THE UNIVERSTY OF YAOUNDE I
UNIVERSITE DE YAOUNDE I

FACULTY OF SCIENCE
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DEPARTMENT OF PLANT BIOLOGY
DEPARTEMENT DE BIOLOGIE ET DE PHYSIOLOGIE VEGETALES

Impact of untreated informal slaughterhouse wastewater from markets on socio-sanitary and physical environment in Yaounde, Cameroon

A Masters in Science DISSERTATION submitted in partial fulfilment of the requirements for the award of a Master in plant Biology

Option: Plant Biotechnology

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Academic year 2017 – 2018

DEDICATION.

This work is dedicated to:

The Almighty God for His love and kindness towards me;

my late father and my ever present mother:

Dr. Agendia Philip Lekeanyi

and

Mrs. Emesong Magdalene.

ACKNOWLEDGEMENT.

The realisation of this work was possible thanks to the University of Yaounde I and the theoretical lessons received from the teachers of the Department of Plant Biology, with the support of the Wastewater Research Unit of the Laboratory of Biotechnologies and Environment of the University of Yaounde I, as well as to the various supports and advice of academic supervisors, parents, colleges and friends. I want to thank especially:

- Professor YOUMBI Emmanuel, Head of the Department of Plant Biology and Physiology, who spares no effort in spreading the influence of this Department through the scientific rigor and quality of the teaching provided;
- Professor KENGNE NOUMSI Ives Magloire, Associate Professor, who, despite all his occupations, has agreed to supervise this work. His availability, scientific rigor, advice and didactic support allowed me to carry out this work to completion;
- Profound gratitude goes to you; all my seniors from the laboratory of Biotechnology and Environment, who participated in one way or another in the realisation of this work. I especially thank, Dr. LETAH NZOUEBET Wilfred Arsène, Dr. DJUMYOM Guy Valérie, Mr. WANDA Christian, Mr. Nguenang Alex, Mr. Nana Jean Jules, Mr NOUTADJIE Jean-piere, Mr NGANDJUI Yvan, Mrs FOUEDJIO Armelle, Mrs LEGUI Ginette, Mrs. Lakeu Irene, Dr. TEMEGNE NONO Carine and all my other classmates;
- Mr. Guy FENDOUNG for his assistance and help with chemicals;
- my fiancée WANMI MBATCHOU Armelle for her constant moral support;
- my brothers and sister AGENDIA Derek, AGENDIA Carlson, AGENDIA Terry and AGENDIA Brenda. Share with me this joy and that this work is for you an example to follow;
- my grandmother, aunts, uncles and family friends Mary Atabong, BECHA Evaristus, Professor. NKEMGONG John; Professor. Nwaga, Professor. Fonkou for their support and concern
- I do not forget all the people, who from near and far contributed to the development of this work. May they accept my sincere thanks;
- As all human work is far from perfect, I am addressing the Jury, which will have the task of examining this work, my thanks for the criticisms and suggestions, it will make to improve it.

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ABBREVIATIONS.

EC	Electrical conductivity
TSS	Total suspended solids
TDS	Total dissolved solids
COD	Chemical oxygen demand
BOD_5	Biological oxygen demand
FC	Faecal coliforms
FS	Faecal streptococci
CFU	Colony forming unit
MINEPIA	Ministry of Livestock Fisheries and Animal Husbandry
TOC	Total organic carbon
TN	Total nitrogen
TP	Total phosphorous
SWW	Slaughterhouse waste water
CDC	Centre of Diseases Control and prevention
SODEPA	Company of development and exploitation of animal products
WHO	World Health Organisation
MINEPDED	Ministry of environment, nature protection and sustainable development
MINEE	Ministry of Water and Energy resources
CAMWATER	Cameroon water
HYSACAM	Hygiene and health of Cameroon
GPS	Geographic positioning system
PPE	Personal protective equipment
BEA	Bile Esculine Azide agar
TTC	Triphenyl Tetrazolium Chloride

ABSTRACT

The continuous drive to increase meat production for the ever increasing world population has some pollution problems attached. This study aims at assessing the impact of the Mvog-ada and Essos informal slaughterhouse wastewater on the socio-sanitary and physical environment. The research was carried out from January to April 2018. The methodology used in this work included documentary research, field work and laboratory analysis of samples. Survey revealed that 39 pigs, 400 poultry and 21 goats are slaughtered daily in both informal slaughterhouse, 50 % use both tap water and well water for cleaning slaughtered animals, 37.50 % use 15-25L of this water for the process and an approximately 19520 L of wastewater is generated each month, and 37.50% use the watercourse and garbage bin for disposal of this effluents. Water samples were collected (S1-S4) along the Ewoé tributary of Mvog-ada where effluent are discharged and was analysed using standard protocols. The mean range of the physicochemical parameters measured for pH, Temperature, EC, Sal, Colour, TSS, TDS, NO_3^-, PO_4^{3-}, COD, BOD_5 were 6.65-8.08,27.20°C-27.73°C, 328.33-4663.33 µS/cm, 0.16-2.68‰, 84-54208.33 PtCo, 12.67-9666.67 mg/L, 158.27-2600.33 mg/L, 7.73-14.3 mg/L, 2.71-252.6 mg/L, 119-1493.33 mg/L, 33.67-1016.67 mg/L respectively and the range mean of bacteriological parameters measured for FC and FS were 1966.67-1907000 CFU/100 mL and 666.67-612000 CFU/100 mL respectively. 47.95 % of household respondents face daily nuisances such as insects (26.11 %), small rodents (22.12 %), Odour (19.03 %), flood (17.7 %) and noise (15.04 %). 69.86 % of respondents suffered from malaria and waterborne diseases. All age groups were exposed to these diseases. The need to put in place wastewater treatment plants adapted for slaughterhouse effluent is crucial to reduce potential risks which could be caused by their discharge in nature.

Key words: Wastewater management, impact, informal slaughterhouse, health and natural environment, tropical urban area.

RESUME

Les efforts continus visant à accroître la production de viande pour la population mondiale sans cesse croissante ont quelques problèmes de pollution. Cette étude vise à évaluer l'impact des effluents des abattoirs informels de Mvog-ada et Essos sur la santé et l'environnement naturel. La recherche a été effectuée de Janvier à Avril 2018. La méthodologie utilisée dans ce travail comprenait la recherche documentaire, le travail sur le terrain et l'analyse en laboratoire des échantillons. L'enquête a révélé que 39 porcs, 400 volailles et 21 chèvres sont abattus tous les jours dans ces abattoirs informels, 50% utilisent à la fois l'eau du robinet et l'eau de puits pour nettoyer les animaux abattus, 37,50 % utilisent 15-25L de cette eau et 37,50 % utilise le cours d'eau et poubelle pour l'élimination de ces effluents. Des échantillons d'eau ont été recueillis (S1-S4) le long de l'affluent Ewoé de Mvog-ada, où les effluents sont évacués et ont été analysés en utilisant des protocoles standards. La plage moyenne des paramètres physicochimiques mesurés pour le pH, T °, Cnd, Sal, Couleur, TSS, TDS, NO_3^-, PO_4^{3-}, COD, DBO_5 était de 6,65-8,08,27,20-27,73°C, 328,33-4663,33 µS / cm, 0,16-2,68 ‰, 84-54208,33 PtCo, 12,67-9666,67 mg / L, 158,27-2600,33,33 mg / L, 7,73-14,3 mg / L, 2,71-252,6 mg / L, 119-1493,33 mg / L, 33,67- 1016,67 mg / L respectivement et la plage moyenne des paramètres bactériologiques mesurés pour FC et FS étaient de 1966,67-1907000 CFU / 100 mL et de 666,67-612000 CFU / 100 mL respectivement. 47,95 % des ménages interrogés font face à des nuisances quotidiennes telles que insectes (26.11 %), petits rongeurs (22.12 %), Odeurs (19.03 %), inondations (17.7 %) et bruits (15.04 %). 69,86 % des personnes interrogées souffrent de maladies hydriques et de paludisme. Généralement, tout tranche d'âge sont exposés à ces maladies. La nécessité de mettre en place des stations d'épuration adaptées aux effluents d'abattoirs est capitale pour réduire les risques potentiels qui pourraient être causés par leur rejet dans la nature.

Mots clés: Gestion des eaux usées, impact, abattoir informel, santé et environnement naturel, milieu tropical urbain.

CHAPTER I. GENERALITIES.

I.1. Introduction.

The continuous drive to increase meat production for the ever increasing world population has some pollution problems attached. Pollution arises from activities in meat production as a result of failure in adhering to good manufacturing practices and good hygiene practices (Ashok. 2017). Meat production is increasing as a result of the world's population growth and consumption of meat per capita (Henchion et *al.,* 2014). Meat is consumed for a number of reasons such as nutritional needs, dietary patterns, sensory attributes, cultural habits, religious beliefs and wealth (Richardson et *al.,* 1993; Hawkesworth et *al.,* 2010; Font-i-Furnols and Guerrero, 2014). However, meat production is considered as a food product with the greatest environmental impact (Röös et *al.,* 2013).

Slaughterhouses are industries that are involved in the commercial slaughtering of animals such as cattle, goats, and sheep, among others, and processing of the meat for human consumption (Neboh et *al.,* 2013). Slaughterhouses operations generally use large quantities of water for washing the meat and in cleaning various process areas (Sajidu et *al.,* 2007) so they are usually located near water bodies to ease the accessibility of water for meat processing and discharge of wastewater (Adelegan, 2002). It is to be noted that wastes from slaughterhouses typically contains fat, grease, hair, feathers, flesh, manure, grit, undigested food, blood, bones and process water which are generally characterized by high organic level (Deborah et *al.,* 2017). Blood, undigested stomach contents (manure), fat, urine, and meat tissues are washed directly into the flowing water (Liu and Haynes, 2011). This water pollution infects our food in addition to groundwater contamination when used to irrigate crops and poses great risks to public health (Deborah et *al.,* 2017). The major characteristics of Slaughterhouse wastes are high level organic strength, sufficient organic biological nutrients, adequate alkalinity, relatively high temperature (20 to 30 °C) and are relatively free of toxic material (Chukwu, 2008). Blood constitutes the highest pollution load of all the components of slaughterhouse effluents, followed by fat, blood has the highest COD (for instance, 375,000 mg/L) of any effluent from slaughterhouse operations which in turn, leads to the depletions of oxygen in the course of their degradation within the ecosystem (Trift and Schuchardt, 1992). If the blood from a single cow carcass is allowed to discharge directly into a sewer line, the effluent load would be equivalent to the total sewage produced by 50 people on an average day (Aniebo et *al.,* 2009).

The elevated levels of nutrients (nitrogen and phosphorus) in surface water due to pollution accelerates the destruction the aquatic ecosystems and result in eutrophication (Zhang et *al.,* 2015). Eutrophication causes many adverse effects on the water body (Smith and Schindler, 2009; Badruzzaman et *al.,* 2012). In addition, slaughterhouse effluents also contain large quantities of suspended solids, which range from 2333 to 8620 mg/L (Mitta, 2004; Raheem and Morenikeji, 2008). Such levels of suspended solids greatly reduce the light available to photosynthetic organisms and eventually disrupt the balance of the ecosystem as the number of primary producers will be reduced. A number of slaughterhouses in developing countries including Cameroon lack facilities for treatment of slaughterhouse effluents (Abdullahi et *al.,* 2017) and consequently, the disposal of wastewater to both the terrestrial and aquatic environments could lead to transmission of pathogens to humans, the direct outcome of which would be the zoonotic diseases comprising, among others: Bacillosis, Salmonellosis, Brucellosis, and Helminthes (Cadmus et *al.,* 1999). Notably, pathogens associated with animal carcasses include rotaviruses, hepatitis E. virus, *Salmonella spp.*, *E. coli*, *Yersinia enterocolitica*, *Campylobacter spp.*, *Cryptosporidium parvum*, and *Giardia lamblia* (Sobsey et *al.,* 2002). In Uganda high levels of contamination by both *Escherichia coli* and *Enterococcus* spp have been linked to slaughterhouse wastewater, which drains into water bodies that are used as drinking water sources by the population (Svanström, 2014). The consequences of such infections range from temporary morbidity to mortality, especially in high-risk individuals such as the elderly and children. This call for proper management of slaughterhouse waste before its release into the natural environment (Coker, 2001).

Yaounde, the capital city of Cameroon is not margin of this situation in view of the informal slaughterhouse effluent management. Despite their recognition by the Cameroonian Ministry in charge (MINEPIA), the activities of the informal slaughterhouses of Mvog-ada and Essos market are directly linked to environmental concerns. This study aims at assessing the impact of the Mvog-ada and Essos informal slaughterhouse wastewater on health and the natural environment. Specifically the objectives are:

- to assess the actual state of wastewater management in the informal slaughter areas;
- to determine the physicochemical and bacteriological characteristics of the wastewater produced;
- to evaluate the socio-sanitary and environmental impacts of the wastewater from informal slaughterhouse.

I.2. Literature review.

I.2.1. Generalities on pollution.

The industrial revolution, with the prodigious development of human activities has resulted in an increase and diversification of pollution which constitutes serious threats to the future balance of the biosphere, hydrosphere, atmosphere and future generations of our species. Any increase of activity, of production, leads inevitably an increase in waste. If they are not recycled, destroyed or put permanently out of circuit, problems appear: there is pollution (Barbault, 1983 cit.Mbog, 2013). In general, pollution is any anthropogenic modification of an ecosystem resulting in a change in concentration of chemical constituent natural resources, or resulting from the introduction into the biosphere of artificial chemicals, disturbance of the energy flow, the intensity of the radiation, the circulation of the matter or the introduction of exotic species into a natural biocenosis (Ramade, 2005).

Waste that pollutes the environment may be in a gaseous state (products of combustion, volatile products, chemical compounds dissipated in the air by evaporation), in the liquid state (wastewater, rainwater and urban runoff, agricultural runoff) or in solid form (garbage, miscellaneous residues). The present study focuses on liquid discharges and is interested primarily in wastewater.

I.2.1.2. Wastewater.

Generally, wastewater is water that has deteriorated after use (Cors, 2007). Thus, wastewater is defined as “a combination of one or more of:

- domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater);
- . water from commercial establishments and institutions, including hospitals;
- agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter (Corcoran et *al*. 2010);
- industrial effluent, stormwater and other urban run-off;
- Wastewater contains a number of pollutants and contaminants, including:
- plant nutrients (nitrogen, phosphorus, potassium);
- pathogenic microorganisms (viruses, bacteria, protozoa and helminths);
- heavy metals (e.g. cadmium, chromium, copper, mercury, nickel, lead and zinc);
- organic pollutants (e.g. polychlorinated biphenyls, polyaromatic hydrocarbons, pesticides); and biodegradable organics (BOD, COD);

- micro-pollutants e.g. medicines, cosmetics, cleaning agents (Anonymous, 2017).

Based on the origin of the polluting substances there are four categories wastewater (Habib and El Rhazi, 2007)

I.2.1.2.1. Types of wastewater.

I.2.1.2.1.1. Domestic wastewater.

Domestic wastewater consists of black water (excreta, urine and faecal sludge) and grey water (kitchen and bathing wastewater). The mix and composition will depend on the water supply and sanitation facilities available, water use practices and social norms (Anonymous, 2017). Currently, roughly half of the world's population has no means of disposing of sanitary wastewater from toilets, and an even greater number lack adequate means of disposing of wastewater from kitchens and baths (Laugesen et *al.,* 2010).

I.2.1.2.1.2. Agricultural wastewater.

The agricultural use of synthetic chemical fertilizers (phosphate and nitrogen fertilizers), pesticides and livestock effluents are diffuse sources of water pollution from agriculture through soil (leaching, percolation leaching). These chemicals can either infiltrate into the soil or leach the groundwater or be washed by rainwater and drained into the sewage. Fertilizers containing certain metals and metalloids in trace especially superphosphates constituting pollution of the receiving water (Anonymous, 2017).

I.2.1.2.1.3. Storm wastewater.

They are synonymous to clear waters collected in sewer networks. Open channels also collect wastewater and garbage which becomes a health hazard through direct contact (Anonymous, 2017). They are the cause of serious pollution of rivers, especially during stormy periods. Rainwater is loaded with impurities and during their journey they carry residues on roofs and pavements of cities (motor oil, fuels, waste tires and heavy metals).

I.2.1.2.1.4. Industrial wastewater.

Among the possible classifications of industrial wastewaters, one distinguishes between diffuse industrial pollutants, such as those from mining and agri-industries, and end-of-pipe point discharges and mostly illegal discharges from tankers. The former are frequently highly polluting and difficult to contain and treat, while the latter can be contained, controlled and treated in circumstances where there is sufficient political will, regulatory power and resources (economic and human capacity) to ensure compliance (Anonymous, 2017).Indeed, various heavy metals (cadmium, zinc, lead, chromium, mercury), synthetic organic compounds or not readily biodegradable and fats, are often present in large quantities (Ndiaye, 2005). The focus of this study is on wastewater from informal slaughter areas (industrial wastewater) in the Mvog-Ada and Essos market, Yaounde.

I.2.2. Knowledge on slaughterhouses.

I.2.2.1. Definition and presentation of slaughterhouse.

Abattoir also known as slaughterhouse; an abattoir has been defined as a premise approved and registered by the controlling authority for hygienic slaughtering and inspection of animals (such as cattle, goats, and sheep, among others), possessing and effective preservation and storage of meat products for human consumption (Nouri et *al.*, 2008; Neboh et *al.*, 2013). Abattoir operations generally use large quantities of water for washing the meat and in cleaning various process areas (Sajidu et *al.*, 2007). Slaughterhouses produce wastes of sheep, cattle and pigs as follows 53 %, 45 % and 34% of inedible materials respectively (Anonymous, 2006a).

I.2.2.2. History of slaughterhouses.

For years, slaughterhouses were considered temporary or permanent facilities built across the butcher to kill only animals which he intended to sell. At the time when refrigeration did not exist and where the transport of animals was made on foot, slaughterhouses were built near the places of consumption (Anonymous, 2006a). However, there are still problems related to pollution and waste disposal. Nowadays with the revolution of the design of slaughterhouses, advances in refrigeration systems allow the storage and transport of products without degradation or loss of original features. Gradually, the slaughter is conducted in a number of increasingly restricted sites, just over 400 in 1991, against 1,700 in1964 (Anonymous, 2006a), hence the importance of regulations for the construction of slaughterhouses.

I.2.2.3. Notion on effluents from slaughterhouse.

Meat processing effluents are considered harmful worldwide due to the slaughterhouse wastewater complex composition of fats, proteins, fibres high organic content, pathogens, and pharmaceuticals for veterinary purposes. Slaughterhouse effluents are typically evaluated using bulk parameters because of the broad range of slaughterhouse wastewater and pollutant loads. slaughterhouse wastewater contains large amounts of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) (Bustillo-Lecompte and Mehrvar, 2015). The typical characteristics of an actual SWW are summarised in Table 1 below.

Table. I. Typical characteristics of the slaughterhouse wastewater.

Parameter	Range	Mean
BOD (mg/L)	150–8500	3000
COD (mg/L)	500–16,000	5000
TOC (mg/L)	50–1750	850
TN (mg/L)	50–850	450
TP (mg/L)	25–200	50
TSS (mg/L)	0.1–10,000	3000
K (mg/L)	0.01–100	50
Colour (Ptco)	175–400	300
Turbidity	200–300	275
pH	4.9–8.1	6.5

As a result, due to the diverse characteristics of the SWW, it is appropriate to classify and minimize wastewater production at its source. Meat processing effluents are becoming one of the major agribusiness concerns due to the vast amount of water used during slaughtering, processing, and cleaning of the slaughtering facilities (Bustillo-Lecompte and Mehrvar, 2017)

I.2.2.4.International standards for construction and operation of slaughterhouse.

Before the construction of a slaughterhouse, it is important to consider several factors to ensure efficient operation. These factors are (Anonymous, 2003):

- the siting preferably that can provide a good water supply, while facilitating the flow of wastewater;
- ownership of the slaughterhouse for building of slaughtering stations and courts in these slaughterhouses;
- staff;
- the holding pen, the separation of clean and dirty operations;
- treatment of leather, stomachs, intestines and skins;
- blood collection, evacuation of gut contents, inedible offal and meat seizures;
- effluent disposal and adequate water supply.

I.2.3. Slaughterhouse wastewater management.

I.2.3.1. Wastewater treatment.

Treatment methods for SWW are comparable to those used in municipal wastewater treatment and include primary, secondary, and tertiary treatment. However, this does not eliminate the need for primary treatment. There are numerous SWW treatment methods after preliminary treatment (Mital., 2006), which can be divided into four main categories:

- physicochemical treatment (Al-Mutairi et *al.*, 2008);
- biological treatment (Mital.,2006);
- AOPs (Barrera et *al.*, 2012);
- combined processes (Bustillo-Lecompte et *al.*, 2016).

I.2.3.2. Characterization of wastewater from slaughterhouse.

Wastewater is characterised by the measurement of the physicochemical and biological parameters and their values are supposed to be inferior or equal to certain threshold levels of discharge without causing damage to the natural environment (Bustillo-Lecompte and Mehrvar, 2015).

I.2.3.2.1.Physicochemical characteristics.

I.2.3.2.1.1. Macroscopic aspect of slaughterhouse effluent.

Raw effluents are usually reddish in colour, very turbid and contain important elements such as: trimming fragments, blood clots, hooves, horns, skaus materials, and faeces.

I.2.3.2.1.2 Temperature and pH.

The pH of the effluents from slaughterhouse have values close to neutral (6.9-8.2), for all the components of the effluent, be it water, rumens, blood or urine, and have pH close to neutral. Variations in alkalinity or acidity can be observed as a result of products used in the cleaning. This variation permits the survival and multiplications of germs observe in the effluents. Temperature plays a fundamental role in all the chemical reactions that take place in a liquid medium. Temperatures >15 ° C intensify odours while temperatures lowers slow the speed of certain chemical reactions. The speed of degradation of the organic matter in waste water is all the more important as the temperature is high (Sy and Tall, 2003). Temperature of the effluent mostly ranges between 15 and 25 °C. The removal of scalding can provoke rise in temperatures. In most cases, most germs observed are mesophylls, the temperature also provoke the survival and multiplication of germs in the effluent.

I.2.3.2.1.3. Dissolve oxygen, organic matter and turbidity.

There was no literature found on the measurement of dissolve oxygen. These effluents probably had content in dissolve oxygen which permitted the survival and multiplication of germs in strict anaerobic conditions. The standard for sustaining aquatic life is stipulated at 5 mg/l, a concentration below this value adversely affects aquatic biological life, while concentration below 2 mg/L may lead to death for most fishes (Ndiaye, 2005). The content of organic matter in water is expressed in oxygen consumption in acidic or alkaline medium is a probable criterion that oxygen is necessary for biodegradation of organic matter. An increase in the content signifies poor quality and it can be suspected of microbial contamination. A very high D.O content promotes the proliferation of bacteria and uses oxygen. The content in organic matter can be characterised by:

Biological Oxygen Demand for 5 days (BOD_5) and it represents the quantity of biodegradable organic matter in water. Precisely, this parameter is expressed in mg per litre (mg O_2/L), measures the quantity of oxygen necessary to decompose organic matter during oxygenation in aerobic process. To measure BOD_5, we take as reference point the quantity of oxygen consumed in 5 days. The ratio between COD and BOD_5 constitute an indicative measure of biochemical decomposition/ degradation of components present in water.

Chemical Oxygen Demand (COD) and is expressed in mg of oxygen per litre represents the total content of oxidizable matter in water at 18-20 °C temperature. It represents the quantity of oxygen needed to chemical oxidize these matter (Ndiaye, 2005). To completely oxidize these effluent from slaughterhouse permanganate of potassium is used as catalyse. Also the measurement of COD can evaluate the charge of pollutants in wastewater in organic matter before and after physical, biological and chemical treatments. For slaughterhouse effluent before treatment the COD/BOD_5 ratio is 1.8. This ratio is called biodegradability and when compared to municipal wastewater it ranges between 2 and 3. If the ratio is more than 3, the effluent is difficult to be decomposed biologically.

Total Suspended Solids (TSS) which represent generally the mineral and organic particles present in polluted water. It originates from the turbidity of water. We distinguish suspended matter which are been deposited within two hours of sedimentation and colloidal matter which are small particles (10-2 and 10-8mm) which cannot settle.

Turbidity is a primordial parameter to explain the survival of germs in different treatment methods and possible recyclable pathogens and germs.

I.2.3.2.2 Microbiological parameters of wastewater.

The biological parameters that are been studied during characterisation of wastewater are mostly the bio indicators of faecal pollution such as bacteria, protozoans and macro-invertebrates. Wastewater contains numerous pathogenic organisms, which poses threat to human health and aquatic ecosystem (Chedad and Assobhei, 2007). Wastewater contains an average of 10^7 to 10^8 bacteria per mL. The concentration of pathogenic bacteria is in the order of 104/L (Habib and El Rhazi, 2007). In order to estimate contamination; it is done by means of indicators of bacteria faecal pollution, pathogens. The use of microorganisms as indicators for hygienic water quality is dated before 1880 (Anonymous, 2000). These bacterial indicators are faecal coliform (CF) and faecal streptococci (FS).

I.2.3.2.2.1. Faecal coliforms.

Faecal coliforms are experimental germs of faecal contamination commonly used to control the water quality. They constitute a sub-group of total coliforms capable of fermenting lactose at the temperature of 44.5 °C. They are also good indicators of the effectiveness in water treatment plant (Chevalier et *al.*, 2002). The interest in the detection of faecal coliforms is related to indicator organisms that reside in their monitoring in the environment which is equivalent to bacteria pathogens. Moreover their density is generally proportionate to the degree of pollution produced by faecal matter (Chevalier et *al.*, 2002).

I.2.3.2.2.2. Faecal streptococci.

Faecal streptococci are present in about 75 % of human intestines in different concentrations of 105 and 108 bacteria per gram (Chevalier et *al.*, 2002). The presents of enterococci in different types of water can be higher than those of other organisms used as indicators of pollution due to their resistance to disinfectants. This is done by privileged indicators to evaluate the effectiveness of water treatment plant (Anonymous, 2000). The reason been explained by the difference in streptococci compared to coliforms (Escherichia coli inclusive), they are resistant to difficult and persistent environmental conditions over long periods in water (Chevalier et *al.*, 2002).

The mean levels of contamination of urban effluents by bacteria are presented in Table II below.

Table. II. Mean levels of contamination of urban effluents by bacteria (Bechac et *al.*, 1983).

Germs	Mean level of contamination
Total Coliforms	180×10^6
faecal coliform	40×10^6
faecal streptococci	4x106
Salmonella	10^2
Viral particles	10^3

I.2.3.3. Impacts of slaughterhouse wastewater.

Slaughterhouse wastewater is a major form of pollution. It brings about a high level of degradation activity in the receiving aquatic milieu. In addition to the commonly known eutrophication, these effluents have the following sanitary, ecological and economic consequences (Agendia et *al.*, 2000; Bustillo-Lecompte and Mehrvar, 2015).

I.2.3.3.1. Impacts on human health.

The general public health effects of the meat processing industry are related to the direct interaction of human communities with the slaughterhouse activities and indirect interactions with the environment, which can be previously affected by the inadequate management of the liquid effluents, solid waste, and obnoxious odours (Mbuligwe, 2009). People from developing countries in Africa, Asia, and South America have experienced serious gastrointestinal diseases, bloody diarrhoea, liver malfunctions, and, in some cases, death associated with the presence of viruses, protozoa, helminthic eggs, and bacteria in SWW (Barrera et *al.*, 2012; Mbuligwe, 2009). Furthermore, the presence of hepatitis A and E viruses has been reported in the sewage of animal origin in Spain. Microbial pathogens are considered to be critical factors contributing to numerous waterborne outbreaks. Many microbial pathogens in wastewater can cause chronic diseases with costly long-term effects, such as degenerative heart disease and stomach ulcer (Table 1)

Table. III. Acute and chronic health effects associated with microbial pathogens in water.

Pathogen	Agent	Acute effects	Chronic or ultimate effect
Bacteria	*E. coli* O157:H7	Diarrhoea	Adults: death
	Legionella	Pneumonia	(thrombocytopenia)Children: death
	pneumonia	Gastritis	(kidney failure
	Helicobacter pylori	Diarrhoea	Elderly, death
	Vibrio cholera	Diarrhoea	Ulcers and stomach cancer
	Campylobacter	Diarrhoea	Death
	Yersinia	Diarrhoea	Death: Guillain-Barre syndrome
	Salmonella	Diarrhoea	Reactive fever
	Cyanobacter	Fever, Chills	Reactive fever
	Leptosporosis		Potential fever
			Well's Disease

Parasites	*Giardia lamblia*	Diarrhoea	Lactose intolerance, Failure to thrive,
	Cryptosporidium	Diarrhoea	severe hypothyroidism
	Acanthamoeba	Eye infections	Death in immune compromised host
Viruses	*Hepatitis viruses*	Liver infection	Liver failure
	Adenoviruses	Eye infections	
	Enchoviruses	Meningitis	

Source: CDC, 1997

I.2.3.3.2. Impacts on the environment.

Although the environment can handle a certain amount of pollutants through natural degradation processes, as the slaughterhouse wastewater concentration increases, these mechanisms come to be overburdened, where contamination problems commence (Amorim et *al.*, 2007). The impacts of slaughterhouse discharge on the environment are of two categories (Anonymous, 1995), contribution to greenhouse effect during the anaerobic degradation of skua droppings and pollution produced locally by wastewater. In Cameroon, law N° 96/12 of 5th August 1996, relating to environmental management, defines pollution has any contamination or direct or indirect modification on the environment provoked by any act likely to negatively affect a positive use of the environment by man; threaten the health, security and well-being of man, the flora and fauna, air, the atmosphere, waters, soils, collective and individual goods. For the case of slaughterhouses each slaughtering site (also each cattle market) is a point of pollution, nuisance and discomfort (Dihoudi, 2005).

Generally, wastewater from slaughterhouses is discharged in nature and particularly in aquatic milieu. A study carried out in nine slaughterhouses in eight African countries (Burkina Faso, Cameroon, Ivory Coast, Mali, Niger, Senegal, Chad and Togo), in 1991 by a unit Transpaille Lagunage, in Thies Senegal, showed that the entire slaughterhouses considered, pollution was equivalent to 1827 tons COD/year; by implication 200 tons COD/year for SODEPA slaughterhouse of Etoudi (Agiforce, 1993).

I.2.3.3.3. Ecological impacts.

The discharge of untreated wastewater in the environment could lead to the modification of ecosystems which receive it (Agendia et *al.*, 2000). We could name the following:

- the reduction of aquatic biodiversity due to toxicity, and appearance of new species;

- eutrophication of receiving aquatic medium;
- degradation of the aesthetics of the milieu due to bad odour;
- perturbations in microclimate of the receiving medium.

I.2.3.3.4. Impacts on the economy.

The absence of sanitation brings about important economic loss:

- eutrophication and toxicity may bring about enormous loss in the fishing projects;
- a huge amount of money is spent on treating diseases related to lack of or poor sanitation;
- decrease in productivity as a bulk of the population will be affected by water borne diseases;
- loss of aesthetic values in the environment may affect the local touristic industry.

I.2.3.4. Valorisation of wastewater.

Wastewater is been used in intra-urban agricultural activities. It is rich in organic matter, and contains important amendments for the soil; this organic matter has the capacity to increase water retention capacity and gas exchange in the rhizophores. It also ameliorates soil capacity to make these nutrients available to plants which makes wastewater advantageous chemical fertilizers in soils poor in organic matter. The use of residual wastewater in urban agriculture permits economic realization in fertilizers to increase productivity. An example is Dakar, they save about two million dollars in a year on the purchase of pesticides and herbicides fertilizers (Anonymous, 2002). The following table illustrates some guidelines for different discharges either directly (as Storm water), indirectly (sewage) or as water for irrigation crops.

Table. IV. Guideline values for different discharges; directly (stormwater), indirect (sewage) or water for irrigation cultures (Anonymous, 2002).

Parameters	VLR direct discharge	VLR indirect discharge	Wastewater for irrigation
Temperature	30°C	35°C	35°C
pH	6.5-8.5	6.5- 8.5	6.5 -8.5
BOD5	100mg/L	500mg/L	/
COD	500	1000mg/L	2000mg/L
Conductivity	2700	/	8.5ms/cm
CaCO3 (HCO3-)	/	/	518mg/L
Cl^-	Active chlorine C-12(0.2 mg/L)	Surface irrigation	

		350mg/l Irrigation by aspiration 105mg/L
N -NO3	50mg/L	

However, it is worth noting that the use of wastewater in irrigation practices is not used in all crops and in any soil and that not all wastewater is appropriate for irrigation. The effluent should have the following composition:

- absence of toxic substances;
- ability to decompose and be assimilated in the soil;
- absence of potential risk to disrupt the soil structure.

The general characteristics required for irrigation of urban wastewater is equivalent to habitants are 70 g for BOD, 3 g for COD, 70 g for TSS, 12 g and 3 g for nitrates and phosphates content respectively (Anonymous, 2006b).Moreover, the soils destined for irrigation must have a natural drainage especially for swampy or marshy and or in sloppy area. The depth of the soil is preferably in meters. The texture must adapted are for luminous or sandy luminous soils. In the context of irrigation of plants with wastewater, it is important that preliminary treatment takes place to minimize health risk.

I.2.4. Legal and institutional frameworks for sanitation in Cameroon.

Wastewater discharged into a given environment must meet the standards quality of water discharge prescribed by the World Health Organization (WHO), in the context of respect and protection of the environment, in order to limit the risks of pollution and contribute to the process of sustainable development. These rejection or disposal standards in Cameroon are defined by MINEPDED, with well precised physico-chemical characteristics and microbiological conditions, following laws that govern the good ecological status, economic and health aspects of the use of water on the environment. For example the case of characteristics that sewage treatment plant effluents must meet before they are discharged in receiving environments (Anonymous, 2006c). Uncontrolled discharges of wastewater into neighbourhoods without sewage systems are certainly unavoidable, but the existence of hygiene rules applied by communities can mitigate and even reduce their negative effects on the environment. Legal and institutional frameworks are essential elements in the implementation any sanitation operation. They serve as a benchmark to avoid anarchy.

I.2.4.1. Legal framework.

In Cameroon, there exist several texts on the management of the environment and on Establishments grouped as dangerous, unhealthy or obnoxious. But there a lot of lapses on their application have been noticed. The legal and regulatory frameworks applicable to this study area as follows:

-Law no 96/12 of 5August 1996, Frame work law on the management of the environment. It is a law that sets out the general legal framework for environmental management and natural resources in Cameroon based on the following fundamental principles:

- principle of precaution;
- principle of prevention and correction;
- principle of pollute and pay;
- principle of responsibility;
- principle of participation.
- Article17of this law states that; "That any promoter or owner of any physical work, equipment or installation that may cause an adverse effect on the natural environment because of its size or nature of activities is needed to carry out an environmental impact study to assess the direct and indirect impacts of the project on the ecological balance of the settlement area or any other region, the environment and quality of life of people and the impact on the environment in general".
- Law No.89/027of 29th December 1989 on toxic and dangerous wastes. It defines toxic waste As any material containing flammable, explosive, radioactive substances presenting a source of danger to people, animals, plants and the environment as a whole. This law prohibits their introduction, production, storage, transportation, transit and discharge on the national territory. There is an exception of certain institutions that produce it, but the obligation to protect man and the environment. This law provides criminal penalty to those who go against it.
- Law No.98/005 of 14 April 1998 on water regime: This law sets out the legal framework on water regime and the general provisions relating to the protection of the safe guard principles on environmental management and public health as well as on national heritage.
- Law No.98/015 of 14 July 1998 relating to establishments classified as dangerous, unhealthy or obnoxious: This law state that first class structure must always be issued license for the construction and exploitation by the ministry of mines and energy and concern institutions and

the owner of the project must proceed with a study of dangers. These authorization requests are subject to a public inquiry opened by the ministry of mines and energy. This authorization contains conditions for the construction and exploitation and all this under conditions determined by law. The authorization is functional within two years above which it is no longer valid. The structures classified as dangerous, that can pollute the environment are subjected to a payment of a fee to be calculated as indicated by the law. The government of Cameroon encourages the reduction of all forms of pollution by reducing the amount to be paid on dangerous structures. According to texts relating to the classification of establishments, the construction of a slaughterhouse among others is classified as a hazardous or dangerous waste facility because the waste involved or generated here is the type I. The following texts are very important:

- DecreeNo.76-372of 2nd September 1976 carries regulations of classified establishments as dangerous unhealthy or obnoxious and such is divided into three (3) classes;

The first class involves establishments that are to be built very far from residential areas or if it should be built in this area, it must be present in the urban planning.

The second class involves those whose distance from the resident is not strictly necessary but an authorization is needed for its operation.

The third class comprises of establishments that do not have any significant disadvantage on the neighbourhood or public health but their construction requires permission from the Mayor of that area.

- DecreeNo.99/818/PM of 9th November 1999 laying down modalities for the construction and exploitation of classified establishments as dangerous, unhealthy and obnoxious. It indicates the form of applications and procedure to obtain authorization and a statement to indicate if it is a first or second class infrastructure.

- Decree No.2001/165/PM of 8th May 2001, specifying modalities for both surface and underground water protection against pollution. This decree establishes a list of harmful or dangerous substances produced in Cameroon, whose direct or indirect release, deposit or introduction in Cameroon inland waters are either prohibited or subject to prior authorization. The authority in charge of water resource management carries an inventory establishing the degree of pollution of inland waters. This inventory is periodically reviewed or whenever there are suspicious of pollution.

I.2.4.2. Institutional frame

Different ministerial departments intervene at different sectorial levels are concerned in the application of environmental laws during evaluation and control of road works. They are: Ministry of environment, nature protection and sustainable development (MINEPDED) which takes the responsibility of ensuring environmental monitoring and follow-up: Ministry of Livestock Fisheries and Animal Husbandry (MINEPIA), Ministry of Finance (MINFI), Ministry of Land tenure and Survey (MINCAF), Ministry of Territorial Administration and Decentralisation (MINATD), Ministry of Water and Energy resources (MINEE) which assures the management of water resources monitor accidental pollution of water resources.

I.2.8.Conventions and international treaties

The state of Cameroon is signatory to many conventions on the conservation and protection of the environment some of which are:

- Convention on Biological Diversity in 1992 in Rio de Janeiro Brazil signed 14th June 1992 and ratified 19th October 1994;
- Kyoto Protocol on the emission of greenhouse gases in 1997;
- Stockholm Convention on persistent organic pollutants;
- Convention on the protection of cultural and natural heritage in Paris, 1972;
- Vienna Convention and the Montreal Protocol on the Ozone Layer depletion.

I.2.5. Generalities about the city of Yaounde

I.2.5.1. Climate, hydrology and soil.

The Yaoundé region is located at 3°52' north latitude and 11°32' east longitude, the average altitude approaching 750 m. It is on the western edge of the southern Cameroonian plateau and 250 km from the Atlantic coast. Very rugged grounds, this plateau has a wavy surface where alternating hills and valleys saturated with water and is characterized by the abundance of rainfall reaching sometimes 1576 mm / year and varies from year to year (Fig. 1). Still called Yaounde climate, the climate of Yaounde is hot and humid equatorial type. It is composed of four seasons unequally distributed over time:

- a long dry season from December to mid-March;
- a small rainy season from mid-March to the end of June;
- a short dry season from early July to mid-August;
- a long rainy season from mid-August to the end of November.

The average inter-annual temperature is 24.2 ± 2.6° C (Ebang, 2004). The geological formations belong to the mobile zone of Central Africa. The soils are present in general as in all of South Cameroon under three types: ferralitic soils; hydromorphic soils and poorly evolved soils (Ramade, 2005). The red and yellow ferralitic soils are respectively located on the tops of the inter rivers and at the bottom of the slopes. Soils little evolved respectively in swampy valleys and mountainous terrain with steep slopes. The Yaounde region is finally characterized by an equi-tropical rainforest forest with mostly Sterculiaceae and Ulmaceae (Ramade, 2005).

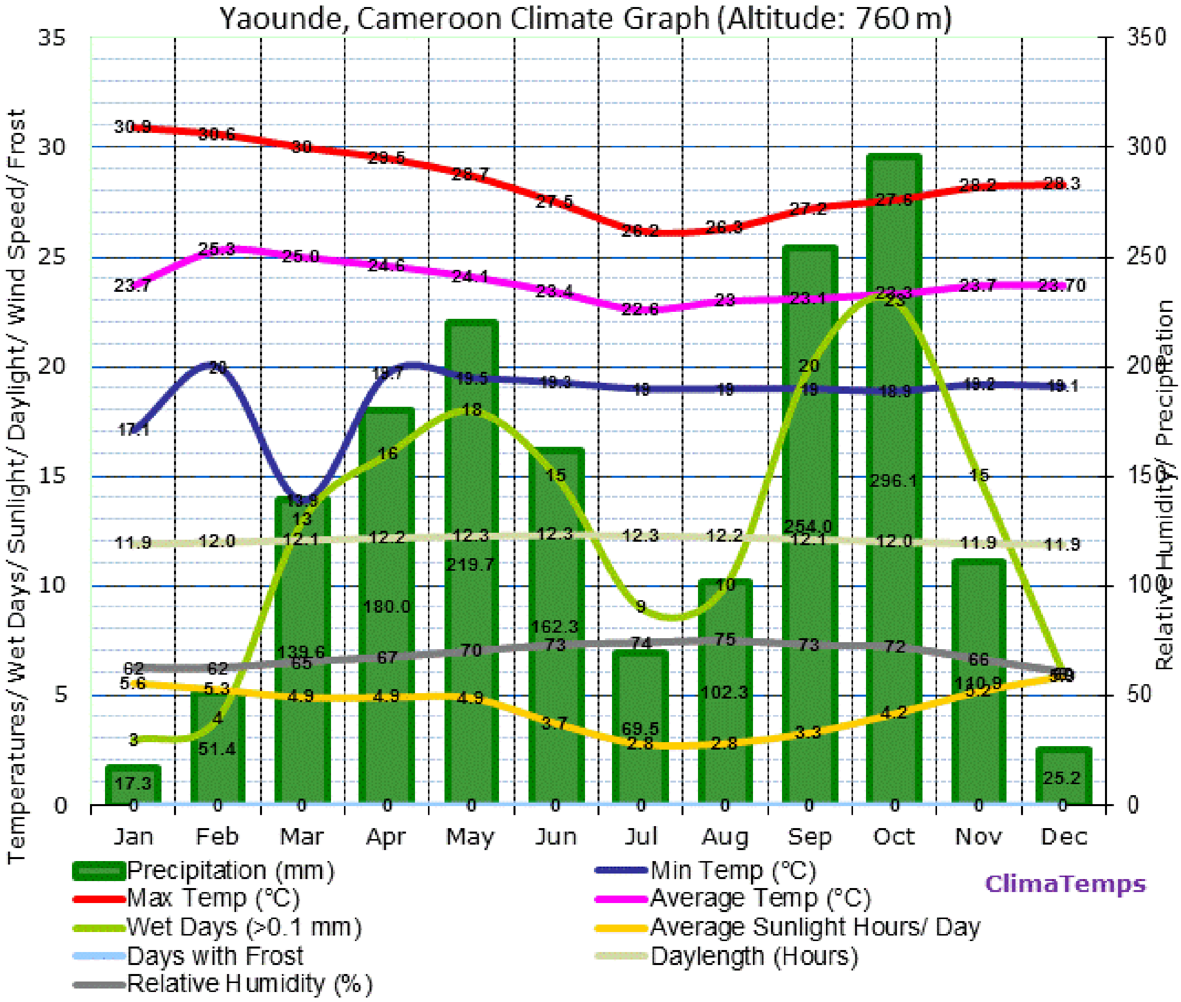

Fig. 1. An idea on ombrothermic diagram of the locality of Yaounde (2014)

I.2.5.2. Relief.

The relief of Yaounde is diversified. With an average altitude of 760 m, Yaoundé extends mainly to the Mfoundi basin. It is dominated to the west and northwest by an area of high hills culminating at nearly 780 m on the edge of the Yaoundé plateau, from Etoudi in the north to Nsimalen in the south, passing by Essos in the East, the plateau of Atemengue very flat summit rises to 760 - 780 m and forms around Yaoundé an arc of circle.

CHAPTER II. MATERIALS AND METHODS.

II.1. Presentation of study area.

This research was carried out from January to April 2018 in the informal slaughterhouses of Essos and Mvog-ada market of Yaounde, the capital city of Cameroon. Yaounde is located at 3°52' north latitude and 11°32' east longitude, the average altitude approaching 750m.The climate is the hot and humid equatorial type. It is composed of four seasons unequally distributed over time: a long dry season from December to mid-March, a short rainy season from mid-March to the end of June, a short dry season from early July to mid-August, a long rainy season from mid-August to the end of November. Annual rainfall reaching sometimes 1576 mm / year and varies from year to year and the average inter-annual temperature is 24.2 ± 2.6 ° C (Ebang, 2004).

These informal slaughterhouses were chosen amongst other informal slaughterhouses due to its location (market) and the immediate presence of households that surround them and may be victims in one way or the other by the activities carried out in these informal slaughterhouses. The Mvog-ada informal slaughterhouse is located along the Ewoé tributary, one of the main tributaries of Mfoundi and lies within the latitudes of 3°51'42''N and 11°31'56''E. The main slaughtering activity is the slaughtering of pigs, poultry, goats and sheep. The informal slaughterhouse is constituted of several pig fences with different owners and an association of independent slaughters under the supervision of veterinary officers from MINEPIA. The slaughtering takes place in an open air. The slaughtering goes on throughout the week from Monday to Sunday. Same for the Essos informal slaughterhouse which lies between the latitude 3°52'10''N and 11°32'33''E (Fig. 2) and has less slaughtering activity as compared to the Mvog-ada informal slaughterhouse, however its functioning is identical to that of Mvog-ada informal slaughterhouse.

Informal slaughterhouse River

Informal slaughterhouse River

Fig. 2. Pictures showing the localisation of the informal slaughterhouses (a: Essos; b: Mvog-Ada).

II.2.Materials.

For the realization of this study the following materials were used:

- geographic positioning system (GPS) for the determination of geographic coordinates of the study areas;
- notebook to take down notes and other information;
- personal protective equipment (PPE), for protection;
- questionnaires for data collection;
- 1.5 L polyethylene bottle for collection of wastewater samples, surface.
- laboratory equipment for analysis;
- a camera for photos;
- laptop for data entry;
- an authorisation from the urban council of Yaounde and MINEPIA.

II.3. Methodology.

For the realization of this study, the methodology used went through the following stages:

- documentary research;
- field work;
- collection of opinion of the workers and the population (those living around the informal slaughterhouses);
- analysis and interpretation of data collected.

II.3.1. Investigation technique.

The investigation technique for this study was done through the use of approved and verified questionnaire (by the wastewater research unit of the University of Yaounde I) and interviews. A semi structured questionnaire was administered to households (41 at Mvog-ada and 32 at Essos) within 500m East, West, North and South of the informal slaughterhouse in both study areas (Weobong and Adinyira, 2011). Questionnaires were also administered to workers (10 at Mvog-ada and 6 at Essos) including the veterinary officer (chief of centre) of each site. Simple random technique according to Omole and Ogbiye (2013) which aims at administrating semi structured questionnaires randomly was implemented in sourcing information. This brought the total number of respondents of households and workers to 73 and 16 respectively. This investigation had as aim the gathering of opinions of the population and workers on the management of their wastewater and its impact on their health and the environment.

II.3.2. Assessment of wastewater management practices in the informal slaughterhouses.

Field visits to the informal slaughterhouses of Mvog-ada and Essos market in Yaounde where the slaughtering process and the evacuation of the wastewater generated was monitored from the point of slaughtering till the final point of discharge. This visits permitted to collect information relative to the management of effluents produced from the informal slaughterhouses by investigations, discussions, and personal observations, interactions with the MINEPIA agents, workers and the nearby population. It was important to know:

- the type and number of animals slaughtered per day;
- type(s) and quantity of water used for cleaning per animal;
- types of waste and wastewater generated and disposal methods;
- the cleaning frequency of informal slaughterhouse and use of special protective equipment by the workers.

II.3.3. Determination of physicochemical and bacteriological parameters of informal slaughterhouse wastewater.

II.3.3.1. Sampling method.

Samples were collected only from the Mvog-ada informal slaughterhouse due to its intense level of slaughtering activity and effluent discharge compared to the Essos informal slaughterhouse which is a little mild. The sampling method for this study was modified from Terrumun and Iorhemen (2015), which consist of collecting water samples from the river at three points: sampling point 1 (S1) located about 100 m upstream of the informal slaughterhouse drainage point into the river i.e. sampling point 2 (S2), sampling point (S3) located about 100m downstream of the discharge point The water samples were collected in 1.5 litre polyethylene bottles held in the middle and immersed about 10-20cm in water against flow (Anonymous, 1998). During sampling, sample bottles were rinsed with the sample water three times and the sample bottles were filled completely to prevent any loss of dissolved gases from the water samples (Ojekunle and Lateef, 2017). Raw informal slaughterhouse effluent (S4) was included among the samples to have a database since this field is still in an embryonic level in Cameroon. Samples were collected within a period of 3 weeks (29th March 2018-12th April 2018) between 9 am and 10am, the time of peak activities at the informal slaughterhouse. The samples were labelled after each sampling and placed in a cooler. Afterwards transported to the laboratory of biotechnologies and environment of the University of Yaounde I and stored in the refrigerator at -4°c for analysis.

II.3.3.2. Laboratory analysis.

The samples collected were analysed in the laboratory for both physicochemical and bacteriological analysis. The physicochemical parameters such as: pH, Temperature (T°), redox potential, Colour, Electrical Conductivity (EC), Salinity, Total Suspended Solid (TSS),Total Dissolve Solids (TDS), Resistivity, Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrates (NO_3^-), Phosphates (PO_4^{3-}) and bacteriological parameters such as Faecal coliform (FC) and Faecal Streptococci (FS) which are indicators of pollution were determined. The analyses was done following standard procedures described by Eaton et *al*., 2005.

II.3.3.2.1. Determination of physico-chemical parameters.

II.3.3.2.1.1. Determination of temperature, pH and redox potential.

Measures of temperature, pH and redox potential were determined using a pH meter of the Hach (HQ11d) mark. After pre-calibrating the pH meter using buffer solutions with pH values 7.00 and 4.01, the green electrode was introduced in 100 ml of sample and the values projected on the digital screen was recorded.

II.3.3.2.1.2. Determination of electrical conductivity, salinity, total suspended solids and colour.

Measures of electrical conductivity was realized using conductimeter (Hach (HQ14d). This apparatus was equipped with a standard tracer that is placed vertically in the solutions to know their concentration. The value of the conductivity was read on the digital screen. This conductivity is expressed in µs/cm or ms/cm following the concentration of the sample.

The salinity was determined using a Conductimeter (Hach (HQ14d), however with a modification of the method of use. The former is expressed per 1000 and the latter in mg/l.

The TSS was determined using the photometric method. The content of TSS was compared to the test experiment and read directly on the digital screen in mg/L or g/L with wavelength of 810 nm.

Colour was determined with the aid of the Hach DR/3900 spectrophotometer after measuring 10mL of the sample the program for colour reading was entered and read on the digital screen in PtCo.

II.3.3.2.1 .3. Determination of Chemical Oxygen Demand.

The measurement of the chemical oxygen demand was done by the method known as "reactor digestion". After homogenization of samples, 2 mL are measured out and introduced in COD tubes, and then incubated in the presence of a control at 150°C for 2 hours in a COD reactor (multi-tube heating apparatus (Hach). The value of each basin is read after cooling of the tubes with the aid of the Hach DR/3900spectrophotometer.

II.3.3.2.1.4. Determination of Biochemical Oxygen Demand.

The determination of the biochemical oxygen demand was done using the "*manometric*" method, with the aid of a BOD_5 apparatus of the Hach (2173B) model. BOD_5 bottles containing a given volume of wastewater from the sampling site was added a nutritive buffer for BOD_5 and were incubated for 5 days consecutively at 20 ^oC. During this period, bacteria used the oxygen present in the superior part of the bottle to oxidize organic matter present in the solution, and release CO_2. The latter was fixed by potassium hydroxide crystals (present in the topper/cupule placed on top of each bottle). An air depression ensues in the bottle, thus creating a rise in the mercury column. The value of the BOD_5 was read directly on the BOD_5 scale situated in front of the apparatus.

II.3.3.2.1 .5. Determination of phosphate.

The determination of phosphorous was done by the "*molybdovanadate*" method. 1 mL of molybdovanadate reagent was added to each water sample as well as in a control (distilled water). The Orthophosphate molecules present, reacted with the molybdate in an acid medium to form the phosphomolybdate complex. In the presence of vanadium, an acid called vanadomolybdophosphoric acid was formed, and had a yellow colour. The intensity of the coloration was proportional to the concentration of phosphates present in the medium. The reading was recorded on the spectrophotometer of Hach DR/3900 mark and the values were displayed in the form of orthophosphate (PO_4^{3-}), and expressed in mg/L.

II.3.3.2.1.5. Determination of nitrate.

Nitrate ions were determined by the cadmium reduction method with the aid of the Hach DR/3900 spectrophotometer. After the introduction of 10 mL of sample in a spectrophotometric cell, a sachet of Nitraver 5 is added therein. The mixture will be then homogenized and allowed to settle for 5 minutes (reaction time). The coloration developed in the presence of NO_3^- was subsequently read on the spectrophotometer at 500 nm. The concentration of the parameter under study will be read on the digital screen of the apparatus with reference to a control consisting of 25 mL of sample. The results are expressed in mg/l.

II.3.3.2. Determination of bacteriological parameters.

Faecal streptococci (FS) and faecal coliforms (FC) present in effluents was determined using the membrane filtration technique and counted in conformity with standard protocols as described by Rodier (2009). The culture medium used for FS is the BEA medium (Bile Esculine Azide agar) while that for FC is the TTC and Tergitol 7 medium.. After decimal dilution of percolate samples using sterilized dilution water, the samples were filtered on membrane with the aid of a vacuum pump. Next, the filter membranes was placed in the respective culture media. These was then placed in an incubator at 35 % for FS and 44.5 % for FC. Incubation time was 24 hours. After incubation, the colonies were counted and their total number estimated using the following formula:

Cfu/ml = (no. of colonies x dilution factor) / volume of culture plate

With CFU= Colony Forming Units for 100 ml.

The following table summarizes the main materials and methods applied at the laboratory level to carry out physicochemical and bacteriological analyses.

Table. V. Materials and methods used for physicochemical and bacteriological characterization.

Parameter	Apparatus	Method
pH	HACH pH meter	Electrode (direct reading)
Temperature (°C)	HACH Conductimeter	Electrode (direct reading)
CND (µS/cm)	HACH Conductimeter	Electrode (direct reading)
TSS (mg/l)	HACH Conductimeter	Electrode (direct reading)
COD	Mixer, COD Reactor, Hach DR/3900 Spectrophotometer	Digestion in the reactor, then reading at 620 nm.
BOD_5	Manometric Apparatus HachDR/3900Spectrophotometer	Molybdovanadate (reading at 430 nm)
NO_3^-	Hach DR/3900 Spectrophotometer	Nitra ver 5 nitrite (reading at 507 nm)
Salinity(Cl^-)	HACH pH meter	Electrode (direct reading)
Redox Potential	Filtration column, incubators	Membrane Filtration and incubation on BEA medium
Faecal Streptococci	Filtration column, incubators	Membrane Filtration and incubation on BEA medium

Faecal Coliforms	Filtration column, incubators	Membrane Filtration and incubation on TTC and Tergitol medium

II.3.4. Evaluation of socio-sanitary and environmental impacts of the slaughterhouse wastewater.

II.3.4.1. Evaluation of socio-sanitary impacts.

The evaluation of socio-sanitary impact was done by evaluating the disease frequencies of the nearby population within a coverage of 500m of the study area susceptible to be impacted by the pollution from the informal slaughterhouse wastewater through a section of the semi questionnaire. Which aimed at:

- knowing the main source of drinking water;
- if any treatment is added to the drinking water;
- if the source of drinking water experiences shortage, the nature of this shortage and its frequency;
- if there is any groundwater contamination;
- disease frequency, season of occurrence, those most likely exposed;
- ideas on potential sources of these diseases.

II.3.4.2. Evaluation of impacts on the natural environment.

To evaluate the environmental impact of the informal slaughterhouse wastewater, field survey was carried out and data was collected relating to the informal slaughterhouses activities and households through semi-structural questionnaire and personal observations (73 questionnaires to households around and 16 to workers). This semi-structured questionnaires had as aim to gather relative information on the:

- distance of households to the slaughter areas;
- nuisances encountered daily;
- if the informal slaughterhouse wastewater arrives their homes;
- elements of the environment affected by this activity;
- the impact of the informal slaughterhouse wastewater on the quality of the nearby river;
- their point of view on the treatment of the informal slaughterhouse wastewater.

II.3.5. Data analysis.

Information gathered through interviews, observations, questionnaires and laboratory measurements were analysed using spread sheets of Microsoft Excel 2013 for data entry and graphical representations. Spss v.25 for data treatment. The questionnaires results and laboratory results was presented using tables, histograms and pie charts.

CHAPTER III. RESULTS AND DISCUSSION.

III.1. RESULTS.

III.1.1. State of management of activities in the informal slaughterhouses.

III.1.1.1. Socio-demographic characteristics of the informal slaughterhouses.

Table. VI. Socio demographic characteristic of workers in the informal slaughterhouses.

Parameters		Informal slaughterhouses		Total
		Essos informal slaughterhouse (n=6)	Mvog-ada informal slaughterhouse (n=10)	
Position occupied	Chief of center	0	1	1
	Slaughterer	1	1	2
	Butcher	5	7	12
	Washer man	0	1	1
	Total	6 (37.5 %)	10 (62.5 %)	16 (100 %)
Age	20-30 years	2 (12.50 %)	5 (31.25 %)	7 (43.75 %)
	Above 30 years	4 (25 %)	5 (31.25 %)	9 (56.25 %)
	Total	6 (37.5 %)	10 (62.5 %)	16 (100 %)
Gender	Male	5 (31.25 %)	9 (56.25 %)	14 (87.5 %)
	Female	1 (6.25 %)	1 (6.25 %)	2 (12.5 %)
	Total	6 (37.25 %)	10 (62.5 %)	16 (100 %)
Education	Uneducated	1 (6.25 %)	1 (6.25 %)	2 (12.25 %)
	Primary	2 (12.50 %)	2 (12.50 %)	4 (24.5 %)
	Secondary	3 (18.75 %)	6 (37.50 %)	9 (56.25 %)
	University	0 (0 %)	1 (6.25 %)	1 (6.25 %)
	Total	6 (37.5 %)	10 (62.5 %)	16 (100 %)
Working period	Less than 1 year	0(0 %)	1(6.25 %)	1(6.25 %)
	1-5 year	3(18.75 %)	2(12.50 %)	5(31.25 %)
	6-10 years	2(12.50 %)	3(18.75 %)	5(31.25 %)
	11-15 years	1(6.25 %)	2(12.50 %)	3(18.75 %)
	Above 15 years	0(0 %)	2(12.50 %)	2(12.50 %)
	Total	6(37.5 %)	10(62.5 %)	16(100 %)

The position occupied by the workers of Essos revealed that 1(16.7 %) was the Chief of centre, 4(66.7 %) were slaughterer and 1(16.7 %) was a butcher while in Mvog-ada 1(10 %) was the chief of centre, 7(70 %) were slaughterers, 1(10 %) was a butcher and 1(10 %) was a washer man. 2(12.50 %) were between 20-30 years and 4(25 %) were above 30 years in the informal slaughterhouse of Essos and 5(31.25 %) were between 20-30 years and 5(31.25 %) were above 30years.in the Essos informal slaughterhouse 31.25 % were males and 6.25 % female while in Mvog-ada 56.25 % were male and 6.25 % were female. Concerning their educational level in the Essos informal slaughterhouse 6.25 % were uneducated, 12.50 % had primary level, 18.75 % secondary level while in the Mvog-ada informal slaughterhouse 6.25 % were uneducated, 12.50 % had primary level, 37.50 % secondary level and 6.25 % university level.18.75 % had been working for 1-5 years, 12.50 % 6-10 years, 6.25 % 11-15 years in the Essos informal house while in Mvog-ada 6.25 % had been working for less than 1 year, 12.50 % between 1-5 years, 18.75 % between 6-10 years, 12.50 % between 11-15 years and 12.50 % above 15 years.

In general of the total number of respondents (16) in both informal slaughterhouses 6(37.5 %) were of Essos and 10(62.5 %) were from Mvog-ada. As for their ages 43.75 % were between 20-30 years and 56.25 % were above 30 years. 87.5 % were male and 12.5 % were females.12.25 % were uneducated, 24.5 % were of primary level, 56.25 % had a secondary level and 6.25 % had a university level. 6.25 % had been working for less than 1 year, 31.5 % had been working for 1-5 years, 31.5 % for 6-10 years, 18.75 % 11-15 years and 12.5 % above 15 years.

III.1.1.2 Types and number of animals killed daily.

The types of animals slaughtered in both informal slaughterhouses obtained from respondents of both informal slaughterhouses and personal observations are; pigs, poultry and goats.

Table. VII. Type and number of animals slaughtered in both informal slaughterhouse.

Informal slaughterhouse	Pigs	Poultry	Goats
Mvog-ada	26	295	15
Essos	13	105	8
Total	39	400	21

As the results shows in the table above the number of animals slaughtered per day according to the workers interviewed vary between informal slaughterhouses with Mvog-ada having a higher number of animals slaughtered with 26 pigs, 295 poultry and 15 goats giving a total of 336 animals slaughtered daily. Essos slaughters 13 pigs, 105 poultry and 8 goats giving a total of 126 animals slaughtered daily. In both informal slaughterhouses 39 pigs, 400 poultry and 21 goats are slaughtered per day

Access was granted to consult the Mvog-ada MINEPIA's register and that of Essos wasn't accessible due to the absence of the old register which was sent back to the regional office previous days before the present field work and a new register was currently in place. The MINEPIA registers keeps only record of the number of pigs slaughtered and that of Mvog-ada revealed an average number of 976 pigs slaughtered monthly within a 3 month period (Table.VIII)

Table. VIII. Number of animals slaughtered in Mvog-ada per month according to MINEPIA.

Date	Number of Pigs slaughtered
18th January 2018 - 18th February 2018	895
19th February 2018 - 19th March 2018	998
20th March 2018 - 21 April 2018	1034
Mean value	976

III.1.1.3. Type(s) and quantity of water used for cleaning per animal.

III.1.1.3.1 Type(s) of water used for cleaning slaughtered animals.

Tap water, well water and borehole water are used by workers to clean the slaughtered animals. These sources of water are located in the markets not far from the slaughter area. As shown in the Fig. 3, 25 % of respondents in the Essos informal slaughterhouse use tap water and well water, 12.50 % use well water whereas in Mvog-ada 25 % use tap water and well water,12.50 % use tap water, 12.50 % use well water and borehole water, 6.25 % use well water and 6.25 % use borehole water.

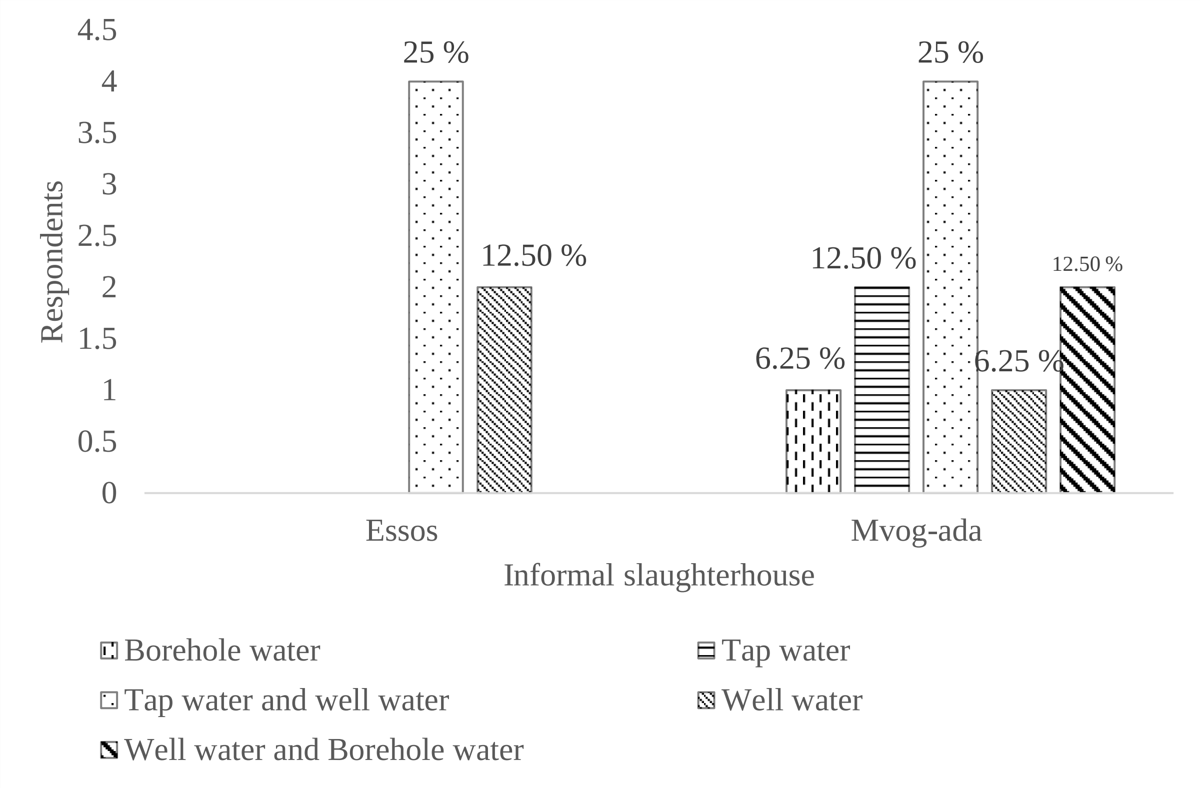

Fig. 3. Type(s) of water used to clean animals in the informal slaughterhouses.

From a general point of view in both informal slaughterhouses: 50 % use tap water and well water, 18.75 % use well water, 12.50 % use borehole water and well water, 12.50 % use tap water, 6.25 % use borehole water (Fig.4).

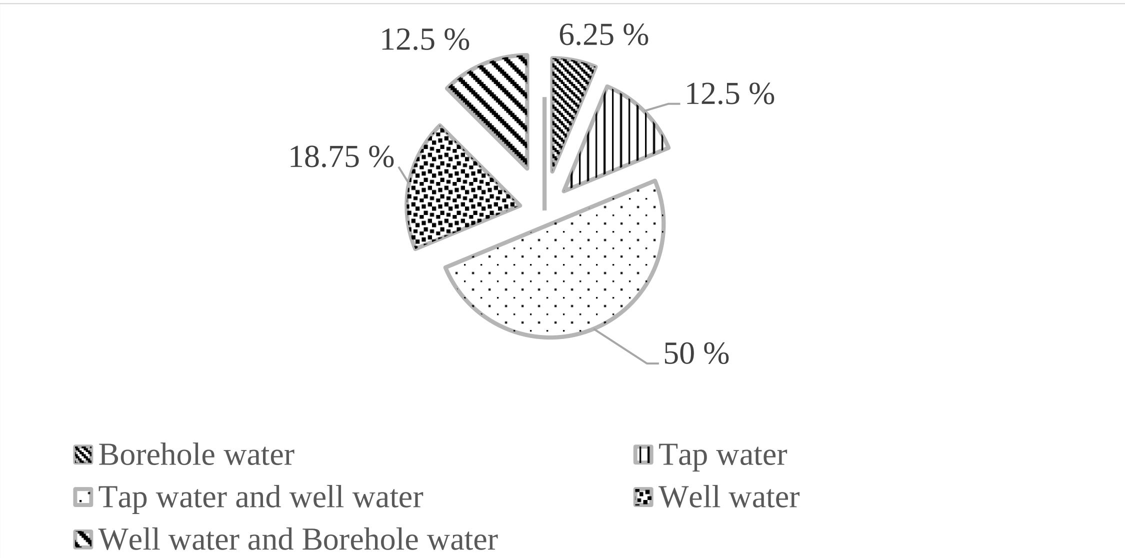

Fig. 4. Overall use of type(s) of water used in cleaning animals in both informal slaughterhouses.

III.1.1.3.2. Quantity of water used for cleaning slaughtered animals.

The results reveal that 20 % use 15-25L, 13.33 % use less than 15L and 6.67 % 35-50L in the Essos informal slaughterhouse for cleaning per animal whereas the Mvog-ada informal slaughterhouse 26.67 % use less than 15 L, 20 % use 15-25L and 13.33 % use 35-50L for cleaning per animal (Fig.6).

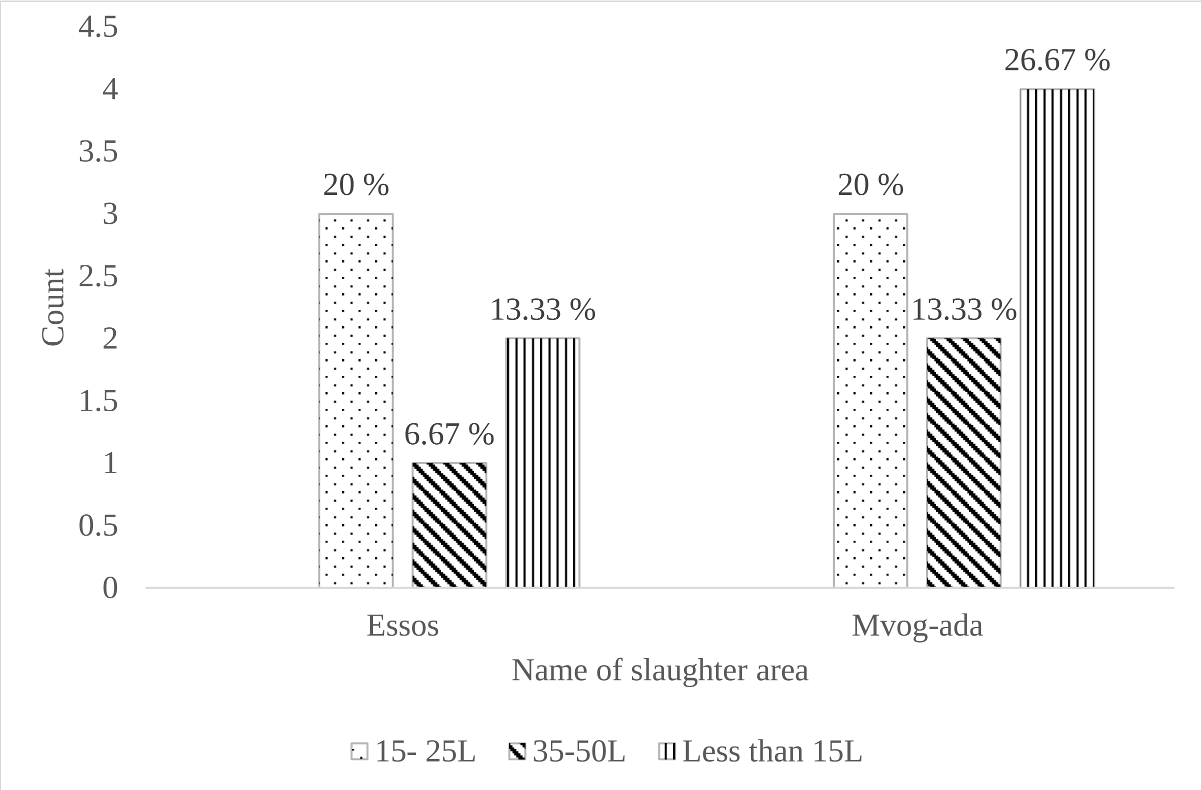

Fig. 5. Quantity of water used for cleaning per animal.

From a general point of view in both informal houses; 37.50 % use less than 15 L, 37.50 % use 15-25L and 18.75 % use 35-50L (Fig.7).

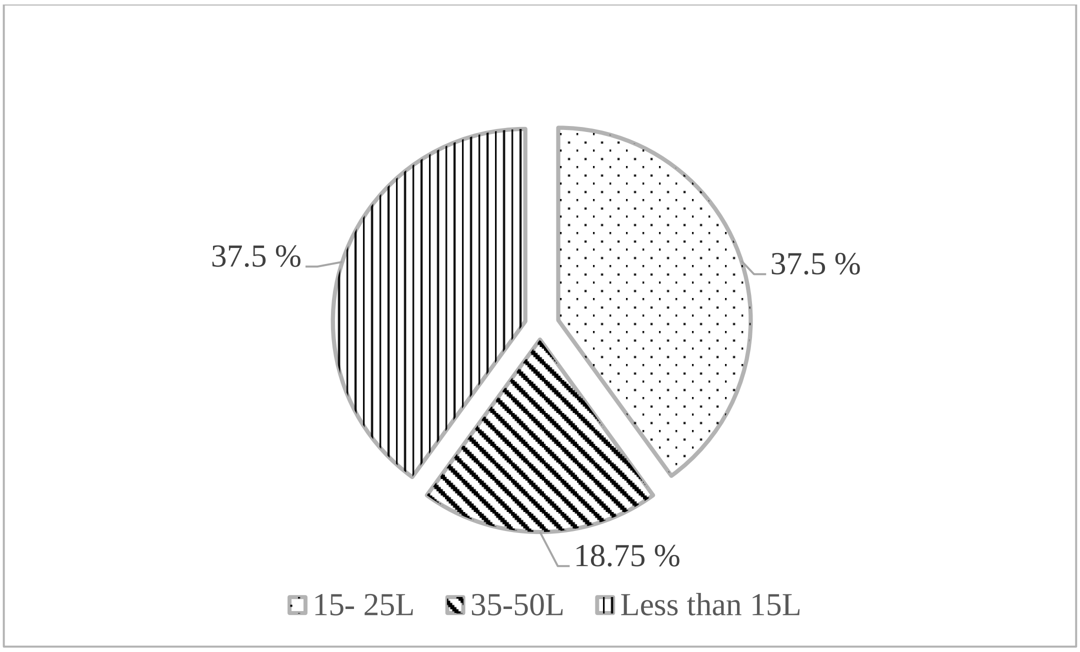

Fig. 6. Overall quantity of water used for cleaning per animal in both informal slaughterhouses.

III.1.1.4. Estimation of Quantity of water used for cleaning Monthly.

The average number of pigs killed according to the MINEPIA register in Mvog-ada (access refused to that of Essos) is 976 and 15-25L (average = 20L) is used to clean 1 animal. Therefore:

- Estimated water used monthly = number of animal killed per month x quantity of water used

= 976 x 20L

= <u>19520L</u>

So, about 19520L is used monthly for cleaning and discharged into the environment without treatment.

III.1.1.5. Types of waste and wastewater generated and disposal methods.

III.1.1.5.1 Types of waste and wastewater generated.

The types of waste produced according to the respondents and personal observations of each type of animal slaughtered with blood as the common waste in all animals are;

Table. IX. Types of waste produced from slaughtered animals.

Type of animal	Waste produced
Pigs	Blood, hoof, waste from gut, hairs, faeces, bristle
Poultry	Feathers, waste from guts, nail, blood, faeces
Goats	Blood, hairs, waste from guts, horns

III.1.1.5.2. Disposal methods of wastewater.

The disposal methods of wastewater in Essos infromal slaughterhouse shows that, 31.25 % use the water and garbage bin, 6.25 % use the watercourse to dispose of their wastewater whereas in the Mvog-ada informal slaughterhouse, 31.25 % use garbage bins, 18.75 % use the watercourse, 6.25 % use the garbage bin and watercourse, 6.25 % use the gutter and watercourse (Fig. 7).

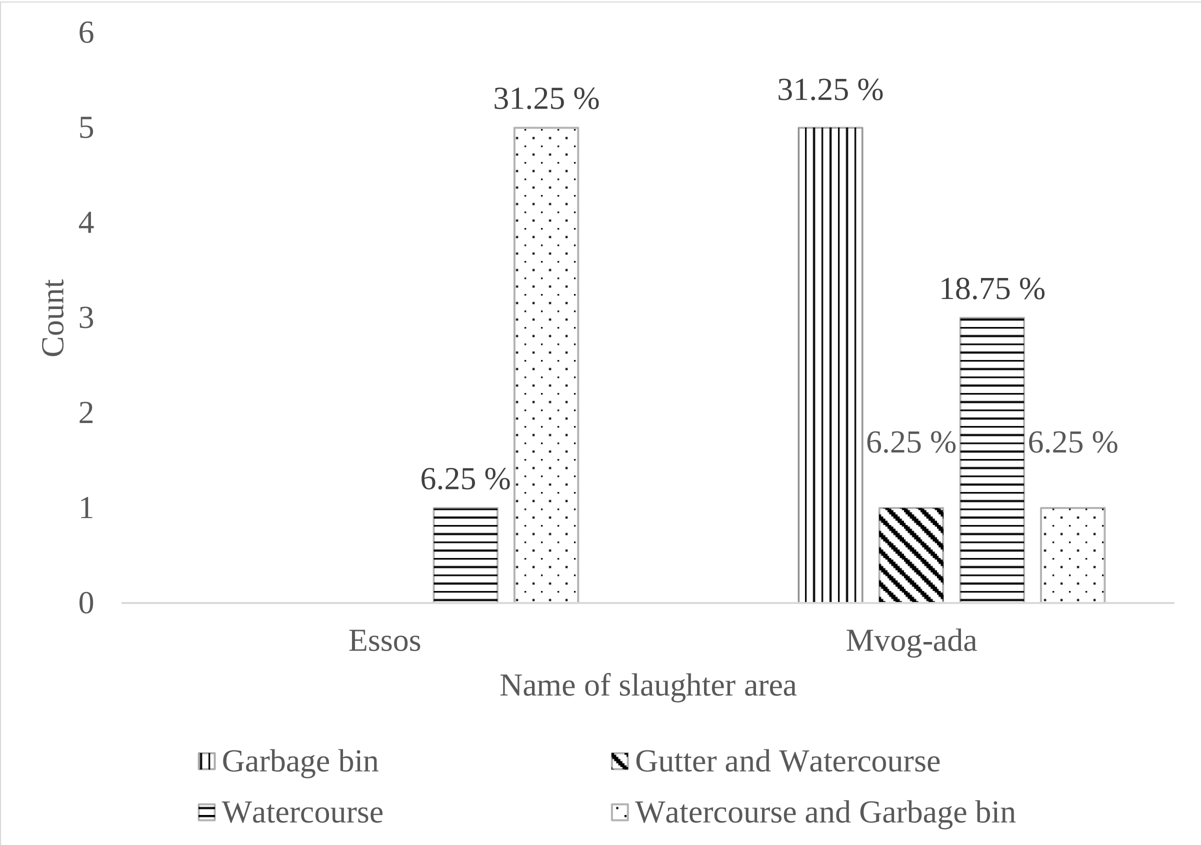

Fig. 7. Disposal methods of informal slaughterhouse wastewater.

Generally in both informal slaughterhouses 37.50 % use the watercourse and garbage bin, 31.25 % use the Garbage bin, 25 % use the watercourse and 6.25 % use the gutter and watercourse (Fig.9).

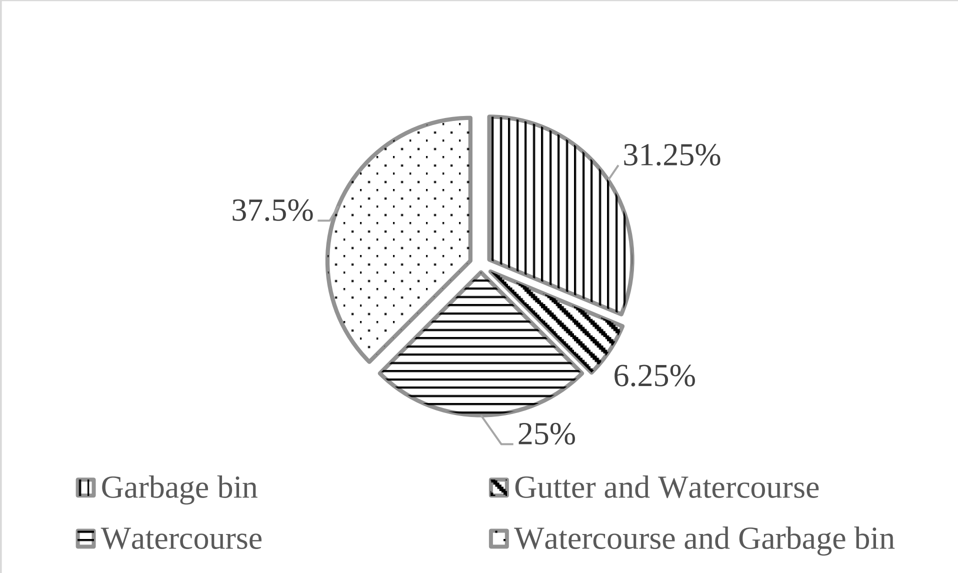

Fig. 8. Overall disposal methods of informal slaughterhouse wastewater in both informal slaughterhouses.

III.1.1.6. Cleaning of informal slaughterhouse and use of special protective equipment.

III.1.1.6.1. Cleaning frequency of the informal slaughterhouses.

The semi-structured questionnaire revealed that in the Essos informal slaughterhouse 37.50 % say they clean the informal slaughterhouse everyday while in Mvog-ada informal slaughterhouse; 43.75 % clean every day, 18.75 % clean once a week (Fig.10).

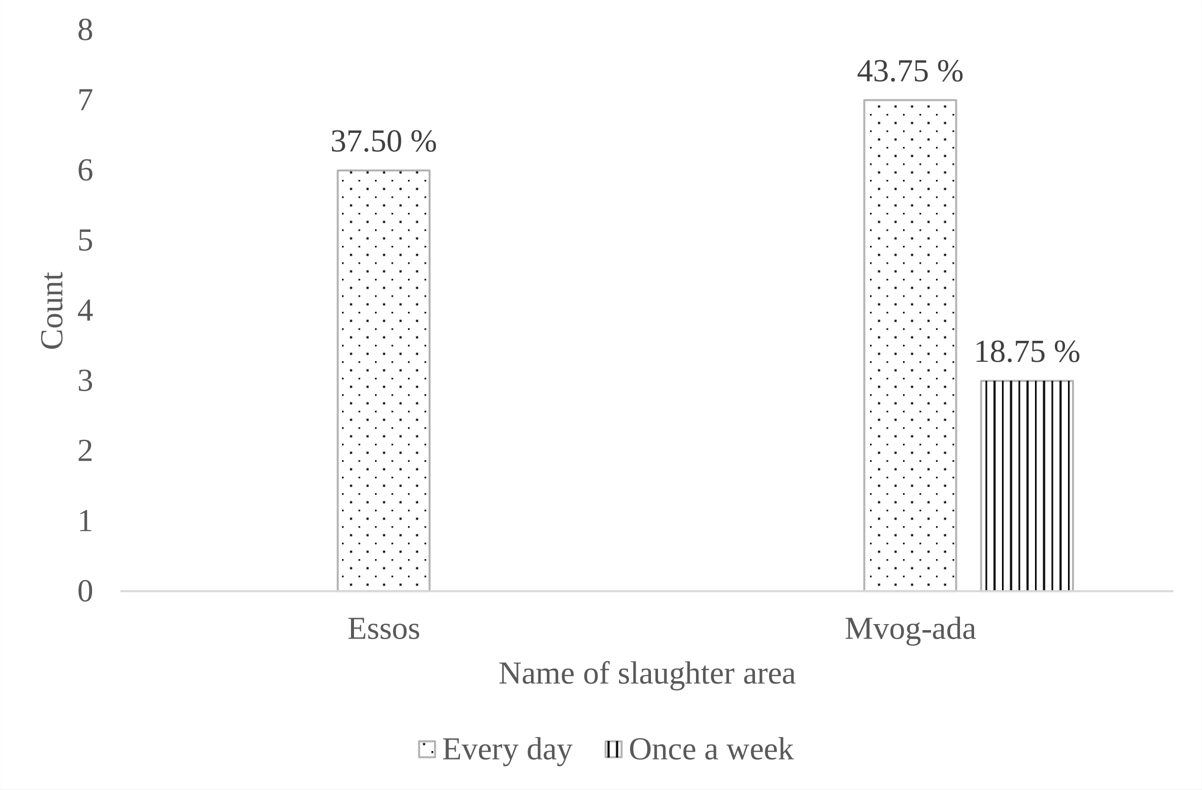

Fig. 9. Cleaning of informal slaughterhouses.

In Overall, in both informal houses 81.25 % clean every day and 18.75 % clean once a week (Fig.10). Through personal observation the water used in cleaning is directly drained into the watercourse.

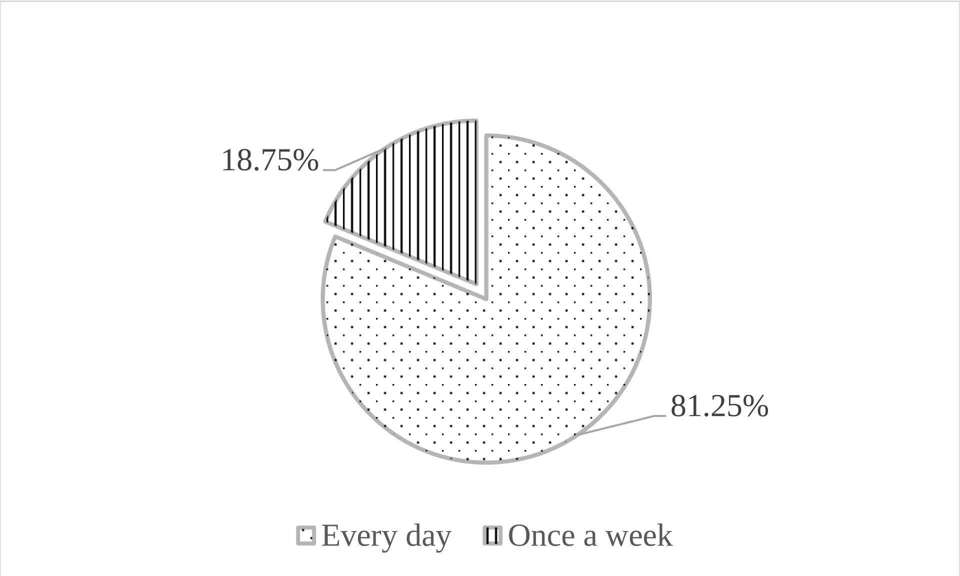

Fig. 10. Overall cleaning of both informal slaughterhouses.

III.1.1.6.2 Use of special protective equipment.

The semi structured questionnaire revealed that among the workers in the Essos informal slaughterhouse; 21.43 % use special protective equipment and 21.43 % do not use it while in Mvog-ada informal slaughterhouse; 35.71 % use special protective equipment and 21.43 % do not use it (Fig.11).

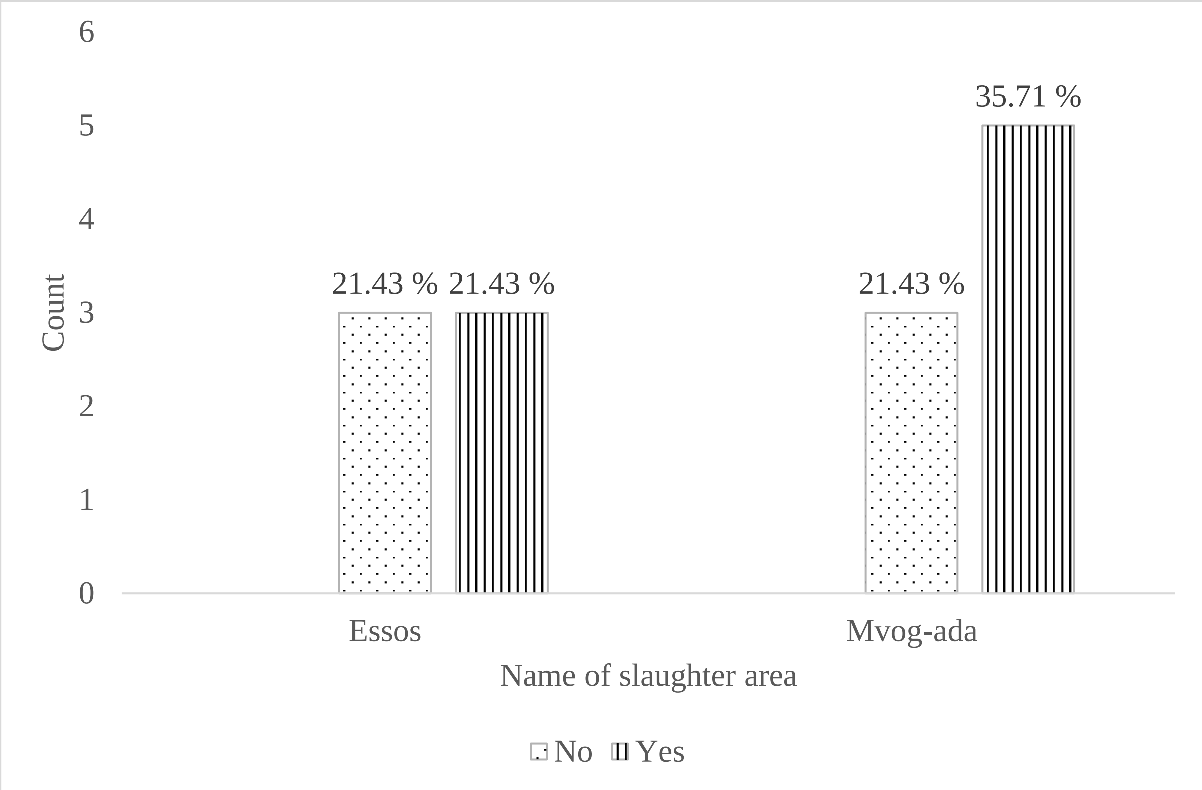

Fig. 11. Use of special protective equipment at informal slaughterhouses.

Overall, in both informal slaughterhouses 50 % use special protective equipment and 37.50 % do not use them (Fig.12).

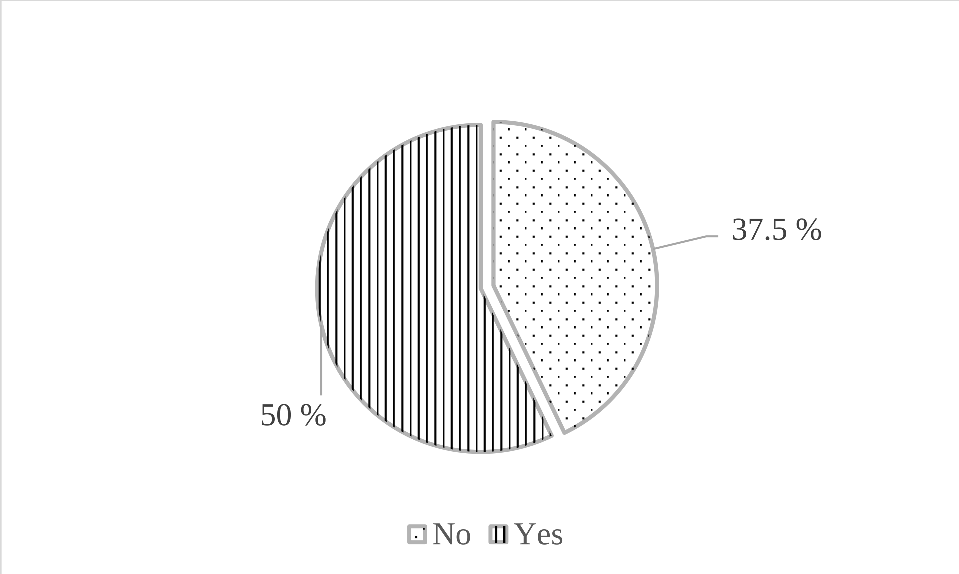

Fig. 12. Overall use of special protective equipment in both informal slaughterhouses.

III.1.2 Physicochemical and microbiological analysis.

III.1.2 1. Physicochemical and microbiological analysis of the Mvog-ada informal slaughterhouse.

The results of the physicochemical and microbiological characteristics of the Mvog-ada informal slaughterhouse wastewater are presented in Table X. This samples revealed high concentrations in chemical and organic substances as well as microbiological pathogens. The mean pH (8.08 ± 1.44) shows that the sample is slightly basic. The mean conductivity value was 4663.33 ± 1678.16 µS/cm. This value far superior to 1000 µS/cm reveals the high mineralisation of informal slaughterhouse wastewater. Chemical parameters such as Nitrates and phosphate revealed the nitrate value to be low(12.37 ± 6.77 mg/L) but phosphate level was high (252.6 ± 175.10 mg/L) when compared to the norms. Organic parameters such as COD and BOD_5 were relatively high.The mean values obtained were 1493.33 ± 1673.46 mg/L and 1016.67 ± 1115.89 mg/L respectively. The wastewater samples revealed very high level of faecal coliforms and faecal streptococci which were of the order of 1907000 ± 2184089.51 and 612000 ± 415249.32 respectively.

Table. X. Physicochemical and microbiological characteristics of the Mvog-ada informal slaughterhouse wastewater.

Sample	Raw effluent	MINEPDEP norms	WHO norms
pH	8.08 ± 1.44	6,5-8,5	6.5-8.5
Temperature (°C)	27.67 ± 1.01	30	<40°C
Conductivity (µS/cm)	4663.33 ± 1678.16	< 200	900
Salinity (‰)	2.68 ± 1.18	/	
Color (PtCo)	54208.33 ± 54944.62	/	less than15 TCU
Total suspended solids	9666.67 ± 10254.83		30 mg/L
Total dissolve solids (mg/L)	2600.33 ± 1108.16	/	<1200 mg/L
Resistivity(Ω/cm)	232.3 ± 113.07	/	/
Redox potential (mV)	-9.47 ± 12.79	/	/
Nitrates (mg/L)	12.37 ± 6.77	30	50 mg/L
Phosphates (mg/L)	252.6 ± 175.10	< 30	0-5 mg/L
COD (mg/L)	1493.33 ± 1673.46	≤ 200	20 mg/L
BOD_5 (mg/L)	1016.67 ± 1115.89	≤ 50	2 mg/L
Faecal coliforms (CFU/100 mL)	1907000 ± 2184089.51	≤ 2000	≤ 2000
Faecal streptococci (CFU/100 mL)	612000 ± 415249.32	≤ 1000	≤ 1000

III.1.2 1. Physicochemical and microbiological characteristics of the Mvog-ada surface water.

The surface water collected at 3 points along the river Ewoé (Mvog-ada) watercourse were analysed and the results are presented in table XI. This result shows that this water generally contains more or less high concentrations in chemical an organic substances as well as microbiological pathogens. The lowest pH was 6.65 ± 0.25 (S1) and the highest value 7.44 ± 0.90. This values are within the Cameroonian (6.5 - 8.5) and WHO norms (6.5 - 8.5), while the lowest value of the temperature was 27.20 ± 1.45 (S2) and the highest value recorded was 27.73 ± 0.56 (S3) also within Cameroonian norms (30°C) and WHO norms (40°C).

Table XI. Physicochemical and microbiological parameters of the watercourse at the Mvog-ada informal slaughterhouse.

Sample	Upstream	Point of contact	Downstream	MINEPDEP norms	WHO norms
pH	6.65 ±0.25	7.11±0.54	7.44±0.90	6,5-8,5	6.5-8.5
Temperature (°C)	27.33 ±1.27	27.20±1.45	27.73±0.56	30	<40°C
Conductivity (µS/cm)	328.33 ±23.86	445.67±44.46	382±14.85	< 200	900
Salinity (‰)	0.16 ±0.01	0.21±0.02	0.18±0.01	/	
Color (PtCo)	84 ±32.05	688.33±524.94	186.33±90.02	/	less than15 TCU
Total suspended solids	12.67 ±1.56	135.33±122.87	19.33±5.80	/	30 mg/L
Total dissolve solids (mg/L)	158.27 ±11.67	215.90±22.43	184.33±7.15	/	<1200 mg/L
Resistivity(Ω/cm)	3040 ±216.56	2255.33±239.69	2616.67±97.41	/	/
Redox potential (mV)	17.87 ±8.87	14.73±6.88	18.43±5.14	/	/
Nitrates (mg/L)	11.0 ±4.24	7.73±4.77	14.3±5.10	30	50 mg/L
Phosphates (mg/L)	2.71 ±2.73	16.70±19.92	4.09±3.62	< 30	0-5 mg/L
COD (mg/L)	119 ±88.46	212.67±85.03	140.33±39.97	≤ 200	20 mg/L
BOD_5 (mg/L)	33.67 ±28.99	191.67±163.27	55.67±34.30	≤ 50	2 mg/L
Faecal coliforms (CFU/100 mL)	1966.67±1665.33	10166.67±5198.40	2833.33±737.11	≤ 2000	≤ 2000
Faecal streptococci (CFU/100 mL)	1033.33±1001.67	2800±2163.33	666.67±450.93	≤ 1000	≤ 1000

Concerning the conductivity along the watercourse 328.33 ± 23.86 µS/cm was recorded at the upstream (S1) and 445.67 ± 44.46 µS/cm was recorded at the point of contact which was found to be above Cameroonian norms 200. µS/cm. Chemical parameters revealed that, the nitrate level in the course of the river was lowest at S2 (7.73 ± 4.77 mg/L) and highest at S3 (14.3 ± 5.10 mg/L) which were acceptable according to the Cameroonian and WHO norms (30 and 50 mg/L respectively) while the Phosphate level was lowest at S1 (2.71 ± 2.73) and highest at S2 (16.70 ± 19.92) found to be acceptable within the Cameroonian norms for surface water discharge (30 mg/L). The Organic substance notably COD and BOD5 revealed that the lowest COD level was 119 ± 88.46 (S1) and the highest was 212.67 ± 85.03 (S2) found to be above WHO norm (20 mg/L) while in the BOD revealed low values of 33.67 ± 28.99 (S1) and the highest values was 191.67 ± 163.27, above WHO norms (2 mg/L). Concerning the microbiological parameters obtained (FC and FS) obtained in this study shows relatively high concentrations. The level of total faecal coliform was lowest at 1966.67 ± 1665.33 CFU/100 mL (S1) and highest at 10166.67 ± 5198.40 CFU/100 mL (S2) above Cameroonian and WHO norms of 2000 CFU/100 mL while the lowest level of faecal streptococci was 666.67 ± 450.93 CFU/100 mL (S3) and 2800 ± 2163.33 CFU/100 mL (S2) which shows that S2 was above Cameroonian and WHO norms of 1000 CFU/100 mL.

III.1.3.Environmental and socio-sanitary impacts of the informal slaughterhouse wastewater.

III.1.3.1. Socio-demographic characteristics of households.

In 71.9 % of the households respondents in Essos are found at lowlands and in Mvog-ada 63.4 % are found at lowlands. In general 67.1 % of the respondents' households in both neighbourhood are found at lowland levels. 49.9 % and 56.1 % of the respondent households in Essos and Mvog-ada respectively were owners of the house, so in both neighbourhoods 52.1 % were owners of the house. Most of those who responded to the questionnaire in Essos were members of the household (34.4 %) and in Mvog-ada most were the head of households (36.6 %). However most of the respondents (34.2 %) were head of the households in both neighbourhoods. About 31.3 % of the respondent households in Essos were in the age range of 31-40 years and 26.8 % of respondents in Mvog-ada were of the age range of 21-30 years. So in both neighbourhoods the respondents were of the age range of 31-40 years (26 %).Of which 79.9 % and 56.1 % in Essos and Mvog-ada respectively were females and 21.9 % and 39 % in Essos and Mvog-ada respectively were males. Most of the respondents in both neighbourhoods were females (63 %). Concerning the level of education 62.5 % and 56.1 % of the respondents in Essos and Mvog-ada respectively ended at secondary level and so in both neighbourhood most of the respondent ended at secondary level (58.9 %). In 37.1 % and 36.6 % in Essos and Mvog-ada respectively have been living in the neighbourhood for more than 15 years and only 31 % and 2.4 % in Essos and Mvog-ada respectively have lived in the neighbourhood for less than 1 year. In both neighbourhoods most respondents (37 %) have lived for more than 15 years. 39.7 % of both neighbourhoods had between 4-6 people living in the household.

III.1.3.2. Environmental impact of slaughterhouse wastewater

III.1.3.2.1. Distance from slaughter area

The semi-structured questionnaire revealed that in Essos 16.44 % of the respondents were found to live between 50-100m, 15.07 % within 0-50m and 12.33 % within 100-500m away from the informal slaughterhouse, while in Mvog-ada 24.66 % were found to live within 50-100m, 16.44 % within 100-500m and 15.07 % within 0-50m away from the informal slaughterhouse (Fig.13).

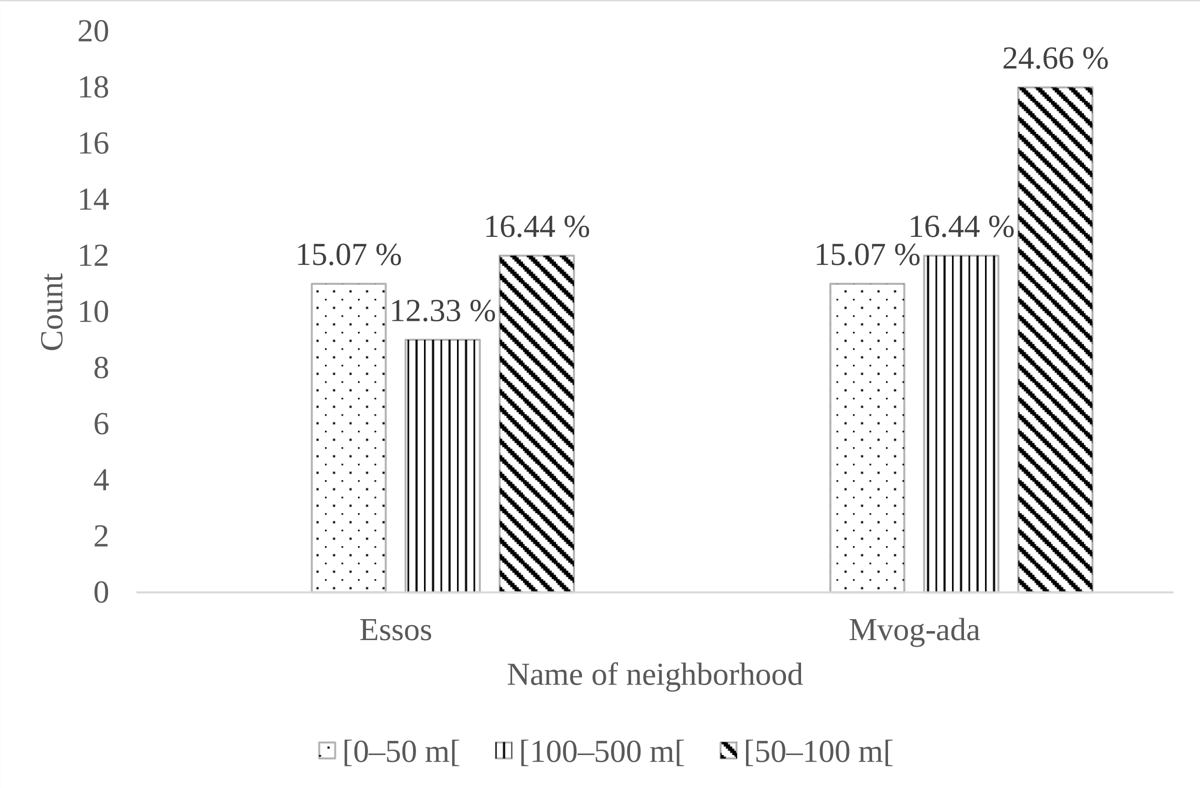

Fig. 13. Distance of households from informal slaughterhouse.

Generally most respondents were found to live within 50-100 m (41.10 %), followed by residents who lived within 0-50 m and 28.77 % within 100-500 m (Fig.14).

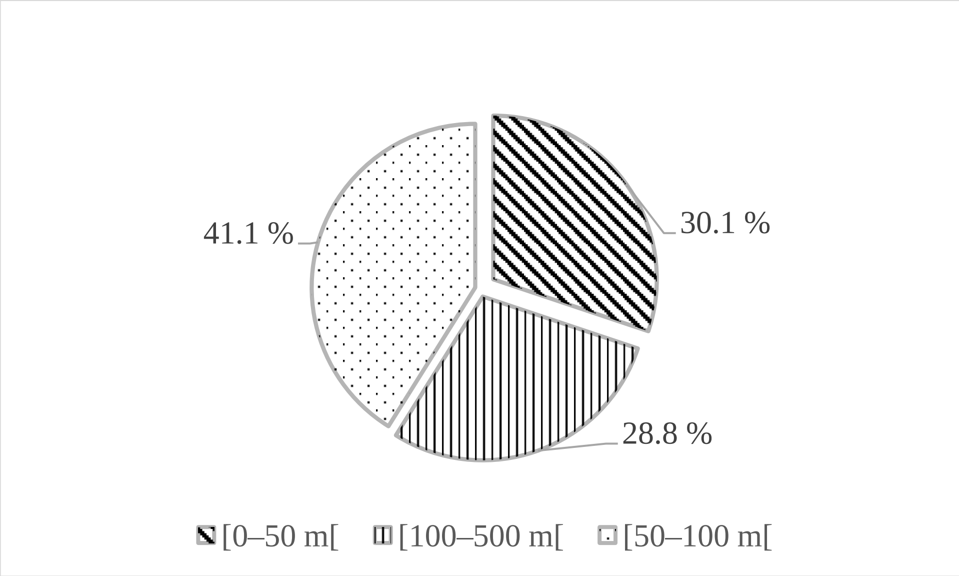

Fig. 14. Overall, distances of households from informal slaughterhouse in both neighbourhoods.

III.1.3.2.2. Nuisances faced daily due to the presence of the informal slaughterhouse.

Respondents in both neighbourhoods confirm to face daily nuisances as seen in figure 16, 20 % said yes ,20 % said no and 1.43 % said they have no idea while in Mvog-ada 30.00 % said yes, 22.86 % said no and 5.71 % said they have no idea.

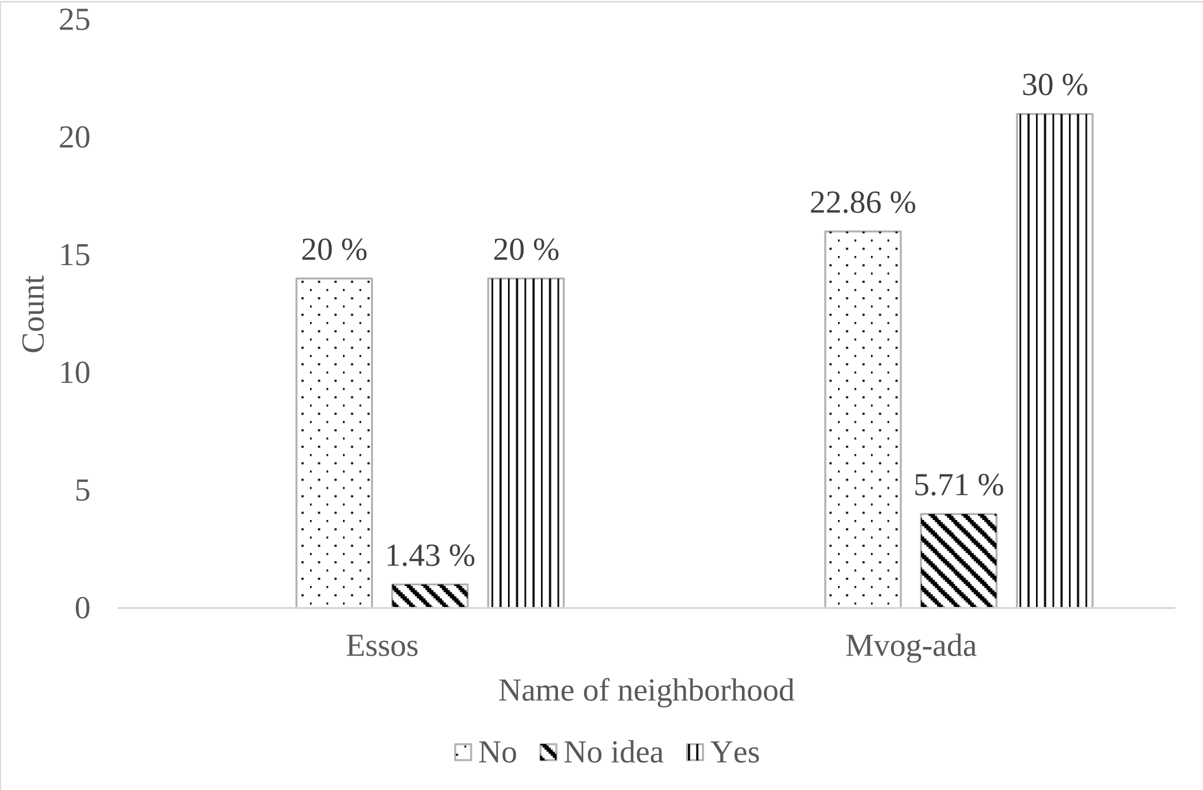

Fig. 15. Nuisances faced daily due to the presence of the informal slaughterhouse.

From a general point of view in both neighbourhoods, 47.95 % of respondents complained of daily nuisance, 41.10 % said no and 6.85 % have no idea (Fig. 16).

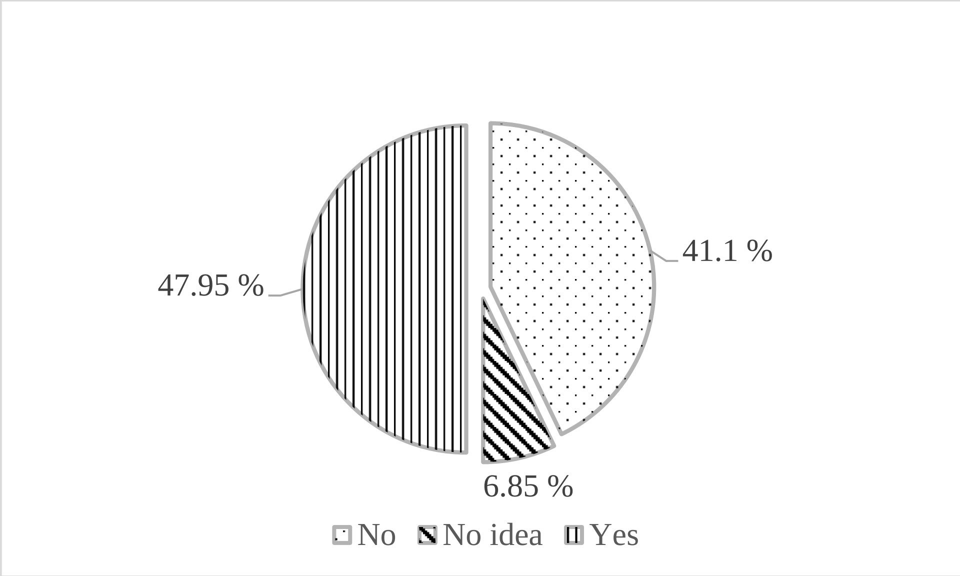

Fig. 16. Overall Nuisances faced daily due to the presence of the informal slaughterhouse.

III.1.3.2.3. Type(s) of nuisances encountered by the respondents daily.

Respondents in both neighbourhoods face daily nuisances due to the presence of the informal slaughterhouse. In Essos 13.04 complain of floods, 21.74% complain of insects (flies, mosquitoes, cockroaches etc.), 18.48 % of small rodents, 9.78 % of noises and 14.13 % of odours. While in Mvog-ada 19.42 % complain of floods, 28.74 % of insects, 23.74% of small rodents, 17.99 % of noises and 21.58 % of odours.

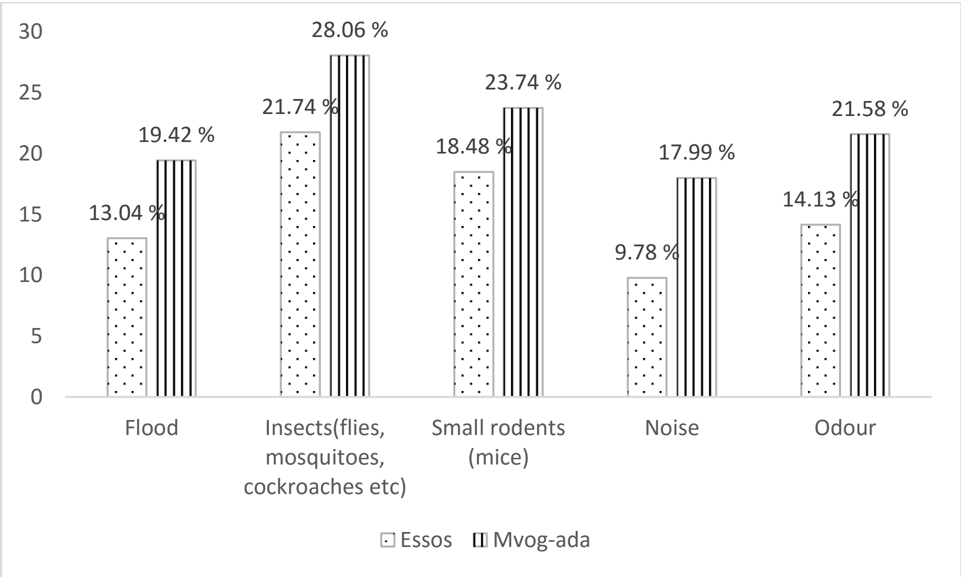

Fig. 17. Type(s) of nuisances encountered by the respondents daily due to the presence of the informal slaughterhouse.

From an overall point of view 26.11 % complain of insects (flies, mosquitoes, cockroaches etc.), 22.12 % complain of small rodents (mice), 19.03 % complain of odours, 17.7 % complain floods and 15.04 % complain of noise (fig.18).

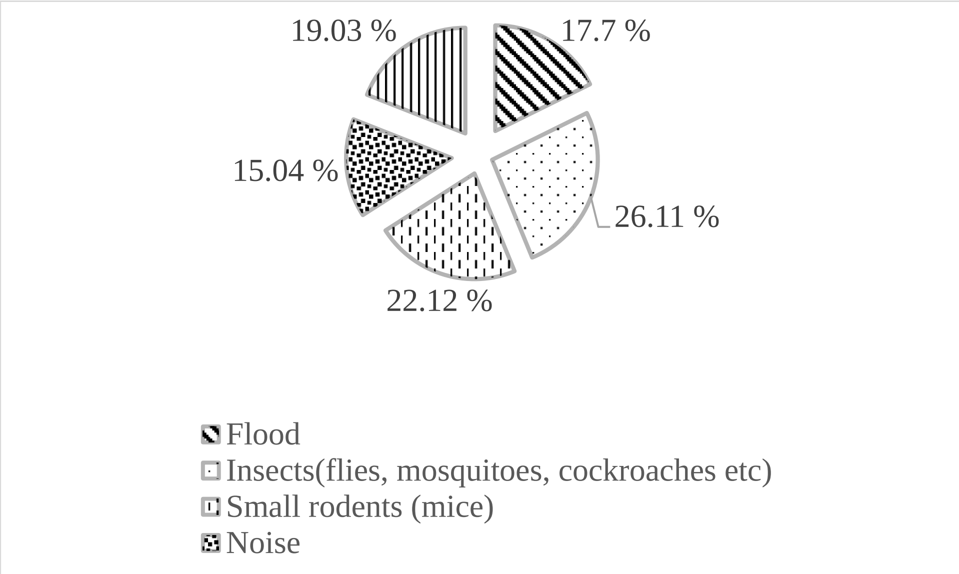

Fig. 18. Overall view of the type(s) of nuisances encountered by the respondents daily due to the presence of the informal slaughterhouse.

III.1.3.2.4. Informal slaughterhouse wastewater arrival in households.

In Essos 31.34 % informal slaughterhouse wastewater doesn't arrive their homes and 13.43 % said yes they experience the informal slaughterhouse wastewater arriving their home while in Mvog-ada 34.33 % said no to the question and 20.90 % said yes (Fig.17).

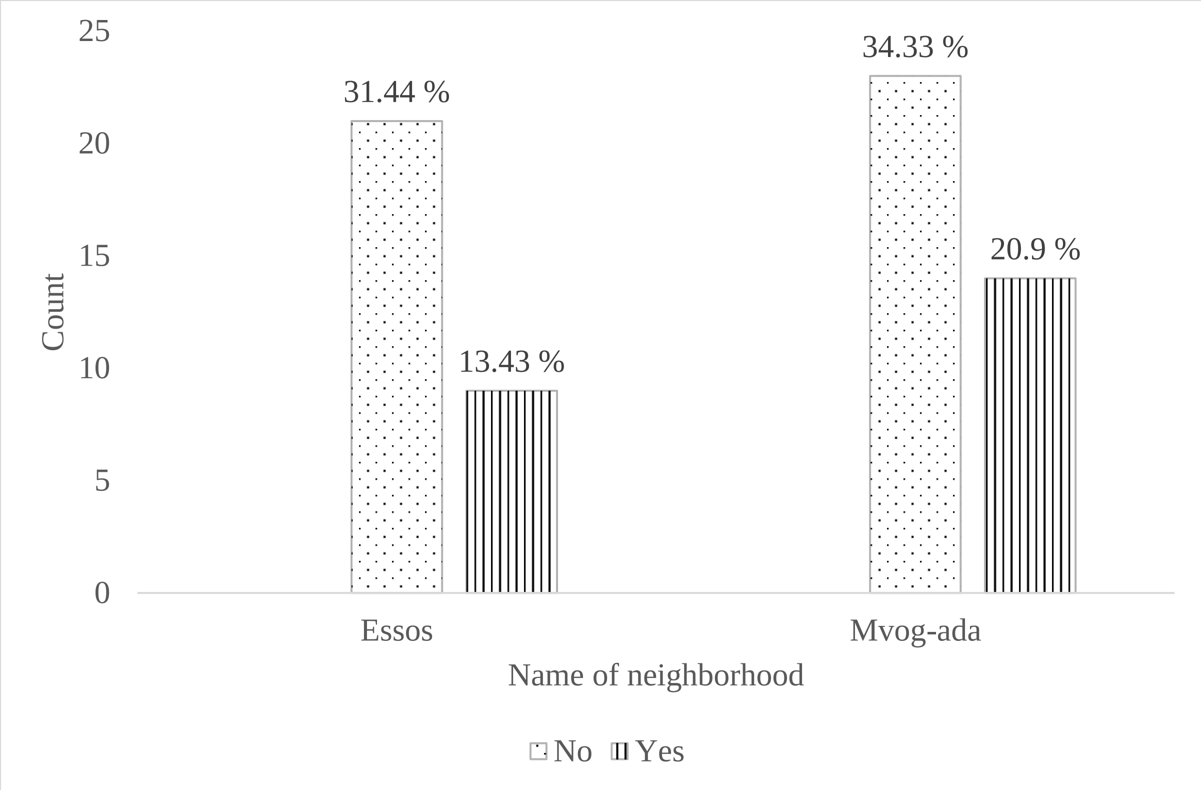

Fig. 19. Arrival of informal slaughterhouse wastewater at households.

From a general point of view as shown in figure.19, 60.27 % said no the waste doesn't arrive their homes and 31.51 % said yes to the question (Fig.18).

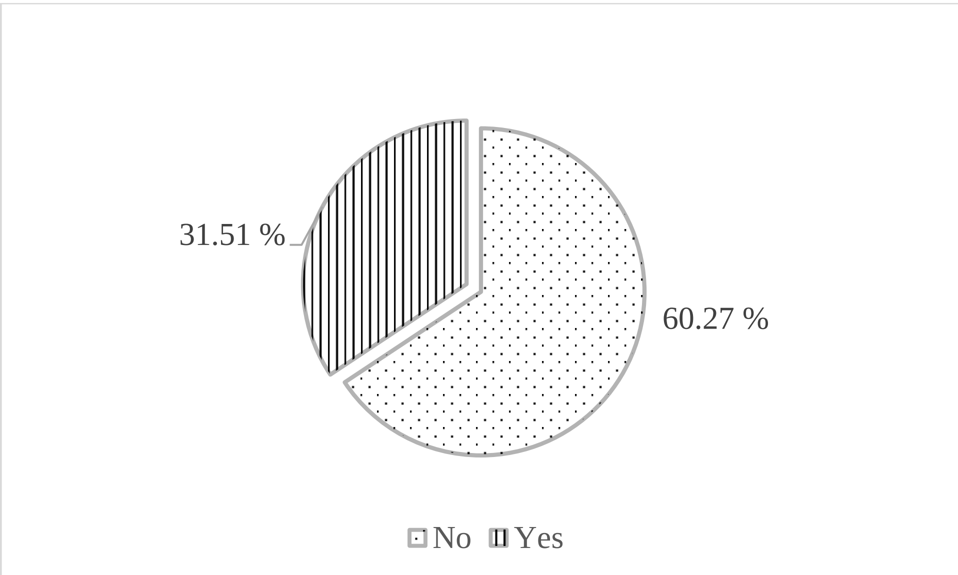

Fig. 20. Overall arrival of informal slaughterhouse wastewater at households in both neighbourhoods.

III.1.3.2.5. Affected components of the environment.

Concerning the components of the environment affected, most of the respondents believed that the air is affected (42.2 %), some said its water (33.03 %) and 24.77 % said the soils (Fig.

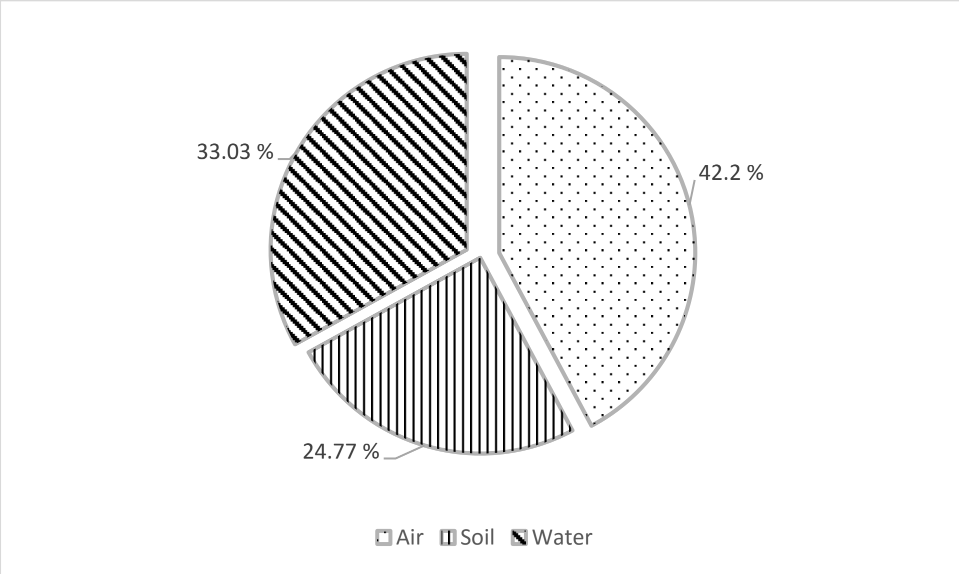

Fig. 21. Opinion of respondents on the components of the environment affected by the informal slaughterhouse.

III.1.3.2.6. Impacts on the environment.

Most respondents believed that it impacts is seen in the colour of the water (38.46 %) and 32.05 % say the impact is felt on the odour produced by the informal slaughterhouse and 19.23 % believe it's the development of vegetation while 10.26 % say the environment is not affected.

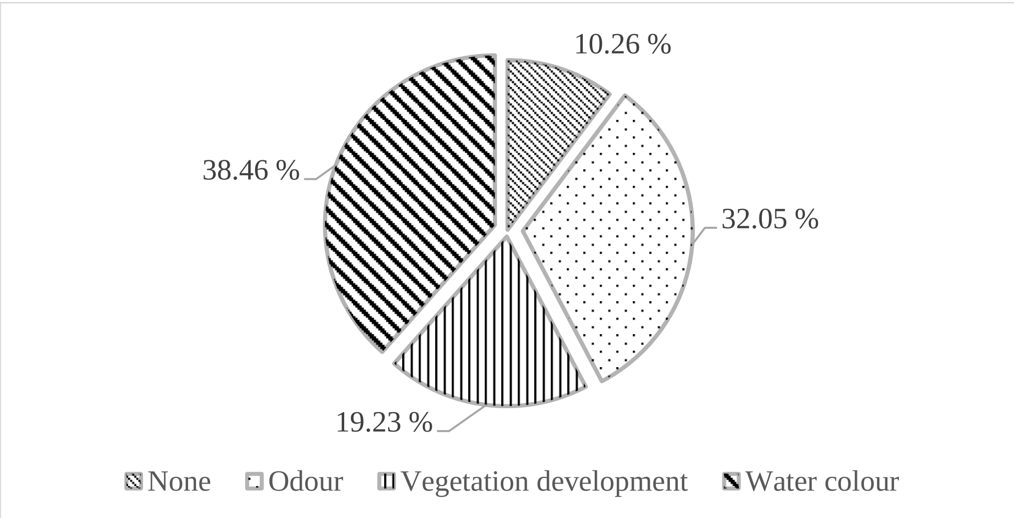

Fig. 22. Opinion of respondents on the impact of the informal slaughterhouses on the environment.

III.1.3.3. Socio-sanitary impacts.

III.1.3.3.1. Main source of drinking water.

The Respondents of both Essos and Mvog-ada use as their main source of drinking water, tap water (41.10 % and 54.79 % respectively). However in Essos 1.37 % drink borehole water and 1.37 % drink both tap water and well water. Meanwhile in Mvog-ada 1.37 % use tap water and mineral water (Fig.19).

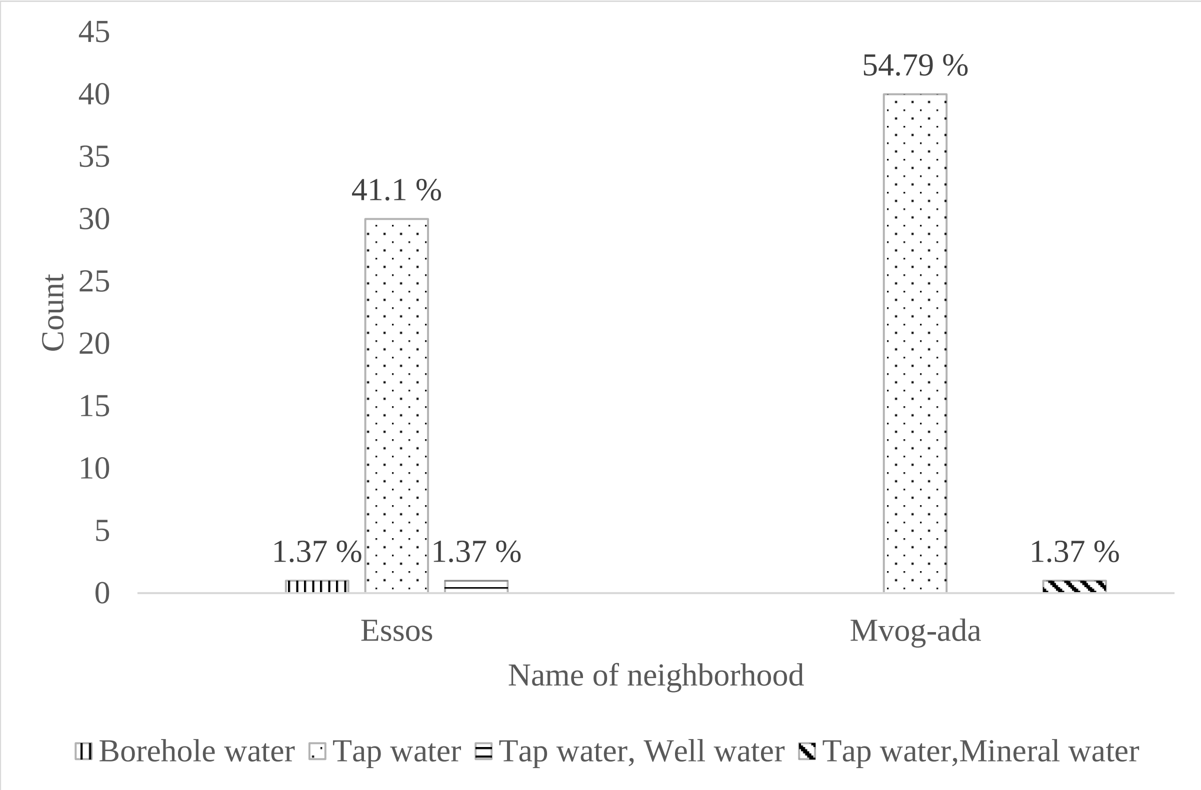

Fig. 23. Main source of drinking water.

In general in both neighbourhoods most respondents use tap water as their source of drinking water(95.89 %) and 1.37 % use borehole water,1.37 % use tap water and well water finally 1.37 % use tap water and mineral water (Fig. 21).

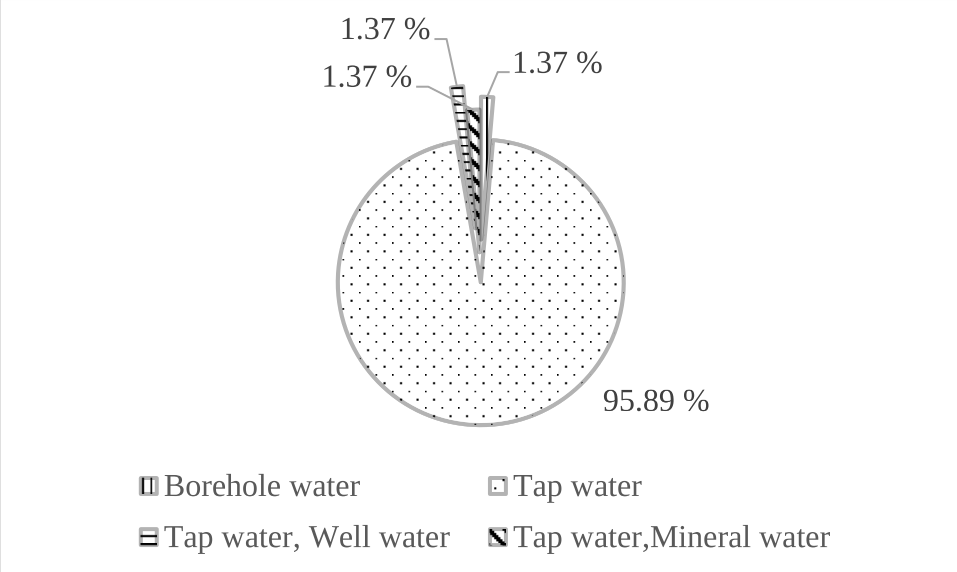

Fig. 24. Overall main source of drinking water.

III.1.3.3.2. Treatment of drinking water.

In Essos 36.23 % of the respondents do not bring any treatment to their drinking water, 2.90 % do filtration before drinking their water and 1.45 % chlorinate their drinking water. However in Mvog-ada 49.28 % do not bring any treatment to their water, 4.35 % filter their water, 2.90 %, chlorinate their water, 1.45 % boil their water as means of treatment, 1.45 % chlorinate and filter their water (Fig. 21).

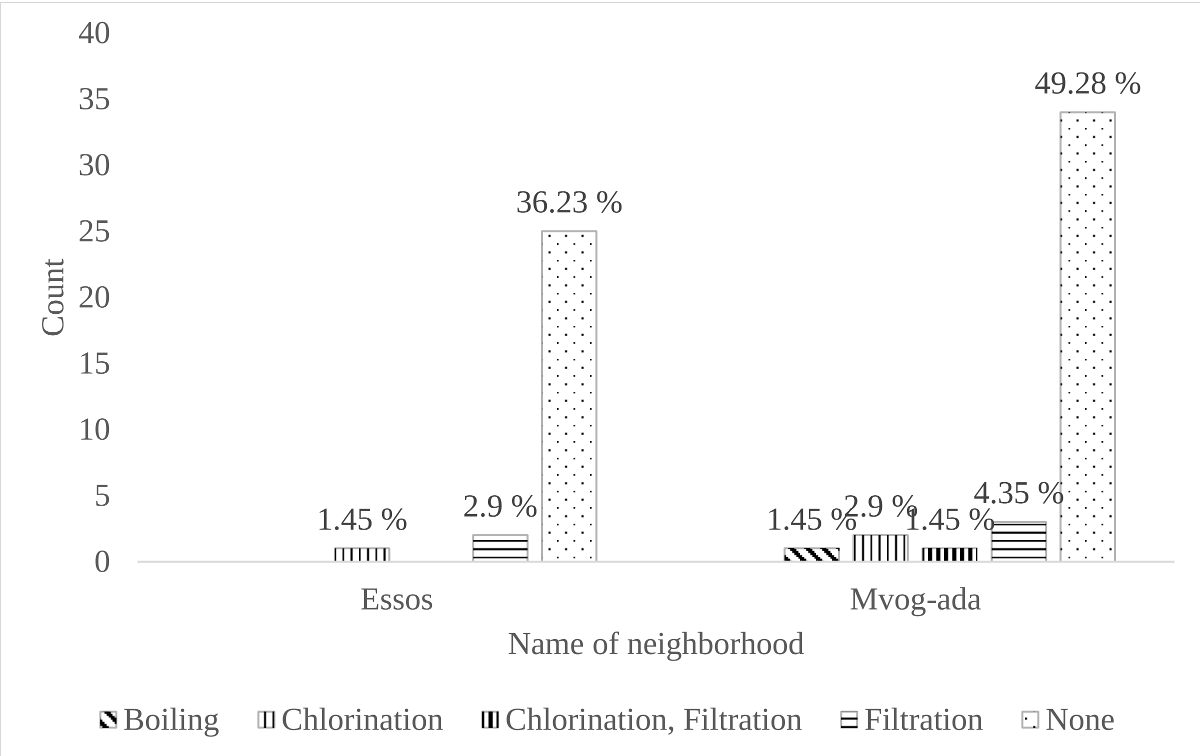

Fig. 25. Different treatments applied on drinking water.

Generally in both neighbourhoods up to 80.82 % do not treat their water, 6.85 % filter their water, and 4.11 % chlorinate their water, 1.37 % and also 1.37 %boil their water. (fig.22).

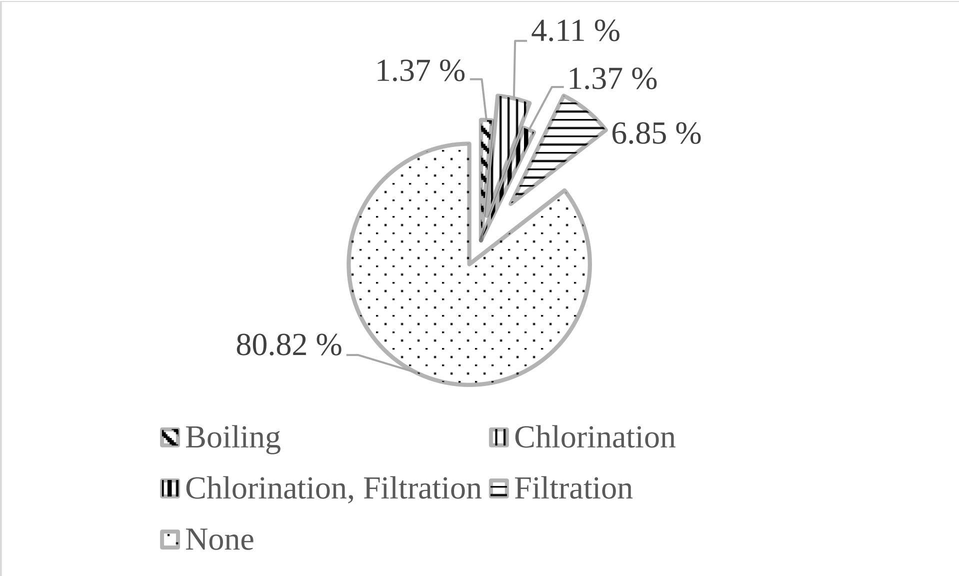

Fig. 26. Overall treatment applied on drinking water in both neighbourhoods.

III.1.3.3.3 Shortage in drinking water.

Concerning shortages in drinking water, 32.86 % complain about shortage on their water source and 11.43 % said no in the Essos while in Mvog-ada 54.29 % also complain and 1.43 % said no.

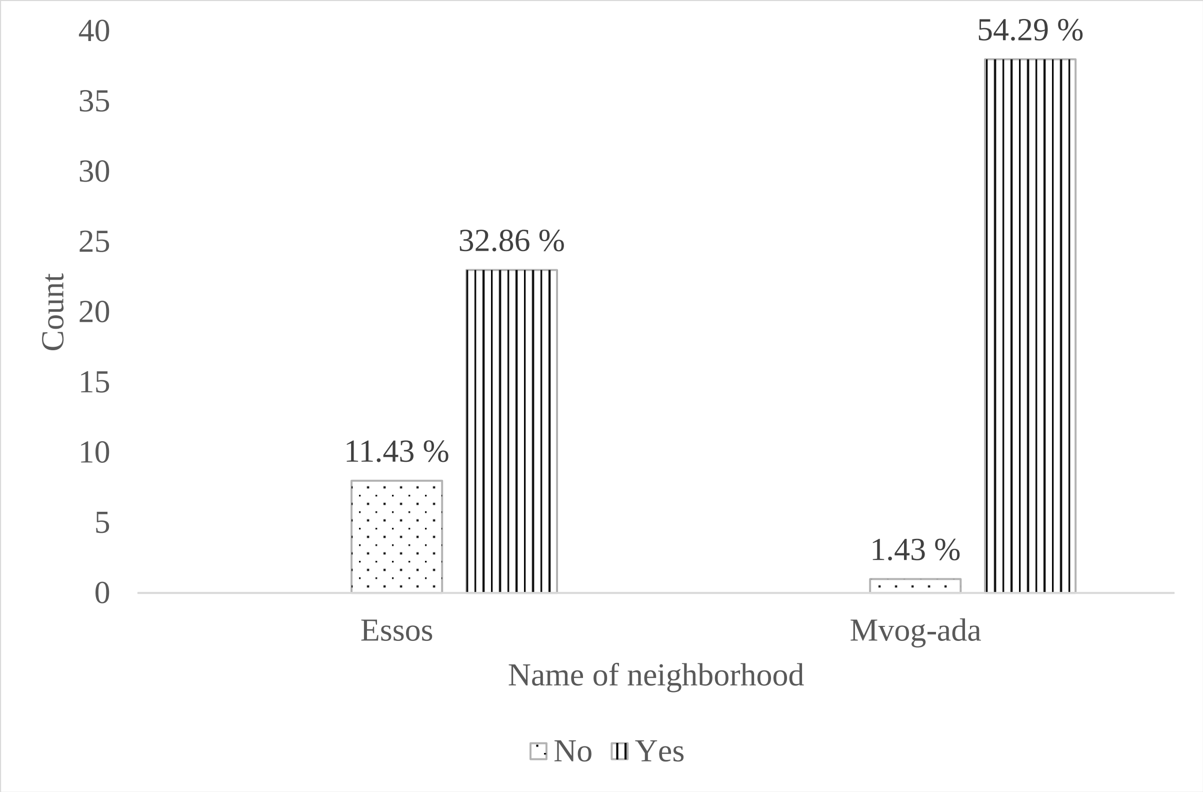

Fig. 27. Shortages encountered in source of drinking water.

According to figure 25 in both neighbourhoods 83.56 % complain of shortages in water and only 12.33 % said no.

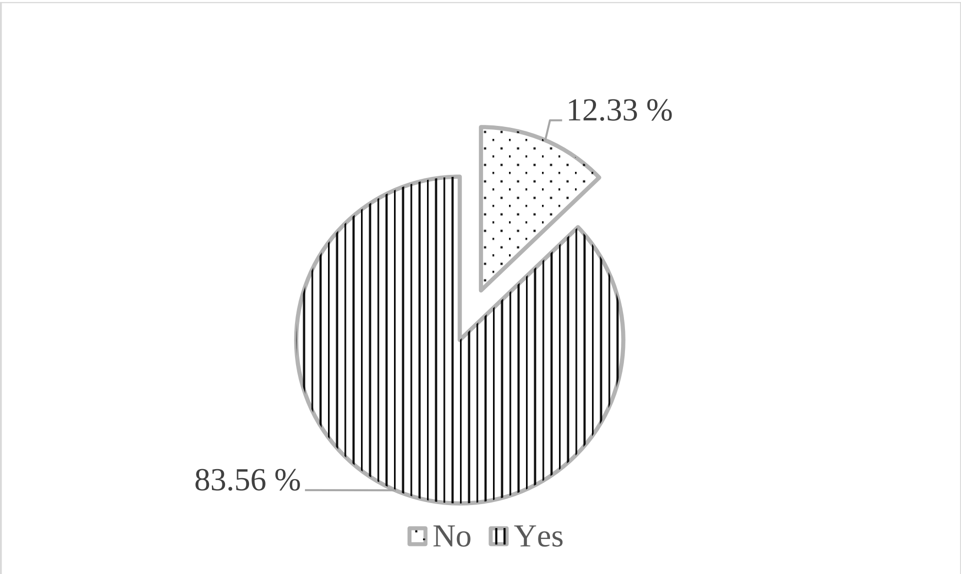

Fig. 28. Overall shortages encountered in source of drinking water in both neighbourhoods.

III.1.3.3.4. Season of shortage.

These shortages occur mostly during some seasons of the year and 19.30 % say this shortage occurs in both season, 10.53 % say it is in the dry season and 5.26 % say it is not frequent meanwhile in Mvog-ada 38.60 % said it happened in both season, 12.28 % said in the dry season, 10.53 % said it is not frequent and 3.51 % said during the rainy season (Fig. 25).

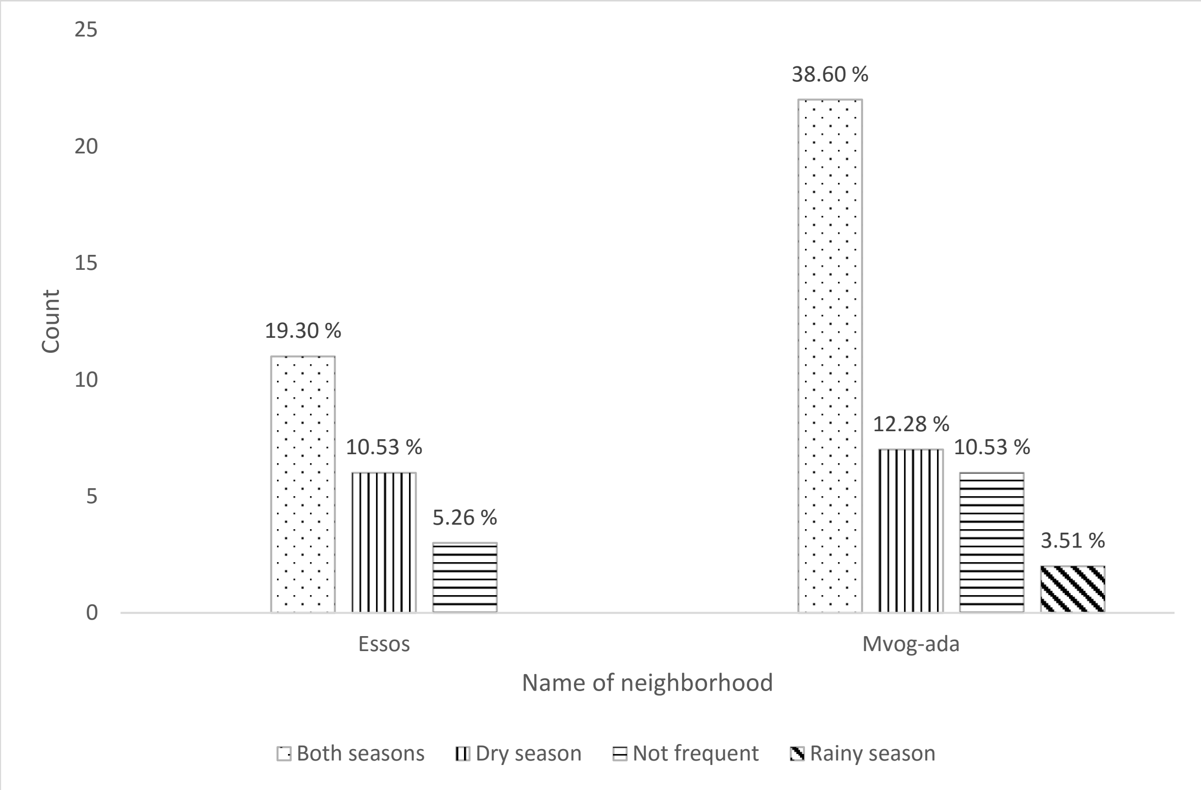

Fig. 29. Different seasons of occurrence of shortage.

In general 45.21 % affirm that the shortage occurs in both season, 17.81 % said during the dry season, 12.33 % said the shortage wasn’t frequent and 2.74 % said it occurs during the rainy season (fig.26).

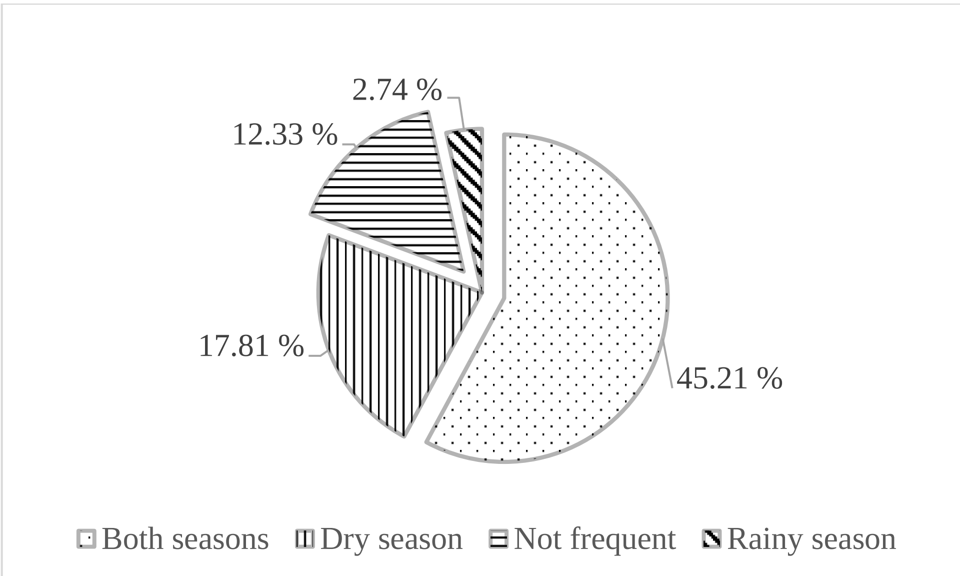

Fig. 30. Overall Season of occurrence of shortage in both neighbourhoods.

III.1.3.3.5. Ground water contamination.

Groundwater is potentially susceptible to be polluted by anthropogenic activities. In Essos 23.44 % believed that their underground water are pollute, 15.63 % said no to the question and 3.31 % said they don’t know while in Mvog-ada 39.06 % said yes their groundwater is polluted and 18.75 % said no (Fig. 27).

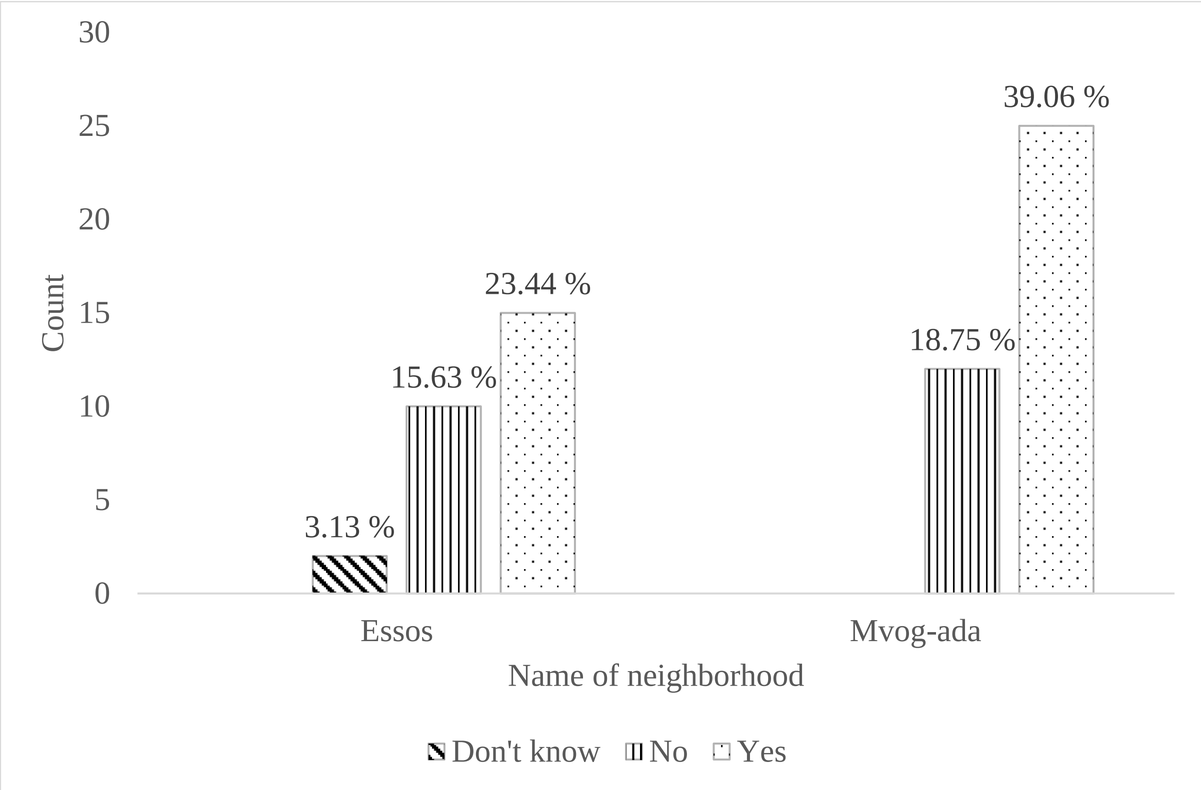

Fig. 31. Opinion of respondent about the groundwater contamination.

In general 54.79 % confirm that their ground water was contaminated, 30.14 % said no there is no contamination while 2.74 % had no idea (fig.28).

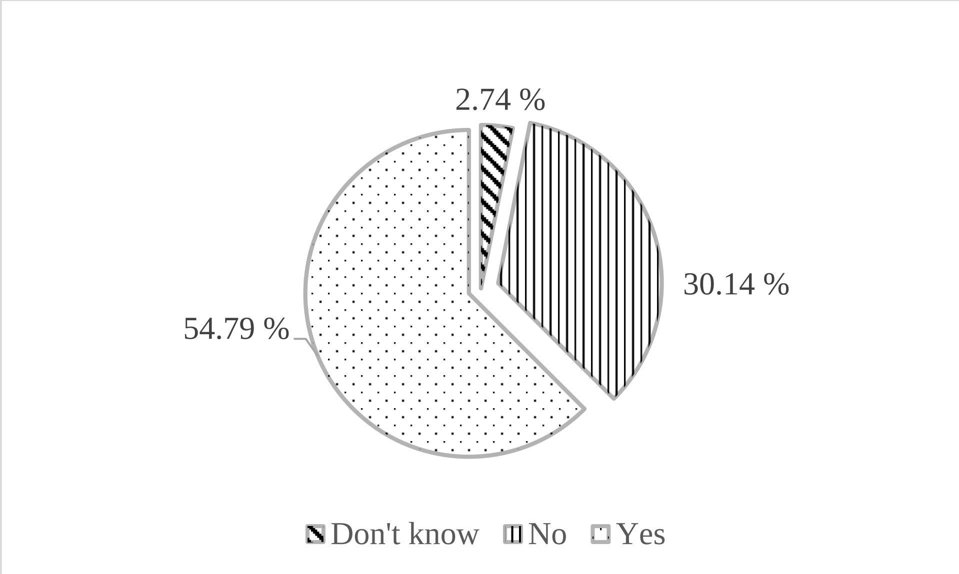

Fig. 32. Overall groundwater contamination in both neighbourhoods.

III.1.3.3.6. Frequency of waterborne diseases.

When asked to find out if they have experienced any diseases for the past 6 months, 25. % of the respondents said yes and 18.06 % said No in Essos while in Mvog-ada 45.83 % said yes and 11.11 % said no. (Fig.29) among which most of this diseases where waterborne diseases and malaria.

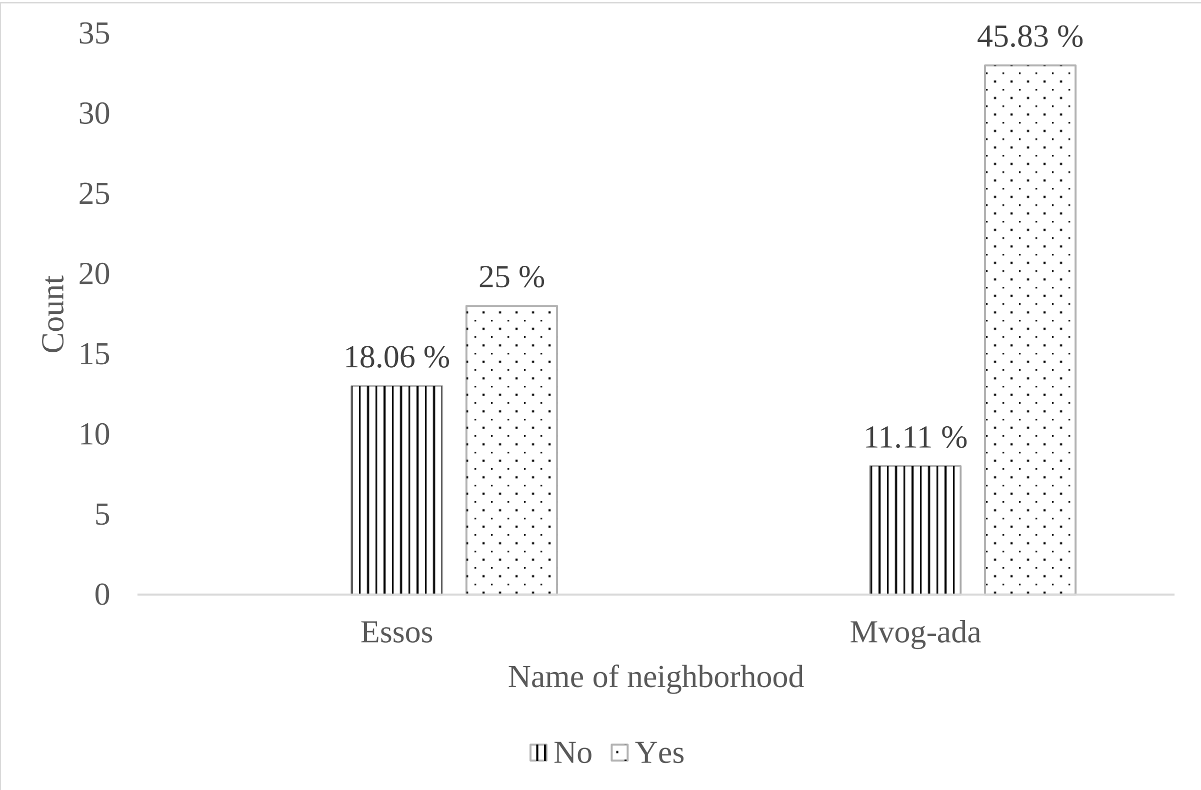

Fig. 33. Opinion of the respondent about the frequency of diseases.

In general 69.86 % of the respondents in both neighbourhood said yes they have experienced health issues in the past 6 months and 28.77 % said no to the question (Fig. 30).

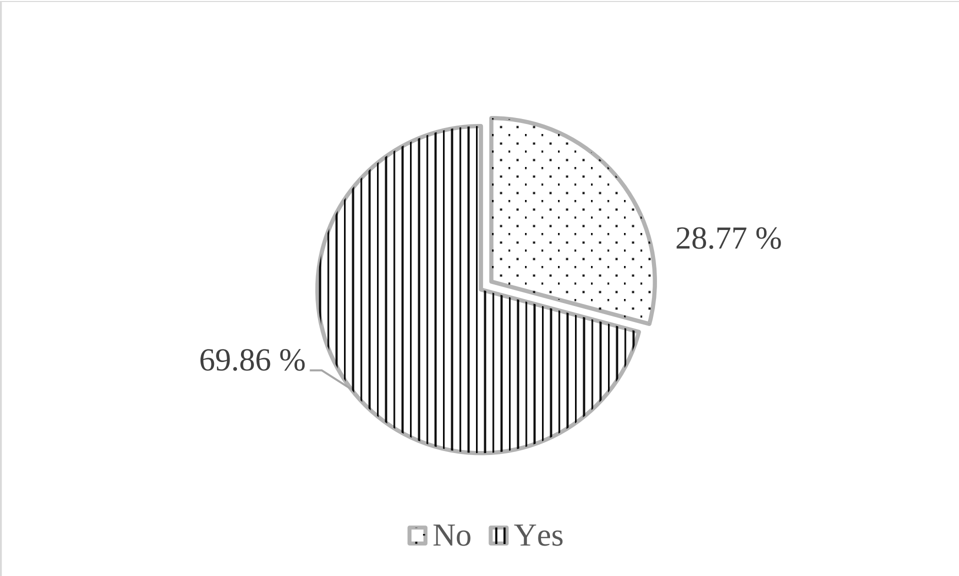

Fig. 34. Overall frequency of diseases in both neighbourhoods.

III.1.3.3.7. Diseases encountered in various neighbourhoods within the last 6 months.

Most respondents have been affected by diseases in the past 6 months which are mostly water related and hence due to the presence of the informal slaughterhouse. In Essos, 17.39 % suffered from Diarrhoea, 4.35 % suffered from dysentery, 10.87 % skin irritation, 8.70 % typhoid, 13.04 % intestinal worms, 36.96 % malaria and 8.70 % from pulmonary infections while in Mvog-ada, 15.22 %, 7.68 %, 13.04 %, 13.04 %, 29.35 %, 21.74 % suffered from diarrhoea, skin irritations, typhoid, intestinal worms, malaria, pulmonary infections respectively (Fig.33).

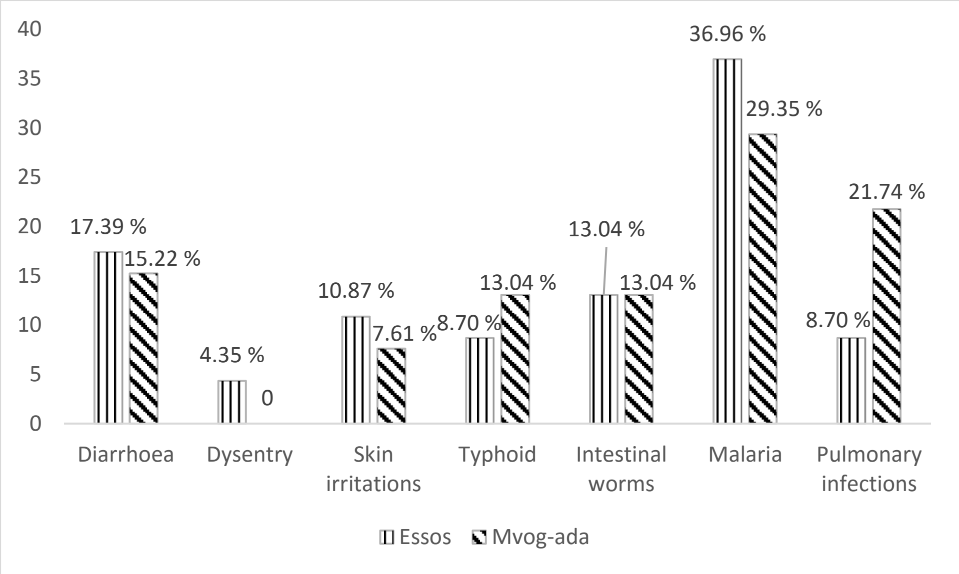

Fig. 35. . Diseases encountered in various neighbourhoods within the last 6 months.

From an overall view, 31.88 %, 17.39 %, 15.94 %, 13.04 %, 11.59 %, 8.70 %, 1.45 % suffered from malaria, pulmonary infections, diarrhoea, intestinal worms, typhoid, skin irritations and dysentery respectively.

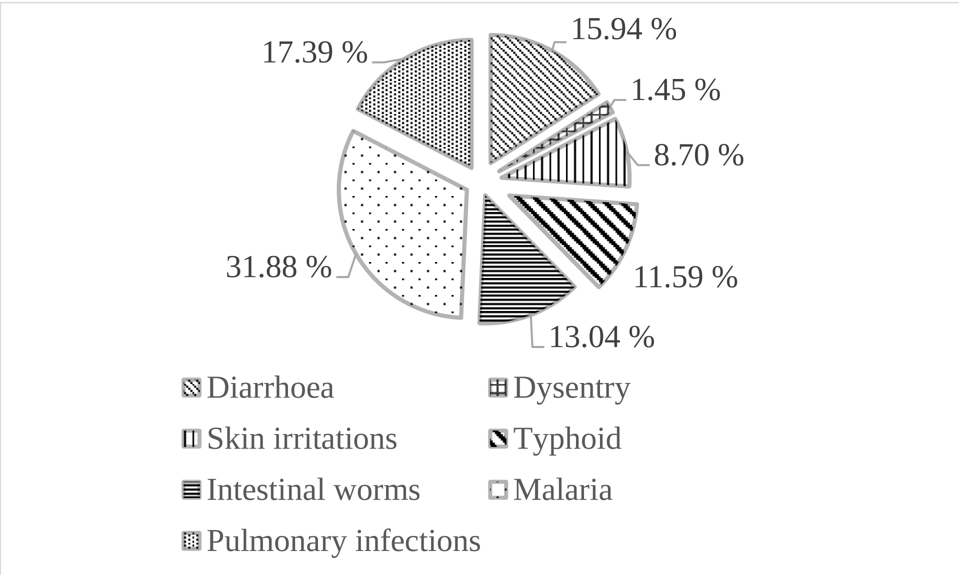

Fig. 36. Overall diseases encountered in various neighbourhoods within the last 6 months.

III.1.3.3.8. Season of occurrence of diseases.

According to the respondents the occurrences of these diseases occur during some seasons. In Essos 17.65 % fell sick both seasons, 9.80 % said during the dry season and 7.84 % said they fell sick during the dry season. However in Mvog-ada 39.22 % confirmed that it was during both seasons, 21.57 % said during the dry season and 3.92 % said it was in the rainy season (Fig.31).

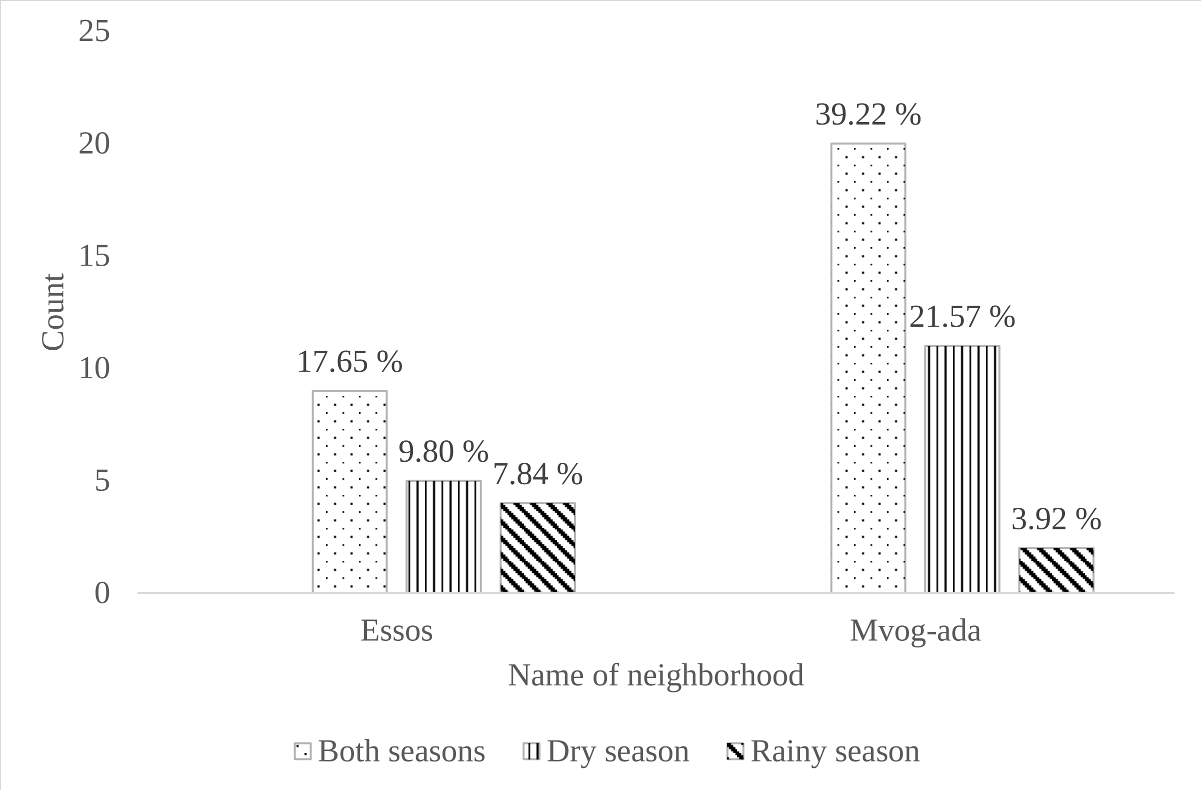

Fig. 37. Opinion of the respondent about season of occurrence of diseases.

From an overall point of view, 39.73 % of the respondents fall sick during both seasons, 21.92 % during the dry season and 8.22 % during the rainy season (Fig.32).

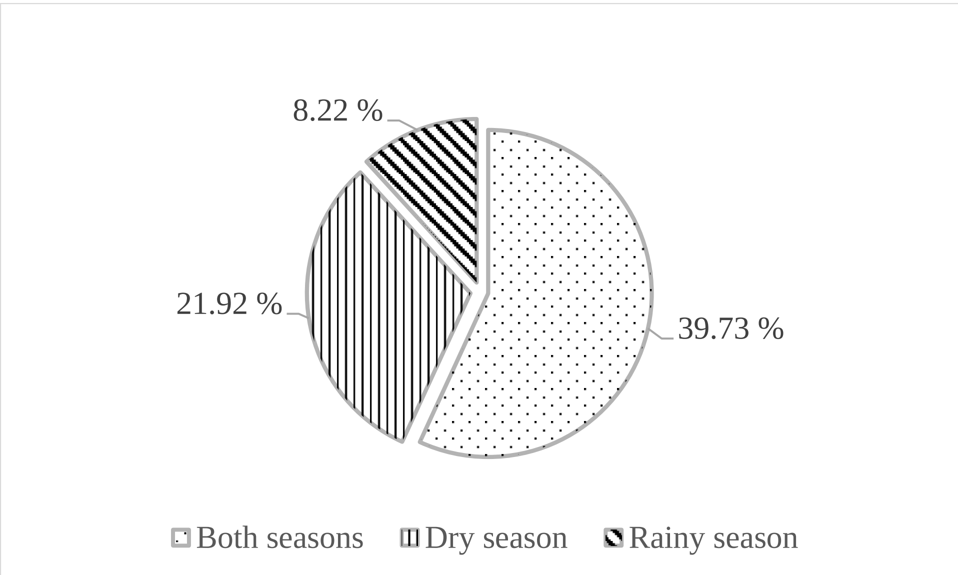

Fig. 38. Overall opinion of respondents on the season of occurrence of diseases.

III.1.3.3.9. Most exposed individuals in various neighbourhoods.

From the semi structured questionnaire it was found that in Essos, 26.32 %. Were children between 0 - 5 years, 26.32 % were adolescents, 36.84 % were adults and 10.53 % were old age people while in Mvog-ada, 37.78% were 0-5 years, 26.67 % were adolescents, 31.11 % were adults and 4.44 % were old aged.

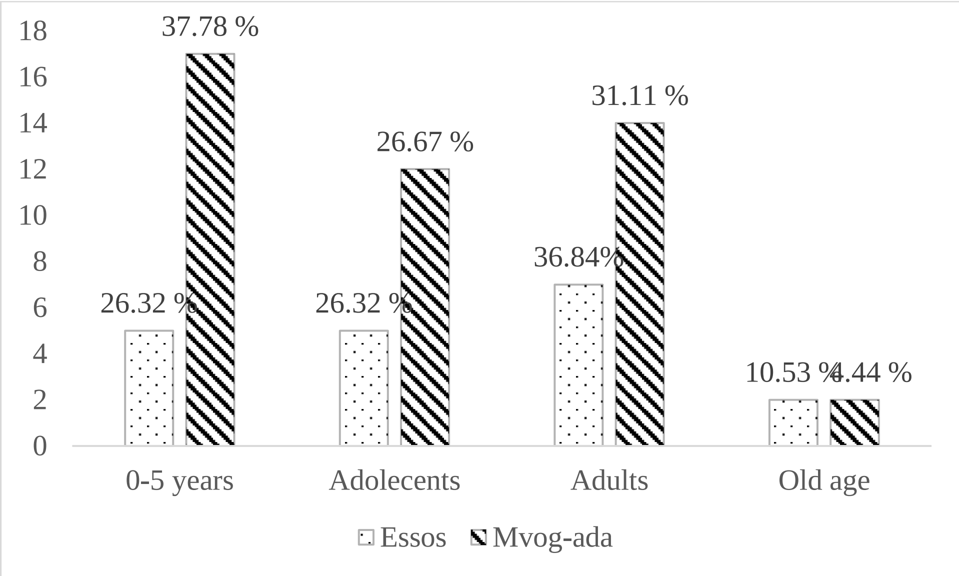

Fig. 39. Most exposed individuals in various neighbourhoods.

In general in both neighbourhoods, 34.38 % were children within 0 -5 years, 32.81 % were adults, 26.56 % were adolescents and 6.25 % were old aged people.

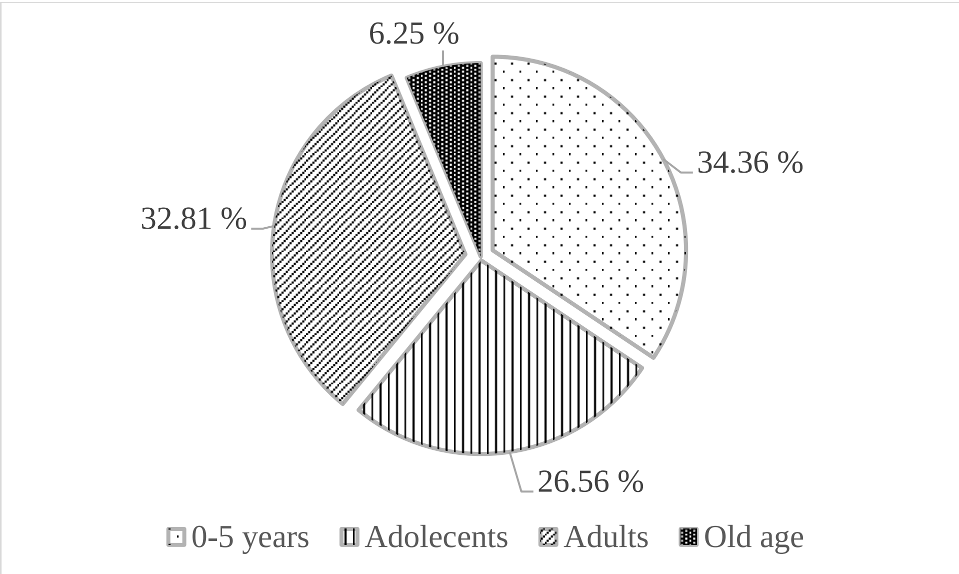

Fig. 40. Overall exposed individuals in both neighbourhoods.

III.1.3.3.10. Causes of encountered diseases in both neighbourhoods.

According to the respondents these diseases are mainly due to poor hygiene (43.49 %), poor water quality (31.88 %) and the presence of the informal slaughterhouse (13.04 %).

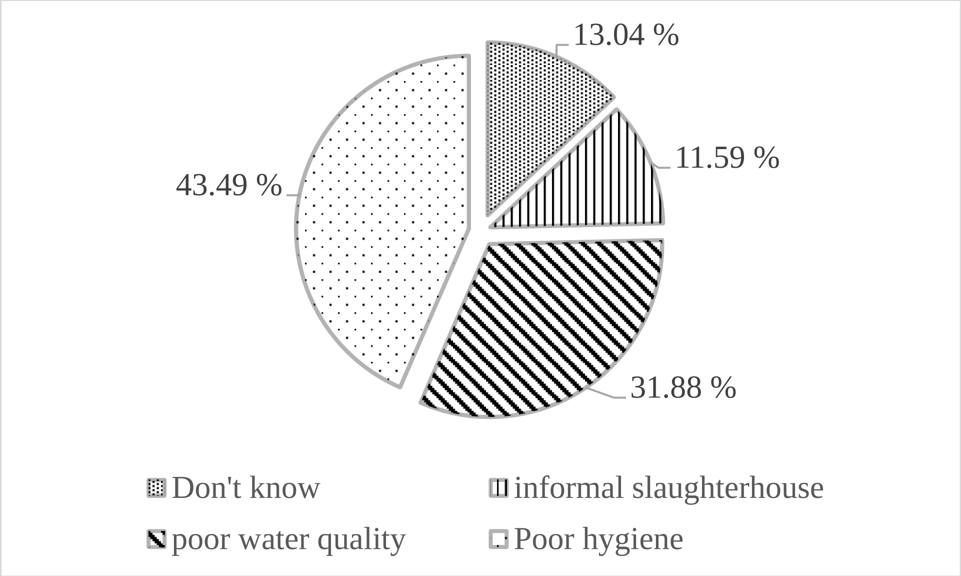

Fig. 41.Overall opinion of respondents on the causes of encountered diseases in both neighbourhoods.

III.2 Discussion.

III.2 1. Actual state of management in the informal slaughterhouses.

The informal slaughterhouse was made up of slaughterers, butchers, cleaners and veterinary officers. Most of these workers are above 30 years (56.25 %) and generally males (87.5 %). 56.25 % had a secondary school and 31.25 % have been working there between 1-5 years and 6-10 years each. This findings corroborates with similar studies Otolorin et *al.* (2015); Abdullahi et *al.*, (2016); Cook et *al.*, (2017) working on public health risk of abattoir operation.

Tap water, well water and borehole water are used by workers to clean the slaughtered animals and most workers use tap water and well water (50 %) and mostly use 15-25l for cleaning per animal. Similar studies was carried out by Cook et *al.* (2017) studying the working conditions and public health risks in slaughterhouses in western Kenya however these authors found out that mostly borehole water was used to for cleaning of animals, this difference could be explained by the fact that Mvog-ada and Essos are old and main neighbourhoods found in the centre of the city of Yaounde and as a result have a good pipe connection these authors did not record the quantity of water used for cleaning per animal due to the fact that they were working only on working conditions and public health risk. The use of this underground water for animal cleaning is a potential health risk since the wastewater (19520 L estimated monthly from pig slaughtering) generated by this activity may leach into the ground water level and using the underground water without prior treatment to clean animals may be a major health concern (Akpor and Muchie, 2011).

The types of waste produced are mainly blood, waste from guts, faeces among others and their main method of disposal are the watercourse and garbage bin (37.50 %). The wastewater generated (19520 L estimated monthly from pig slaughtering) from this activity mainly contains blood and is untreated at disposal. This might lead to the modification of the ecosystem of the environment receiving it (Agendia et *al.*, 2000; Akpor and Muchie, 2011). For these authors, untreated wastewater can be associated to the reduction of aquatic biodiversity due to toxicity, appearance of new species, eutrophication of receiving aquatic medium, degradation of the aesthetics of milieu due to bad odour and perturbations in micro climate of the receiving medium.

Most of the workers (81.25 %) confirm that the clean the slaughterhouse every day and also most use special protective equipment (50 %) yet some do not use these equipment (37.50 %). This frequent cleaning of the informal slaughterhouses implies the use of detergents which contain phosphorous compounds that when in excess can lead to eutrophication when this wastewater is directly discharged into the environment without prior treatment.

III.2 2. Physicochemical and microbiological of the informal slaughterhouse effluents.

The pH ranged from 6.67 - 8.08 which falls within WHO and MINEPDEP standards (6.5 - 8.5) and compared with 7.24 - 7.63 reported by Ojekunle and Lateef (2017) working on the environmental impact of abattoir waste discharge on the quality of surface water and ground water in Abeokuta, where all the samples were slightly alkaline. Therefore, the water samples were unlikely to cause health problems such as acidosis (Asamoah and Amorin, 2011) However, pH played a significant role in determining the bacterial population growth and diversity in surface water. Microorganisms frequently change the pH of their own habitat by producing acidic or basic metabolic waste products (Prescott et *al.*, 1999). Temperature is the most important factor which influences the chemical and biological characteristics of the aquatic system. The temperature of the samples ranges between 27.2°C - 27.7°C these range in results are slightly different to the study done by Ojekunle and Lateef (2017) who identified in their study of most slaughterhouses with temperature of 27.8°C - 28.3°C. The temperature falls within the MINEPDEP standards (30°C) and WHO standard of permissible limit (< 40°C). Temperature also influences the amount of dissolved oxygen in water which in turn influences the survival of aquatic organisms

Electrical conductivity is the ease to which a substance allows free flow of electricity through the ions in electrolytes of water sample The mean values of EC ranged from 382 to 4663.33 µs/cm where the raw effluent (S4) had the highest values and the upstream recorded the lowest value The EC at the upstream was lower than the Downstream which was lower than the point of contact which was lower than the raw effluent. This difference could be explained by the healing ability of the watercourse in that the effluents are very saline but when they come in contact with the watercourse there is a dilution effect which explains the drop in the mean values along the watercourse compared to the raw effluent. The EC along the watercourse(S1, S2, S3) were within the limits of WHO maximum permissible level of the conductivity of 900 µs/cm while the raw effluent(S4) was found to be above the maximum permissible level This shows that the water samples along the watercourse are not saline(except that of the raw effluent salinity which is 2.68 ‰) , the concentration of salts dissolved in the water is minimal(salinity values range; 0.16 - 0.21 ‰,) and the salt content of a water body is determined by its ability to conduct an electric current the higher the salt concentration, the larger the current that can be conducted and the higher the EC of the water. The conductivity of most freshwaters ranges from 10 to 1, 000 μs/cm and in polluted water may exceeds 1,000 μs/cm (Chapman, 1996). Akin results were obtained by Ojekunle and Lateef, (2017) who obtained values within the WHO permissible limit along the river. Any level above WHO standards can pose health risk of defective endocrine functions and also total brain damage with prolonged exposure. It is obvious that unpolluted water is colourless so that colour can be used as one parameter in measuring pollution status of water The mean colour values were; raw effluent (54208.3 PtCo), upstream (84 PtCo), discharge point (688.3 PtCo) and downstream (186.3 PtCo) of the watercourse The increment in the downstream was arising from discharge of slaughterhouses wastewater dominated by blood and other organic substances. Muluh et *al.,* (2015) working on the impact of slaughterhouse wastewater on water quality of Modjo and Akaki River in Central Ethiopia observed an increase along the rivers with mean colour values in the discharge point, upstream and downstream of Little Akaki River were 2030, 676, and 1530 units PtCo respectively. Similarly, the colour levels in the discharge point, upstream and downstream of Modjo River were 523.33, 116, and 1973.66 units PtCo respectively. However regardless of the sampling points, the levels of colour were found above the WHO drinking water guidelines limit less than15 TCU (WHO, 2008).

TSS values in this study ranged from 12.67 - 9666.67mg/L and TDS ranged from184.33 to. 2600.33 mg/L. The mean values along the watercourse (S1-S3) fell under the WHO maximum permissible limit for TSS (30 mg/L) and TDS (<1200 mg/L). The increment in the magnitude of this parameter at downstream compared to the values at upstream is due to the influence of the slaughterhouses wastewater on the receiving water bodies. However the raw effluent (S4) was way above this limit in both TSS and TDS, this could be explained in that TSS relatively measures the physical or visual observable dirtiness of a water resource while TDS are an indication of the degree of dissolved substances such as metal ions in the water as reported by Efe (2001) So this high mean values of TSS and TDS are contributed by blood, undigested materials and animal dung that are released as waste after slaughtering the animals. Ojekunle and Lateef, (2017) obtained 15.20 to 16.14 mg/L along a watercourse in an earlier study. From the nitrate value obtained, the concentration ranged between7.73 mg/L to 14.3 mg/L values below the WHO and MINEPDEP guideline value of 50 mg/L and 30 mg/L respectively. The highest concentration of nitrate was observed at the downstream (14.3 mg/L), followed by a decline with the raw effluent of the slaughterhouse (12.37 mg/L) and further decrease at the upstream (11.0 mg/L), and the lowest concentration at the discharge point (7.73 mg/L). The observed unusual trend is probably due to the end product of aerobic decomposition of organic nitrogenous matter is nitrate. So that its concentration is expected maximum at highly aerated zone of the watercourse of which the downstream is most aerated zone. Its presence in high concentration in drinking water has a health risk for young children causing methemoglobinaemia known as blue babies syndrome (Kudryavtseva, 1999). Observed unusual trend of this result was also reported by Muluh et *al.*, 2015. The major peaks in phosphate were found at the outlets of slaughterhouse (252.6 mg/L) followed by a decline from the discharge points (16.70 mg/L) to the downstream (4.09 mg/L) and the lowest concentration were registered in the upstream (2.71 mg/L) of the watercourse. Of all samples only the upstream and downstream were within WHO maximum permissible value of 0-5 mg/L. Possible sources of phosphate might be from the phosphorus rich liquid and solid by-products of slaughterhouses activities such as blood, bone and manure. In addition to this extensive uses of phosphate based detergents for cleaning purposes in the slaughterhouses industries may also have considerable contribution. So the effluent discharged from the slaughterhouses was enough to cause eutrophication on receiving rivers. Similar studies of Muluh et *al.*, 2015 corroborates with this result.

Both BOD and COD are important water quality parameters and are very essential in water quality assessment (Chapman., 1996). These are important parameters, used to determine whether a water body is polluted or not. The higher the BOD and COD values would be depleting the higher DO concentration in the receiving rivers by organic and inorganic pollutants present in the effluents. The mean BOD and COD concentrations of the watercourse along with the outlets of the informal slaughterhouse follow similar trend (as seen in table). The highest values for both BOD_5 and COD was at the point of contact (1016.67 mg/L and 1493.33 mg/L respectively) and lowest at the upstream (33.67 mg/L and 119 mg/L respectively). These values were large enough to cause damage on the normal functions of the receiving rivers. The observed BOD_5 and COD levels were also noticed to be above the WHO limit value for undisturbed river (2mg/L and 20 mg/L respectively) and the MINEPDEP standards (≤ 50 mg/L and 2 mg/L respectively). These high levels of BOD and COD could deplete the DO in the water system. The result indicated that the water bodies sampled were deteriorated due to continuous discharge of untreated effluents. High COD could likely cause nutrient fixation in the soil resulting to reduce rate of nutrients fixation in the soil resulting to reduced rate of nutrient availability to plants. Chemical oxidants affect water treatment plants by Chemical oxidants affects water treatment plants by causing rapid development of rust (Chukwu, 2008).

The MINEPDEP value for wastewater discharge into the environment for fc and FS are of the order of < 2000 and < 1000 CFU/100 mL respectively. According to the results the total coliform are all above MINEPDEP maximum permissible value except the upstream (1966.67 CFU/100 mL) and same as the SF which are also all above MINEPDEP maximum permissible value except the downstream (666.67 CFU/100 mL). Waterborne human pathogens: viruses, bacteria, and protozoa, which may get washed into either drinking water supplies or receiving water bodies, come from animal and human faecal wastes (Akpor, 2011) and are indicators of either poor sanitation or poor disposal of faecal waste as well as waste from a number of anthropogenic activities (EPA, 2015). As a matter of fact, contaminated water supplies are the source for several waterborne diseases including: cholera, typhoid fever, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporidiosis and Hepatitis A (Anonymous, 2004).

III.2.3. Environmental and Socio-sanitary impact of informal slaughterhouse wastewater.

III.2.3.1. Environmental impact of slaughterhouse wastewater.

The nuisances that occur in these neighbourhoods were mostly, insects (26.11 %), small rodents (22.12 %), odour (19.03 %), flood (15.04 %) and noise (17.7 %). The results revealed that 47.95 % of respondents said they face this nuisances. This may be due to their proximity to the informal slaughterhouse (41.10 % lived within 50-100 m). This is caused by the slaughterhouse wastewater that has no canals and travels in the environment without any prior treatment. The noise is due to the fact that the slaughterhouses are found within renowned and populated markets within the city of Yaounde and also the noise generated by the workers during the slaughtering process. The pungent smell is as a result of the decomposition of the effluents. These results in air, water and land pollution on the receiving environment. This corroborates with similar studies of Bello and Oyedemi (2009) working on the impact of abattoir activities. Law no 96/12 of 5 August 1996 , framework on the management of the environment in article 17 stipulates that "any promoter or owner of any physical work, equipment or installation that may cause an adverse effect on the natural environment because of its size or nature of activities needs to carry out an environmental impact or an environmental audit study to assess the direct and indirect impacts of the project on the ecological balance of the settlement area or any other region, the environment and quality of life of people and the impact on the environment .This affects the inhabitants negatively and their rights to live in a clean environment and poses potential hazard.

III.2.3.2. Socio-sanitary impacts.

The results revealed that 69.86 % of the respondents in both neighbourhoods had fallen sick within the past 6 months, the diseases recorded by the respondents were mostly water related diseases high prevalence of malaria (31.88 %), pulmonary infections (17.39 %), diarrheal (15.94 %) and others were recorded. These water related diseases are mainly due to the proliferation of insects such as mosquitoes and flies due to the presence of the informal slaughterhouses (effluents generated by their activities) which are great vectors of these diseases and the pulmonary infections are due to the air contamination generated by burning of animals and pungent smell released from the decaying of the effluents this sites. All aged group of people were affected by these diseases where children between 0-5 years (34.38 %.), adults (32.81 %), adolescents (26.56 %) and old aged people (6.25 %) all this health hazards are greatly contributed by the presence of the informal slaughterhouse in these neighbourhoods. The non-compliance to law no.89/027 of 29th December 1989 on toxic and dangerous wastes. This law prohibits their introduction, production, storage, transportation, transit and discharge on the national territory. There is an exception to certain institutions that produce it, but the obligation to protect man and the environment.

CHAPTER IV.CONCLUSIONS, RECOMMENDATIONS AND PERSPECTIVES.

IV.1.Conclusion.

At the end of this research, the general objective of which was assessing the impact of the Mvog-ada and Essos informal slaughterhouse wastewater on health and the natural environment in Yaounde. , it appears that most of the workers were males (56.25 %) of which most have been working for periods between 6-10 years (31.5 %) and they mostly slaughter pigs, fowls and goats. MINEPIA records an average of 976 pigs slaughtered monthly in Mvog-ada. 50 % use tap water and well water with about an average of 15 – 20L (37.50 %) for cleaning a slaughtered animal. This gives an estimation of about 19,520L of wastewater generated by pigs slaughtered per month in Mvog-ada. This wastewater is directly disposed into the watercourse and garbage bin (37.50 %) without any prior treatment. This revealed a great environmental concern.

From a physicochemical point of view, the quality of the wastewater generated were mostly above the WHO and MINEPED guideline while along the receiving watercourse the parameters analysed were mostly within the standards of WHO and MINEPED but were generally at the point of contact (S2) above these standards. On the other hand, from the bacteriological point of view, they are loaded in control germs of faecal pollution, namely faecal coliforms and streptococci.

From an environmental point of view, the informal slaughterhouse is at the root of numerous nuisances such as proliferation of insects (26.11 %), small rodents (22.12 %) the emission of unpleasant odours (19.03 %) and floods (17.7 %). The uncontrolled discharge of the effluents and presence of these informal slaughterhouses is also causing environmental degradation, resulting in eutrophication, colour change of the receiving water.

In terms of health, most of the population drink tap water (95.89 %) without any treatment (80.82 %). However various diseases have been recorded in the population of Mvog-ada and Essos (69.86 %). These include malaria (31.88 %), pulmonary infections (17.39 %), diarrhoea (15.94 %) and other water related diseases. These water related diseases are mostly due to the proliferation insects which serves as vectors for these diseases transmission and air pollution due to the presence of these informal slaughterhouses. All groups are affected, 34.38 % were children within 0 -5 years, 32.81 % were adults, 26.56 % were adolescents and 6.25 % were old aged people.

IV.2.Recommendations.

From the results obtained the following recommendations are proposed:

- Yaounde city council should employ the services of a consulting firm to carry out an environmental audit in the informal slaughterhouses. The firm should come out with an elaborate environmental management plan for the management of both wastewater and solid wastes;
- Yaounde city council should relocate the slaughterhouses classified as dangerous establishments under decree No.76-372 of 2nd September1976 carries regulations of classified establishments as dangerous unhealthy or obnoxious.

IV.3.Perspective.

From the results obtained the following could be domains for further research:

- Effect of longer period and for both seasons (rainy and dry seasons) for comparative analysis and appraisal of the socio-sanitary and environmental impacts;
- An analysis of the groundwater should be carried out in order to understand better their impact on the transmission of diseases;
- a research study can be done to evaluate the performance of wastewater treatment plant to be adapted for the treatment of these effluents.

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APPENDIX.

Appendix 1. Semi-structured questionnaire administered to households

UNIVERSITY OF YAOUNDE I | **FACULTY OF SCIENCE**
UNIVERSITE DE YAOUNDE I | FACULTE DES SCIENCES

<u>STRITEMENT CONFIDENTIEL</u>: *Les informations contenues dans ce document sont strictement confidentielles au terme de la loi N°91/023 du décembre 1991 sur les recensements et enquêtes statistiques qui stipule en son article 5 que « les renseignements individuels d'ordre économique ou financier figurant sur tout questionnaire d'enquête statistique ne peuvent en aucun cas être utilisées à des fins de contrôle ou répression économique»*

000/- GENERALITES

001- Nom de l'enquêteur:/………………………………………………/ 002 Date:/....................................../

003- Nom du quartier: /……………………………. / 004 -Numéro de la fiche/.................../

005 - Position topographique /__/ 1-Crête 2-Mi pente 3-Bas-Fonds.

100/- CONNAISSANCE DU MENAGE

101- Statut d'occupation de la maison /____/
1-Propriétaire 2-Locataire 3-Maison familiale
4-Autre à préciser/……………………………………./

102- Statut du répondant /___/
1- Chef du ménage 2- Conjoint (es) du chef de ménage 3- Actif du ménage
4- Autres (à préciser) /……………………………………………………………………../

103- Age: ……… Genre: /__/ 1- M 2- F

104. Niveau d'instruction: /___/ 1- Primaire 2- Secondaire 3- Université 4- Sans niveau

105. Durée d'intégration dans le quartier? ………………………

106. Taille du ménage : /………………/

II. IMPACT ENVIRONNEMENTAL DES REJETS D'ABATTOIR/AIRE D'ABATTAGE

201- A quelle distance se situe votre habitation par rapport à l'abattoir/__/
1-[0 – 50 m [2- [50 – 100 m [3- [100 – 500 m [4- [500 – 1000 m [5- Plus de 1000 m

202- Quels types de nuisances faites-vous face au quotidien ? /____/ /____/ /____/
1- Odeurs 2- Insectes (mouches, moustiques, cafards…) 3- Petits rongeurs (souris, …) 4- Inondation
5- Autres (à préciser) /………………………………………………………. /

203-Pensez-vous que ces nuisances sont liées à l'abattoir ?/____/

1- Oui 2- Non 3- Aucune idée

204- Est-ce que les déchets rejetés par les abattoirs/aires d'abattage arrivent chez vous ? /___/
1- Oui 2- Non

205- Si oui lesquels ? /_______/
1-Sang d'animaux 2–Eaux usées issues des aires d'abattage 3–Particules solides d'animaux 4-Matières stercoraires (matières fécales) 5-Autres (à préciser)/……………………………………………………………/

206- Selon vous quelles composantes de l'environnement sont affectées par les rejets d'abattoir/aires d'abattage ? /____/ /____/
1- Eau 2 - Sol 3- Air

207- Selon vous est-ce que les effluents ont un impact sur la qualité des eaux ? /___/
1- Développement de la végétation 2- Couleur de l'eau 3- Odeurs 4- Aucun

208- Pensez-vous qu'il est important de traité les effluents d'abattoir avant de les rejetée dans l'environnement? /____/
1- Oui 2- Non

209. Bénéficiez-vous de la présence de l'abattoir/aires d'abattage? /__/
1- Oui 2- Non

210- Si oui, comment…………………………………………………………………………………………

II. IMPACTS SANITAIRES ENCOURUS PAR LES REJETS D'EFFLUENT D'ABATTOIR/AIRE D'ABATTAGE DE YAOUNDE

301- Quel est votre principal mode d'approvisionnement en eau boisson? /___ /
1-Le réseau CDE (eau de robinet) 2- Source 3- Forage 4- Fontaine publique
5- Puits 6- Autres…………………………………………………………………………………………

302- Si la source d'approvisionnement est une eau souterraine, Y-a-t-il d'autres ménages qui utilisent cette eau ? /____/
1- Oui 2- Non

304- Si oui combien de ménages ? /____/

305- Quel type de traitement apportez-vous à votre eau de boissons ?/___/
1- Ajout de javel 2- Ajout filtre 3- Décantation 4- Ebullition 6- Autres (à préciser)………………………

306- Votre source d'approvisionnement connait elle souvent une pénurie ?/___/
1-Oui 2- Non

307- si oui de quelle nature ? /___/
1-Coupures d'eau 2- Tarissement du point d'eau 3- Assèchement

308- A quel période cette pénurie se produit-elle ?/___/
1-Saison pluvieuse 2- Saison sèche 3- Tout le temps 4- Autres (à préciser)……………….

309- Que fait vous pour pallier à cette pénurie ? /___/
1-Eau de forage 2- Eau de source 3- Eau en sachet 4- Eaux minérales 5- Autres……………...

310- Pensez-vous que les eaux souterraines de votre quartier sont polluées ?/___/
1- Oui 2- Non

311- Si oui quels sont les sources potentielles de pollution/____/
1- Eaux usées de l'abattoir 2- Latrine 3- Déchets ménagers 4- Autre

312- Avez-vous souffert des problèmes de santé au cours des 06 derniers mois? /___/
1- Oui, les noter : /___/ 2- Non

1- Diarrhée 2- Vers intestinaux 3- Irritation cutanée 4- Typhoïde 5- Aucun
5- Autre (préciser)……………………………………………

313- A quelle période êtes-vous tombés malade ? /___/
1- Saison sèche 2- Saison pluvieuse 3- Les deux saisons.

314- Quels étaient les individus les plus exposés à ces problèmes de santé ?/___/
1- 0-5ans 2- Adolescents 3- Adultes 4- Femmes enceintes 5- Personnes âgées 6.Autres…………………………………………………..

315- Selon vous quelle peut être l'origine de ces maladies? /___/
1- Mauvaise qualité de l'eau 2- Abattoir 3- Mauvaise hygiène 4- Ne sais pas

316- Si abattoir, pourquoi ? /___/
1- Proximité 2- Apparence des eaux 3- Apparence du sol 4- Odeurs 5- Bruits
6-autres /……………………………/

317- que faite vous lorsque vous êtes malade? /___/
1- Aller dans un dispensaire / hôpital/ clinique 2- Automédication 3- Médecine traditionnelle
4- Autre (à préciser)
318-Dans quelle clinique/hôpital………………………………………………………………………………

319- Avez-vous une parcelle agricole autours du cours d'eau ?/___/
1-Oui 2-non

320- Utilisé vous les eaux d'abattoir pour vos pratiques agricoles ?/___/
1-Oui 2.Non

321- Si oui, pourquoi l'utilisez-vous ?/___/
1-Fertilisant 2-Unique source d'eau 3-Autre

322- Savez-vous que cette pratique est à risque ?/____/
1-Oui 2-Non

323-Si oui, pourquoi?...

324- Que suggérez-vous pour l'amélioration des conditions de vie des populations dans la zone /__/

1-Fermeture de l'abattoir 2- traitement des eaux 3- indemnisation 4- assistance santé 5- ne rien faire 6-amenagement de l'abattoir 7.Autre

Merci pour votre contribution !!!!!

Appendix 2. Semi-structured questionnaire administered to workers of the informal slaughterhouse

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Noms de l'enquêteur………………………………. Le……………………

GUIDE D'ENTRETIEN AVEC LE PERSONNEL

001- Nom de l'abattoir/aire d'abattage: …………………………………..

002- Poste occupé:…………………………………………………………

003- Nombre d'employés:…………………………………………………

004-A votre avis combien d'abatteurs y'a-t-il autour de vous?..

005- L'âge du répondant/__/
1. <17 ans 2- 17-20 ans 3- 20-30ans 4- ≥30 ans

006- Sexe du répondant/__/
1. Masculin 2. Féminin

007- Niveau d'étude : /__/
1. Primaire 2. Secondaire 3. Supérieur 4. Non scolarisé

008- Depuis combien de temps travaillez-vous ici ?...

009- Quel type d'animaux abattez-vous ? /__/ /__/ /__/ /__/

1. Porcs 2. Bœufs 3. Vol ailles 4. Chèvres 5. Moutons 6. Autres à préciser………………….

010- Quel nombre d'animaux abattez-vous par jour ?

Type d'animaux	Nombre
Bœuf	
Porc	
Volaille	
Autre	

011- Quels types de déchets sont produits ?

Type d'animaux	Déchets produits (citer……)
Bœuf	
Porc	
Volaille	
Autre	

012- Où jetez-vous les déchets issus des abattages ? /__//__//__/
1. Egout municipal 2. Rigole/caniveau 3.Sol 4. Cours d'eau 5. Autre à préciser ……………

013- Quel type d'eau utilisez-vous pour le nettoyage : /__//__/
1- Eau de la CDE 2- Eau de puits 3- Eau de rivière 4- Autre à préciser…………………

014- Quelle quantité d'eau utilisez-vous pour le nettoyage par animal ? /__/
1. Moins de 15 l 2. 15-25 l 3. 25-35 l 4- 35-50 l 5- Plus de 50 l

015- Quelle est la fréquence de nettoyage de l'abattoir/aire d'abattage ?/__/
1. Chaque jour 2. Une fois/semaine 3. Une fois/mois 4. Aucune fois
5. Autre…………………………………………

016- Faites-vous usage des produits chimiques au sein de l'abattoir/aire d'abattage ? /__/
1. Oui 2. Non (**Si Non passé à 018**)

017- Si oui lequel:/__//__//__/
1. Détergents 2. Eau de javel 3. Savons
4. Autre à précise……………………………………………

018- Disposez-vous d'un site/station de traitement des effluents ? /__/
1. Oui 2. Non (**Si Non passé à 020**)

019- Si oui, est-elle toujours opérationnelle ?/__/
1. Oui 2. Non

020- Avez-vous reçu des plaintes des populations environnantes ? /__/
1. Oui 2. Non (**Si Non passé à 022**)

021- Si oui lesquels……………………………………………………………………...

022- Quelle (s) disposition (s) avez-vous prises ?
……………………………………………………………………………………..

II. IMPACTS SANITAIRES ENCOURUS PAR LES REJETS D'EFFLUENT D'ABATTOIR/AIRE D'ABATTAGE DE YAOUNDE

101- Quel est votre principal mode d'approvisionnement en eau boisson? /__//__/
1. Le réseau CDE (eau de robinet) 2. Source 3. Forage 4. Fontaine publique 5. Puits
6. Autres………………………………

102- Quel type de traitement apportez-vous à votre eau de boissons ?/__//__/
1. Ajout de javel 2. Ajout filtre 3. Décantation 4. Ebullition 5. Aucun
6. Autres (à préciser)………………………

103- Etes-vous au courant des risques de maladies que peuvent générer les rejets d'abattoir ?:/__/

1. Oui   2. Non (**Si Non passé 205**)

104- Si oui par quel moyen avez-vous été mis(e) au courant de ces risques ? /__//__/
1. Média (télévision, radio)   2. Culture générale   3. Abattoir
4. Autres (à préciser)……………………………………

105- Avez-vous souffert des problèmes de santé au cours des 06 derniers mois?/__/
1. Oui: 2. Non (Si Non passé à 107, puis aller a 113)

106- Si oui quelle(s)/__//__//__/
1. Diarrhée   2. Vers intestinaux   3. Irritation cutanée   4. Typhoïde
5. Autre (préciser)………………………………………………

107- Avez-vous une idée de combien de personnes sont affecté ici par ces maladie? /__/
1. 0   2. 1-3   3. 4-6   4. 7 et plus   5. Je ne sais pas

108- A quelle période êtes-vous tombés malade? /___/
1. Saison sèche   2. Saison pluvieuse   3. Les deux saisons.

109- Que faite vous lorsque vous êtes malade? /__//__/
1. Aller dans un dispensaire / hôpital/ clinique   2.Automedication   3. Médecine traditionnelle
4. Autre (préciser...)……………………………………………………………..

110- Dans quelle clinique / hôpital……………………………………………………………….

111- Pensez-vous que les rejets d'abattoirs sont à l'origine de certaines de vos maladies ? /__/
1. Oui   2- Non (**Si Non passé à 113**)

112- Si oui pourquoi ? /__//__/
1. Contact avec le bétail   2. Les déchets 3. Odeurs 4. Bruits 5. Autres ………………………..

113- Cette activité nécessite-t-elle des équipements de protection spéciaux ? /__/
1. Oui   2. Non

114- Si oui lesquels? /__//__//__/
1. Gants   2. Bottes   3. Lunette   4. Blouse   5. Autre……………………………….

115- Utiliser vous ces équipements? /__/
1-Oui   2-Non

116- Y-a-t-il souvent des visites des inspecteurs/contrôleurs de l'administration ? /__/
1. Oui   2. Non

117- Si oui de quelle administration ?/__//__//__//__//__/
1. MINEPDED   2. MINMIDT   3. MINEE   4. MINSANTE   5. MINEPIA

Merci pour votre contribution

Appendix 3. Frequency and percentage of the respondents on how they overcome water shortage.

Modalities	Percent
No response	17.8
Another tap	1.4
Drilling water	5.5
Mineral water	19.2
Mineral water, Seek elsewhere	1.4
Reserves of water	15.1
Sachet water	11
Sachet water, Mineral water	1.4
Sachet water, Mineral water, Reserves of water	1.4
Seek elsewhere	5.5
Spring water	11
Spring water, Mineral water	1.4
Wait	4.1
Well water	2.7
Well water, Seek elsewhere	1.4
Total	100

Appendix 4. Essos slaughtering site.

Appendix 5. Eutrophication of the tribute Ewoé (Mvog-ada).

Appendix 6. Garbage bin used in the Mvog-Ada informal slaughterhouse.