo Abattoir Facility on its receiving water body, Mpazi River and its users.

## 1.2 Problem Statement

Generally there is no treatment of wastewater from various industrial facilities within Kigali city. Wastewater from these facilities may affect downstream surface water, wetlands and groundwater. Onsite disposal or pretreatment prior to discharge to the local drainage is required by the Environmental Organic Law; however this is widely not respected or enforced. Commercial and industrial facilities are believed to be discharging highly toxic contaminants in many of the drainages (MININFRA, 2006).

Like any industrial process, meat processing industry is associated with significant effluent management issues that could negatively impact the environment. These issues include high water consumption, the generation of high organic strength effluent streams, high energy consumption, odors, high nutrient load, and the management of solid wastes (Rajendra, 2007).

Industrial wastewater effluent from Nyabugogo abattoir is one of the major threats to its natural environment because it contributes to uncontrolled organic and nutrient loads in Mpazi River where it is discharged.

The main reason for these adverse environmental impacts to occur is that in Rwanda and some other developing countries, it is common to site industries without carrying out an Environmental impact assessment; consequently no appropriate mitigation measures are available. This was the case for Nyabugogo Abattoir. Therefore, it has become necessary to study the impacts of the abattoir on Mpazi River and its users.

Emphasis was on the impacts of the abattoir effluent to the receiving Mpazi River and its users; as abattoirs are among the main polluters of the environment through their wastewater disposal into water bodies.

## 1.3 Study Objectives

The main objective of this research was to study the environmental impacts of Nyabugogo abattoir facility on the receiving Mpazi River and its users.

The specific objectives were:

i. To quantify the amount of water used and wastewater generated in the abattoir.

ii. To identify and characterize the impacts of Nyabugogo abattoir effluent on Mpazi River and its users.

iii. To determine the significance of impacts.

iv. To propose mitigation measures for minimizing or preventing adverse impacts.

## 1.4 Significance of the Study

Rwanda, like any other country of the world is embarking on the actions to protect and improve the quality of the environment; and this cannot be achieved unless water quantity and quality are preserved and pollution is stopped in an integrated manner. The protection and safeguarding of the environment has become an important concern in Rwanda as the country's economy depends on agriculture (88.6%) as a result creating a need to safeguard natural resources (water and land inclusive).

Nyabugogo abattoir, being one of the polluting industries of Mpazi River by discharging effluents into it, was constructed without an Environmental Impact Assessment (EIA) being carried out.

The concept of EIA is not new in Rwanda, but its application was not compulsory for many development projects in past years. Environmental Impact Assessments were usually conducted for projects funded by the World Bank or other global institutions like UNDP, but the government itself did not usually require its application either for public or private projects. The application of EIA became an obligation after the Environmental Organic Law in 2005 (Kente & Dushimire, 2008).

This study will generate data and strategies for proper environmental management of the Nyabugogo Abattoir and other similar facilities. This goes a long way towards a cleaner and healthier environment.

## 1.5 Scope of the Study

This study was limited at identifying the impacts of the Abattoir Facility on Mpazi River where its effluent is discharged, and also identifying its impacts on the people living in its vicinity.

Water used and wastewater generated were quantified in order to propose better practices to minimize or prevent the adverse impacts.

## 1.6 Description of the Study Area

### 1.6.1 Description of Rwanda

#### *1.6.1.1 Location*

Rwanda is a small and landlocked country located between the eastern and central Africa. The country is bordered to the East by Tanzania, to the West by the Democratic Republic of Congo, to the north by Uganda and Burundi to the south, as shown by Figure 1.1. It has 26, 338 sq. Km of total surface area, of which approximately 90% are made up of land and about 10% are occupied by water bodies (MINITERE, 2005).

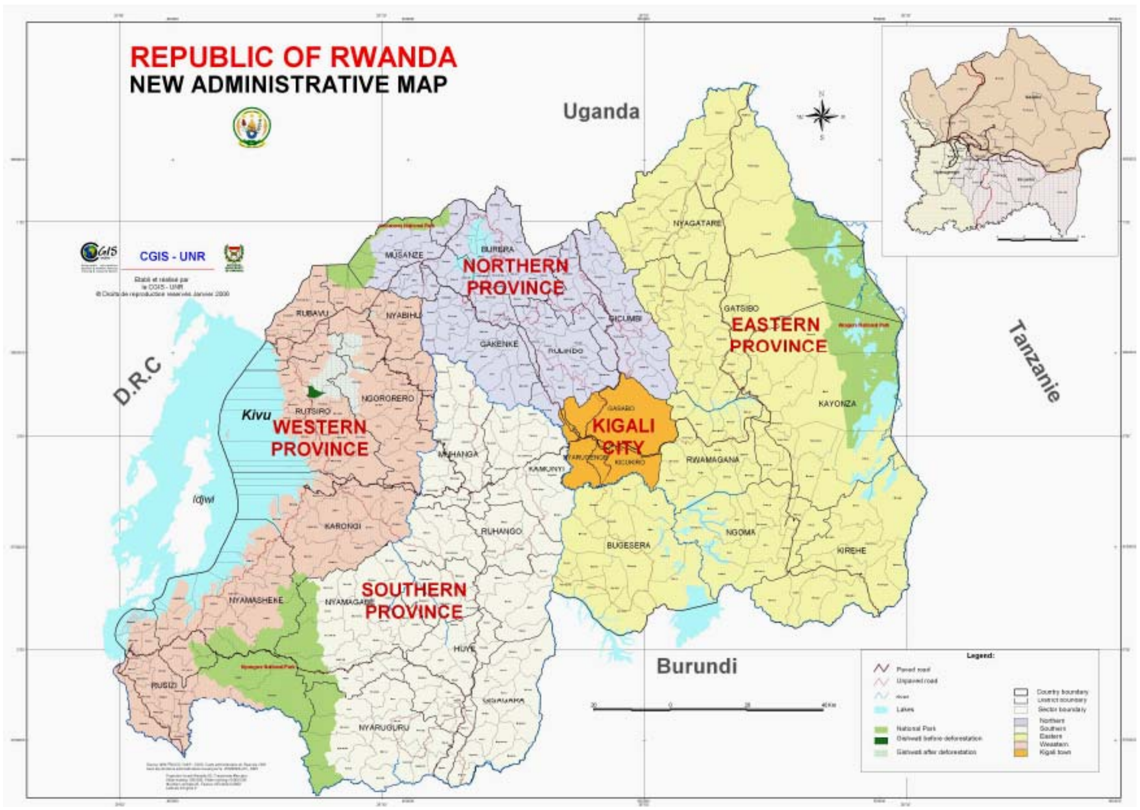



**Figure 1.1: Map of Rwanda, showing the location of Kigali City**

*Source: MINALOC/UNR/CGIS, Carte administrative du Rwanda, 2007*

### *1.6.1.2 Climate*

The climate of Rwanda is made of two wet seasons and two dry seasons. The short wet season lasts from September to November, and the long rainy season lasts from mid-March to the end of May. The short dry season starts in December to end mid-march and the long dry season start from June till the end of August.

#### *1.6.1.3 Population*

The current population is estimated at 10,186,063 people (CIA, 2008). Rwanda's population density is among the highest in Africa and is about 340 habitants per sq. Km. for the year 2007, with an annual population growth of 2.8 % (MININFRA, 2007).

### 1.6.2 Description of Kigali City

Kigali City is the capital of Rwanda, the most populated city, with 1,027,993 habitants (EDAW *et al.*, 2006).The population increased in Kigali, after the 1994 Rwandan genocide, where many refugees came back from their host countries.

This increment has changed the urban planning of the capital completely; new houses were built; roads and sanitations facilities provided altogether without planning. Consequently, the town is becoming more and more over populated; with less provision of basic services like potable water supply and sanitation facilities.

According to a recent demographic study on Kigali, the city will continue to grow at an annual growth rate of around 5.4% for the next 15 years, and will face increasing population pressures (MININFRA, 2006). There is no municipal industrial wastewater treatment plant; industries are discharging their pre-treated or untreated wastewater directly into natural water courses, the case of Nyabugogo abattoir. Figure 1.2 shows Kigali city, its districts and the location of Nyabugogo area.

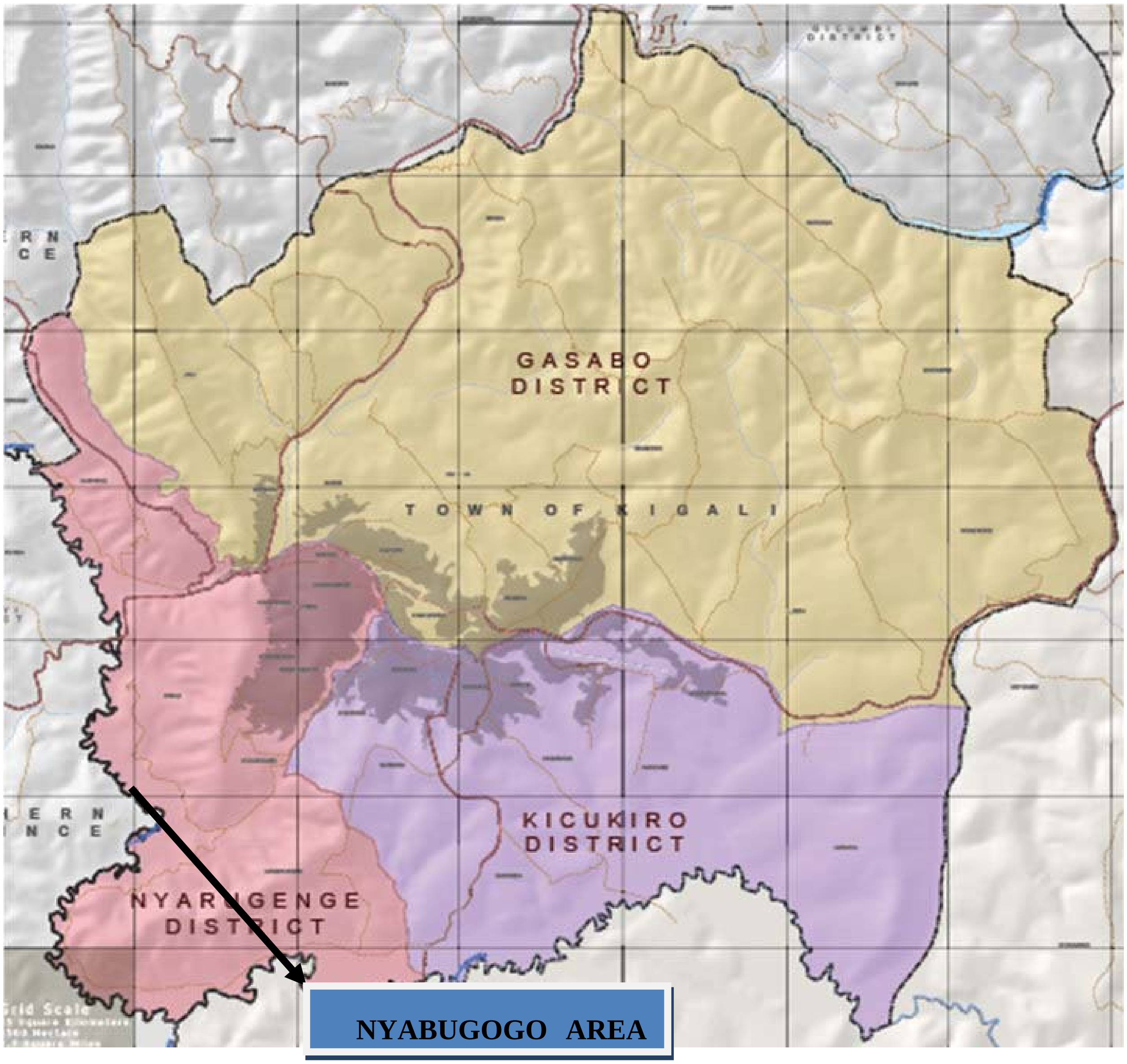



**Figure 1.2: Map of Kigali city, showing its three districts and Nyabugogo area**

*Source: MININFRA, 2006*

## 1.7 Organization of the Dissertation

Chapter one gives an overview of the research. The motivation and driving forces of the research, together with the research objectives are presented in chapter one.

Chapter two gives the literature review. It initially addresses the environmental problems encountered in abattoirs and then it gives an overview of the abattoir processes and operations. Water use and waste generation in abattoirs are also reviewed. Finally, cleaner production in abattoirs is highlighted.

Chapter three gives the methodology used in this research and illustrates how the abattoir effluent quality, the river water quality, the people's perceptions about the abattoir were obtained and used to reach the aims of the research.

Chapter four presents the analysis and discussion of the results obtained in this research.

Chapter five provides conclusions and recommendations emanating from this research.

A list of references is provided at the end of the dissertation.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

### 2.1.1 Definitions

- An abattoir has been defined as a premise approved and registered by the controlling authority for hygienic slaughtering and inspection of animals, processing and effective preservation and storage of meat products for human consumption (Alonge, 1991).
- Environmental pollution is viewed as any condition or situation in which any substance or combination of substances present in the ecological system is detrimental to the health of man, plant, and animal or affects the welfare of man now or at a later time (Chukwu *et al*, 2007).
- Environmental impacts are viewed as any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services (AS/NZS ISO 14001 definition 3.4).

### 2.1.2 Environmental Problems Encountered in Abattoirs

Environmental problems have increased in geometric proportion over the last three decades with improper management practices being largely responsible for the gross pollution of the aquatic environment with parallel increase in water borne diseases especially typhoid, diarrhea and dysentery. Abattoirs are generally known all over the world to pollute the environment either directly or indirectly from their various processes (Adelegan, 2002).

Slaughterhouse wastewater is very harmful to the environment. Quinn and Mcfarlane (1989) observed that effluent discharge from slaughterhouses has caused the deoxygenation of rivers.

Effluent from slaughterhouses has also been known to contaminate ground water (Sangodoyin and Agbawhe, 1992). The pollution potential of meat-processing and slaughterhouse plants has been estimated at over 1 million population equivalent in the Netherlands (Sayed, 1987) and 3 million in France (Festino and Aubart, 1986).

Tritt and Schuchardt (1992) reported during a study in Germany that blood, one of the major dissolved pollutants in slaughterhouse wastewater, has a chemical oxygen demand (COD) of 375,000mg/L. This impacts high organic pollutants on receiving waters consequently creating high competition for oxygen within the ecosystem. This COD value is far higher than the maximum limit of 80 mg/l set by Federal Environmental Protection Agency/Federal Ministry Environment (FEPA/FMENV, 1991), Nigeria.

As population grows and urbanization increases, more water is required and greater demand is made on ground and surface water and an even greater amount of organic and inorganic wastes are speared back into water sources and  less potable water becomes available (Shuval, 1972).

While the slaughtering of animals result in meat supply and useful by-products like leather and skin, livestock waste spills can introduce enteric pathogens and excess nutrients into surface waters and can also contaminate ground waters (Meadows, 1995).

Abattoir operations produce a characteristic highly organic waste with relatively high levels of suspended solids, liquid and fat. The liquid waste is usually composed of dissolved solids, blood, gut contents, urine and water.

In the production of animal for food, more attention should be focused on the interactions between animal production and the environment, realizing environmental conditions and structures in animal production, which not only seek to produce wholesome and safe animal food but should also avoid environmental pollution and the associated human health risks (Adeyemo, 2002). The food industries must be aware of the contents of the wastes they generate with the view to making them environment friendly .This is more so when it is realized that waste from food industries has the potential of polluting the environment in all the three possible states – solid, liquid and gas( Chukwu *et al*,2007).

In abattoirs there is also a large potential for the transmission of zoogenic diseases such as Q-fever and anthrax to humans (EPA, 2005).

### 2.1.3 Environmental Challenges in Rwanda

Environmental challenges in Rwanda date back several decades and they are manifested in the context of poverty and socio-economic development efforts meant to improve the welfare of people. Recently, the Government of Rwanda has undertaken strong commitment to understand its current and future environmental challenges as a necessary step in the pursuit for sustainable development. Current national environmental challenges are exacerbated by low levels of environmental awareness, inadequate technical human resources and low intra-sectoral coordination on environmental issues (REMA, 2006). In order to effectively manage environmental challenges such as soil erosion, deforestation, wetland drainage, water degradation, climate change and the loss of biodiversity, the Government of Rwanda established Rwanda Environmental Management Authority (REMA), to coordinate and oversee all aspects of environmental management for sustainable development.

As found out by different researches done in other countries like Nigeria (Osibanjo, O. and Adie, G.U, 2007), abattoirs are likely to be negatively impacting the environment. They are also among the industries in Rwanda that threatens the environment through their waste disposal in water bodies without prior treatment.

The abattoirs facilities exist in our environment and are the main generators of wastes. Since the existing environment within which they operate is the only one we have, and shared by both the consumers, and operators of other sectors of the economy, there is the need therefore, to ensure the preservation of the environment in as natural and as ecologically balanced state as possible for the use of all. This must and should be made to be the motivating factor during the design, construction and operation of all industrial set up. Industrial waste is a major source of environmental pollution**.**

## 2.2 **Overview of the Abattoir Processes and Operations**

The common processes that take place at abattoirs are stunning, bleeding, hide removal or treatment, evisceration, carcass dressing and washing (Hansen *et al.*, 2000). Many abattoirs also have a boning process in which finished carcasses are cut into retail portions. Most abattoirs also have casings and offal processing departments, which produce value-added products from casings (intestinal tract) and edible offal. The basic process for slaughtering and processing of cattle along with wastewater generation sources is shown in figure 2.1. It includes plant services and ancillary activities as well as the basic meat processing steps, associated wastes and processes, by-products recovered or reclaimed (EHSG, 2007; Masse *et al.*, 2000).

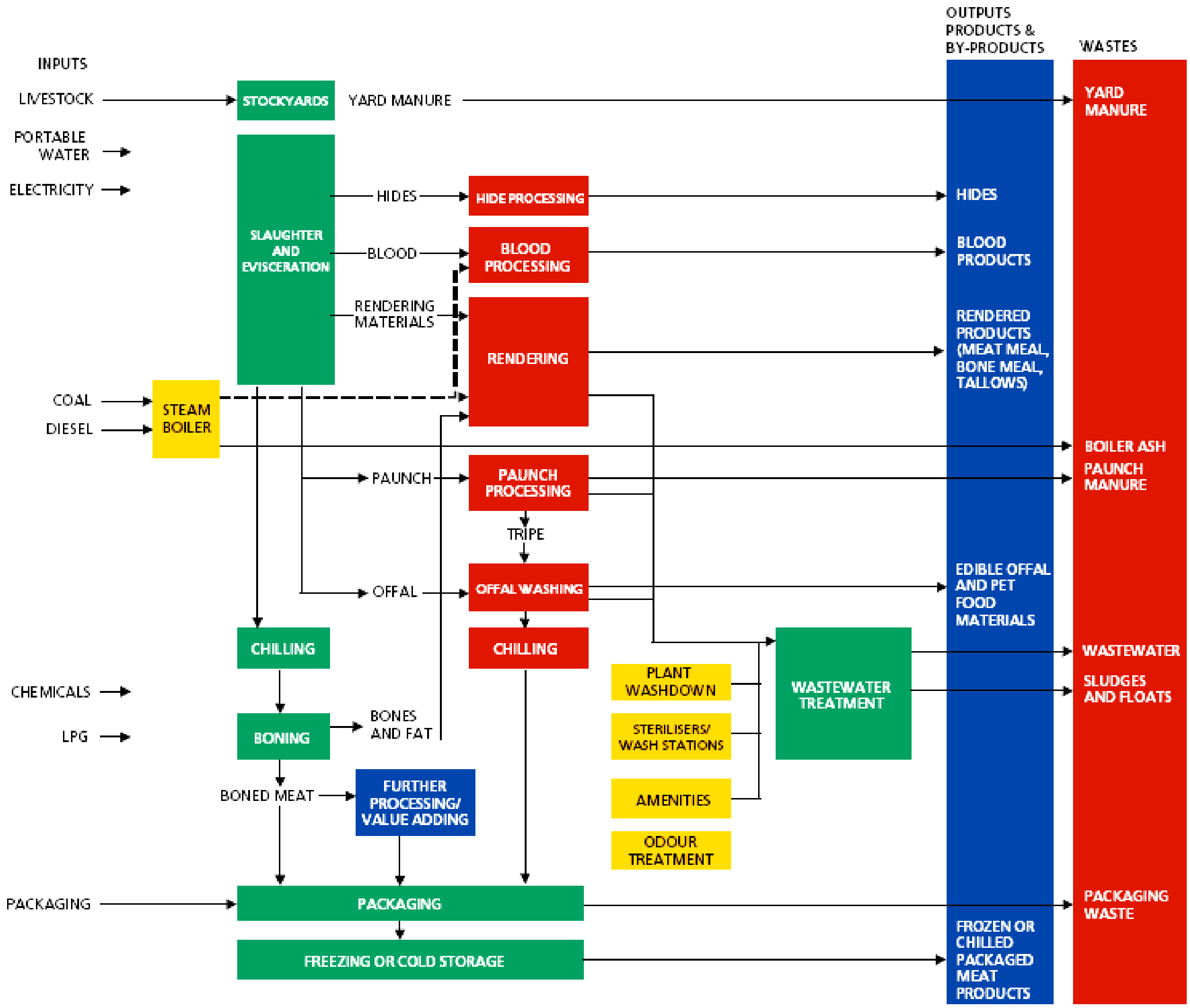



**Figure 2.1: Process flow chart for a typical meat processing industry showing input and output**

*Source: MLA, 2002*

The main inputs are livestock, water, energy, packaging, chemicals and lubricating oils. Outputs are the products, co-products and waste generated from process.

The main products from meat plants are chilled or frozen meat and edible offal. Rendering converts by-products into value-added products such as tallow, meat and blood meals.

There is not a major difference in the process of slaughtering of cattle to processing of other animals such as sheep and goats (IPPC, 2003).

### 2.2.1 Pre-handling

Before the animal enters the facility, pre-handling is the first step in the overall processing operation to be conducted. Animal held for one to two days in holding yards. They are generally fasted for a day to reduce the amount of intestinal contents. The animals are inspected, and those that are sick, thus unfit for human consumption are removed from the facility, where they are placed into quarantine pens to avoid contamination. The cows are weighed live to enable accurate determination of yield before they are moved into the stunning and bleeding area (IPPC, 2003).

### 2.2.2 Stunning and Bleeding

The cattle are led to the stunning area where they are made unconscious using a bolt pistol or electric shock. Once the animal is stunned, they are shackled by hind leg and hoisted onto an overhead rail or similar suspension device.

The next step after stunning is bleeding or sticking. In this phase the animal is allowed to bleed out known as exsanguinations, which may take from two to ten minutes, depending on the level of cleanliness desired. If blood is recovered and sold to rendering plants, the bleeding time is usually extended, which also serves to reduce the amount of blood present in wastewater streams. The slaughtering operation is the largest single source of waste load in an abattoir, and blood is the major contributor. Blood is rich in BOD, chlorides, and nitrogen. It has an ultimate BOD of 405,000 $mgl^{-1}$ and a $BOD_5$ between 150,000 and 200,000 $mgl^{-1}$ (IPPC, 2003).

### 2.2.3 Dressing and Hide Removal

After complete bleed out, bodies are laid along another conveyor to the slaughter hall where dressing and hide removal take place. This can either be done while animal is attached to overhead rail, or the animal can be removed and placed in cradle. The head and hooves are removed to prevent contamination of the carcass by dirt and manure dropped from hooves. The head is cleaned with high-pressure water, and the brain and tongue are removed for use as edible. The hides are then removed from the process room and preserved by salting or chilling before they are shipped for leather processing (Nicholas, 1992).

### 2.2.4 Evisceration

After skinning, blood-free carcasses are then opened to remove the viscera in a process called evisceration. The abdomen is opened from the top and the organs are loosened and removed from the body. The remaining organs are inspected, and the stomach, intestines are cleansed to remove any remaining manure. The removed organs are sorted into edible offal. Once the organs have been completely removed, a handsaw or other cutting tool is used to cut the carcass in half along with backbone to create what is commonly known as a “side of beef”. The beef sides are then washed again to remove manure, blood, or bone dust before they are physically or chemically decontaminated. Physical decontamination method involves subjecting the carcass to high-pressure water or stream, while chemical decontamination involves using acetic or lactic acids, or solution containing chlorine, hydrogen peroxide, or other inorganic acids (James and Robert, 1979 ).

### 2.2.5 Cutting and Boning

The cleaned sides of beef are then sent to an area where they are boned. It is the process when meat is manually cut away from bone. This can either be done after the carcass has been refrigerated or directly following evisceration and decontamination. In the past, bone and meat removal was the last process done in the facility. Beef remained in sides until it was received by the butcher, who then cut the side into primal joints or wholesale cuts, which were then suited for retail sales. The current practice is to break down the side into primal joints, then vacuum pack the meat and prepare for shipment.

### 2.2.6 Inspection

Carcasses and viscera are inspected to determine if they are suitable for human consumption.

### 2.2.7 Cleaning Phase

Equipment and floors are hosed down or manually scraped to remove solid wastes and other easily removable materials. This process differentiates between wet and dry cleaning. Dry cleaning is preferred by a wide margin, as the wet process unnecessarily introduces large volumes of high-strength wastes into the treatment systems (Nicholas, 1992).

The equipment, walls, floors and work surfaces are cleaned, scrubbed and sanitized, and then re-rinsed ( Massé *et al*., 2000). Water, detergents and foam are applied to scrub the wastes from the surfaces, as well as to essentially disinfect the work surfaces. The detergent are then washed and scrubbed to remove the chemicals, which are normally alkaline in nature to remove fats and proteins from the plant and work surfaces. These chemicals are commonly removed by hosing, scraping, or a combination of the two.

Areas that have high levels of fatty tissue residues, such as boning and other cutting areas usually require high volumes of water to remove very sticky wastes.

Lastly, only water is used to effectively remove all traces of chemicals and wastes from the surfaces, which are then ready for the next shift to commence.

### 2.2.8 By- products Recovery

At various stages in the process, inedible by-products such as bone, fat, heads, hair and condemned offal are generated. These materials are rendered either on site or offsite into feed materials.

## 2.3 Water Use in Abattoirs

In processing and quality control, water helps to clean the product, to convey and remove unwanted materials. Large quantities of water are used in abattoirs, thus substantial amounts of wastewater are generated. In wastewater handling, water flushes organic and inorganic matter to the sewer. Wastewater treatment is basically a processing system to separate the organic and inorganic matter from the water that collected it. Thus, keeping organic and inorganic matter out of the water omits the necessity for treatment. Abattoirs are large users of town water and borewater.

Volumes of wastewater from meat processing are generally 80-95 percent of the total freshwater consumption (MRC, 1995). The United Nations Environmental Program, Cleaner Production Assessment in Meat Processing (2000), estimates a range of 4.1 to 16.6 $m^3$ of water used per Live weight killed ton of animal in the United States. Between 44-60 percent of water is consumed in the slaughter, evisceration and boning areas (MRC, 1995).

Table 2.1 illustrates the breakdown (%) of water used in various processes of an abattoir.

**Table 2.1: Breakdown of water consumption in an abattoir**

| **Meat Processing Activities** | **Percent of total fresh water consumption** |
|---|---|
| Stockyard (wash down and animal watering) | 7-24 % |
| Slaughter, evisceration | 44-60 % |
| Boning | 5 - 10 % |
| Inedible & edible offal processing | 7 – 38 |
| Casings processing | 9-20 % |
| Rendering | 2 - 8 % |
| Chillers | 2 % |
| Boiler losses | 1 – 4 % |
| Amenities | 2 – 5 % |

*Source: Meat and Livestock Australia Ltd, 2007*

The slaughter and evisceration areas are the largest water users and responsible for the majority of cleaning and equipment sterilization. Cleaning and carcass washing operations typically count more than 80% of total water use and effluent volume (IPPC, 2003).

Reduction in water usage would have a direct impact on reducing wastewater volume hence making wastewater treatment and disposal easier and cheaper (MLA, 1998).

## 2.4 Waste Generation in Abattoirs

The different production processes in abattoirs generate wastewater and solid wastes.

**Table 2.2: Production stages and resulting wastes**

| **Production stage** | **Wastewater and solid waste** |
|---|---|
| Lairage | The major pollutants are urine and faecal matter from daily washing of floors. |
| Stunning, sticking and bleeding | Although most blood is caught and collected, small quantities are inevitably lost. Blood has a very high oxygen demand and is a major pollutant. |
| Carcass processing | Some solid matter is conveyed in the wastewater. |
| Offal handling | Rough Offal: The wastewater from this area is extremely high in suspended matter from stomach contents.<br>Red Offal: Small quantities of wastewater are generated containing small amounts of blood. |
| By-products processing | The primary source of wastewater in by-products processing is the water used to wash out the cookers after the rendered charge has been removed. Although low in volume this wastewater can contain a high pollution load. An additional source of wastewater from this area is from the condensers used to condense malodorous vapors from the cookers. |

| | |
|---|---|
| Miscellaneous wastewater sources | Large amounts of wastewater are generated at the end of each day when an intensive wash down programme is carried out. Process areas are given special attention, all fittings and floor areas are washed, sanitized and rinsed using sanitizers, detergents and/or enzymatic cleaning systems. Other sources of wastewater are from laundries, boot washing and knife sterilizing basins. |

## 2.5 Cleaner Production in Abattoirs

### 2.5.1 Introduction

Cleaner Production means the continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency. This leads to improved environmental performance, cost savings, and the reduction of risks to humans and the environment. Its concept was introduced by UNEP in 1989 as a response to the question of how industries could work towards sustainable development.

It can be applied to industrial processes, products and services:

- For production processes, CP includes conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and waste before they leave the process.

- For products, CP focuses on reducing impacts along the entire life cycle of the product, from raw material extraction to the ultimate disposal of the product.
- For services, using a preventive approach involves design issues, housekeeping improvement, and the better selection of material inputs (in the form of products).

The concept is about a preventive environmental approach, aimed at increasing resource efficiency and reducing the generation of pollution and waste at source, rather than addressing and mitigating just the symptoms by only technically "treating" an existing waste/pollution problem. In abattoir wastewater management the following essential elements of cleaner production remain valid: pollution prevention, waste minimization, process efficiency, reuse and recycling of materials, life cycle approach, and least impact treatment with resource recovery.

### 2.5.2 Application of Cleaner Production Concepts to Abattoir Processes and Operations

The implications of the application of cleaner production concepts are summarized in table 2.3 .The cleaner production approach emphasizes on pollution prevention and resource recovery (blood, fat and nutrients). This is achieved by avoiding mixing, dilution, and transport of waste and is best achieved by onsite or decentralized management of wastewater (Nhapi and Hoko, 2002).

**Table 2.3: Cleaner production principles and management practices in abattoirs**

| **Principle** | **Practice** |
|---|---|
| Use lowest amount of input material, energy or other resources per unit of product. | Large amounts of water are used in abattoirs processes like cleaning while options like dry cleaning are available and efficient |
| Do not use input material of higher quality than strictly necessary | Water treated to drinking water standards is used to clean floors and flush wastes into sewers |
| Do not mix different waste flows | At Nyabugogo Abattoir, various wastewater flows are combined (blood, manure, fat, detergents and chloride). After disposal into the river, this combined waste is mixed further with urban runoff that contains industrial effluent. Obviously this practice makes reuse of specific components in the mixed waste flow less attractive and less feasible. |
| Evaluate other economic function and uses of by-products before considering treatment and final disposal | Abattoir wastewater is discharged into open water resources either with or without prior treatment. Blood, fat, manure and sawdust are mixed, discharged into rivers without prior treatment. By-products recovery should be promoted like blood into pet food, manure and paunch content into compost |

## 2.6 Wastewater Treatment in Abattoirs

Untreated wastewater is unsuitable for direct disposal into a receiving water body. Even if part can be segregated and is relatively uncontaminated, some form of treatment is required as an environmental safeguard (MLA, 1998). In general, treatment should be designed to ensure:

- reduction of pollutants to levels required by the state environmental authority,
- that the discharged effluent is at around neutral pH and ambient temperature,
- that suitable disinfection is provided to meet microbiological quality levels required by the state environmental authority,
- that salt and nutrients levels are acceptable( for discharge to inland waters) and
- that there are no detrimental effects on the receiving water or its surrounding environment.

The level of treatment required for disposal to surface waters is much higher than land or sewer disposal schemes. Treatment processes can be either extensive or compact.

The treatment of wastewater from abattoirs and associated industries is a sequential process comprising a number of stages mainly:

- minimization of water use through good plant design and operation including housekeeping ,

- primary treatment in which fats and solids are removed ,
- secondary treatment in which bacteria and algae break down the organic matter and
- re-use or disposal.

Further treatment can target the removal of specific hazardous or environmentally damaging components of the waste stream such as nutrient.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Introduction

### 3.1.1 Site Description

Nyabugogo Abattoir is situated in Kigali city, on the northwestern side of the city of Kigali, Nyarugenge district, Gitega sector.

It was constructed in 1978 as a property of the government and privatized in 1998. Since then until 2001, it was being rehabilitated and modernized. The abattoir occupies a surface area of 2 hectares. The largest area is occupied by the lairage, where animals are received and kept before being slaughtered. The rest is occupied by the slaughterhouse for cattle and another one for goats and sheeps and an administration building.

The Abattoir is located very close to Mpazi River, which has a catchment area of 7.5 $km^2$ and 3.9 km length between the Mount Kigali and the town centre. Mpazi River used to be a source of a lot of environmental problems because it used to be flooded during rainy seasons and water would even enter people's houses. Since last year, Nyarugenge district started a project of building (channeling) the river to overcome those problems. The Mpazi River passes through highly populated areas such as Nyamirambo, Nyakabanda and Muhima suburbs on its right bank, and Kimisagara on its left bank. The population densities range from 200 – 300 people per sq.km.

Besides the diffuse source of pollution of domestic wastewater from the population, the main point source polluters of the Mpazi River are Centre Hospitalier Universitaire de Kigali (CHUK), the Central Prison of Kigali, the Nyabugogo Abattoir and Nyabugogo Tannery downstream. Figure 3.1 shows the aerial view of Nyabugogo abattoir location.

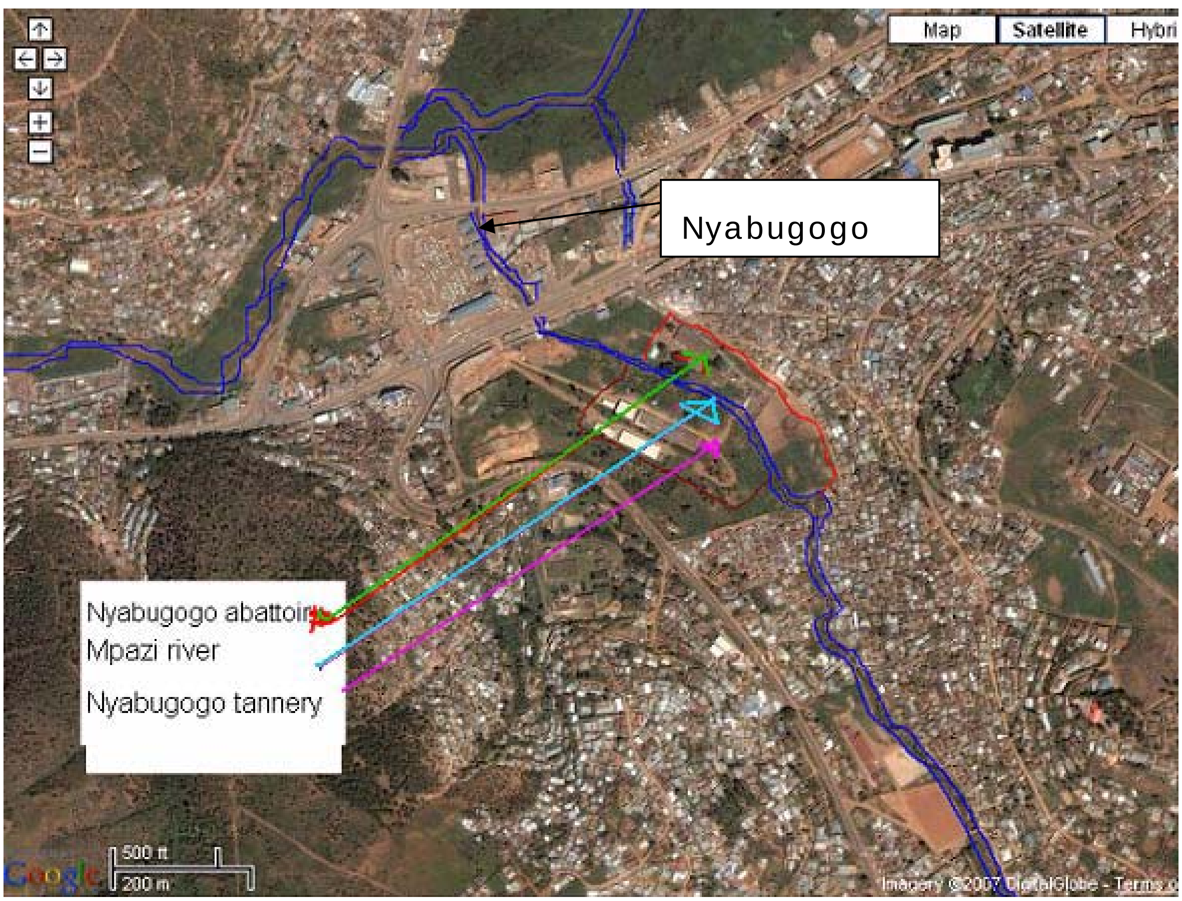



**Figure 3.1: Aerial view of Nyabugogo area**

*Source: Google Earth*

The activities of the abattoir start midnight up 9am. In average, Nyabugogo abattoir slaughter 65 cattle and 135 goats and sheeps per day. The number used to be higher but it lowered because they are now exported to Bukavu, in Democratic Republic of Congo. An average of 50 $m^3$ of water is used in the abattoir, supplied by ELECTROGAZ, the Rwandan company of production, transport and distribution of water, electricity and gas. There is a 55 $m^3$ septic tank which is no longer functional, thus no by-products recovery.

### 3.1.2 Production Processes of Nyabugogo Abattoir

The slaughtering process at Nyabugogo Abattoir is a series of unit processes, briefly described below, carried out in different areas of the abattoir:

#### *3.1.2.1 Off-loading (receiving)*

The animals are off-loaded and channeled to the lairage area. At or near the off-loading point vehicles are washed to rid them of manure before leaving the abattoir site.

#### *3.1.2.2 Lairage*

Lairage is the area where the animals are kept for a few hours prior to being moved to the stunning area. At Nyabugogo abattoir, they are kept for 24 hours.

Drinking water is provided but the animals are not fed to limit the paunch contents that need to be disposed of after slaughtering. Lairage is washed down and cleaned once a day.

*3.1.2.3 Stunning*

Cattle are channeled to the stunning area where they are stunned by mechanical means using a bolt from an air gun or stunning pistol. There is no stunning for goats and sheeps, they are immediately slaughtered.

*3.1.2.4 Sticking*

The next process is sticking, where the throat is slit over a bleeding trough. There is no blood collection. As the body moves along the rail, the blood pours into a drain on the floor the length of the bleeding rail. All the blood is mixed with other wastewater. While approximately 40 to 60 percent of the blood exits the body during bleeding, about 3 to 5 percent remains in the muscles and the remainder is held in the viscera. Wastewater from this process contributes highly to the pollution load of Mpazi River. Figure 3.2 shows the blood into a drain which is mixed with cleaning water and other wastewater.

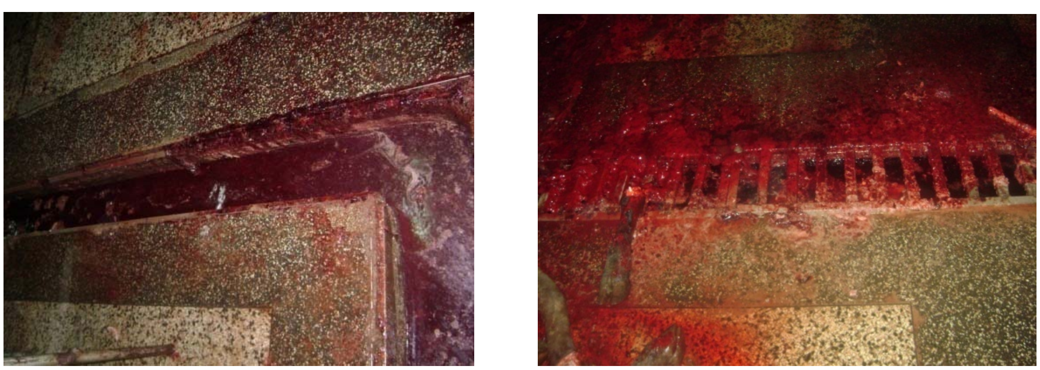


**Figure 3.2: Blood from the sticking process**

#### *3.1.2.5 Hoof, Head and Hide Removal*

Hoof and head removal is carried out manually .This processing area is hosed down periodically and wastewater discharged to drain.

Removal of hides is carried out mechanically by hide pullers. The hides undergo washing, trimming and salting before being sent to Nyabugogo tannery for further processing.

#### *3.1.2.6 Evisceration*

This is the process of mechanically cleaving the carcass and allowing the stomach, intestines and internal organs to fall onto a pan conveyor. After cleaving, the two sides are washed with hand-held water sprays. After evisceration, the head and feet conveyor, the carcass conveyor and the viscera conveyor are all synchronized to pass an inspection point where all the parts of a single animal are inspected simultaneously to determine the suitability of the animal for human consumption. In the event that the animal is condemned, all parts are transferred to a condemned room. Later they are transported to a solid waste disposal site, located in Butamwa. Figure 3.3 shows the wastewater from the evisceration process.

**Figure 3.3: Wastewater from the evisceration process**

#### *3.1.2.7 Chilling*

Chilling is done in order to remove residual body heat thus inhibiting microbial growth and reducing evaporative weight loss. The carcasses are conveyed into a corridor leading to the chillers by the rails. Temperatures in the chillers can be controlled using an automatic control system. At the end of the process the chiller is washed out with water.

#### *3.1.2.8 Boning*

The boning room is air conditioned at $10^{\circ}$ C or below. The chilled quarters are boned out mainly on the rail, with boning of ribs on tables. Primals are trimmed to remove excess fat, wrapped individually in polyethylene film and packed.

#### *3.1.2.9 Freezing and Cold Storage*

Few carcasses in Nyabugogo abattoir undergo the freezing process because the owners of the cattle say that it somehow gives a bad taste to the meat after being freezed, yet it is recommended in order to kill microbes present in the flesh.

Wastewater is produced in this process and it is screened before being discharged into Mpazi River. Freezing occur at temperatures below $0^{o}C$

#### *3.1.2.10 Red Offal Handling*

Red offal, consisting of hearts, kidneys, livers and lungs, undergo cold water washing to remove blood. Small quantities of wastewater are generated and passed to drain.

#### *3.1.2.11 Rough Offal Handling*

This involves the opening up of paunches and intestines for washing which is carried out in two stages; first a cold wash to remove loose dirt followed by a hot water wash to clean the offal to required standards for human consumption. This area has the highest water consumption in the abattoir. The intestines and paunches contents have large quantities of suspended solids, which contribute to a very high organic load of the wastewater.

#### *3.1.2.12 Cleaning*

Nyabugogo abattoir's regulations require that all the equipments used during processing of all animals for human consumption be thoroughly cleaned after every 8 hours of operation to maintain good sanitary conditions. During cleanup, all equipment, walls, and floors are rinsed to remove easily detachable particulate matter. Then they are scrubbed and rinsed again to remove detached particulate matter, detergents, and sanitizing agents used during the scrubbing phase of cleanup activities. Phosphorus-based detergent are used and chlorine solutions as bactericidal compounds.

#### *3.1.2.13 Solid Wastes Disposal*

Before, solid wastes were discharged near Mpazi River and it was causing many adverse impacts on the River and the local population. After being required by the government to abandon such practices, the abattoir management decided to prepare a disposal site in Butamwa, outside the city, approximately 10 km from the abattoir . It has been seven months since they started using that site.

Horns, manure, and condemned meat are brought to that site.

The problem is that the condemned meat is buried in 10meters depth pits which are not cemented inside; there is just a concrete cover. Also the personnel at that site are not given appropriate equipment such as protective mask, and yet they have direct contact with the wastes.

**Figure 3.4: Condemned meat discharged and buried at Butamwa landfill**

### 3.1.3 Design of the Study

Data used in this research was collected from primary and secondary sources.

The study design was based on Investigative Survey Research Approach (ISRA) (Chukwu, 1994). The ISRA for obtaining data entails the schedule of a series of visits to the abattoir facility. The tasks accomplished during such visits include the following:

- Inspection and witnessing processing operations,
- Collection of liquid wastes from the abattoir and Mpazi river water for laboratory analysis
- Interviewing relevant and competent staff of the abattoir and residents of the abattoir area and administering questionnaires to them.

Two types of data were sought for in the abattoir and its surrounding environment. These are qualitative and quantitative in nature and are based on: observations, measurements, existing records; information from questionnaires, expert opinions, and reliable publications.

Approach, data collection and analysis instruments used for different study objectives are described below:

## 3.2 Identification and Characterization of Impacts

In order to identify and characterize the impacts of Nyabugogo abattoir effluent on Mpazi River and its surrounding environment, and also to determine their significance, documents on abattoirs operations and processes in general were revised. This gave a general overview of pollution that can occur from each abattoir process and the way to manage its impact on the environment, especially on the receiving water body.

Questionnaires were administered to the people living in abattoir area and interviews with abattoir authorities were conducted.

Also, interviews were conducted with Kigali city environmental and inspection departments' personnel and Rwanda Environmental Management Authority staff. This gave an overview of the environmental problems caused by abattoirs in Kigali city and the ongoing or future strategies to overcome this problem.

Finally wastewater and River water samples were collected and analyzed for pH, COD, BOD, DO, TSS, nitrates and phosphates.

### 3.2.1 Sampling Design

Wastewater samples were taken in order to determine the quality of the effluent before being discharged into the river. Also water samples from the river were taken upstream in order to have a basis for analysis and downstream to see the impact of the discharged effluent.

Sampling was carried out weekly, each Friday from 28th March 2008 to 02nd May 2008. Six samples were taken at three fixed monitoring stations as follows:

- the outfall point , where all the waste water passes before being discharged,
- upstream Mpazi River, before effluent discharge, 40 meters to the outfall and
- downstream Mpazi River, after effluent discharge, 30 meters from the outfall.

All the sampling bottles were adequately washed. The liquid samples were first mixed completely and taken in plastic bottles .They were preserved and analyzed in each case using Standard Methods recommended by the American Public Health Association (APHA/AWWA/WEF, 2005).

Sampling was done between the hours of 10.00 am and 11.00 am when the discharge of effluent into the river always occurred.

Appendix 1 shows the schematic representation of the sampling site.

### 3.2.2 Wastewater and River Water Data Analysis

The water quality parameters considered are pH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BDO), Dissolved Oxygen (DO), Total Suspended Solids (TSS) and nutrients (nitrates and phosphates). They were analysed using Microsoft Excel Package (t-test). These parameters were compared to WHO standards and

Environmental, Health and Safety Guidelines (EHSG) in order to determine the resulting impacts significance on Mpazi River and its users.

***t-Test Paired Two Samples for Means theory***

The test analysis tool test for equality of the population means that underlie each sample. The tool employs assumption that the population variances are equal.

For this test, a t-Statistic value, t, is computed and shown as "t Stat" in the output tables. Depending on the data, this value, t, can be negative or nonnegative. Under the assumption of equal underlying population means, if $t < 0$, "P (T <= t) one-tail" gives the probability that a value of the t-Statistic would be observed that is more negative than t. If t >=0, "P(T <= t) one-tail" gives the probability that a value of the t-Statistic would be observed that is more positive than t. "t Critical one-tail" gives the cutoff value, so that the probability of observing a value of the t-Statistic greater than or equal to "t Critical one-tail" is Alpha (0.05).

"P(T <= t) two-tail" gives the probability that a value of the t-Statistic would be observed that is larger in absolute value than t. "P Critical two-tail" gives the cutoff value, so that the probability of an observed t-Statistic larger in absolute value than "P Critical two-tail" is Alpha (0.05).

For our case, statistical significance was set at $p < 0.05$ for t-Test (t-Test: Paired Two Sample for Means) analysis in the comparison of means of samples taken from Mpazi

River, upstream (monitoring station 1) and downstream (monitoring station3) as shown in the sketch of the sampling site, in Appendix 1.

The value of P (T<= t) two tail was compared to 0.05 to determine statistical significance, i.e if $p<0.05$, there is difference between a given parameter value upstream and downstream the river caused by the introduction of the effluent at the outfall point, thus adversely impacting the quality of the river downstream.

If $p>0.05$, it means that there is no significant impact of the introduction of the effluent in the river.

### 3.3 Water and Wastewater Quantification

In order to quantify the amount of water and wastewater generated in the abattoir, the number of cattle, goat and sheep slaughtered per day was collected from the abattoir records. The average number of cattle, goats and sheeps slaughtered was calculated from the data of animals slaughtered from May 2007 to April 2008, obtained from the abattoir records.

The average total water consumption was calculated from a daily water consumption of two months (March and April 2008).

To estimate the wastewater volume, literature was reviewed to know the average amount of blood loss per cattle, goat and sheep slaughtered and the intestine content volume.

Assuming that 10% of the total amount of water used in the abattoir is lost through different production processes and 8% for other uses like bathing, flushing toilets, cleaning administration offices and washing cars and the remaining 82% being used in the abattoir processes, the daily wastewater generated was estimated.

### 3.4 Mitigation Measures

In order to propose mitigation measures for minimizing or preventing adverse impacts, outcomes of the objective 1, 2 and 3 were used.

Also literature review using internet, published journals, and consultations with knowledgeable persons in the field, reports and existing studies on environmental impacts of similar facilities, mitigation measures for adverse impacts were developed.

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

This chapter gives the water consumption and wastewater generation of the abattoir. It also presents the analysis of the effluent for the abattoir and the river water quality before and after discharge. The data collected from the questionnaire survey on the people's perceptions about the abattoir and its possible impacts is also discussed.

Possible improvements of the abattoir processes and operations such as cleaner production, blood collection, wastewater treatment system are discussed.

## 4.1 Water Consumption and Wastewater Generation in Nyabugogo Abattoir

Nyabugogo Abattoir has many different production processes and operations which demand considerable amounts of water and generate wastewater.

This section highlights overall water use and wastewater generation. This will form a basis of proposing best practices of minimizing or preventing the adverse impacts of the abattoir on the river and its users.

### 4.1.1 Number of Livestock Slaughtered

The daily average number of cattle slaughtered at Nyabugogo abattoir averaged at 65 cattle and 135 goats and sheeps. This was estimated from the number of animals slaughtered from the period of May 2007 to April 2008, given by the abattoir officials.

The abattoir production varies from month to month depending on the consumption patterns of the people in Kigali. It is high during the month of December. Thus water use and waste generation are high during that month. Figure 4.1 shows the monthly averages of livestock slaughtered.

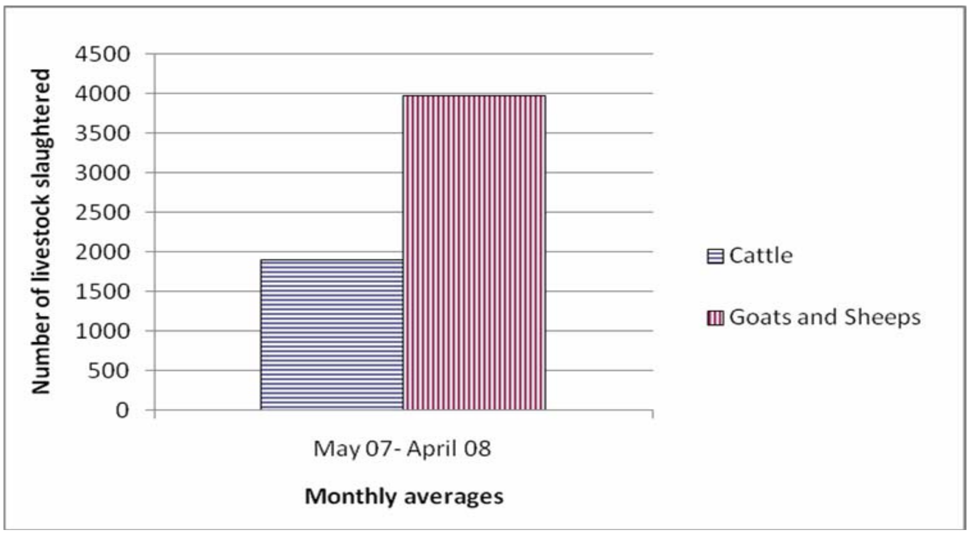



**Figure 4.1: Monthly averages of livestock slaughtered (May 2007 to April 2008)**

*Source of data: Nyabugogo Abattoir officials.*

### 4.1.2 Water Consumption and Wastewater Generation

The total daily water consumption of Nyabugogo abattoir was estimated at 50 $m^3$ per day from the daily records of the abattoir and own meter readings. Out of that amount, approximately 10% (5 $m^3$) is lost through different processes of the abattoirs, and 8 % (4 $m^3$**)** is used for other purposes like bathing, flushing toilets, cleaning the administration offices and washing cars.

It was not easy to estimate the quantity of water used for each processes because they have only one central water meter where the readings are taken. Water consumption is not systematically monitored in the plant.

The daily wastewater discharged (from the cattle and goats/sheeps abattoirs) into the river was estimated as follows:

- Total daily water consumption = 50 $m^3$
- Water losses through the different processes of the abattoir = 5 $m^3$
- Water used for bathing, flushing, cleaning administration offices and car washing = 4 $m^3$ (8%), estimated from the number of personnel of the abattoir (77) and a per capita per day water consumption of 50l.
- The water consumed in the cattle and goat/sheep abattoirs = 50 $m^3$-(5 $m^3$+4 $m^3$)

  = 41 $m^3$
- Thus the annual water consumption in the abattoirs = 41 $m^3$ * 365 days= 14,965 $m^3$ per year.

The average blood loss per head of cattle killed is 8 litres and 12 litres of paunch and intestine content which gives 20 litres of waste volume .For goats and sheeps, there are

3 liters of blood and 6 litres of paunch content, giving 9 litres of waste volume. From these figures, the average wastewater volume can be estimated as follows:

- Wastewater generated by Cattle slaughter = 20L* number of cattle slaughtered/day * 365 days

  = 20 L* 65* 365 days

  = 474,500 l/year

  =474.5 $m^3$/ year

- Wastewater generated by goat and sheeps slaughter = 9L* number of goat and sheeps slaughtered per day * 365 days

  = 9L * 135* 365 days

  = 443,475 L/ year

  = 443.475 $m^3$/year

The total annual volume of wastewater generated is obtained by adding the annual water consumed in the abattoir processes to the wastewater generated from cattle, goat and sheeps slaughter, i.e.:

14,965 $m^3$+474.5 $m^3$+ 443.475 $m^3$= 15,883 $m^3$/year = 43 $m^3$/day

Thus, approximately 43 $m^3$/day of wastewater are discharged in Mpazi River, untreated.

## 4.2 Impacts Identification, Characterization and Significance

These objectives were achieved by determining the quality of the effluent before discharge and the river water quality upstream and downstream Mpazi River.

The results were discussed and compared to standards and also to the results of similar study done in Nigeria titled as "Impact of effluent from Bodija Abattoir on the physicochemical parameters of Oshunkaye stream in Ibadan City, Nigeria" ( Osibanjo, O. and Adie, G. U.,2007).

### 4.2.1 Quality of Wastewater and Mpazi River Water

The analytical methods used for the determination of the parameters except for nitrate were from the American Public Health Association (APHA/AWWA/WEF, 2005), series of standard methods of examination of water and effluent.

Average, standard deviation, maximum and minimum values of river water and wastewater quality variables during the study period, for upstream the river (before discharge), for the outfall point (where effluent is released into Mpazi river), and downstream the river (after discharge) are shown in Tables in Appendix 2.

Most of these parameters analyzed exceed the limits for effluent discharge into perennial streams and rivers. Table 4.1 shows different parameters and their limits from different sources.

**Table 4.1: Effluent guidelines**

| **Parameters** | **Limits** | **Source** |
|---|---|---|
| pH | 6-9 | EHSG,2007 |
| Chemical Oxygen Demand | 250 mg/l | EHSG,2007 |
| Biochemical Oxygen Demand | 50 mg/l | EHSG,2007 |
| Dissolved oxygen | 75 mg/l | WHO,1984 |
| Nitrate | 2mg/l | WHO,1984 |
| Phosphate | 1.5 mg/l | WHO,1984 |
| Total Suspended solids | 50 mg/l | EHSG,2007 |

#### *4.2.1.1 pH*

The pH is a measure of the acidity of a wastewater sample. Figure 4.1 is showing the variations of pH values of the Mpazi River upstream (before effluent discharge), the pH of the effluent at the outfall point where it is discharged and the pH of the river 40 m from the point of discharge (downstream).

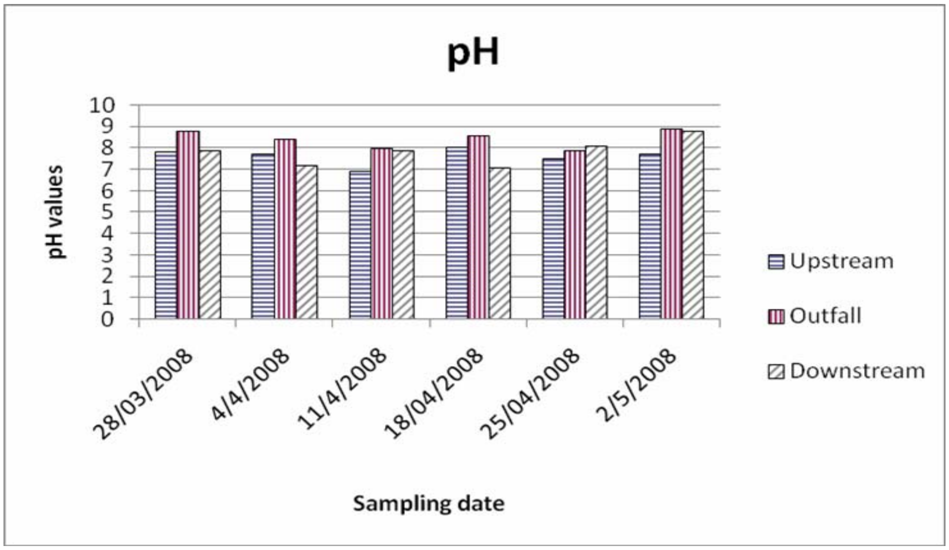



**Figure 4.2: Variations of pH at different monitoring stations**

The average pH of the river upstream before discharge was 7.62 and 7.83 downstream after discharge. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3). It shows P (T<=t) = 0.57, higher than 0.05, and statistical significance was set up at $p < 0.05$; therefore there is no significant change between pH of Mpazi River before and after the discharge of effluent from the plant.

It can be concluded that the wastewater from Nyabugogo Abattoir does not increases the pH of the Mpazi River. Also, all the pH values (upstream, downstream and outfall) are within the limits as per Table 4.1. That is between 6-9 (EHSG, 2007)

*4.2.1.2 Chemical Oxygen Demand*

COD is the amount of oxygen required to oxidize the organic matter in an acid solution and to convert it to carbon dioxide and water. COD is used to test the strength of wastewater that is either not biodegradable or contains compounds that inhibit activities of microorganisms. Figure 4.3 shows the variations of COD at different monitoring stations.

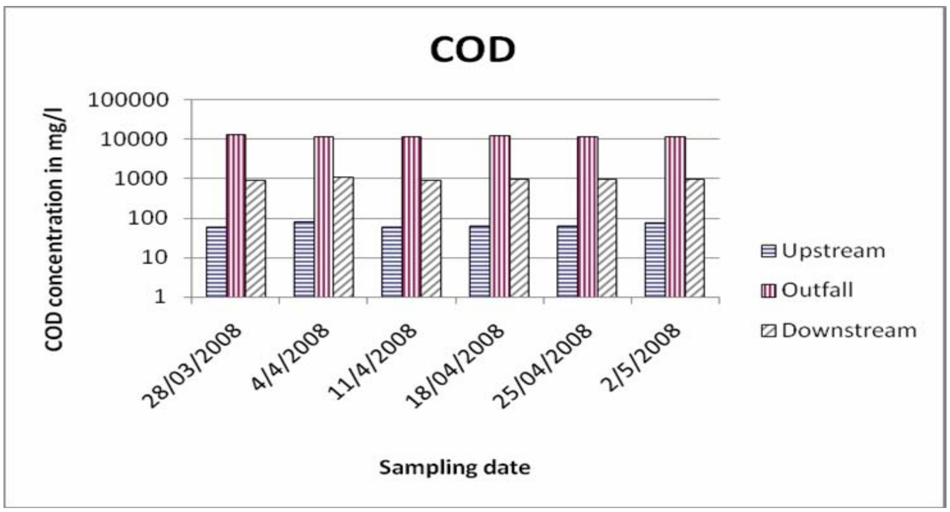



**Figure 4.3: Variations of COD at different monitoring stations**

The average COD concentration of the river upstream before discharge was 67.5 mg/l and 971.33 mg/l downstream after discharge. This increase was caused by the high COD concentration at the outfall point. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3).It shows P (T<=t) = 0.00000077, far much lower than 0.05, and statistical significance was set up at $p < 0.05$;

therefore there is significant change of COD of Mpazi River before and after the discharge of effluent from the plant.

It can be concluded that the wastewater from Nyabugogo Abattoir increases the COD of the river, mainly due to blood, chemicals and fats content in the effluent.

Also, according to effluent guidelines, the COD of the effluent before discharge into perennial streams should not exceed 250 mg/ l (EHSG, 2007). For our case, we have 12,177.66 mg/l.

High COD concentration in the river harms the aquatic species due to high inorganic compounds. It might also harm downstream users and increase the cost of treatment.

Also due to chemicals contained in the effluent , skin diseases might occur for children playing in the river and also for those who use it for washing clothes.

***4.2.1.3 Biochemical Oxygen Demand***

$BOD_5$ is the amount of oxygen used over a five-day period by microorganisms as they decompose the organic matter in sewage at a temperature of 20° C.

BOD serves to determine the relative oxygen requirements of wastewater, effluent and polluted water (WQM, 2007).

The average BOD concentration of the river upstream before discharge was 38.16 mg/l and 325.5 mg/l downstream after discharge. This increase was caused by the high BOD concentration at the outfall point. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3). It shows P (T<=t) = 0.00000032, far much lower than 0.05, therefore there is significant change of BOD of Mpazi River before and after the discharge of effluent from the plant. It can be concluded that the wastewater from Nyabugogo Abattoir increases the BOD of the river. Also, according to effluent guidelines in *Table 4.1*, the BOD of the effluent before discharge into perennial streams should not exceed 50 mg/l (EHSG, 2007). For our case, we have 11227.3 mg/l. This implicates the presence organic biological constituents, mostly in blood.

Figure 4.4 shows the variations of BOD at different monitoring stations

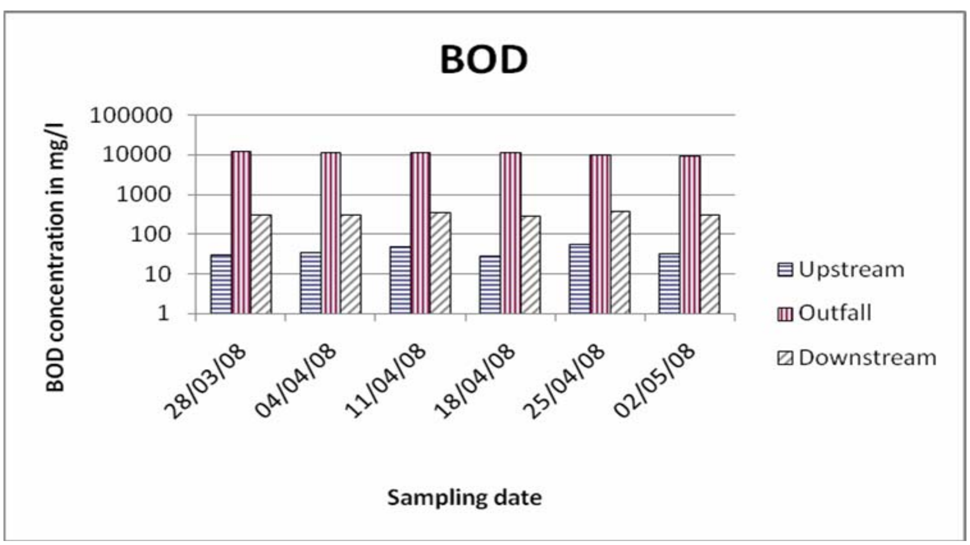



**Figure 4.4: Variations of BOD at different monitoring stations**

High BOD in River water causes the proliferation of algae bloom. Also the cost of treatment might be very high.

#### *4.2.1.4 Dissolved Oxygen*

The average DO concentration of the river upstream before discharge was 0.23 mg/l and 0.02 mg/l downstream after discharge. This decrease was caused by the highly concentrated effluent which does not contain any dissolved oxygen. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3). It shows $P (T<=t) = 0.0002$, far much lower than 0.05, and statistical significance was set up at $p < 0.05$; therefore there is significant change of DO of Mpazi River before and after the discharge of effluent from the plant.

It can be concluded that the wastewater from Nyabugogo Abattoir decrease the DO of the river but the impact is not significant because even before discharge the DO of the river was very low.

Also, according to effluent guidelines in *Table 4.1*, the DO of the effluent before discharge into perennial streams should be less than 75 mg/l.

This implicates anoxic conditions of Mpazi River. This caused bad smells and unsuitable living environment for aquatic species in Nyabugogo Rive, for which Mpazi River is the tributary. As observed in the field, after discharge of the effluent from the abattoir, water downstream Mpazi River had bad smells.

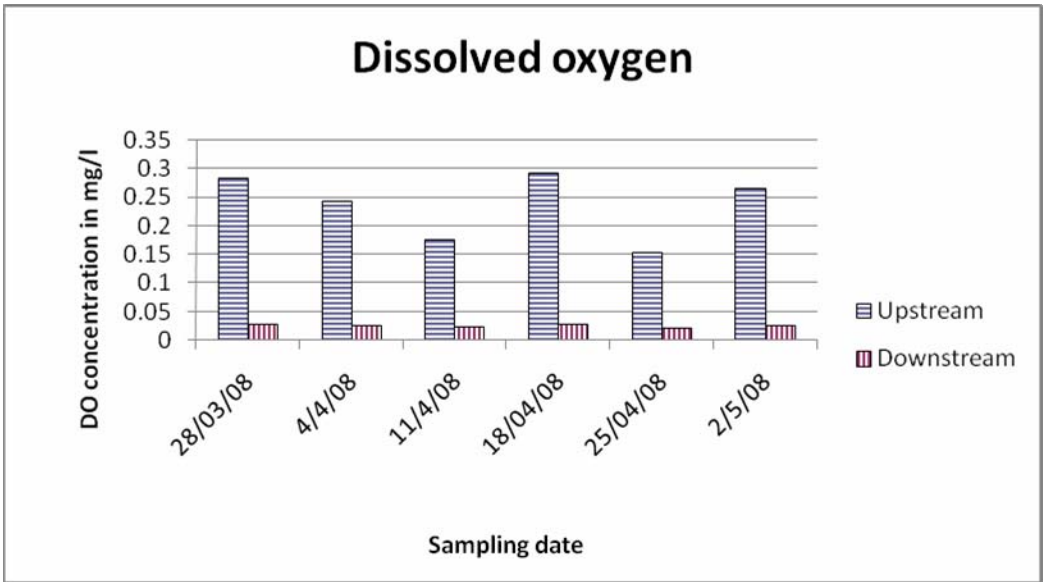



**Figure 4.5: Variations of DO at different monitoring stations**

### *4.2.1.5 Total Suspended Solids*

The average TSS concentration of the river upstream before discharge was 67.5 mg/l and 848 mg/l downstream after discharge. This increase was caused by the high TSS concentration at the outfall point. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River See Appendix 3) . It shows P (T<=t) = 0.000000014, far much lower than 0.05, and statistical significance was set up at $p < 0.05$; therefore there is significant change of TSS of Mpazi River before and after the discharge of effluent from the plant.

It can be concluded that the wastewater from Nyabugogo Abattoir increases the TSS of the river.

Also, according to effluent guidelines in *Table 4.1*, the TSS of the effluent before discharge into perennial streams should not exceed 50 mg/l (EHSG, 2007). For our case, we have 3114.5 mg/l.

Intestine and stomach content in the wastewater are the main sources of TSS.

Figure 4.6 shows the variations of TSS at different monitoring stations.

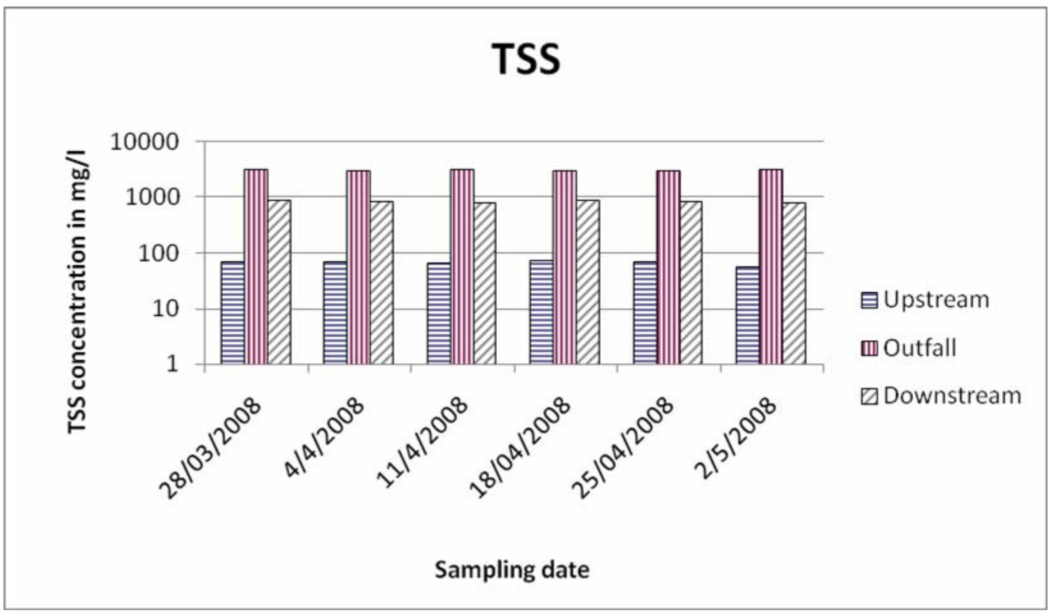



**Figure 4.6: Variations of TSS at different monitoring stations**

High TSS means the water is turbid, which reduces light penetration in the water, thus reducing the rate of photosynthesis.

#### *4.2.1.6 Nitrates*

The average nitrates concentration of the river upstream before discharge was 7.33 mg/l and 21.35 mg/l downstream after discharge. This increase was caused by the high nitrate concentration at the outfall point. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3). It shows P (T<=t) = 0.0011, lower than 0.05, and statistical significance was set up at $p < 0.05$; therefore there is change of Nitrate of Mpazi River before and after the discharge of effluent from the plant. It can be concluded that the wastewater from Nyabugogo Abattoir increases the nitrate of the river. Also, according to effluent guidelines in *Table 4.1,* the nitrate concentration of the effluent before discharge into perennial streams should not exceed 2mg/l. For our case, we have 69.16 mg/l. High concentration of nitrates means more nutrients in the river, which will lead to eutrophication of the river. Figure 4.7 shows the change in nitrates concentration at different stations.

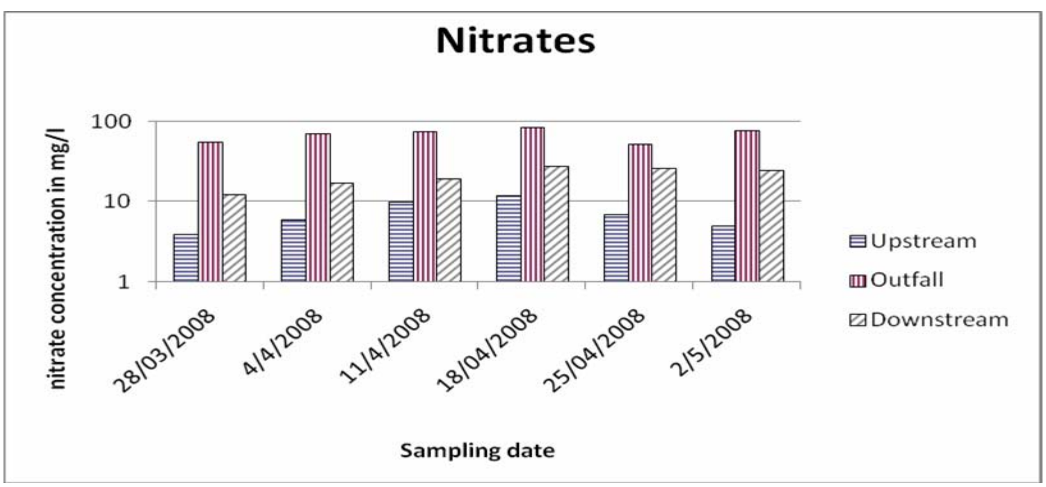



**Figure 4.7: Variations of nitrate at different monitoring stations**

#### *4.2.1.7 Phosphates*

The average phosphate concentration of the river upstream before discharge was 18.61 mg/l and 27.68 mg/l downstream after discharge. This increase was caused by the high phosphate concentration at the outfall point. The reason could be that much detergent was used to clean. t-Test: Paired Two Sample for Means was used for statistical analysis of samples from Mpazi River (See Appendix 3). It shows P (T<=t) = 0.019, lower than 0.05, and statistical significance was set up at $p < 0.05$; therefore there is change of phosphate of Mpazi River before and after the discharge of effluent from the plant.

It can be concluded that the wastewater from Nyabugogo Abattoir increases the phosphate concentration of the river.

Also, according to effluent guidelines in *Table 4.1*, the phosphate concentration of the effluent before discharge into perennial streams should not exceed 1.5 mg/l. For our case, we have 72.62 mg/l.

High concentration of phosphate cause algal bloom occurrence in surface water, thus there is need to control the amount of phosphorous compounds from domestic and industrial waste discharges and natural runoff (Metcalf and Eddy, 2003).

Figure 4.8 shows the variations of phosphate at different monitoring stations

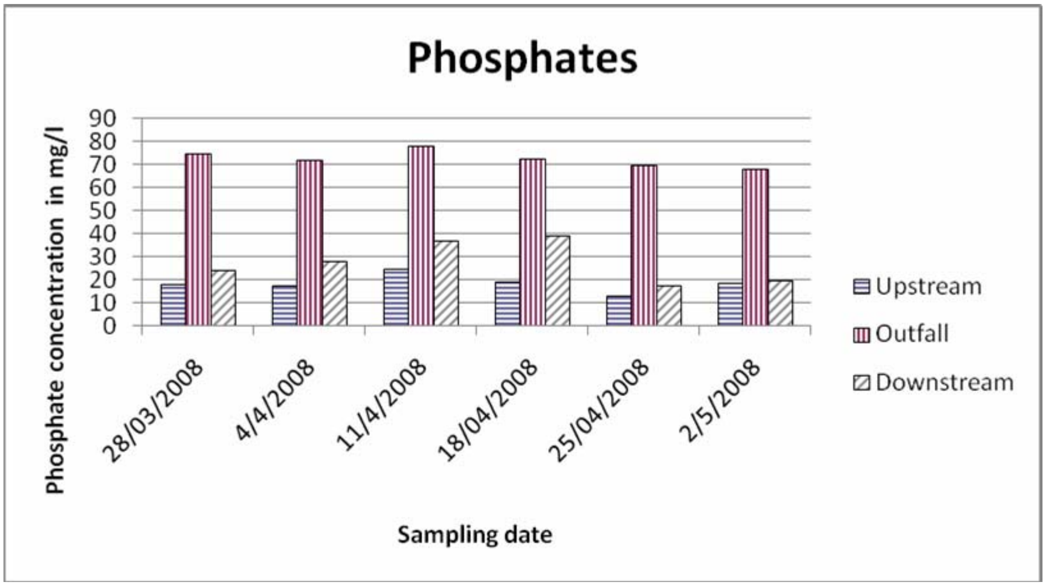



**Figure 4.8: Variations of phosphate at different monitoring stations**

The combination of high levels of phosphates and nitrates mainly from sewage effluent, with low velocity of water will allow eutrophication and the related threat of toxic algal blooms to persist throughout the surface water body for which Mpazi is a tributary.

For COD, BOD, TSS, nitrates and phosphates, the concentration was decreasing from the outfall point to downstream the river. This could be due to net dilution from monitoring station 2 to 3 and also decomposition of organic load as they move away from source. For DO, it went on increasing.

This study has shown that abattoir effluent discharged into Mpazi River resulted in the presence of high concentrations of pollutant in the water. The pollutants have been shown to be present in concentrations which may be toxic individually to different aquatic organisms. Pollution of the aquatic ecosystem poses a serious threat to aquatic organisms and ultimately the entire ecosystem. The long term impact of abattoir effluent discharge into the River is not known.

#### *4.2.1.8 Comparison of Results with Other Studies Results*

Comparing our results for Mpazi River water samples with the ones of Oshunkaye stream which receives the effluent from Bodija abattoir in Nigeria, we can conclude that some parameters like pH, TSS and COD are almost similar.

**Table 4.2: The Comparison of Mpazi River water quality and Oshunkaye stream**

| **Parameters** | **Mpazi River U/S-D/S** | **Oshunkaye Stream U/S-D/S** |
|---|---|---|
| pH | 7.84-7.88 | 7.06-7.45 |
| COD | 67.5-971.33 | ND-1223 |
| TSS | 67.5-848 | 41-1143 |
| Nitrates | 7.33-21.35 | 1.77-93 |
| Phosphates | 18.617-27.68 | 17-109 |

This table shows the comparison of Mpazi River water quality upstream and downstream and Oshunkaye stream before and after discharge (all parameters are in mg/l except pH)

These parameters are almost in the same range apart from the nutrients (nitrates and phosphates) for downstream Oshunkaye. The values are higher than Mpazi River's nutrients downstream. This might be due to different reasons like the distance from the points of discharge to the site where samples were taken, or the constituents of the effluent used, for example detergents in the case of phosphates.

BOD and DO were not measured for Oshunkaye stream.

### 4.2.2 Impacts of Nyabugogo Abattoir on Mpazi River Users

In order to know the impacts of the abattoir on Mpazi River water users and on people living in the abattoir vicinity, questionnaires were used. They included 14 questions. To analyze the questionnaire data, the information was split into four categories:

***Social-economic factors***

- What are respondents' gender, age and education level?

- How long they have been living there?

***Domestic water source and use***

- What is the main source of water for domestic use?

- Whether Mpazi River water is used? For which uses?

***Health impacts***

- Are there possible adverse health impacts for those using Mpazi River water? Which ones were experienced? How many people affected? Their age.

- What kind of health assistance looked for when affected?

***Perceptions about the abattoir***

- Are they concerned about the about the abattoir being in their neighborhood?

- Do they have an idea of the quality of the effluent discharged from the abattoir?

Fifty questionnaires were distributed and the willingness to respond was high, even though sometimes the exercise was done during working hours and some members of households would not be around.

***4.2.2.1 Socio Economic Factors***

This section of the questionnaire shows socio economic factors such as gender, education level, age and the time the respondent have been living in the surroundings of the abattoir.

Out of 50 respondents, 38% were male and 62% female. Most of them were between 20-30 years of age (36%). 64% have primary education, 30% secondary education and only 6% university education.

Few people were living in the area for more than 15 years (8%) as shown by Figure 4.9; probably because in urban area, people keep on moving from one place to another. For that reason, it was not easy to obtain baseline information about the study area.

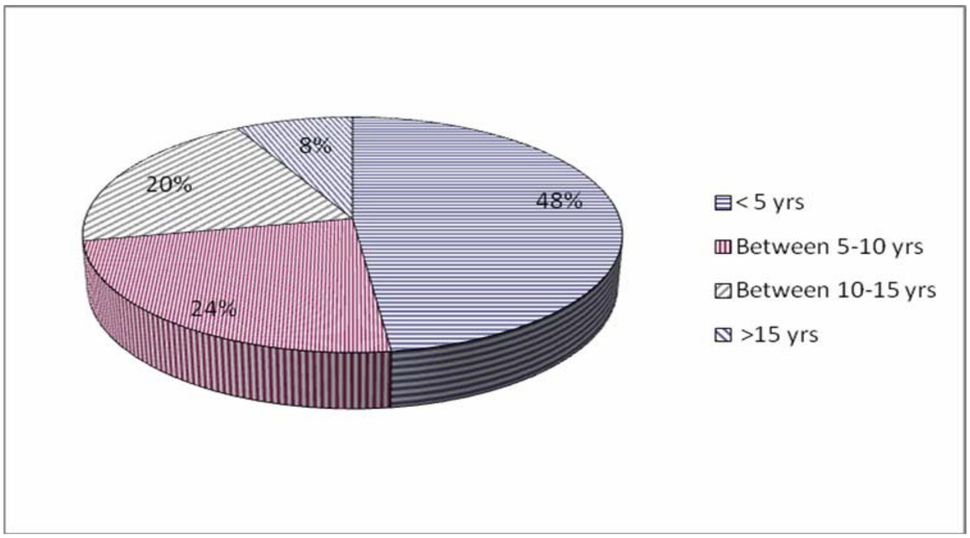



**Figure 4.9: Number of years of living in the abattoir vicinity**

### *4.2.2.2 Domestic Water Source and Use*

Most respondents said to use public kiosk as their main source of water as shown by Figure 4.10 As it is a low standard residential area, only 4% have house connection.

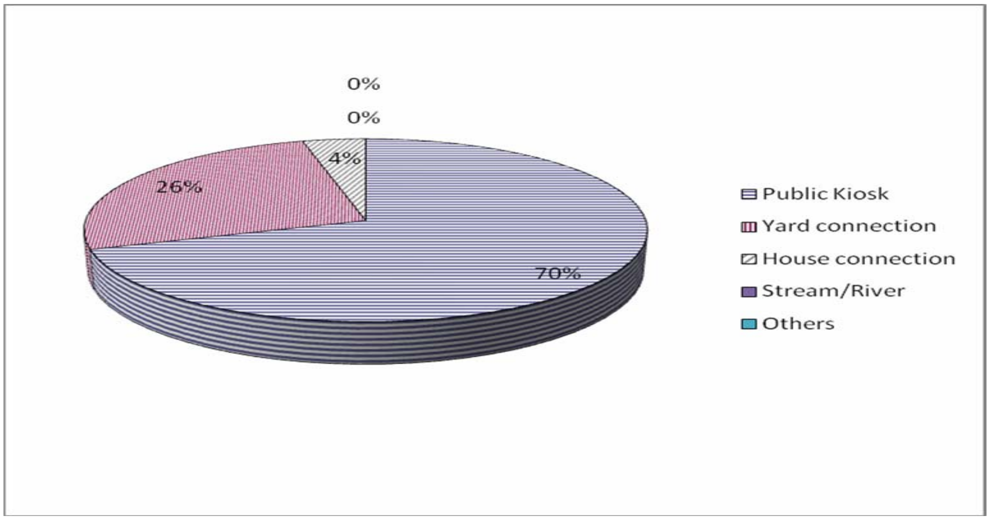



**Figure 4.10: Main sources of water for domestic use**

No respondent said to use Mpazi river water for drinking but 4% said to use it for bathing and 20% for washing. This negatively impact on their health because of the poor water quality. Some respondents also said to use it for cleaning floors. Children also play in the river. Figure 4.11 shows how the river water is used as per respondents and Figure 4.12 shows children playing in the river and someone washing using the river water.

This might be due to the fact that most of the population in the area is not educated, so they might not be aware of the adverse health impacts of using that water.

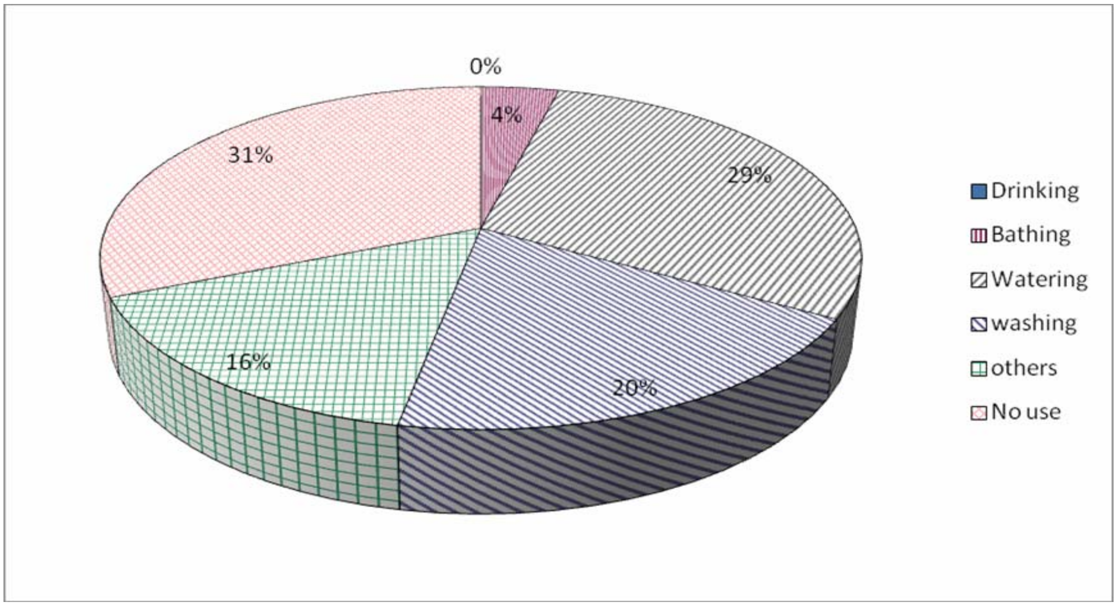



**Figure 4.11: Mpazi River water use**

**Figure 4.12: Washing and recreational uses of the river.**

### *4.2.2.3 Health Impacts*

Most respondents (72%) were aware of the risk of using the river water because of its quality 20 % did not have an idea of the quality of the river water and 8% did not know.

This might be the reason why some of them would even use it for washing their clothes, unaware of the risks associated.

There were different health problems experienced by the respondents for the last two months, especially skin irritations, as said by 40% of respondents. Their children have had complains about that problem. As the COD of the effluent is very high and caused by the presence of different chemicals,   skin diseases are likely to occur.

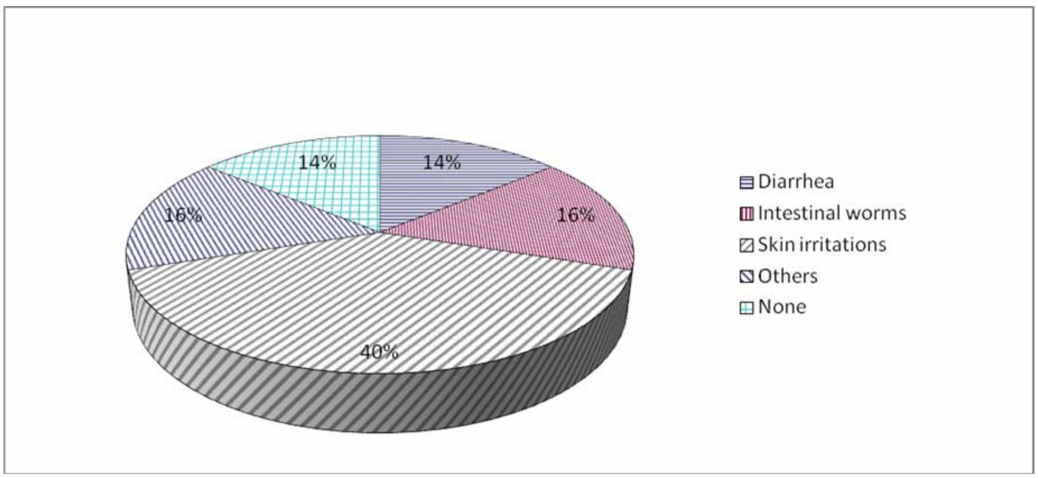



**Figure 4.13:** **Health problems encountered by the respondents.**

It was found out that for 56% of cases, those diseases are caused by poor water quality. This was mostly emphasized by mothers saying that their children have those problems and it is not easy to stop them from playing in the river. Poor sanitation services was thought to be the reason of health problems for 24% of respondents and 20% did not know.

Among the visited households, 44% had 1 to 3 people affected by one of those diseases for the last 2 months and 50% were not affected.

Age is also an influencing factor because most of them (86%) are beyond 15 years of age. Figure 4.14 shows the age range of people affected.

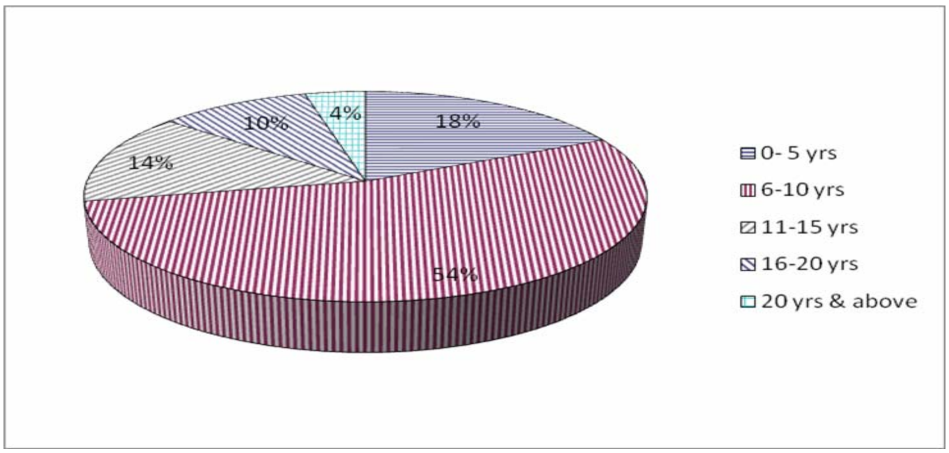



**Figure 4.14: Age range of respondents affected by the diseases**

Results showed that 58% seek assistance from dispensaries or hospitals, 28% buy medication in shops and 14% do nothing about it.

That area being a low standard residential area, sanitation facilities are very poor and it plays a big role in causing different health hazards.

#### *4.2.2.4 Perceptions on the Abattoir*

People living in the vicinity of the abattoir have concerns about the abattoir, mostly because of bad odors coming from the abattoir, especially between 10.30am and

12.30pm, when the effluent is being discharged. Also the poor water quality of the river is one of their worries.

Also, Kigali city authorities and Rwanda Environmental Management Authority are very much concerned about the abattoir effluent management of the abattoir and they are urging them to install an appropriate wastewater treatment to treat the effluent to required standards before discharge.

## 4.3 Mitigation Measures for Minimizing or Preventing Adverse Impacts

The large quantities of waste from the Abattoir, and the need to meet the environment standards, are the main incentives for investigating possible options for the safe disposal of abattoir waste. Nyabugogo Abattoir consumes a considerable quantity of water and discharges significant quantity of wastewater, whilst generating other by-products. These will continue to increase with population growth in Kigali city and the abattoir operations will expand. For these reasons, cleaner production opportunities and a wastewater treatment system are proposed.

### 4.3.1 Strategies for Wastewater Volume and Pollution Load Reduction

The main problem at Nyabugogo abattoir is high water consumption and highly concentrated wastewater generated. The high concentration of the effluent is mainly caused by blood, which is not collected at all. It is mixed with other wastewater from the abattoir and discharged into the river. Blood collection and processing is one of the methods that can be used to reduce the effluent discharge.

Also, cleaner production methods can be applied to some processes of the abattoir to reduce up to 60% the amount of water used.

#### *4.3.1.1 Blood Collection and Processing*

Blood collection is the single most efficient clean technology measure for abattoir wastewater. Ten to twenty liters of blood per head of cattle slaughtered can be collected (European commission, 2005). Blood being one of the major dissolved pollutants in abattoir wastewater, has the highest COD of any effluent from abattoir processing operations. Liquid blood has a COD of about 400,000 mg $l^{-1}$ and congealed blood has a COD of about 900,000 mg $l^{-1}$(Massé *et al*., 2000; IPPC, 2003), it has COD of around 375,000 $mgl^{-1}$ (EPA, 2004) and the BOD 150,000 to 200,000 $mgl^{-1}$. If the blood is coagulated prior to drying, the serum (blood water) has BOD of 30,000 mg/l (IPPC, 2003). This can be eliminated by evaporation of the blood water or by drying of the whole blood into a profitable by-product. Therefore, blood recovery can contribute to the reduction of concentration of organic materials in abattoir effluent.

Blood from Nyabugogo Abattoir can be dried into pet food. The blood is almost totally contained and collected in a blood collection system. By enlarging the curbed area to be used for blood collection and the bleeding time, by installing separate sewers for blood drainage and for clean-up, and by the use of dry cleaning and after the use of high pressure- low volume clean-up hoses, the potential concentration of waste will be substantially reduced. The whole blood is sent directly to blood dryers and used for fish and chickens feed. The practice will incorporate the use of indirect contact or low emission direct dryers which minimize the release of odors and particulates in the gas streams. Dryer exhaust gas from contact dryers should be treated through a condenser for removal of vapors. The practice will require:

- Fresh blood to minimize odor emission
- Control and monitor dryer operation to eliminate the creation of offensive odors by burning blood
- Dryer exhaust equipped with wet scrubber using water as scrubbing liquor.

Figure 4.15 shows how blood can be collected

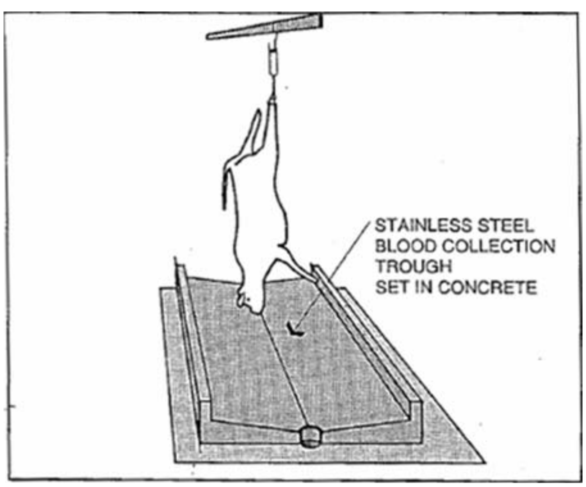



**Figure 4.15: Stainless steel blood collection trough set in concrete**

*Source: Australian Meat Technology, 1995*

Troughs are installed under the carcass conveying line in the slaughtering area to keep as much blood, trimmings, bone dust and other material off the floor with substantial waste load reductions. A scraper shaped to fit the troughs is used during clean-up to transfer all collected materials to the inedible processing operations before wash-up.

#### *4.3.1.2 Dry Cleaning*

Areas that have high levels of fatty tissue residues, such as boning and other cutting areas usually require high volumes of water to remove the normally very sticky wastes.

Environmental Quality (MLA,1998) showed that anywhere from 27 to 56 percent of the total BOD and COD waste load is contained in the clean-up wastewaters. As the clean-up is the major contributor to the waste load. It also leads to a significant loss of recoverable by-products.

The techniques and procedures that should be used during clean-up will greatly influence the water use in Nyabugogo Abattoir and the total concentration of organic material in wastewater.

Dry cleaning of floors prior to wash down to remove scraps and dry scraping of the remaining blood after its recovery from the bleeding area into the blood sewer is the first steps. A light washdown, draining to the blood sewer before the normal washdown, definitely decreases the pollution load from clean-up.

Solids should be swept scraped from the surface, including boning, slicing and packing tables, cutting boards, work platforms and floors areas, before any surface areas are hosed with water

This method is highly recommended to Nyabugogo abattoir because considerable amounts of water are used.

Figure 4.16 shows the method of dry cleaning.


**Figure 4.16: Dry cleaning**

*Source: Australian Meat Technology, 1995*

#### *4.3.1.3 Application of Cleaner Production Concepts to Nyabugogo Abattoir Processes and Operations*

The implications of the application of CP concepts are summarized in table 4.3 and the strategies required are explained. The cleaner production approach emphasizes on pollution prevention and resource recovery (blood, fat and nutrients). This is achieved by avoiding mixing, dilution, and transport of waste and is best achieved onsite or decentralized management of wastewater (Nhapi & Hoko, 2002).

**Table 4.3: Application of cleaner production principles to Nyabugogo abattoir effluent management**

| **Cleaner production principle** | **Implication for Nyabugogo Abattoir wastewater management** |
|---|---|
| 1. Use lowest amount of input material, energy or other resources per unit of product. | Large amounts of water are used in abattoir processes like cleaning while options like dry cleaning are available and efficient |
| *2.* Do not use input material of higher quality than strictly necessary. | Water treated to drinking water standards is used to clean floors and flush wastes into sewers and streams. |

| | |
|---|---|
| 3. Do not mix different waste flows | In Nyabugogo Abattoir various wastewater flows should be segregated (blood and manure, wastewater). After disposal into septic tank this segregated waste is managed separately. Obviously this practice makes reuse of specific components in the separated waste flow attractive and feasible. |
| 4. Evaluate other economic function and uses of by-products before considering treatment and final disposal | Blood, fat, and manure should not be mixed and discharged into Mpazi River without prior treatment. By-products recovery should be promoted:<br>Blood into blood meal, Manure into fertilizer, and paunch content into crop production |

### 4.3.2 Environmental Management Opportunities and Options of Nyabugogo Abattoir Effluent

The abundance of biomass as waste from the Abattoir, and the need to meet the environment standards, are the main incentives for investigating possible options for the safe disposal of abattoir waste. For this reason, environmental management opportunities and options described in Table 4.6 are suggested. These are based on results from various demonstration projects in the abattoir sectors and focus on increasing product yields and reducing volume and pollutant load of effluent discharges.

Many processes in Nyabugogo Abattoir are not automatic because of the irregular shape and weight of the animal carcasses. This means that individual operators' practices have a significant impact on the overall performance. Therefore, many of the environmental management opportunities described in this study relate to housekeeping practices, work procedures, maintenance regimes, and resource handling as related to technological changes. The options are categorized by technique, ranging from good housekeeping to technology that will be used.

**Table 4.4: Environmental Management Opportunities and Options Suggested for Nyabugogo Abattoir.**

| **Environmental management opportunities** | **Cleaner production options Good housekeeping** | **Major benefits** |
|---|---|---|
| | **1. Water consumption** | |
| Analyse water use patterns carefully. | Addition of water through measurement by installation of water meters. | Better and consistent quality of the product, resource conservation in form of chemical, water etc. |
| Undertake survey of all process area and ancillary operations to identify wasteful practices. | Input water if necessary, Water use for essential processes can be investigated. | Water savings. |

| | | |
|---|---|---|
| Water reuse, recycle within the process, can be considered for non-critical applications (without compromising meat quality). | Use of recycled water for floor washing, operation, use of piston grip self closing valves in pipes used for floor washing. | Reduced load into the effluent, reduced water consumption. |
| **2. Effluent** | | |
| Avoiding the discharge of pollutant substances (blood, undigested stomach contents, fat and scraps of meat) to the effluent streams. | Processing of blood and composting of undigested stomach content. | Reduced load into the effluent, reduced water consumption. |
| Blood recovery is an important cleaner production initiative. It can decrease organic loads by 40 % (Jones, 1974). | Processing of blood and collection of undigested stomach content to be used in crop production. | Reduced load into the effluent, reduced water consumption. Increase the income and productivity of land. |
| **3. By-products**<br>Better process control/ modification/ optimization | | |
| As a small plant, Nyabugogo Abattoir can incorporate integrated on-site rendering and blood processing facilities into bone meal, pit meal and tallow. | Blood processing<br>Manure application to land for food production. | Reduce effluent load and increase the income and productivity of the plant. |

| | | |
|---|---|---|
| **4. Livestock reception** | | |
| Holding livestock on site for 1 to 2 days, prior to slaughter to reduce the quantity of stomach content, screen wastewaters from truck before being discharged to the effluent systems. | Separate cattle according to the day of reception and to ensure that each spend two days in holding area. | The decrease of the quantity of manure, and undigested stomach content, therefore reduce effluent load. |
| **5. Stunning and bleeding** | | |
| Try to maximize raw blood collection and its subsequent processing into blood meal or other value-added by-products. | Allow cattle to bleed for at least eight minutes, blood processing. | Reduced load of the effluent, Money saving. |
| Avoid crass contamination of blood and wastewater, two-way drain diversion systems and two drain outlets can be used in bleeding area, one to the blood tank and the other to the effluent system. | Segregation of blood and other waste especially in bleeding area. | Reduced load of the effluent, Money saving for wastewater treatment. |

| 6. Hide removal and dressing | | |
|---|---|---|
| About 350 kg of salt per tonne of hide are consumed, if hides are stored longer (6 week or less, salt use can be reduced to 150 kg per tonne of hides. Application of biocide can reduce salt to 50 kg per tonne. It can reduce the concentration of salt in wastewater. | Control the application of salt and the use of biocide. | Reduce salt concentration in the effluent. Money saving. |
| **7.Evisceration and casing** | | |
| By-products should be transported dry on conveyors or small containers. Certain parts of casings can be processed into a number of value-added products. Reduce the quantity of undigested materials in the intestinal tract to make the evisceration process easier. | Composting of undigested stomach content. | Reduce salt concentration in the effluent. Money saving for wastewater treatment. |

| **8. Cleaning**<br>Input material change / elimination / reduction | | |
|---|---|---|
| Undertake dry cleaning before cleaning with water. First scrape and sweep solid material from all surfaces, boning, packing tables, cutting boards, work platforms and floors. Wash down in preparation for cleaning with detergents and monitor their consumption. | Scrap meat, manure and undigested material. | Less load, resource recovery. |
| Waste reduction, separation and reuse opportunities not taken advantage of at the moment. | Development of additional by products ( e.g. processing pit feed)<br>Establishment of an integrated waste management system. | Reduce the cost for wastewater treatment and resource consumption. |

### 4.3.3 Choice of a Wastewater Treatment System to be Used at the Abattoir of Nyabugogo

It is very necessary to treat the abattoir effluent prior to discharge even after applying cleaner production.

There are different systems for wastewater treatment such as:

1. Anaerobic systems (Septic tank systems)
2. Aerobic systems (Activated sludge systems)
3. Natural systems (Constructed treatment wetlands)

Considering the high BOD loading rate of an abattoir effluent (>$10^3$ mg/l), the anaerobic process cannot effectively handle the treatment of wastewaters from an abattoir as the treated effluent will not meet the established standards for effluent disposal. Some pollutants, especially sulfates, are reduced to hydrogen sulfide under the anaerobic conditions, a toxic gas. Likewise, nitrates and organic nitrogen compounds are reduced to ammonia. Because of the anaerobic conditions, fermentation processes take place, which ultimately generate carbon dioxide and methane, both of which are known greenhouse gases.

The fermentation processes cause the contents of an anaerobic treatment system to be anoxic with a low redox potential, which keeps phosphate in a soluble and thus mobilized form. Because phosphate can be the limiting nutrient for plant growth in many ecosystems, the discharge from an anaerobic treatment system into the environment can trigger prolific plant growth including algal blooms which can also include blooms of potentially toxic cyanobacteria (blue-green algae). Also, phosphate will cause a threat of eutrophication to surface waters. That is the reason why a septic tank is not an option for the treatment of abattoir effluent.

Activated sludge (AS) systems are the commonly used aerobic systems to deal with industrial wastewaters using biological processes. The atmospheric air is bubbled through the industrial wastewater combined with organisms to develop a biological floc which reduces the organic content of the sewage.

Figure 4.17 shows a typical schematic layout of an activated sludge system.

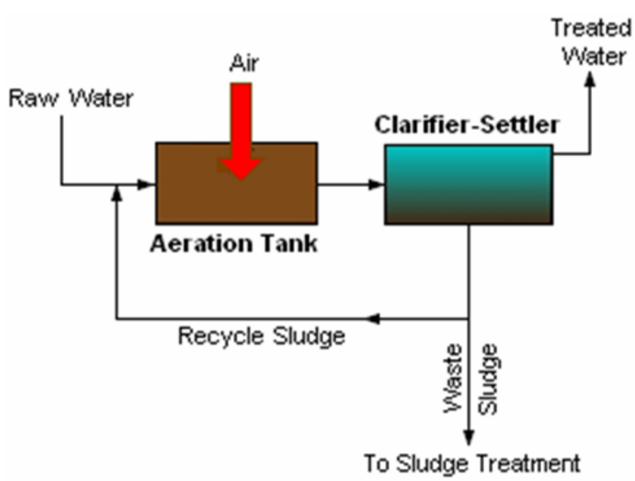



**Figure 4.17: Schematic layout of an activated sludge system**

Activated sludge systems are usually mechanized treatment systems. Complete mix stirred tank reactor (CSTR) is a commonly designed type of aeration basin for activated sludge systems of industrial wastewater treatment plants, but nowadays package systems are industrially produced and ready to install with well known and easy-to-manage effluent quality.

Natural treatment systems can also be used as an alternative. These are also biological treatment systems that rely only on natural processes for the wastewater treatment. The commonly used are the constructed treatment wetlands (CW). Constructed wetlands are present in a variety of free water surface wetlands (FWS) or horizontal sub-surface flow wetlands (HSSF). Subsurface flow constructed wetland technology is an ecologically sustainable alternative treatment system for both municipal and industrial wastewater treatment. The treatment mechanisms involved in HSSF are physical, chemical, biological and ecological processes.

The table 4.5 shows the comparison between the activated sludge systems and the constructed treatment wetland systems for the treatment of industrial wastewaters.

**Table 4.5: Advantages and disadvantages of activated sludge v/s constructed wetlands**

| **Activated Sludge v/s Constructed Wetland** | | |
|---|---|---|
| *Systems* | *Advantages* | *Disadvantages* |
| ***Activated Sludge (AS)*** | - Less space<br>- Technology is well mastered<br>- Effluent quality is easily managed | - Very costly<br>- Electrical energy always required<br>- Requires skilled people for maintenance<br>- Produces large quantities of sludge which require further on- site treatment or off-site disposal |
| ***Constructed Wetland (CW)*** | - Less costly<br>- No electrical energy required<br>- Less maintenance | - Technology still under study and not yet mastered<br>- Much space required<br>- Effluent quality not well managed because of the influence of weather condition |

Considering energy availability and cost in Rwanda, which is very high, the most appropriate treatment system for Nyabugogo Abattoir is a subsurface flow constructed wetland, which does not require electrical energy.

Also, considering that the abattoir does not have enough space, a subsurface flow constructed wetland was chosen instead of a surface flow constructed wetland, which requires much space.

But this can be efficient only in case the treatment system is well designed.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

From the analysis of the results obtained by this study the following conclusions can be drawn:

i. There is no doubt that the pollution generated by Nyabugogo abattoir effluent is a clear evidence that the meat processing industry in Rwanda has a potential for generating large quantities of concentrated effluent which would worsen scarcity of clean water availability to the generality of the population. Comparing the quality of Mpazi River before and after discharge , it could be concluded that the abattoir effluent has further polluted the River.

ii. Large amounts of water are used and generate a lot of wastewater at Nyabugogo abattoir. This study estimated 50 $m^3$ and 43 $m^3$ of water and waste water per day respectively.

iii. The effluent from Nyabugogo abattoir is highly concentrated and it is discharged in Mpazi River without treatment. The existing septic tank is no longer functional. Significant pollution of Mpazi River was observed for COD, BOD, nutrients and total suspended solids.

iv. Blood is not collected separately, it is mixed with other wastes and cleaning water. It highly contributes to the pollution load in the river by increasing its BOD and COD.

v. Public health hazards to the people living in the abattoir and the river vicinity were observed through different uses like washing, recreation.

vi. Solid wastes like condemned meat are disposed off in Butamwa landfill, but potential contamination of groundwater was observed because the pits into which the condemned meat is buried are not cemented.

## 5.2 Recommendations

i. Swift intervention by the government and other stakeholders by putting in place effluent treatment facilities to treat wastes from abattoirs in Rwanda as well as adoption of cleaner technologies will go a long way to curb the environmental health risks posed by these hazardous effluents from abattoirs.

ii. Blood should not be mixed with other wastewater because it has the highest COD of any effluent from abattoir processing operations and highly contributes to the pollution load in the river. It should be collected separately and recovered into other useful by-products such as pet food.

iii. Reduction of the amount of water used by dry cleaning and use of high pressure hose pipes, as one of the cleaner production methods will reduce the amount of waste water generated and also the cost of water.

iv. Future similar studies, Mpazi River water quality and effluent monitoring programmes should also consider total nitrogen, not only nitrate because it is just one component of total nitrogen along with nitrite, organic nitrogen and ammonia (all expressed as N). Total phosphorous should also be considered instead of phosphorous only.

v. Considering the high concentrations of COD, BOD and nutrients, an appropriate wastewater treatment such as sub-surface flow constructed wetland system should be used to treat the effluent before disposal.

vi. Appropriate landfill of condemned meat should be considered, for example cementing the bottom and side surfaces of the holes in order to prevent possible groundwater contamination.

vii. Integrate an environmental and resource monitoring into Nyabugogo Abattoir framework.

viii. Abattoir staff should be trained in environmentally safe practices as well as occupational health. This will assist in improving the present situation.

ix. The government should put in place an awareness raising programme for the people's knowledge on the quality of water they use.

**REFERENCES**

Adelegan JA (2002), "Policy and Slaughterhouse Waste in Nigeria", *Proceedings of the 28th WEDC Conference*, Kolkata (Calcutta) India. pp. 3-6

Adeyemo,O.K.,Ayodeji,I.O. and Aiki-Raji,C.O (2002), "The water quality and sanitary conditions in major abattoir(Bodija) in Ibadan, Nigeria", *European Journal of Scientific Research* .www.eurojournals.com/ejsr ,retrieved on Monday, 28th January 2008

Alonge, D. O. (1991), *Textbook of Meat Hygiene in the Tropics* Farmcoe Press, Ibadan, Nigeria. 58pp

APHA/AWWA/WEF, (2005), *Standard Methods for the Examination of Water and Wastewater.* 21st ed., American Public Health Association /American Water Works Association/Water Environment Federation, Washington DC

Australian Meat Technology (1995), *Water and Waste Minimisation: Optimisation of Water Use and Control of Wastes in Abattoirs,* Mc Benny, Cannon Hill

Chukwu , O. (1994) *Technical Evaluation of Rice Threshers in Use in Niger State, Nigeria.* M. Eng.Project, Dept of Agric. Engineering, University of Nigeria,Nsukka,Nigeria

Chukwu,O., Sunday,E.A.A, Onifade,K.R., Jimoh,O.D (2007), "Environmental Impact Auditing of Food Processing Industry in Nigeria: The Case of Climate and Air Quality". Federal University of Technology Minna, Niger State, Nigeria

CIA (2008), *The World Factbook – Wikipedia, the Free Encyclpedia*, www.cia.gov/cia/publications/factbook/index.html, retrieved on Saturday, 26th April 2008, (Google search)

EDAW, Architecture, O., Tech, T., Sypher, ERA, Geomaps, Borders-USA, E. w., and People, W. f. (2006), *DRAFT-Kigali Master Plan, Existing Conditions Analysis*. Rwanda Ministry of Infrastructure, Kigali

EPA (2005), *Abattoirs*, www.environment.nsw.gov.au/mao/abattoirs.htm , retrieved on Friday, 7th December 2007

FEPA (1991), *National Environmental Protection (Effluent Limitation) Regulations (S.1.8)*, FEPA, FGPL, Lagos, Nigeria

Festino, C. and Ch. Aubart. (1986), *Épuration d'effluents liquides et valorisation énergétique de déchets solides d'abattoir par voie anaérobie. Entropie* 130-131:57-67

Hansen,P., Christiansen, K., Hummelmose, B. (2000), *Cleaner production assessment in meat processing*. Paris, UNEP and Danish Environmental Protection Agency. 92: 807 – 1844 on http//WW. Agrifood forum. net/publications/Index.asp

IPPC (2003), *Guidance for the red meat processing (Cattle, Sheep and Pigs) sector,* UNEP. www.unepie.org. retrieved on Monday ,17th March 2008

James V.C., Robert R., and Roye C. (1979), *Spinoff on meat processing water and wastewater management*. North Carolina State University, Science and Education, USDA, Washington, DC

Jones H.R.,(1974). *Pollution control in Meat, Poultry and Seafood Processing*. Noyes Data Corporation. Park Ridge, New Jersey

Judith A. R. (2006), "Urban Water and Sanitation Services, an IWRM Approach". Global Water Partnership Technical Committee (TEC) No. 11, ISBN, Sweden

Kente L.S. Hategekimana D.A. (2008), "The EIA Process in Rwanda" in *Environmental Impact Assessment*: Lecture notes, p18

Marsalek J. Kramouz, M. (2006), *Urban water cycle processes and interaction*, Internationl Hydrological Programme (IHP), UNESCO, Paris

Massé, D.I., Masse, L., and Bourgeois (2000), *Anaerobic processing of slaughterhouse wastewater in a sequence batch reactor*. Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, Lennoville, Quebec

Meadows, R. (1995), *"Livestock Legacy" Environmental Health Perspectives* 103 {12} 1096 ;1100

Meat & Livestock Australia (1998), *Best practice wastewater treatment, Wastewater Manual.* Project RPDA 308b

MININFRA (2006), *Kigali conceptual Master Plan- Existing Conditions Analysis*, Draft.Kigali

MININFRA (2007), *Rwamagana, Rwanda Conceptual Master Plan- Existing conditions* .Draft. Kigali

MINITERE (2005), *Technical assistance for the preparation of the National Water resources Management project*. Kigali

Massé D.I and Massé L. (2000), *Characterization of wastewater from hog slaughterhouses in Eastern Canada and evaluation of their in-plant wastewater treatment systems*. Agriculture and Agri-Food Canada *42: 139 – 146.* Lennoxville, Quebec, Canada

Meat Research Corporation (1995), *Devices and Approaches in the Meat Industry*, http://wrrc.p2pays.org/p2rx/subsection.cfm, retrieved on Wednesday, 16th January 2008

Metcalf, and Eddy (2003), *Wastewater Engineering, Treatment and Reuse*, McGraw-Hill. New York, 4th Edition

Nhapi, I. and Hoko Z., 2004. "A cleaner production approach to urban water management: Potential application in Harare, Zimbabwe". Water Science Technology 47 (7 -8)11-18.

Nicholas J. F. (1992), *Wastewater Effluent Treatments and Control Technologies*

Olanike K. Adeyemo (2002), "Unhygienic operation of a city abattoir in South western Nigeria: Environmental implication". University of Ibadan, Ibadan, Nigeria

Osibanjo,O., Adie, G.U.(2007), "Impact of effluent from Bodija Abattoir on the physico-chemical parameters of Oshunkaye stream in Ibadan City, Nigeria". *African Journal of Biotechnology Vol. 6 (15), pp. 1806-1811*

Quinn J.M. and P.N. McFarlane (1989), *Effects of slaughterhouse and dairy factory wastewaters on epilithon*: A comparison in laboratory streams. Water Research 23:1267-1273

Rajendra G. K. (2007), *An experimental research on the application of sub-surface flow constructed wetlands for meat processing industry effluent and nutrient removal*. Thesis in Environmental Engineering, Murdoch University, Australia

REMA (2006), *General guidelines and procedures for Environmental Impact Assessment*, p2

Sangodoyin, A.Y. and O.M. Agbawhe. (1992), "Environmental study on surface and groundwater pollutants from abattoir effluents". *Bioresource Technology 41:193-200*

Sayed SKI (1987), *Anaerobic Treatment of slaughterhouse Wastewater using UASB Process*.Ph.D Thesis.Wageningen, The Netherlands: Agricultural University of Wageningen

Shuval, H. T. (1972)**,** *Advances in Water Pollution Research*, Oxford Pergamon Press

Tate E., Sutcliffe J., Conway D. and Farquharson F. (2003), *Water balance of Lake Victoria: update to 2000 and climate change modeling to 2100*. Hydrological Sciences Journal.Vol.49, Issue 4:pp563-574. (2004)

Tritt, W.P. and F. Schuchardt. (1992), "Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany". *Bioresource Technology 41:235-245*

Tsuno, O. (2006), *Water environmental monitoring and protection in Sewage works and stormwater drainage technology*, Osaka City government, Japan

Turdukulov (2003), *Determination of Water Quality parameters using imaging spectrometry* (Case study of Sajo floodplain, Hungary). The International Research Institute for Geo-information science and Earth observation. Enschede, The Netherlands

Turk, J. (1980), *Introduction to Environmental Studies*, W.B.S. Company Philadelphia

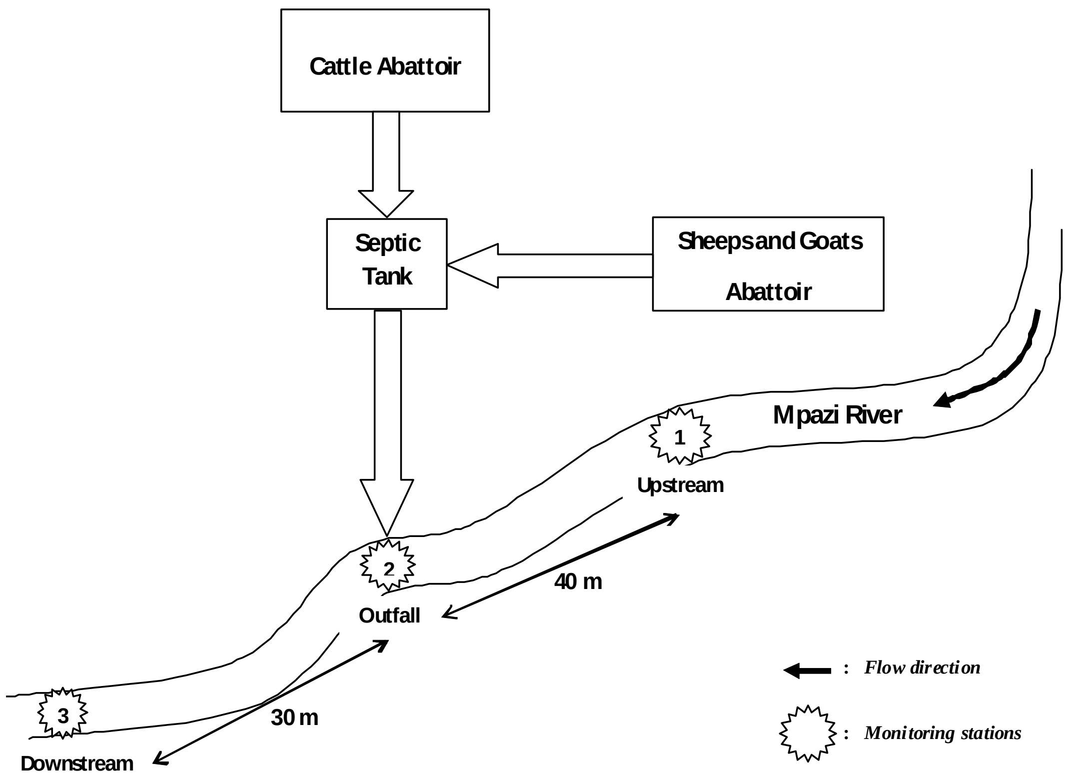
Umuhoza (2007), *Assessment of Wastewater Management practices in Kigali city*. Master's thesis in Water Resources and Environmental Management, National University of Rwanda

World Bank (2003), *Water Resources and Environment*, Technical Note D1, Water quality: Assessment and protection .Series editors Richard Davis, Rafik Hirji, Washington DC, USA. p 9

World Bank Group (2007), *Environmental, Health and Safety Guidelines for Meat Processing*, www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines, retrieved on Thursday, 26th May 2008

# APPENDICES

## Appendix 1: Sampling Site



## Appendix 2: Analysis of results of effluent and River water samples

***Analysis results for water quality upstream Mpazi River (all parameters are in mg/l except pH)***

| Monitoring station | Sampling date | pH | COD | BOD | TSS | NO3-N | PO4-P | DO |
|---|---|---|---|---|---|---|---|---|
| Upstream | 28/03/08 | 7.84 | 60 | 30 | 71 | 4 | 18 | 0.284 |
| Upstream | 04/04/08 | 7.7 | 81 | 35 | 69 | 6 | 17.7 | 0.244 |
| Upstream | 11/04/08 | 6.92 | 59 | 48 | 65 | 10 | 25 | 0.177 |
| Upstream | 18/04/08 | 8.07 | 63 | 29 | 73 | 12 | 19.5 | 0.294 |
| Upstream | 25/04/08 | 7.5 | 65 | 55 | 70 | 7 | 13 | 0.155 |
| Upstream | 02/05/08 | 7.72 | 77 | 32 | 57 | 5 | 18.5 | 0.266 |
| **Average** | | **7.625** | **67.5** | **38.167** | **67.5** | **7.3333** | **18.62** | **0.237** |
| **Min** | | 6.92 | 59 | 29 | 57 | 4 | 13 | 0.155 |
| **Max** | | 8.07 | 81 | 55 | 73 | 12 | 25 | 0.294 |
| **Std dev** | | 0.3928 | 9.2466 | 10.759 | 5.788 | 3.0768 | 3.855 | 0.058 |

***Analysis results for water quality downstream Mpazi River (all parameters are in mg/l except pH)***

| **Monitoring station** | **Sampling date** | **pH** | **COD** | **BOD** | **TSS** | **NO3-N** | **PO4-P** | **DO** |
|---|---|---|---|---|---|---|---|---|
| Downstream | 28/03/08 | 7.88 | 904 | 301 | 886 | 12.4 | 24 | 0.028 |
| Downstream | 04/04/08 | 7.2 | 1123 | 320 | 843 | 17 | 28 | 0.026 |
| Downstream | 11/04/08 | 7.9 | 897 | 351 | 822 | 19.3 | 37 | 0.024 |
| Downstream | 18/04/08 | 7.1 | 950 | 299 | 891 | 28 | 39.4 | 0.028 |
| Downstream | 25/04/08 | 8.1 | 974 | 374 | 829 | 26.4 | 17.7 | 0.022 |
| Downstream | 02/05/08 | 8.8 | 980 | 308 | 817 | 25 | 20 | 0.027 |
| **Average** | | **7.83** | **971.33** | **325.5** | **848** | **21.35** | **27.68** | **0.026** |
| **Min** | | 7.1 | 897 | 299 | 817 | 12.4 | 17.7 | 0.022 |
| **Max** | | 8.8 | 1123 | 374 | 891 | 28 | 39.4 | 0.028 |
| **Std dev** | | 0.6247 | 81.975 | 30.468 | 32.61 | 6.1037 | 8.904 | 0.002 |

***Analysis results of effluent from Nyabugogo Abattoir at the outfall point (all parameters are in mg/l except pH)***

| **Monitoring station** | **Sampling date** | **pH** | **COD** | **BOD** | **TSS** | **NO3-N** | **PO4-P** | **DO** |
|---|---|---|---|---|---|---|---|---|
| Outfall | 28/03/08 | 8.8 | 12900 | 12628 | 3126 | 55 | 75 | ND |
| Outfall | 04/04/08 | 8.4 | 12007 | 11651 | 3098 | 71 | 71.8 | ND |
| Outfall | 11/04/08 | 8 | 11984 | 11983 | 3200 | 76 | 78 | ND |
| Outfall | 18/04/08 | 8.6 | 12574 | 11500 | 2981 | 84 | 72.6 | ND |
| Outfall | 25/04/08 | 7.9 | 11649 | 9978 | 3107 | 52 | 70 | ND |
| Outfall | 02/05/08 | 8.9 | 11592 | 9624 | 3175 | 77 | 68.32 | ND |
| **Average** | | **8.4333** | **12118** | **11227** | **3115** | **69.167** | **72.62** | |
| **Min** | | 7.9 | 11592 | 9624 | 2981 | 52 | 68.32 | |
| **Max** | | 8.9 | 12900 | 12628 | 3200 | 84 | 78 | |
| **Std dev** | | 0.4131 | 518.92 | 1176.3 | 76.49 | 12.859 | 3.482 | |

## Appendix 3: Statistical analysis for Mpazi River water samples

### pH

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 7.625 | 7.83 |
| Variance | 0.15431 | 0.3902 |
| Observations | 6 | 6 |
| Pearson Correlation | -0.28715 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -0.60652 | |
| P(T<=t) one-tail | 0.285324 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 0.570649 | |
| t Critical two-tail | 2.570582 | |

**BOD**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 38.16667 | 325.5 |
| Variance | 115.7667 | 928.3 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.997803 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -35.6454 | |
| P(T<=t) one-tail | 1.64E-07 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 3.27E-07 | |
| t Critical two-tail | 2.570582 | |

**DO**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 0.236667 | 0.025833 |
| Variance | 0.003334 | 5.77E-06 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.987522 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | 9.326464 | |
| P(T<=t) one-tail | 0.000119 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 0.000239 | |
| t Critical two-tail | 2.570582 | |

**COD**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 67.5 | 971.3333 |
| Variance | 85.5 | 6719.867 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.8855 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -29.9536 | |
| P(T<=t) one-tail | 3.89E-07 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 7.78E-07 | |
| t Critical two-tail | 2.570582 | |

**TSS**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 67.5 | 848 |
| Variance | 33.5 | 1063.2 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.747118 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -66.9807 | |
| P(T<=t) one-tail | 7.02E-09 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 1.4E-08 | |
| t Critical two-tail | 2.570582 | |

**NITRATES**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 7.333333 | 21.35 |
| Variance | 9.466667 | 37.255 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.543137 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -6.69212 | |
| P(T<=t) one-tail | 0.000563 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 0.001127 | |
| t Critical two-tail | 2.570582 | |

**PHOSPHATES**

t-Test: Paired Two Sample for Means

| | *Upstream* | *Downstream* |
|---|---|---|
| Mean | 18.61667 | 27.68333 |
| Variance | 14.86167 | 79.28967 |
| Observations | 6 | 6 |
| Pearson Correlation | 0.750254 | |
| Hypothesized Mean Difference | 0 | |
| Df | 5 | |
| t Stat | -3.40096 | |
| P(T<=t) one-tail | 0.009616 | |
| t Critical one-tail | 2.015048 | |
| P(T<=t) two-tail | 0.019231 | |
| t Critical two-tail | 2.570582 | |

## Appendix 4: Questionnaire for social impacts of the Abattoir on local population

1. Sex

    A. Male

    B. Female

2. Age:

    A. Between 20- 30

    B. Between 31- 40

    C. Between 41- 50

    D. Between 51- 60

    E. Over 60

3. Level of Education:

    A. Primary

    B. Secondary

    C. University

4. For how long have you been living here?

    A. Less than 5 years

    B. Between 5-10 years

    C. Between 10-15 years

    D. Over 15 years

5. What is your main source of water for domestic use?

A. Public kiosk

B. Yard connection

C. House connection

D. From stream / river

E. Others (specify)

6. Do you ever use Mpazi River water?  If yes, for which uses?

A. Drinking

B. Bathing

C. Watering

D. Washing

E. Others (specify)

F. No use

7. If you use Mpazi river water, do you think it can have adverse impacts on your health?

A. No

B. Do not know

C. Yes

If yes, which ones?

______________________________________________________________________________
______________________________________________________________________________

8. What kind of health problems has any member of your household experienced within the last two weeks, month, and year?

A. Diarrhea

B. Intestinal worms

C. Skin irritation

D. Other (specify)

E. None

9. If any of the diseases above is complained about, what do you think could be the reason?

A. Low river water quality

B. Poor hygiene

C. Do not know

10. How many people were affected in this household?

A. 0

B. 1-3

C. 4-6

D. 7 and above

11. What is their age?

A. 0-5years

B. 6-10 years

C.11-15 years

D. 16-20 years

E. 20 years and above

12. What kind of health assistance do you look for when affected by one of these diseases above?

A. Go to the dispensary/ hospital

B. Buy medication in a shop

C. None

13. Do you have any concern about the abattoir being in your neighborhood?

A. Yes

B. No

If yes, what are they?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

14. Do you have an idea of the quality of the effluent discharged from the abattoir?

    A. Yes

    B. No

    If yes, what do you think about it?

______________________________________________________________
______________________________________________________________
______________________________________________________________

15. Are you in a way or another benefiting from the Nyabugogo Abattoir?

    A. No

    B. Yes

    If yes, how

    ___________________________________________________________
    ___________________________________________________________
    ________________________________________________________