CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Proposal of Water Purification Unit for ELICO Tannery Addis Ababa, Ethiopia

Diploma thesis

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Supervisor:

doc. Ing. Vladimír Krepl CSc.

Author:

Mgr. Petr Kopeček

Declaration

I hereby declare that this master thesis entitled “Proposal of Water Purification Unit for ELICO Tannery Addis Ababa, Ethiopia” is my own work and all the sources have been quoted and acknowledged by means of complete references.

In Prague, 23rd April, 2015 . . . .

Petr Kopeček

Acknowledgement

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Abstract

Tanning industry represents significant ecological burden for local habitat by solid, air and water waste production. Wastewater from Awash tannery was investigated and suitable water purification units were proposed for effluent improvement. Collected samples and primary data from Awash tannery were evaluated. Findings show exceeding of effluent standards limit in several indicators such as COD, $N\text{-}NH_3$, SS, Cr^{3+}, TDS, Cl^- and others. Environmental effects of tannery effluent were discovered and suitable secondary (biological) treatments with consideration of local conditions were proposed. Estimated calculations show positive results of proposed units. Application of suggested units – AIWPS and EAAS will lead to reduction of pollution load and fulfilling Ethiopian and Czech effluent standards in most of the indicators. Effluents can be possible reuse for factory operations and with special conditions also for irrigation purposes.

Key words: Addis Ababa – Ethiopia, Effluent purification, ELICO, Tanning industry, Water pollution

Abstrakt

Koželužní průmysl představuje ekologickou zátěž pro své okolí díky produkci vzdušného, vodního a jihého znečištění. Na základě analýzy odpadních vod z koželužny Awash byly pro tuto továrnu navrženy vhodné čistící jednotky, které kvalitu odpadních vod významě zlepšují. Odebrané vzorky vody a získané data byly pečlivě vyhodnoceny. Výsledky ukazují, že u většiny zkoumaných indikátorů zněčištění, jako například CHSK, amoniak, trivalentní chrom, chlor, celkové rozpuštěné látky, nerozpuštěné látky a jiné, byly překročeny místní emisní normy. Na základě těchto zjištění byly indikovány ekologické dopady a navrženy vhodné způsoby čištění s přihlédnutím k místním podmínkám. Předběžné kalkulace ukázaly kladné výsledky při použití doporučených způsobů čištění. Aplikací navržených jednotek AIWPS a EAAS dojde ke snížení vodního znečištění a současně budou splněny limitní normy pro většinu sledovaných ukazatelů. Vyčištěná odpadní voda může být dále zužitkována, jak k provozu v koželužně, tak pro možné zavlažování, avšak s přihlédnutím k dalším podmínkám.

Klíčová slova: Adis Abeba – Etiopie, Čištění odpadních vod, ELICO, Koželužský průmysl, Znečištění povrchových vod

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Acronyms and Abbreviations

AA	-	Addis Ababa
AFP	-	Advanced Facultative Pond
AIWSP	-	Advanced Integrated Wastewater Ponds System
AS	-	Activated Sludge
ASP	-	Algae Settling Ponds
BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
CLRI	-	Central Leather Research Institute
EAAS	-	Extended Aeration Activated Sludge
ELICO	-	Ethiopian Leather Industry Plc.
EPA (US)	-	United States Environment Protection Agency
EPA	-	Environmental Protection Authority (of Ethiopia)
EPE	-	Environmental Policy of Ethiopia
EIA	-	Ethiopian Investment Agency
EMS	-	Environmental Management System
ETP	-	Effluent Treatment Plan
FDI	-	Foreign Direct Investment
F:M Ratio	-	Food to Mass Ratio
FDRE	-	The Federal Democratic Republic of Ethiopia
GWI	-	Global Water Institute
HRP	-	(Algal) High Rate Pond
ICT	-	International Council of Tanners
IFC	-	International Finance Corporation
IMF	-	International Monetary Fund
LIDI	-	Leather Industry Development Institute
MLSS	-	Mixed Liquor Suspended Solids
MP	-	Maturation Pond

MSMEs	-	Micro and Small/Medium Enterprises
MZV-CR	-	Ministry of Foreign Affairs of the Czech Republic
NIEHS	-	National Institute of Environmental Health Sciences
RAS	-	Return Activated Sludge
SRT	-	Sludge Return Time
SS	-	Suspended Solids
SNNP	-	Southern Nations, Nationalities and People's Region
UASB	-	Up-flow Anaerobic Sludge Blanket
UNIDO	-	United Nation Industrial Development Organization
VŠCHT	-	Vysoká Škola Chemicko-technologická v Praze
WB	-	The World Bank
WBG	-	The World Bank Group
WSP	-	Waste stabilization ponds
WWDR3 (4)	-	World Water Development Report 3 (4)

1. Introduction

“The challenge of securing safe and plentiful water for all is one of the most daunting challenges faced by the world today… Too often, where we need water we find guns.”

Ban Ki-moon

“Access to a secure, safe and sufficient source of fresh water is a fundamental requirement for the survival, well-being and socio-economic development of all humanity. Yet, we continue to act as if fresh water were a perpetually abundant resource. It is not.”

Kofi Annan

There are various challenges that today´s world is facing like poverty, lack of education, gender inequality, political instability, health care, environmental problems and so on, which are actually also the objects of United Nations project Millennium Development Goals (MDG, 2014). Although these issues are especially characteristics of developing countries, it does not mean that there is no impact on the whole society and environment worldwide as there are no borders in this case. Furthermore, they are accompanied by each other, creating very complex situation. However, there is a substance among all those traps, which has always been vital and scarce precondition of the life – the water. Water is precious commodity which has crucial impact on human being and it is considered as fundamental topic of future development, because it links and transform levels of problems from “the local to the regional”, bringing together global questions of public health, food security, urbanization and energy.

Despite the fact that the topic of water is well-known mainly from the “third world countries“, it is becoming more and more discussed and actual even in developed countries as the fear of water scarcity and its shortage creates the threat of the future.

Africa is considered as the world´s second-driest continent after Australia. The statistics claim that “more than 300 of the 800 million people in sub-Saharan Africa live in a water-scarce environment – meaning that they have less than 1,000 m3 per capita per year.” (UN, 2014) This condition must significantly influence their daily regime, so that “more than a quarter of the population spends more than half an hour per round trip to collect water.” (UN, 2014) Surprisingly, finding and fetching water is a sovereign responsibility of women in many countries.

According to the latest census in 2012, population of Sub-Saharan Africa is 910.4 million (WB-DATA, 2014). Lack of water together with rising population seems to be highly unsustainable, especially when "Africa´s population average natural rate of increase was 2.6% per year, compared to the world average of 1.2%." Predictions argue that its population will grow to 1,245 million by 2025and to 2,069 million by 2050. (UN, 2014)

Generally, the improving of access to water, improves health and education outcomes, increases agricultural productivity and boost gender equality and women's empowerment. However, there is also significant effect of climate change, which is another real and growing threat. Without good planning and adaptation, hundreds of millions of people are at risk of hunger, disease and energy.

Staying on the "Land of Sahara," let this thesis to introduce you one of the most populous countries of Africa and its water challenges within a specific study case of proposal of water purification unit for ELICO tannery in Addis Ababa, Ethiopia.

Despite the current economic growth, Ethiopia belongs among the poorest countries in the world. Because of this reason, Ethiopia is included to the highest category of priority countries of development aid of Czech Republic, mainly in the agriculture, water and sanitation and education sector (MZV-CR, 2014). Necessity of drinking water is clear and obvious, although it is not only about the access to the source of water, but also about the water quality. Then we can see narrow connection between river which is polluted by the industry or agriculture and a final harmful impact on the human, animals and environment using that polluted water. This schema is present also in our project, when tannery is releasing toxic wastewater.

Thanks to the sophisticated technologies developed within field of water, we already know many particular ways, methods and devices which are successful in water purification. However, there are so many different kinds of pollutants and so many specific parameters formed by individuality of each case, that it is important to choose and imply correctly the most appropriate method.

To preserve the Ethiopian traditional heritage of tannery industry, make it sustainable and safe for its surrounding, it is necessary to solve the question of pollution especially caused by chromium and others which is characteristic for the tannery wastewater. The thesis is providing description of specific experience of suggesting appropriate water purification technology, providing exact data and results. Moreover, the study is showing the picture of developing project.

1.1. Background of the case study

Tanning industry in Ethiopia is currently one of the biggest contributor supporting economic development of the country by generating foreign currency, which is necessary for further development. On the other hand, the industry is also pollutant intensive sector that threatens the environment at the large scale.

Ethiopian tanneries are on a new path of adding values to the leather products that essentially requires a series of additional individual process steps and varieties of chemical inputs. Those steps possibly intensify the pollution load of the waste water effluent. By investments in efficient of processes and new technologies we can dramatically reduce load of pollutions.

The environment and development integration in a leather industry has to be strengthened to achieve the intended sustainable economic benefits for the whole human well being with consideration of environment protection.

2. Literature review

2.1. Ethiopia in the world context

Ethiopia or officially The Federal Democratic Republic of Ethiopia (FDRE) is one of the world’s oldest civilizations. The roots of the civilization are dating back to the 2nd millennium BC. Ethiopia was a monarchy for most of its history and especially in the time of the Kingdom of Aksum was one of the great world powers. Modern history goes back to the 19th-century, when Ethiopia was the only African country to defeat a European colonial power. During the reign of Emperor Haile Selassie I (1930-1974) modernization of Ethiopia started and Ethiopia became one of the leading countries of Africa. On the one hand, Ethiopia has one of the fastest growing economy in the world with growth rates averaging 10% over the past 10 years, on the other hand, GDP per capita is one of the lowest in the world with

$1,256 (IMF, 2012). Ethiopia is forcing numerous problems such as wide spread poverty, poor sanitation, poor cultivation practices, economy structural problems and other. Ethiopia is also considered as cradle of humankind[1] and origin place of coffee, grain sorghum and castor bean (Index mundi, 2014).

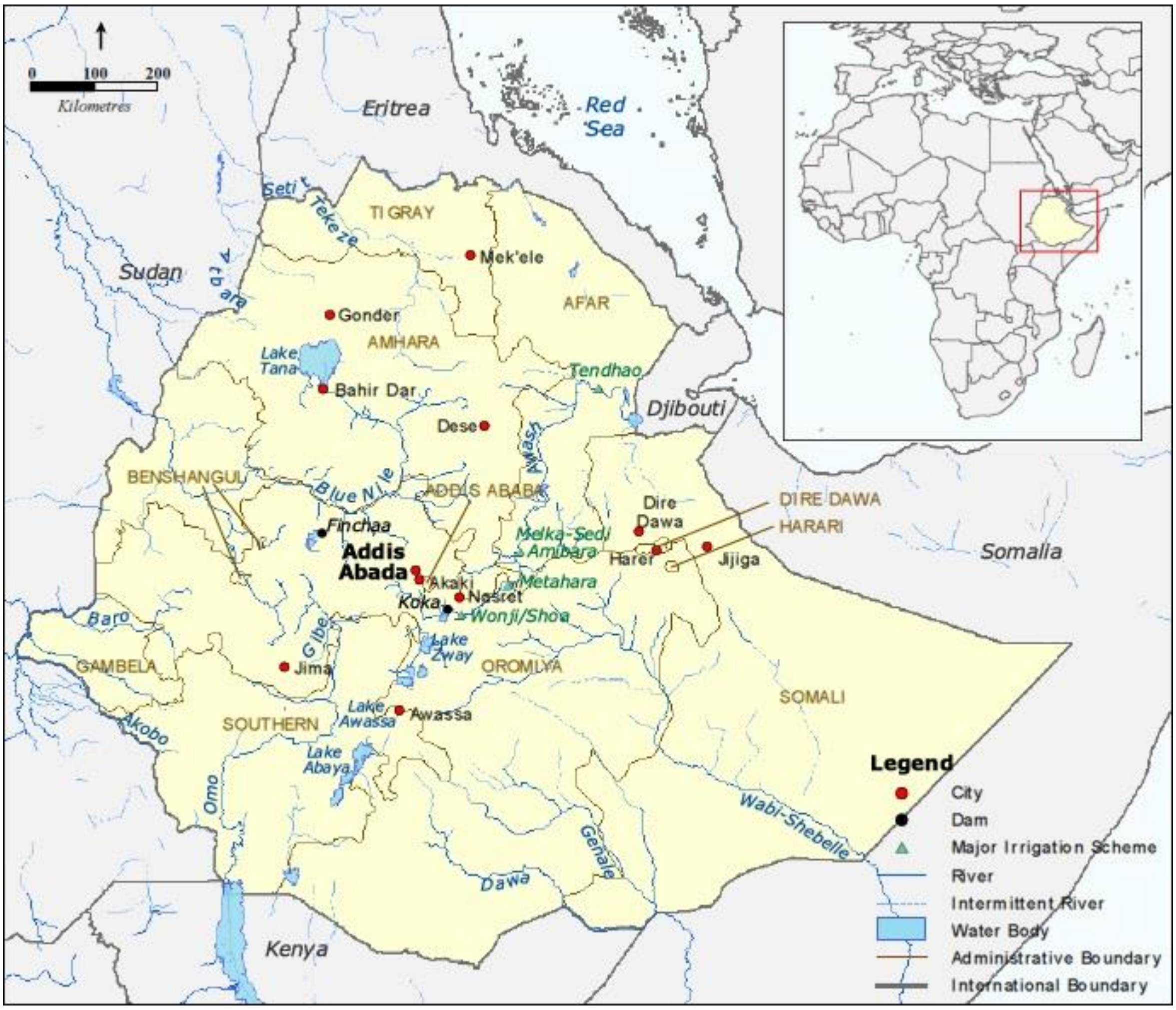

Figure 1**. Map of Ethiopia** (Source: Index mundi, 2014)

2.1.1. Ethiopia country profile

Ethiopia is located in Africa continent in its eastern part called Horn of Africa. Capital city is Addis Ababa, which is also the largest city within the country. In 1993 Ethiopia lost de jure access to Red see due to independency of Eritrea (24 May 1993). After this separation act, Ethiopia became the most populous landlocked country in the world (CIA, 2014).

[1]Due to discovery some of the most famous hominid fossils such a Lucy, Omo I and Omo II (The Ethiopian brief, 2012).

Geography

Ethiopia is huge country. In the raking of largest countries in the world take 27th place (7th largest in Africa). Country total area is 1,104,300 sq. km (land - 1 million sq. km, water: 104,300 sq. km). Its size is comparable with Bolivia or 2x area of Texas. Nowadays, Ethiopia has borders with 6 countries: Djibouti, Eritrea, Kenya, Somalia, South Sudan and Sudan. Geography of Ethiopia is formed by high plateau, that varies from 1,290 to 3,000 m above the see level with the highest mountain Ras Dashen reaching 4,533 m. Central mountain range is divided by Great Rift Valley and surrounding by numerous of lowlands. Number of rivers and lakes cross the plateau and creating river net with huge water-energy potential. Well known is especially Lake Tana, which is starting point of Blue Nile river.

Climate

Country climate varies due to different topographical regions. The central highlands have a moderate climate with small seasonal temperature variations during whole year (6°C - 26°C). In lowlands, the temperature variation is greater and could reach up to 60°C in deserts areas. Rainfall occurs mostly during June, July and August. Average annual precipitation varies from 122 cm in central plateau to 10 cm in the northern provinces (FDRE 2012).

Population

Ethiopia is the second most populous country in Sub-Saharan Africa and 13th most populous in the world with a population more than 91.73 million people. The structure of population is very variegated with more than 80 different languages, dialects and culture variations. The most populate ethnic groups are Omoros (around 34%) and Amharas (around 29%). Annual average country grow rate is around 2.6%. The country is one of the world's poorest countries with average annual income 380 USD and with 29.6% of population living under national poverty line. Religion structure is influent of long tradition of Ethiopian Orthodox Church (around 43%), following Muslims (around 34%) and Protestant (around 18.6%) and other (WB - ETHIOPA, 2014).

Table 1. Ethiopia HDI and other indicators

	HDI value	HDI rank	Life expectancy	Years of schooling	GNI per capita (PPP USD)
Ethiopia	0.396	173	59.7	8.7	1,017
Sub-Saharan Africa	0.475		54.9	9.3	2,01

Source: (MALIK, 2013)

Government

Ethiopia adopted a new constitution that established federal parliamentary republic in 1995. The Prime Minister Hailemariam Desalegn elected by parliament in in September 2012 is the head of government, whilst President Mulatu Teshome elected by the House of Peoples' Representatives in October 2013. Executive power is exercised by the government while legislative power is vested in the Parliament. The Judiciary is fairly independent. There are 9 administrative regions and two self-governing administrations (Addis Ababa and Dire Dawa) delimited on the basis of settlement patterns, language, identity and consent of the peoples concerned (FDRE 2012).

The Regional States of Ethiopia:

Afar, Amhara, Benishangul- Gumuz, Gambella, Harari, Oromia, SNNP, Somali, Tigray

Economy

The structure of Ethiopian economy dominated agriculture and service sectors, both with share around 45% of GDP. Industry with 10% of GDP has still small position. Annual GDP growth is regionally on high level with 7.8%. Ethiopian export is based on coffee production. From total export coffee represent around 60%, other export articles are precious metals such as gold, leather products, oilseeds etc. (FDRE 2012).

2.2. Ethiopia water challenges

Ethiopia has a substantial amount of water resources. The surface water resource potential is enormous, but little developed. The country possesses twelve major river basins, which form four major drainage systems, namely:

- The Nile basin - covers 33% of the country
- The Rift Valley - covers 28 % of the country
- The Shebelli-Juba basin - covers 33 % of the country
- The North-East Coast covers 6 % of the country

Most of the rivers in Ethiopia are seasonal, with runoff (around 70%) culminated in June-August. Dry season flow originates from springs which provide base flows for small-scale irrigation. The groundwater potential of the country is not map out well yet. Traditional wells are widely used by nomads. Ethiopia has also several lakes (about 7 000 km^2), a number of saline and crater lakes as well as several wetland areas. Ethiopia has many different size reservoir dams constructed for hydropower generation, irrigation and drinking water supply with total capacity of 5.56 km^3 (FRENKEN, 2005).

As many African countries, also Ethiopia is forcing water problems, especially water shortages, poor sanitation, and a lack of access to clean water sources. In Ethiopia just nearly 50% of people have excess to improve water, but the situation is not the same in all areas, how it is visible in table 2 (THE WORLD BANK, 2011).

Table 2. Improve drinking water and sanitation facilities

	Use of improve drinking water 2011 (%)	Use of improve sanitation facilities 2011 (%)
Rural areas	39.3	19.4
Urban areas	96.6	27.3
Country total	49	20.7

Source: (UNICEF, 2013)

Changing weather patterns, in addition to other environmental changes including land over exploitation and deforestation, have increased soil degradation and led to water stress, drought, and crop failure. Agriculture sector suffer the most and farmers are often forced to compete over dwindling natural resources mainly water for cattle and irrigation.

Pastoral areas are located mostly around borders, using water resources, which are often trans-boundary. This situation is very challenging especially around the Nile and its tributaries (Abbay, Tekeze and Baro-Akobo), which are life important rivers for Sudan and Egypt and could lead to water wars (FRENKEN, 2005).

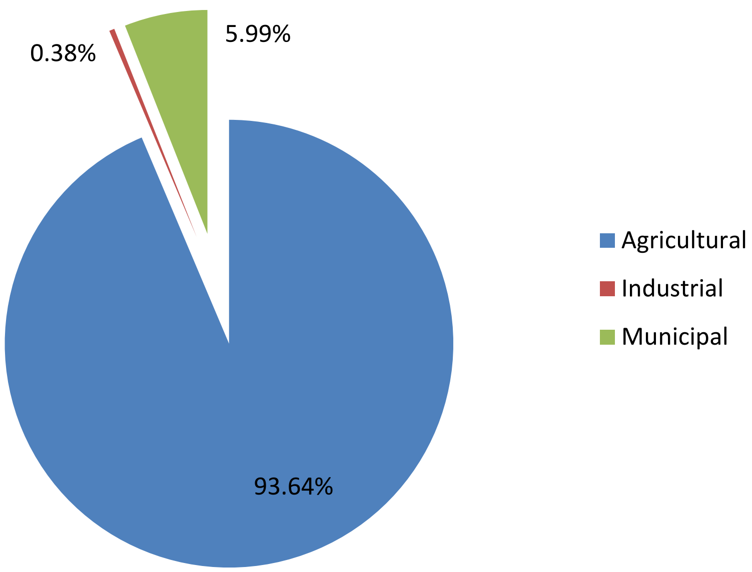

Figure 2. **Ethiopia – Sectoral withdrawals** (Source: UN-WATER, 2014)

Another Ethiopian water challenges are connecting with possibilities of drought with more than three decades experiences. Ethiopia has deadly droughts including in years 1972/73, 1984 and 2002/03. Communities whose livestock is often the most devastated by drought are located mostly in the Afar, Oromia, Somali and Southern regions. Different kinds of problems are caused by floods. Intense rainfalls lead to particularly flooding along the Awash river and in the lower Baro-Akobo and Wabe-Shebelle river basins, causing damage to standing crops infrastructures and environmental problems. The construction of dykes mitigated the problem, but has not provided a long-lasting solution (NDARUZANIYE, 2011).

2.2.1. Addis Ababa hydrology

The city of Addis Ababa lies in the Akaki catchment (see figure 3.) and consists from the Akaki River and 4 water reservoirs. Three of them, namely Gefersa, Lege Dadi and Dire dam, have been constructed as supply water reservoirs for the city. The last one, namely Lake Aba Samuel, has been used for water supply and hydropower generation. Now it is a non-functional swamp (basically waste-damping site), which retains highly-polluted surface and groundwater effluents from Addis Ababa (Ayenew at al., 2008).

The Akaki River, commonly known as the Big Akaki River, is consists of a several small and relatively big rivers and streams which drain the area of Addis Ababa from the northeast and east and characterize the whole Akaki River catchment (see figure 3.). The other equally significant river is Little Akaki River which drains the western part to the catchment area. Several tributaries, as Kebena River, flow from northeast and join the Big Akaki River. The whole catchment has an area of about 1500 km^2 (Tegegn, 2012 via Molla et al., 2006).

In the south outskirt of Addis Ababa lies one of the most important ground water protection zone the Akaki well field. The Akaki well field is the part of drainage basin of Dengora and Keta rivers, which join to Sakelo River flows to the Big Akaki River.

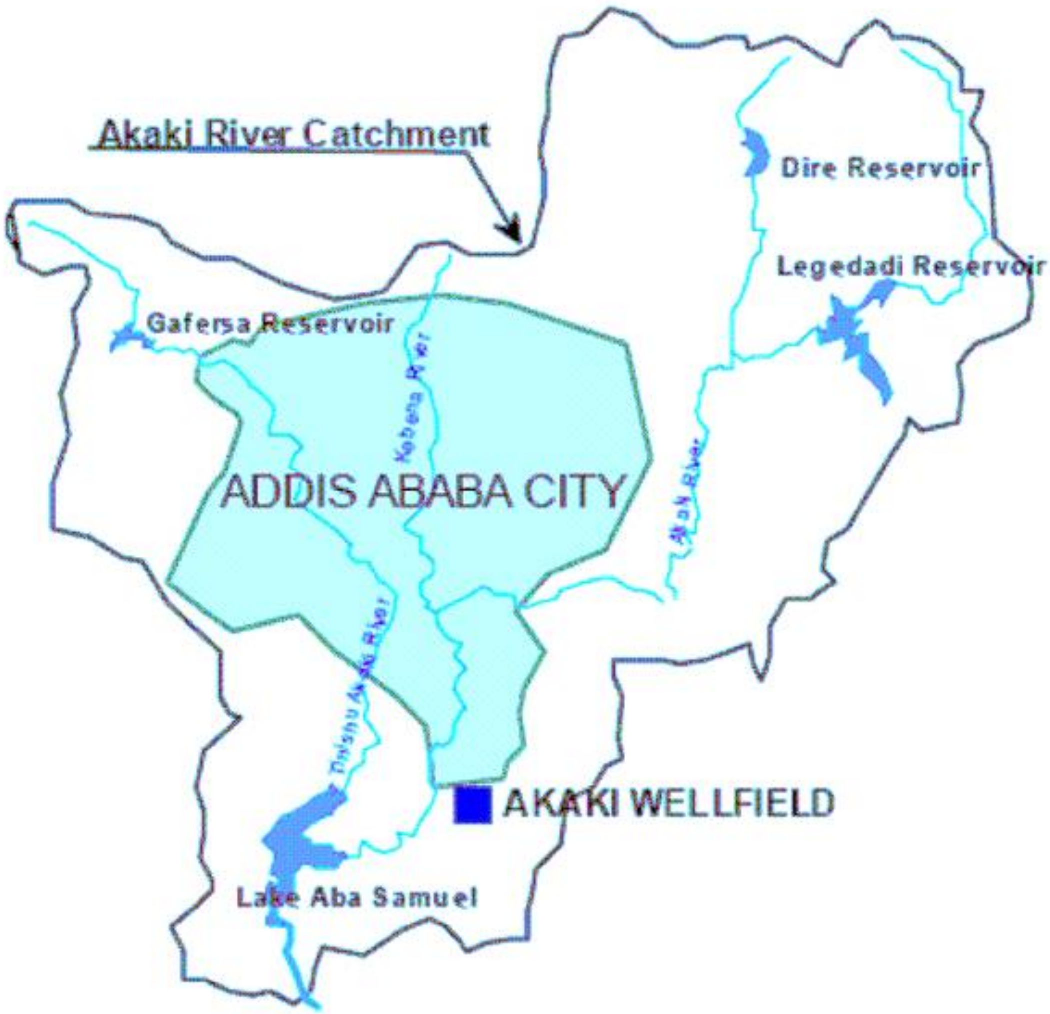

Figure 3. **The Akaki catchment area** (source: Tolera, 2007)

The Akaki catchment is heavy polluted due to industrial and human activities within the capital city. Chapter 5.3 provides more information about a pollution of the Akaki basin.

2.3. Water pollution

Worldwide, around 2 billion people drink contaminated water which is harmful to their health. Every day, 2 million tons of human wastes are disposed of in waters. In developing countries 70 % of industrial waste is dumped untreated into watercourses which contribute to pollution of fresh water. The food sector participates in the production of organic water pollutants in high-income countries from 40 % and in low-income countries from 54 % (UN-WATER, 2014).

Fresh water sources are under increasing threat from contamination, with far-reaching consequences for the health of human, for the economic and social development of communities and nations. According to NIEHS[2], water pollution is contamination of water with chemicals or other foreign substances that are harmful to people, plants, or animals (NIEHS, 2014).Other simple definition offers WWDR3[3], which states that pollution usually refers to chemicals or other substances in concentrations greater than would occur under natural conditions (UN-WATER, 2009: 163).Basically, we can say that water pollution is change in the chemical, physical, biological, or radiological quality of water, which is harmful for an aquatic ecosystem, water use or water activities. The term “water pollution” generally refers to anthropogenic changes to water quality, which are mainly caused by industrial practices, agricultural activities and human settlements.

The substances that can cause these changes are mainly fertilizers and pesticides from agricultural runoff; sewage and food processing waste; heavy metals such as lead and mercury; chemical wastes from industrial discharges; and chemical contamination from hazardous waste sites (examples are listed in Table 1).

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[2]National Institute of Environmental Health Sciences is part of Department of Health and Human Services United States, focus on basic science, disease oriented research, global environmental health and other.

[3]World Water Development Report 3

Table 3. Types of waste

Basic state	Mixed state	Sub state	Example
Solid	Solid	Organic	Sugar
		Inorganic	Salt
	Solid in Liquid	Organic	Food Processing Waste
		Inorganic	Electroplating Waste Treatment
	Solid in Gas	Organic	Plant Aerosols
		Inorganic	Incinerator Particulates
Liquid	Liquid	Organic	Gasoline
		Inorganic	HCL
	Liquid in Solid	Organic	Garbage
		Inorganic	Uncured Concrete
	Liquid in Gas	Organic	Air Stipper Mist
		Inorganic	Mist
Gas	Gas	Organic	Toluene
		Inorganic	Air
	Gas in Solid	Organic	Floats
		Inorganic	Methane Storage Tank
	Gas in Liquid	Organic	Anaerobic Decomposition
		Inorganic	Dissolved Air Flotation

Source: (ALLEY, 2007)

We can categorize water pollutants according to their primary sources as point or non-point sources (see Table 2). Point sources are pollutants mostly from pipelines and other effortlessly identifiable sources such as an industrial and sewage treatment plants connect directly to a water body etc. Non-point sources are noxious substances creating by precipitation as it flows over the land and infiltrates the soil (UN-WATER, 2009: 163).Major causes of non-point sources pollution could be agriculture activities, land development, storm-water runoff, Onsite Sewage Systems, Forestry, Atmospheric Deposition or Marine activities (MELP[4], 1998).

[4] Ministry of Environment, Lands and Parks

Table 4. Comparison of point and non-point sources of water pollution

Point sources	Non-point sources
Fairly steady volume and quality	Highly dynamic; occurs at random intervals closely related to hydrologic cycle
Variability of values typically less than one order of magnitude	Variability of values can range across several orders of magnitude
Most severe water quality impacts typically occur during low-flow summer periods	Most severe water quality impacts occur during or after storm events
Enters receiving waters at identifiable points, usually through pipelines or channel sources	Entry point to receiving waters usually cannot be identified; typically arises from extensive land areas
Can be quantified with traditional hydraulic techniques	Difficult to quantify with traditional techniques
Primary water quality parameters are organic water pollutants (biological oxygen demand), dissolved oxygen, nutrients, suspended solids and sometimes heavy metals and synthetic organic chemicals	Primary water quality parameters are sediments, nutrients, heavy metals, synthetic organics, acidity and dissolved oxygen
Control programs typically applied by government agencies	Control programs involve individuals not normally considered in pollution control programs (such as farmers and urban homeowners)

Source: (UN-WATER, 2009)

Basically, there are a few type of classification of pollutants according to their effect on water quality. Generally, we can recognize the following pollutants:

1. Physical pollutants: We can categorize physical pollutants as follow: solids content, solids type, colour, odour, taste, conductivity, temperature. Each of these categories can have chemical or biological source of origin.

2. Chemical pollutants: There are two types of chemical pollutants - organic or inorganic. We can find a thousand of organic pollutants consisting of various combinations of carbon, hydrogen and oxygen or many other inorganic or organic molecules. For indication of water quality we can use tests based on chemical characteristic, which are simpler, less expensive and more indicative than complex a chemical compounds tests (see Table 3).

Table 5. Lists description of basic chemical indicator tests

Chemical Indicator Tests	Description
Acidity	is an indicator of capacity of water to react with a strong base to a designated PH. Titration with a standard alkali solution to an end point of 3.8 pH is used for most wastewaters. Acidity is reported in mg/l of $CaCO_3$.
Alkalinity	is primarily a function of the carbonate(CO_3), bicarbonate (HCO_3) and hydroxide (OH) content of wastewater. Titration with a standard acid to an end point of 8.3 pH is reported as phenolphthalein alkalinity and titration to an end point of approximately 4.5 is reported as total alkalinity. Alkalinity is measured in mg/l as $CaCO_3$.
Conductivity	is a quantification of the ability of water to carry an electric current. Most conductivity tests are accomplished with an instrument.
Total Hardness	is generally a measure of the capacity of water to precipitate soap. Hardness is either calculated from the results of separate calcium and magnesium tests or is determined from a colour change when titrating a sample with ethylenediaminetetracetic acid (EDTA)
Oil and Grease	quantify substances that are soluble in trichlorotrifluoroethane. These tests will include the presence of certain sulphur compounds, organic dyes and chlorophyll that is not volatilised.
pH	is used to indicate the intensity of the acidic or basic character of a solution.
Salinity	is a measure of the dissolved salts in solution. [mg/l]

Source: (ALLEY, 2007)

3. Biological pollutants: As these pollutants use oxygen for energy, the tests can involve the measurement of either carbon content or oxygen demand, or an actual bacterial count. The Biological Oxygen Demand (BOD) test is used in order to determine the oxygen requirements of wastewaters. The Chemical Oxygen Demand (COD) test is a measure of the oxygen required from a strong chemical oxidant for the destruction of an organic material. The Total Organic Carbon (TOC) test is more direct indication of organic content than the BOD or COD test. The TOC test indicates the total organic matter present and is independent of the oxidation state of the pollutant. The Theoretical Oxygen Demand (THOD) test expresses the stoichiometrically determined oxygen needed to convert all carbon molecules in pollutants to CO_2, and all NH_3 by balancing equations (ALLEY, 2007).

2.3.1. Industrial water pollution

Every day, 2 million tons of wastes are disposed of in watercourses. In developing countries 70 % of industrial wastes are dumped untreated into waters where they pollute the fresh water supply. But not only industry contaminates our water resources, so does also agriculture (see Table 4). The contribution of the food sector is surprisingly high. This sector produces organic water pollutants with ratio 40 % in high-income countries and 54 % in low-income countries. (UN-WATER – WQF, 2013). Industrial wastewater around is one of the important pollution sources in the pollution of the water environment. It is generally reported that approximately 20% of the world's freshwater withdrawals are used by industry, while around 70% of the world's freshwater withdrawals are used by agriculture and rest, about 10 %, is used for municipal purposes. We have to take into account that a huge varieties exist between different regions and countries (UN-WWDR4, 2012).

Table 6. Water withdrawal by the sector around 2006

Total withdrawal by sector						
	Municipal	Industrial	Agriculture	Municipal	Industrial	Agriculture
	km^3/year	km^3/year	km^3/year	%	%	%
Africa	28	11	175	13	5	82
Americas	135	285	409	16	34	50
Asia	228	244	2036	9	10	81
Europe	72	188	73	22	56	22
Oceania	5	3	11	26	15	59
World	468	731	2704	12	19	69

Source: (FAO, 2012)

Industry sector can use water in multiple ways: for cleaning, heating, cooling, for generating steam, for transporting dissolved substances or particulates, as a raw material, as a solvent and as a part of products (beverage industry). Industry creates more pressure on water resources from the impacts of wastewater discharges and their pollution potential than by the quantity used in production (UN-WATER, 2009). In fact the wastewater is an essential by-product of modern industry and it plays a major role as a pollution sources in the pollution of water environment. There are many types of industrial wastewater based on different industries and contaminants. Each sector produces its own particular combination of pollutants (see Table 5). Like the various characteristics of industrial wastewater, the treatment of industrial wastewater must be designed specifically for the particular type of effluent produced. The amount of wastewater depends on the technical level of process in each type of industry sector and will be gradually reduced with the improvement of industrial technologies. The increasing rates of industrial waste water in developing countries are much higher than those in developed countries. This fact predicts that industrial wastewater pollution, as a mean environment pollution problem, will be redirect from developed countries to developing countries in the early 21st century (YI, 2009).

Table 7. Water pollutants - industrial sector

Sector	Pollutant
Iron and steel	BOD, COD, oil, metals, acids, phenols, and cyanide
Textiles and leather	BOD, solids, sulphates and chromium
Pulp and paper	BOD, COD, solids, Chlorinated organic compounds
Petrochemicals and refineries	BOD, COD, mineral oils, phenols, and chromium
Chemicals	COD, organic chemicals, heavy metals, SS, and cyanide
Non-ferrous metals	Fluorine and SS
Microelectronics	COD and organic chemicals
Mining	SS, metals, acids and salts

Source: (YI, 2009)

2.3.2. Questions and limits of environmental legislation and policy in industrial sector especially in tanning industry

The sustainable development among others builds on the requirement that any new legislative proposal must include an assessment of their potential economic, environmental and social costs and benefits. Desire to promote economic development remains the dominant policy goal for government at all levels. There appears to be widespread public concern about unanticipated consequences of continuing industrial development. Collision between sustainable development and potential environmental threats are obvious. The new economic policy adopted by the government is envisaged to encourage the acceleration of local as well as foreign investment in the industrial and agricultural economic sectors. The expected rapid development will have both positive and negative impacts (Abele, 2011 via EPA, 1995).

However, government agency EPA is trying to push forward Environmental Policy of Ethiopia (EPE) to balance sustainable development with environmental practises. The implementation of environment related policies have been characterized by significant gaps between policy and implementation, and limited stakeholders participation. The real challenge is to develop cost-effective pollution reduction systems of industrial pollution to suitable local conditions under easy control mechanism without strengthening the institutional capacity. After that, the government is required to put the enforcement laws and regulations in place.

The country Supreme law gives a right for development (f. e. article 42, 43 and 92) with respect to policies and projects affecting the community and levels of the adverse impacts generated.

Based on these articles the country formulated three proclamation, two prevention, and regulation control drafts and one policy:

295/2002 - Environmental protection organs establishment proclamation
299/2002 - The environmental impact assessment proclamation
300/2002 - Environmental pollution control proclamation

Environmental policy (1997)
Provisional standards for industrial pollution control in Ethiopia (2003)
Industrial Pollution Prevention and Control Regulation (Draft in progress)

Those are the basic legal instruments use in administering the industrial sector's compliance with the environment law. Environmental sustainability is recognized in the constitution and in the national economic policy and strategy as a key prerequisite for lasting success. However, there is no overall comprehensive formulation of cross-sectoral and sectoral issues in a policy framework on natural resources and the environment to harmonize these broad directions and guide the sustainable development. There are serious weaknesses in the use of the strategy of environmental policy integration in industrial sector especially in the tanning area. (Abele, 2011 via Baker, 2006 and EPA 2005).

Gashaw tried to underline that especially tanneries should select key strategy to maintain achievement and enhance its performance that extends beyond compliance in promoting EMS in general in tanning process, transfer technological and eco-friendly management practice. According to him the tanneries development path way should comply with five pillars of sustainable development: ecologically protective, socially acceptable, economically productive, environmentally just, efficient (Abele, 2011 via Gashaw, 2007).

From this points of view, some tanneries trying to consider the environmental issue as part of the manufacturing process. Of the 23 tanneries, two of them have effluent treatment plant of up to secondary level, seven of them have primary treatment plant and in addition to that some of them have chrome recovery recycling units. ISO 14001:2004 based on environmental management system is implemented in two of tanneries.

The factors complicate the effort of tanneries of accepting environmental protections are high installation cost, high operation and maintenance costs. The other point the factories facing is the decreasing of profit which freezes investment to expand the business. (Abele, 2011 via Dagnew and Daniel, 2011).

2.4. Tanning industry

Tanning industry sector is one of the most profitable agro based industry in the world (MWINYIHIJA and QUIESENBERRY, 2013). This sector uses hides and skin which are by-products of the meat and dairy industry. Final output is leather, with applications in downstream sectors of the consumer goods industry such as footwear, garment, furniture, automotive and leather goods industries (see simplified inputs and outputs chart figure 3).

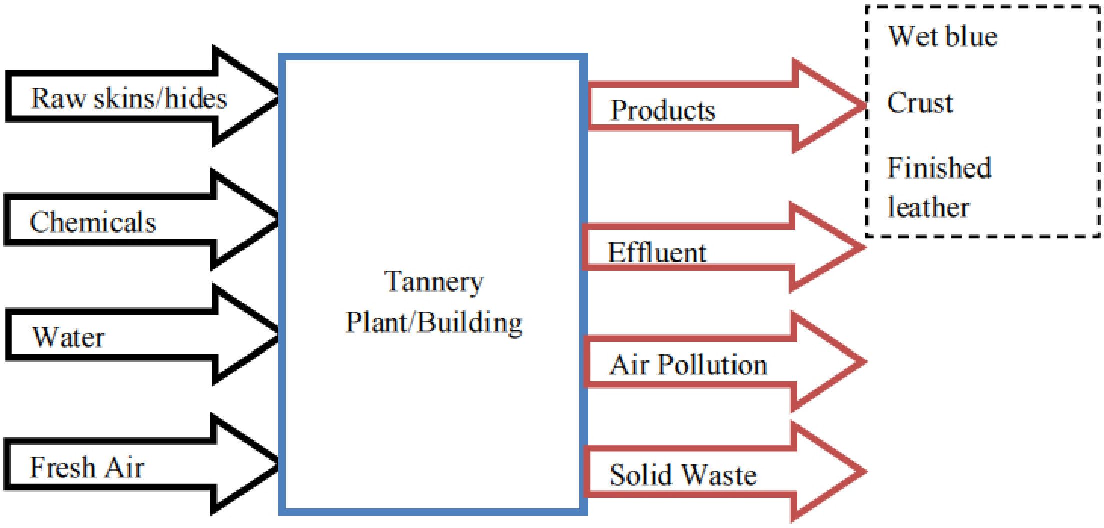

Figure 4. **Simplified inputs and outputs of tanneries** (source: Abajihad, 2012)

More than 50 percent of bovine hides and approximately 40 percent of sheep and goat skins is processed into footwear, while the remaining is used for the production of garments, furniture, travel goods and others list above (FAO, 2003).The processing of hides and skins also generates other by-products like fertilizers or bio-fuel which finds outlets in several industry sectors such as agriculture or energetic (ICT, 2009). The leather sector is also characterized with a long value chain with multiple socio-economic dimensions such as enhanced employability, creation of wealth and acts as a tool towards rural development (MWINYIHIJA and QUIESENBERRY, 2013).

Table 8.Raw Hides and Skins, Leather and Leather Footwear (average 2008-2010)

	Raw hides and skin		Leather	Footwear
	Livestock population (milion head)	Production (thousand t.)	Production (thousand t.)	Production (million pairs)
BOVINE HIDES AND SKINS				
World	1,591.5	6,080.7	542.9	4,534.0
Developing Countries	1,277.4	3,587.5	394.3	3,540.6
Developed Countries	314.1	2,493.2	148.6	993.4
SHEEPSKINS AND GOATSKINS				
World	1,978.1	711.3		
Developing Countries	1,953.5	504.1		
Developed Countries	384.6	207.1		

Source: (FAO, 2011)

Tanning industry has been also categorized as one of the highly polluting industries. Unfortunately, it has been under increasing pressure from different fronts concerning compliance with environmental regulations. By its very nature, the leather processing requires enormous amounts of water and involves the use of several chemicals in varying amounts. The effluent discharged from tanneries becomes a significant source of environmental water pollution. That's why searching for alternative resources to modify its processing methods to ensure a sustainable manufacturing industry for the future is in the trend. Due to lack or weak of proper environmental policies, some tanneries are moving from developed to developing countries where regulations are still less stringent and the labour costs are lower (FAO, 2003). This leads us to African continent. Africa producing 21% of the global livestock population, 14% of the worldwide hides and skin production and only 3.5% of value added leather and leather products. Total earnings for Africa leather sector represent amount of 4 billion USD annually in comparison to global earnings of 100 billion USD annually. This situation is indicative of the high losses, low value addition initiatives and unexplored opportunities that are eminent in the continent's leather industry (MWINYIHIJA and QUIESENBERRY, 2013).

2.4.1. Tanning industry in Ethiopia

Ethiopia is one of the countries with the largest livestock number in the world (7th – 10th place) and number one in Africa continent (IQUBAL, 2013). According to government Central statistical agency estimations, total livestock number of Ethiopia stands at 22.6 million goats, 24.2 million sheep and 52.13 million head of cattle (CSA, 2012). As the Ethiopian government heavily support leather industry and farmers, especially in security of supplies of feed and water for large herds, the livestock number still increasing (ELICO, 2014). Estimations indicate that the country is able to collect 3.7 million cattle hides, 8.4 million sheep skin, 7.7 million goat skin. The sheep and goat skin are preferred for leather garments, gloves or in addition can be used for shoe upper. The cow hides are mostly using for shoes or garments and leather accessories (UNIDO, 2012).

In Ethiopia, there are 26 tannery industries (see table 9). Two largest industries are Ethiopia Tannery with 12,000 sheep and goat skin and 1,200 cowhides soaking capacity per day and ELICO with 15,500 sheep and goat skin and 1,050 cowhides soaking capacity per day, both situated in Addis Ababa. Total Sheep and goat skin capacity for soaking per day is

153,650 and 9,725 cowhides soaking capacity per day. Together whole tannery industry employs more than 4500 persons (UNIDO, 2012).

Table 9. Tannery industry - Companies profiles

No.	Name of factory	Location	Soaking capacity per day		Number of employees
			Sheep and goat skin	Cow hides	
1	Ethiopia tannery	Mojo (Oromiya)	12000	1200	682
2	Kolba tannery	Mojo (Oromiya)	8000	500	290
3	Gelan tannery	Mojo (Oromiya)	3000	0	87
4	Mesako Global tannery	Mojo (Oromiya)	3000	0	40
5	East Africa tannery	Mojo (Oromiya)	8000	0	92
6	Mojo tannery	Mojo (Oromiya)	8000	500	360
7	Friendship tannery	Mojo (Oromiya)	10000	1000	100
8	Farida tannery	Mojo (Oromiya)	7000	0	
9	Vasen United tannery	Mojo (Oromiya)	5000	0	
10	Bale tannery	Debrezeit (Oromiya)	2000	400	80
11	Hora tannery	Debrezeit	7000	0	210
12	ELICO[5]	Addis Ababa	15500	1050	1128
13	Dire tannery	Addis Ababa	6000	600	425
14	Walia tannery	Addis Ababa	5000	1000	150
15	Batu factory	Addis Ababa	8000	1000	360
16	Addis Ababa tannery	Addis Ababa	2400	1200	190
17	Christal tannery	Addis Ababa	1750	100	80
18	China Africa tannery	Sululata (Oromiya)	10000	0	450
19	Debreberhan tannery	DebreBerhan (Amhara)	6000	0	80
20	Hafde tannery	Sebeta (Oromiya)	6000	250	430
21	Blu Nile tannery	Sebeta (Oromiya)	3500	0	78
22	Kombolcha tannery	Komoblcha (Amhara	6000	0	145
23	Mersa tannery	Mersa (Amhara)	6500	325	161
24	Sheba tannery	Wukro (Tigray)	6000	600	373
25	Bahirdar tannery	Bahirdar (Amhara)	4000	0	125
26	Habesah tannery	Bahirdar (Amhara)	4000	0	112
	Total		163650	9725	4577

Source: (UNIDO via LIDI, 2012)

The footwear sector is consisting from 13 large mechanized shoes factories and many of MSMEs. All large shoes companies, except Sheba, are located in Addis Ababa and suburbs of the city. Collectively they can produce 10, 000 pair of shoes per day. Most of the MSMEs

[5]ELICO Industry included Abyssinia Tannery and Awash Tannery

are located in the "Merkato"[6] area in Addis Ababa. The specific number of MSMEs is not known. Estimations show that we could count with numbers around 40 units of medium scale producers, 75-100 units of small scale producers and 400-500 units of micro enterprises. Collectively the can produce around 12, 000 pair of shoes per day. Formal shoe factories sometimes contract out certain steps or parts of their production via MSMEs. The leather goods and garment sector included, according to official statistics, 13 large scale industries but the actual figures may be higher.

During the years 2003-2011 was leather sector targeted as suitable investment area and total in-flow of FDI had increasing tendency with total capital of 1.8 billion birr (USD 109,133,000).They could provide 6288 permanent and 7206 temporary employment. Most of the licensed projects are situated in the manufacturing of leather products and tanneries. According to the EIA, 36 projects are in their pre-implementation stage, 5 in implementation stage and 14 in operation stage (UNIDO, 2012).

Table 10.Exports of leather and leather products (million USD)

Product category	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
LLPI	66.9	74.3	89.5	101	75.7	56.5	101.34
Pickle	28.2	28.4	30.5	32.1	18.9		
Wet Blue	21.9	28.7	27.1	29.3	15.1		
Crust	9.4	10.5	19.5	17.7	23.1	37.7	70.14
Finished leather	3.1	5.7	6.9	12.3	11.2	12.8	25.34
Shoes	3.4	1.6	5.5	9.7	7.2	5.7	8.64
Leather garment and articles	0.03	0.3		0.02	0.1	0.13	0.24
Total Ethiopian export	847.2	1000.3	1185.1	1465.7	1447.9	2003.1	2747.1
LLPI export as % of total export	7.8	7.5	7.5	6.8	5.2	2.8	7.5

Source: (UNIDO via LIDI and National bank of Ethiopia, 2012)

Ethiopian trade with leather and leather products has increasing tendency. Export of those articles increased from 67 million USD in 2005 to 104 million USD in 2011. Due to the

[6]"Merkato" is huge open market (est. 114 hectares) with informally employed street vendors. In this market operate over 13,000 employees, 7,100 business entities, 2,500 retail shops, most in open stalls, 1,500 service businesses, and 80 wholesale operators. Around 14,800 formal businesses in total (CITY GOVERMENRT OF ADDIS ABABA, 2012)

financial crisis and other factors, export declined in 2009/10 but picked up steeply in 2010/11. On average, the leather and leather products industry contributed 5.9 % to the total export earnings for the years 2004/05-2010/11. According to FAO (2010) the global trade of light leather was 16.6 billion USD in 2010 (UNIDO, 2012).

2.4.2. Typical manufacturing processes in Tannery

First step starts after salty hides are brought to the tannery and stored before they will be processed to the genuine leather. The whole process is consisted of many steps, which are in proper order, but we could find a little difference among every particular tannery. It depends on many factors such as type of hides which are processing, types of methods which are using, types of chemicals which are applying and others. The whole process in Awash tannery is illustrated on diagram below (figure 4).

Before the whole process start in tannery, skin must by obtain from animal. Consequently, skin or hides are curing with salt to protect them against putrefaction of the protein substance (collagen) from bacterial growth. After those steps are hides brought to the Awash tannery, where are processing in first section of tannery called beam-house. There, hides are soaked using clean water to wash all left over salt and other natural dirt. Soaking is increasing the moisture of hides for further processing. The moisture should be around 65%, which is natural moisture of raw hides. Following step is liming, which is processing in the same drum. This process is based on increasing pH value of water by adding lime and sodium sulfide into load. Due to chemical reactions hairs and other substances like natural oils and proteins, are remove from the hides. We can consider soaking and liming as one process, which typically lasts around 24 hours. After this process is hide called pelt. The last step in beam-house is fleshing. Excess flesh and fatty tissue under the pelts are mechanically removed and unwanted parts of pelts such as tail, navel or kneecaps areas are cut off. If the beam-house is well managed, it produces no solid waste. Leftovers from hides are used for production of glue and gelatine or they can be used as fuel for biogas station (FAO, 1996; HEINEN, 2006).

The second operation section of tannery takes place in tan-yard. This part starts with tanning itself, which including a several operation, which could be list themselves. The processes are: de-liming, bating, pickling, tanning, and basification. In first two sub steps (de-liming and bating) are alkaline pelts neutralized de-liming) with acid ammonium salts and treated with enzymes (bating). The pelts become softer due to added enzymes. In pickling process pH value is set to 3 by adding acid and salt. This value is suitable for the addition of tanning agent (in our case – chromium salt $^{3+}$).When the pH value is low, the chromium molecules are very small and can easily penetrate the pelt and become integrated in the skin fibres. During another step - basification, the pH-value is slightly raised, which makes the chromium particles in the pelt grow larger and connect with the skin collagen in at least two places. The connection between tanning agent (chromium $^{3+}$) and pelt material is called tanning. The chromium tanning dyes the pelt into a bluish colour, that's why after tanning pelts are called "wet blue" (FAO, 1996; HEINEN, 2006).

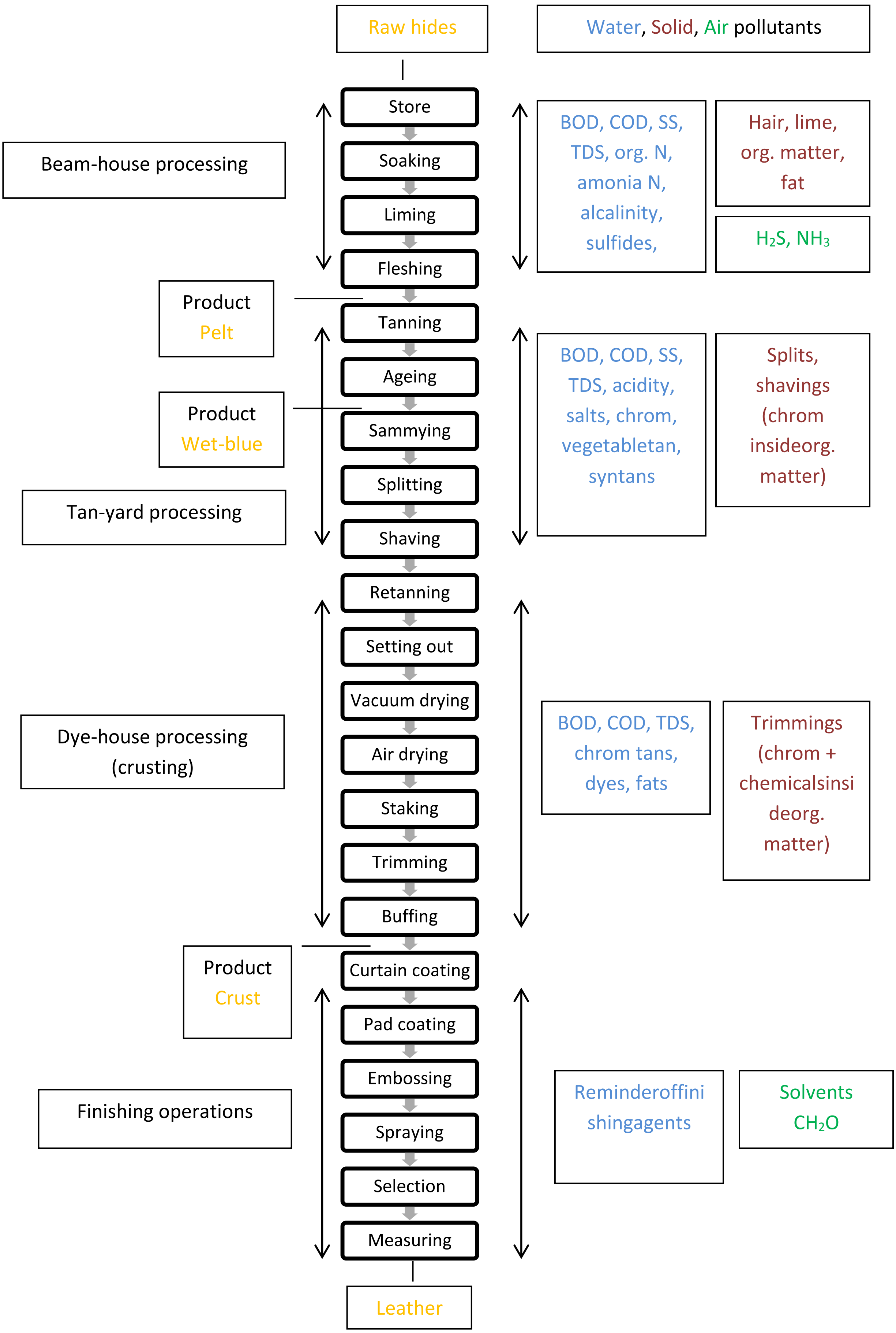

Figure 5. **Leather processing from Awash tannery** (source: Awash tannery diagram)

The wet blue, which is soaking wet, is placed on the sammying machine (therefore this step is called sammying) and two felt rollers press out a part of the water under high pressure. Splitting and shaving is done to obtain the desired thickness of the pelt. Complete pelt is cut into two sides, due to easier handling in further processing.

Another processing section takes place in part of the tannery called dye-house. Here, we are starting with process called re-tanning. During this step leather is getting special and customer-specific characters such as softness, feel, elasticity and other features of the leather. This step consist of a several sub steps which are following: Neutralization, re-tanning, dyeing, and fat liquoring. During the first sub step (neutralization), the wet blue's pH value is adjusted to a particular value (4.5 – 6.5) for the adding of dyeing, tanning, and greasing chemicals. In stage of re-tanning itself additional tanning agents are added to the wet blue to give the leather the character that is wanted. Follow the process of dyeing, when wet blues are coloured and last step of re-tanning stage is fat-liquoring, where fats, oils and waxes are fixed to the leather fibres to make the leather water repellent and reduce the leather's ability to absorb water. Next step is called setting out. In these step setting-out machine flattened and stretched the grain side of wet-blue with blunt blades. The leather surface becomes smoother, more even and this process also removes excess water. Follow processes of drying. During vacuum drying the leather is dehumidified with temperature around 40° centigrade and fibres are fixed by doing this. The last drying process is carried out by air drying. Here, any remaining moisture in the leathers evaporates. The leather is dried to various moisture levels usually 14-25%. Following step is staking. During this process the leather is softened by heavily vibrating metal pins, the fibres are loosened up towards each other and become more flexible. The leather becomes smoother and displays a better surface. Next process is trimming, where fringes and other unwanted parts of the leather are removed. Ensuing step is the buffing, where abrasion of the surfaces to reduce defects from both sides is applied. After all these steps the leather is called "crust". This type of processed leather is ready to use, because all the further working steps are only changing the surface and visual characteristic of final product (BULJAN, KRAL, 2011; HEINEN, 2006)

The last processing stage is surface coating or simply finishing stage of leather processing. The purpose of finishing is to improve the properties of the leather, to protect it from wetting and soiling, to level out patches and grain faults, to apply an artificial grain layer and to split or corrected grain leather. Furthermore to modify the surface properties (shade, lustre, handle, etc.), which may contain solvents, plasticizers, binders and pigments. These solutions are applied by pads (pads coating), curtain coating or spraying. Pad coating is process, where pad coats are applied by means of a plush pad - a wooden board covered with a soft velvet-like cloth. It is done by hand and ensured that the finish is worked well. In curtain coating, the solution is pumped into a reservoir above the conveyor carrying the leather and flows down onto it. In most cases, painted or sprayed leathers are not dried in ovens, but on trays on shelves. This practice provides a wide evaporating surface and contributes to air pollution. Next step is embossing. Using high pressure and high temperatures, a metal plate embosses the desired pattern onto the leather, which caused different visual surface structure for the eye. Technically, the skin is unchanged. Following step is spraying. Different products such as grounding agents, binding agents, dyestuffs, lacquers, or touch modifiers are sprayed on the leather surface. Small corrections in colour and adjustments to the desired end tint are carried out.

Two last steps are selection and measuring. Before all leather skin are measured, selection process, where the leather thickness, colour tone, feel and faultiness of each side is checked. Since this is a natural product, small variations are possible. Leather is sold by the square meters, each single leather side is measured at the end of the production process and finished leather can be send to the customers (DEAN, 2011 and HEINEN, 2006).

2.4.3. Special tannery pollution

Leather industry is categorized as one of the highly polluting industries and there are concerns that leather-making activities can have adverse impact on the environment (KANAGARAJ, VELAPPAN, 2006). According to Alebel Abebe Belay, tannery effluents are ranked as the highest pollutants among all industrial wastes (Belay, 2010). Tanneries are creating special kind of pollution, which we can partly compare to meat industry, where fats, hairs and similar organic and chemical substances predominate. We can divide this pollution into three kinds:

1. Solid waste
2. Air pollution
3. Wastewater

Solid wastes generated in leather industries contribute mainly skin trimmings, fleshing wastes, keratin wastes, shaving wastes, buffing wastes and others. It constitutes proteins as the main components. According to Kanagaraj and Vellapan (2006) out of 1000 kg of raw hide, nearly 850 kg is generated as solid wastes, Ramasami (2001) and Ludvik (1996) quote solid waste number around 800 kg in leather processing. Only 150 (200) kg of the raw material is converted into leather. Solid waste during the leather processing constitutes beam house around 80%, tanning around 19% and finishing nearly 1%. The solid wastes can be hydrolyzed and used as a useful by-production many ways (KANAGARAJ, VELAPPAN, 2006).

FAO (1996), according to Buljan, estimated, that the solid waste production per 1000 kg of raw hide is about 450-600 kg. Collection and safe disposal of solid waste is associated with costs. Conversion of solid waste into by-products reduce pollution load and it can also be commercially beneficial. This represents huge potential for producing increased returns to tannery processing through deriving value from wastes. In any event, reduction of waste is essential nowadays, in order to meet demands for reduced pollution load from leather industry (FAO, Buljan, 1996).

Tanneries are well known for generating typical odour. Substances are released into the air from ongoing chemical reactions, in the form of vapours of solvents, dyes and also like dust particles (IFC, 2007). Rehydration of salted hides and skin ordinarily emit odour of volatile fatty and amino acids evolved in the course of biological decomposition in presence of water. Toxicity of hydrogen sulphide along with acids, fats and carbohydrates in liming, de-liming and tanning processes is predominant within tanneries. H_2S at concentration of 20 ppm (30 mg/m3) in ambient air is fatal to humans. Ammonia (NH_3) escaping from de-liming processes to atmosphere is odorous and pungent. Maximum admissible level of ammonia in air is 50 mg/m^3. Various phenols (monohydric, dihydric, trihydric) are emitted into air during processing of hides in the post-tanning and finishing operations. The venting out of malodorous substances to ambient air are responsible for atmospheric pollution(KANAGARAJ, VELAPPAN, 2006).An important part of the air pollution by leather tanneries is caused by the need for energy, which has connection with emissions of CO, CO_2, NO_2(FAO, 1996).

The tanneries are one of the most water intensive plants. The quality of water mostly depends on the type of hides, mechanical and chemical methods used in tanning and others. The tannery effluents are generally characterized by high contents of dissolved, suspended, organic and inorganic solids giving rise to high oxygen demand, toxic metal salts and also chromium metal ions. The disagreeable odours emanating from the decomposition of proteinous waste material and the presence of sulphide, ammonia and other volatile organic compounds are also associated with tanning processions (KANAGARAJ, VELAPPAN, 2006). The water consumption is greatest in the pre-tanning areas (beam-house). Those wastewaters are generally collected together. They may contain hide substance, dirt, blood, or dung and they have significant loads of organic matter and suspended solids. Wastewaters from tan-yard processes may contain sulphides, ammonium salts, and calcium salts and are alkaline. Finishing wastewaters may contain lacquer polymers, solvents, colour pigments, coagulants and others (IFC, 2007).

Table 11.Special tannery pollution on base of different processes

Process	pollutants
Soaking	salts (Cl), fat, protein, preservatives
Fleshing, trimming, bating	lime, ammonium salts, ammonia, proteins, sulphides
Tanning	chromium(salts) and polyphenolic compounds
Wet-finishing	dye and solvent chemicals

Source: (FAO, 1996)

During the tanning processes at least 300 kg of chemicals (lime, salts etc.) are added per 1000 kg of hides. Excess of non-used salts will appear in the wastewaters. Because of the changing pH value, these compounds can precipitate and contribute to the amount of solid waste or suspended solids. Every tanning process step, excluding crust finishing operations, produces on average 35 m^3 wastewaters per 1000 kg of raw hides (FAO, 1996). In well managed tanneries it could be around 30 m^3 (BULJAN, KRAL, 2011) or 20 m^3 (MULDER, BUIJSEN, 1994). The tradition methods of leather conservation can demand 50 m^3 of water per 1000 kg of raw hides (MULDER, BUIJSEN, 1994, KANAGARAJ, VELAPPAN, 2006) or even more, up to 80 m^3 (THE WORLD BANK GROUP, 1998). The modern ones could go down to 15 m^3 or lower (DOBLE, KUMAR, 2005).

Table 12. An example of pollution load during conventional processes

Parameter	Typical pollution load, conventional process, kg/tone of wet salted hides	A tannery with daily input of 5 t wet salted hides conventional process discharge per day approx.
BOD_5	90	450 kg
COD	180	900 kg
Suspended solids, SS	90	450 kg
Cr^{3+}	7	35 kg
$S2^{-}$	7,5	37.5 kg
Total Nitrogen TKN	7,5	37.5 kg
Cl^{-}	225	1125 kg
SO_4^{2-}	63	315 kg
Oil and grease	6	30 kg
TDS	450	2250 kg
pH	6 to 9	

Source: (UNIDO, 2011)

Wastewater treatment can facilitate by separation of certain substances within the production process (hairs, fats, agents, chromium). Segregated materials such as glue stock may be further processed and we can reduce pollution load and get by-products. Treatment station should not process any solid waste, since there may only be removed with the slurry, which means that they can no longer be used. Precondition for any recovery of substances is their mutual separation already in the race (Petrů, 1957).

2.4.4. Water purification methods for tanneries

Wastewater treatment is strongly related to the standards[7] and expectations set for the effluent quality. Wastewater treatment processes are designed to achieve improvements in the quality of the wastewater discharge back to the water bodies (WB-WATER, 2014).Before turning to treatment itself, it is important to consider a several observations:

- To design an effluent treatment plant (ETP) is always connected to follow specific requirements of tannery. There are no two identical ETPs.

[7]Many countries have a national environmental protection agency (EPA), which is responsible for all aspects of the environment regulation, sanitation and wastewater management (WB-WATER, 2014).

- Pollutants in effluent cannot disappear by themselves. They can be only converted into something which is environmentally more acceptable or easier to dispose of.
- The same amount of pollutants at lower water consumption means lower hydraulic load (volume) but higher concentration, which is not always easy to treat.
- It is very important to realize strong connection between the leather technologies applied and wastewater treatment in order to reduce the overall cost of treatment (BULJAN and KRAL, 2011).

Widely used terminology refers to three levels of wastewater treatment: primary, secondary, and tertiary (WB-WATER, 2014). Another sources use before primary stage pre-treatment phase of wastewater treatment and can also add post-treatment phase (BULJAN and KRAL, 2011).

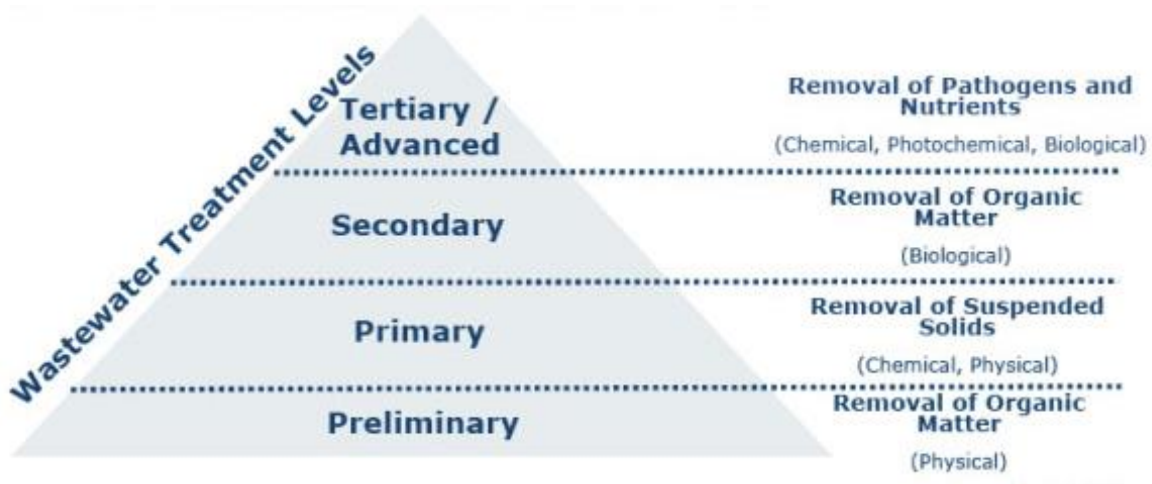

Figure 6. **Wastewater treatment levels** (Source: WATERTAP, 2013)

- Preliminary treatment phase: Is designed to remove large particles, sand, grit and grease, but also to significantly reduce the content of chrome and sulphides before the effluent is discharged into the collection network.
- Physical-chemical treatment (primary) phase: Is designed to remove gross, suspended and floating solids from raw sewage by sedimentation and remove materials that will float by skimming. This phase reduces approximately BOD by 25-50%, total suspended solids by 50-70% and oil and grease around 65%.
- Biological treatment (secondary) phase: Is designed to remove biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes,

where micro-organisms metabolized the organic matter in the wastewater, producing more micro-organisms and inorganic end products (CO_2, NH_3, H_2O).

- Advanced treatment (tertiary) phase: Is designed to reduce residual COD load, when specific wastewater constituents are not removed by previous treatment stages.

- Sludge handling and disposal phase: Aim of wastewater treatment is remove solids and some potentially hazardous substances. Biologically degradable organic substances are converted into bacterial cells. Products are “clean” effluent and sludge (BULJAN and KRAL, 2011).

Most tanneries (nowadays mostly in developing countries) use conventional systems for treatment of the mixture of all production effluents. Such an approach makes it possible to meet environmental regulations, but because of the high cost of the treatment facilities, its implementation has been scarce, especially in developing countries, where water treatment can be absent completely. With the waste reduction (elimination) concept into account, an alternative strategy for water treatment management is proposed, based on individual treatment of the effluents from different processing steps to obtain multi-quality recycled water for various reuse purposes, materials recovery and complete reuse of treated water (NACHEVA et. al, 2004). In this case, is very important to segregate these streams from different stage of processing and to pre-treat them separately according to their characteristics.

There are three main categories of tannery wastewaters, each of them with very specific characteristics:

- Effluents emanating from the beam-house – liming, de-liming, bating, water from fleshing and splitting machines; they contain sulphides, their pH is high, but they are chrome-free.

- Effluents emanating from the tan-yard (tanning and re-tanning, sammying) – high Cr content, acidic.

- Soaking and other general effluents, mainly from post-tanning operations (fat-liquoring, dyeing) – low Cr content

By doing that we can avoid possibilities of safety risks (formation of deadly hydrogen sulphide) and we can reduce the cost of treatment and sludge disposal by avoiding of contamination the sludge with chromium. The mixing of liming and tanning streams gives rise typical odour of poorly managed tanneries. The resulting lethally poisonous gas H_2S, is still by far the most frequent killer in tannery accidents, which occur mainly in inadequately ventilated spaces, especially in pits and channels (BULJAN and KRAL, 2011).

Parameter	Unit	France		Italy		India	
		Surface	Sewer	Surface	Sewer	Surface	Sewer
pH	–	6.5-8.5	6.5-8.5	5.5-9.5	5.5-9.5	5.5-9.0	5.5-9.0
COD	mg/l	125	2000	160	500	250	–
BOD_5	mg/l	30	800	40	250	30	350
Suspended solids	mg/l	35	600	40-80	200	100	100
Ammonia nitrogen (as NH_4)	mg/l	–		15	30	50	50
TKN	mg/l					100	
Nitrate nitrogen (as N)	mg/l	–		20		–	
Total nitrogen in sensitive areas	mg/l	30 15	150			–	
Sulphide (S^{2-})	mg/l			1	2	2	–
Hexavalent chromium, Cr^{6+}	mg/l	0.1	0.1	0.2	0.2	0.10	2.0
Trivalent chromium, Cr^{3+}	mg/l	1.5	1.5	-	4.0	–	–
Total chrome (as Cr)	mg/l	–		2.0	4.0	2	2
Iron + aluminium	mg/l	5	5			–	
Phenol index	mg/l	0.3				1[1]	5[1]
AOX	mg/l	1.0	1.0			–	
Chlorides (as Cl^-)	mg/l	***		1200*	1200	**	**
Sulphates (as SO_4^{2-})	mg/l	***		1000*	1000	1000	1000
Aluminium (as Al)	mg/l	–	–	1.0	2.0	–	–
Iron (as Fe)	mg/l	–	–	2.0	4.0	–	–

Figure 7. **Discharge limits for treated tannery effluents** (Source: Buljan and Kral, 2011)

2.4.5. Emerging treatment strategies for tannery wastewater

Conventional wastewater treatment usually deals with operations such as coagulation and flocculation within primary stage. In secondary (biological) stage are using anaerobic and aerobic processes for reduction of biodegradable material. Constructed wetlands and ponds are another suitable option for this stage of treatment. Nowadays, many new or improved ways of tannery wastewater treatment are introduced. They are listed as hybrid or advanced ways of wastewater treatment (see figure 8).

Membrane processes

This group is covered processes such as microfiltration, ultra-filtration, nano-filtration and reverse osmosis which are mostly use in chromium recycle units, reusing of wastewater and chemicals from the de-liming/bating liquors, reducing of the polluting load of unhairing and degreasing process stages, removing of salts in the biological treatment of tannery effluents for reusing. Reverse osmosis could be use as post treatment to remove refractory organic compounds (chloride, sulphate) and subsequently this effluent could be use within production cycle and lead to reducing water consumption.

Membrane bioreactors

Membrane Bio-Reactor has deserved attention within engineers due to the numerous advantages over conventional activated sludge process such as elimination of settling basins, independence of process performance from filamentous bulking or other phenomena affecting the settleability.

Advanced oxidation processes

Advanced oxidation processes, to treat tannery wastewater and chemicals, use strong oxidizing agents (O_3, H_2O_2) and/or catalysts (Fe, Mn,TiO_2) sometimes supported by high energy radiation (UV light). These processes are all based on the production and utilization of hydroxyl radicals which are powerful oxidants that quickly and unselectively oxidize a broad range of organic compounds.

Advanced oxidation processes covered Fenton based processes, Photo-oxidation processes, Ozone based processes, Photo-catalysis and Electro-chemical treatment.

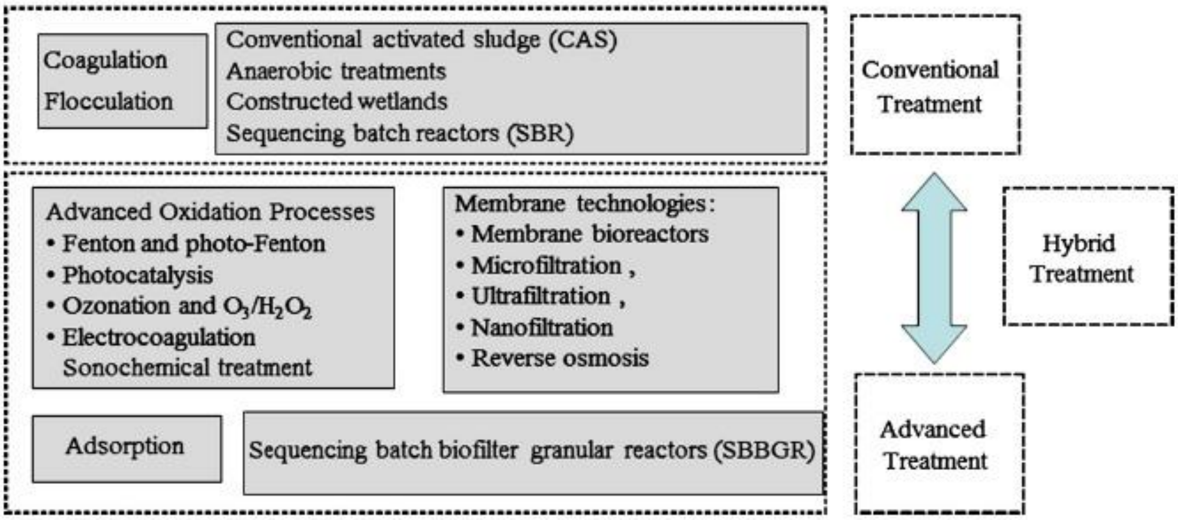

Figure 8. **Scheme of tannery wastewater cleaning strategies** (source: LOFRANO, MERIC, ORHON, ZENGIN, 2013)

2.5. Target factory - Elico - Awash tannery

Modern history of Ethio-Leather Industry Plc. or ELICO started in August 1997 after private investor Sheikh Mohammed H. Al Amoudi entered the leather industry in Ethiopia. ELICO consist from 2 different parts: 2 tanneries (Awash and Abyssinia) and 2 factories for leather processing (Universal leather products, Fontanina shoes factory). This case study is focus on Awash tannery located in the capital city Addis Ababa.

Table 13.Major products of Awash Tannery

No.	Product Type	Thickness	Colour	Remarks for variation
1	Sheep Napa upper (shoe for men's & women's)	0.9-1.1mm and more	Black, Brown and Fashion colours	As per customers order
2	Sheep dress glove leather	0.4-0.5mm 0.45-0.55mm 0.55-065mm & more	Blake Brown Fashion colours	As per customers order
3	Sheep golf glove leather	0.35-0.55mm & more	Silver white Snow white	As per customer order

Source: (ELICO – Awash tannery, 2014)

History of Awash tannery goes back to the year 1957 when the tannery was established. Awash tannery is the largest and the second oldest factory in Ethiopia produces finished leather products from sheep skin and bovine hide. It is also specialized in the manufacture of the finest and world-class leather and leather products.

Figure 9. **Awash tannery front gate** (source: ELICO, 2014)

The unit produces finished shoe upper leather, different leather articles and upholstery from hides. Garments and lining leather from pickled sheep skin are also processed in Awash Tannery. Everything is produces for the local and international leather markets. Samples of production you can see in table below (ELICO, 2014).

Table 14.The production capacity for Awash Tanning Division

Awash Tannery		Production Capacity			
		Per day		Annual (280 working days)	
		In Pieces	In square Meters	In Pieces	In square Meters
1	Sheep Skin (1 piece – 0.39 m^2)				
2013	Sheep crust (finished)	8.000	3158.7	2,240,000	884,436.9
2006	Sheep crust (finished)	6.000	2566.4	1,820,000	718,605.0
2001	Constructed capacity production	12,857	5,074.7	3,600,000	1,421,416.5
2	Hide (1 piece – 2.32 m^2)				
2013	Hide crust (finished)	1050	2438.7	294,000	682,837.3
2006	Hide crust (finished)	1050	2438.7	294,000	682,837.3
2001	Constructed capacity production*	1414	3286.4	396,000	919,740.0

Source: (author's compilation based on ELICO, 2014 and Bekele, 2007)

Awash is made up of two plants. The first one is processing hides while the second one is focus on lambs and goatskins processing. Together they employ around 800 workers. The factory is located on a 123,000m² site in industrial park (south part of the city), of which 1,566m² and 2,778m² provide the tannery buildings and the raw material and chemical storage facilities (see figure 8).

Figure 10. **Map of Awash factory site** (source: author's compilation by using Google Earth)

2.5.1. Awash Tannery as pollution contributor of Little Akaki basin

Awash tannery belongs to the Little Akaki basin, to be precious, to its middle part, which lies basically inside the city of AA before the river leaving the suburbs of Kality and Akaki town (see figure 9 and 10). The river is also traversing through highly populated and big commercial sections of the city. Down below the middle catchment there exist a very intensive concentration of large and medium size industries, workshops and big garages (industrial park). The type of industries in the area include, except our tannery, Walia tanneries, AA Abattoirs, oil factories, beverage factories and others (Tegegn, 2012 via Girma, 2004).

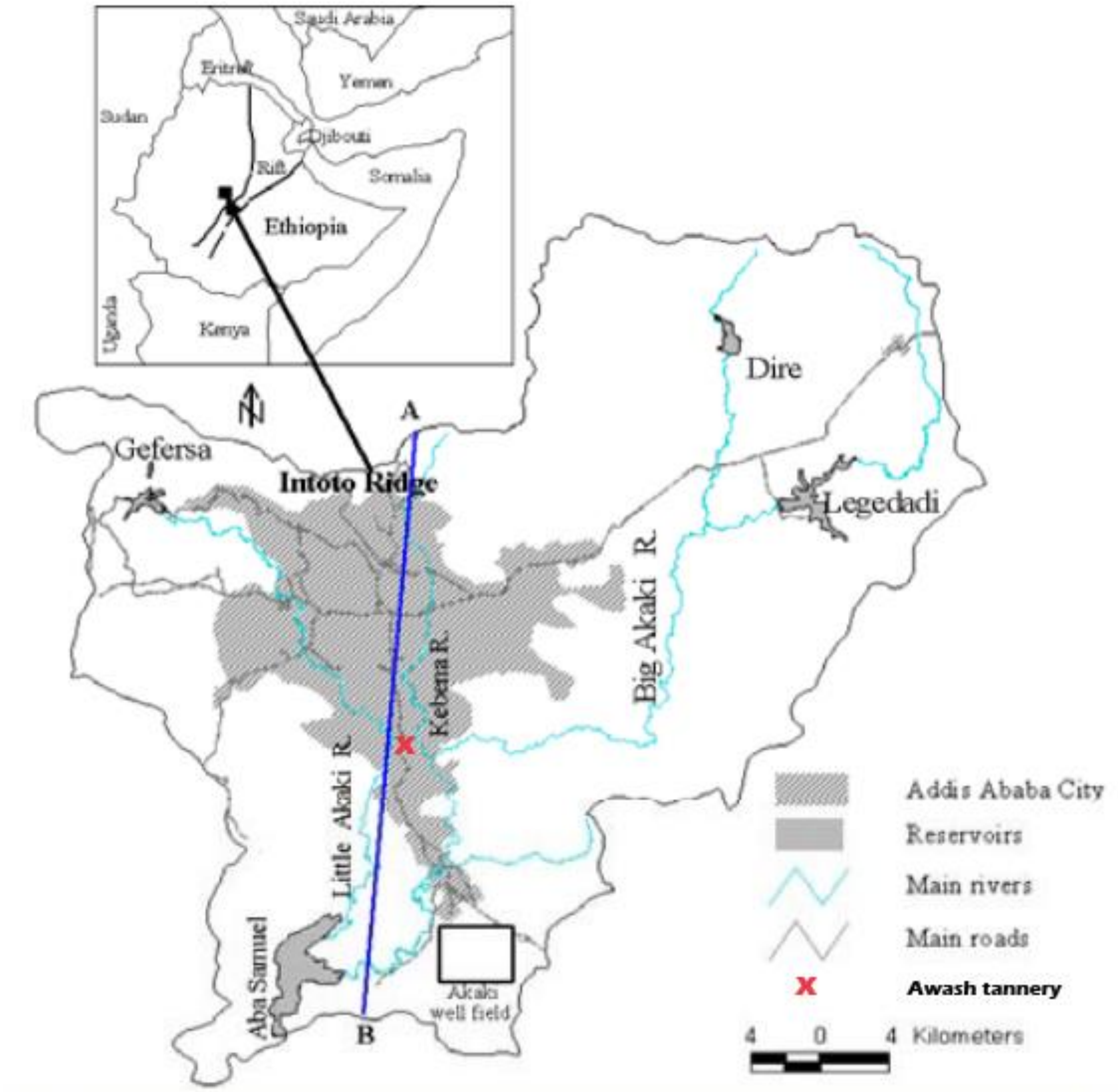

Figure 11. **Akaki River basin – overview map** (source: Ayenew at al., 2008)

In this part of the catchment horticultural crops are grown and irrigated by the river water. The irrigation system also extends toward the farming field of Akaki in the lower catchment. The river near by the tanneries is usually highly polluted since it is serving as recipient of effluent from the factories. The effect of this scenario is expressed by different indicators. The Little Akaki among others is one of the best examples of polluted water body (see figure 10). The residents around the river reported the death of their cattle, dried up of green plants, water born diseases and bad smell resulted due to the death of micro organisms that in turn caused by depletion of dissolved oxygen. Even though the incidences are merely the result of discharges from tanneries but it is impossible to deny the fact that the discharge from tanneries, including Awash tannery, has its own contribution (Abebe, 2011 via Dagnew and Daniel, 2011).

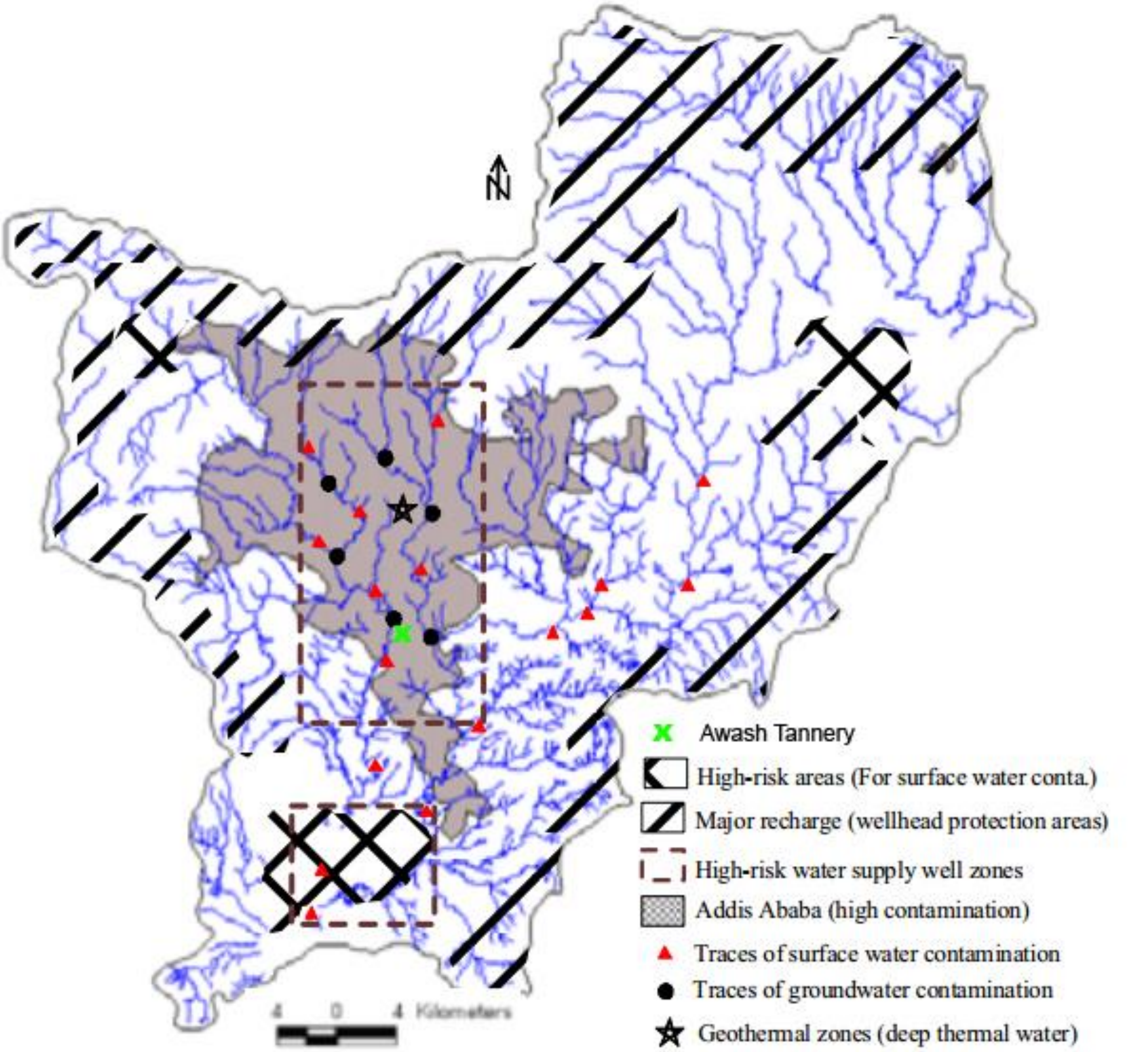

Figure 12. **Akaki River basin - contamination map** (source: Ayenew at al., 2008)

The results from Tolera research show that Awash tannery is significant pollution contributor of Little Akaki river. A high concentration of pollution indicators were measured from its effluents. Beyond others we might notice following indicators with increased values: Na (86mg/l), K (40mg/l), electrical conductivity 1060 µS/cm, increased temperature 27°C, Cl^- (50mg/l) and SO_4^{2-} (43mg/l). These and other substances from effluent such as BOD_5 contributed to the pollution of Little Akaki River (Tolera, 2007).

2.5.2. Trends and ecological future perspectives of Awash tannery

Awash tannery has reached the western and other markets and became the leading company in the leather producing segment in Ethiopia. In 2004 factory established Quality management system ISO 9001, followed by Environmental management system ISO 14001. Awash tannery is also equipped by ETP in primary stage (economical acquisition 8 million Birr, about 9.5 million of CZK, with annual running cost 550 000 Birr, about 650 000 CZK). In 2011 tannery reached another milestone and became certified as Africa tannery of the year (2^{nd} place in whole Africa) (ELICO, 2014).

3 main ecological management systems applied in Awash tannery:

Solid management system

- Recovered hair from sheepskins is sold for blanket or garment manufacturing industries.
- Lime flesh split and drained limed trimmings are sold for glue manufactures.
- Raw trimmings are disposed of landfill.
- Chrome shavings are compressed and deposed to the landfill.
- Dewatered sludges from effluent treatment are deposed to the landfill.

Gaseous emission management

With regard to air pollution /bad odour, gaseous emission from different manufacturing processes and degradation of the row material are the sources.

- Salt de-dusting is practiced prior to loading wet-salted material to reduce salinity in the soaking liquor.

Liquid waste management system

- Chrome recovery

- Effluent treatment - The primary treatment plant is constructed

Despite those achievements, many of challenges are still in stock. The tannery represents a huge environmental burden and it has to face many ecological issues. From environmental point of view, the principal challenges are not only connected with water treatment policy, but also with improving solid waste management and air pollution management. Other challenges are connected with partials steps during producing stages or with efficiency of energy consumption processes and so on.

2.5.3. ETP - Awash tannery

In 2001, new ETP for Awash tannery was finished and in the same year also started its operative training. The new effluent plant (see figure 11), build and equipped by Italian company, was commissioned earlier this year and became the most modern in whole Ethiopia. The cost of the investment reached 8 million Birr while the operational costs are about 550,000 Birr per year. The plant is able to recover and recycle spent chrome and has the capacity to meet all the international discharge regulations up to primary level. ETP is consisted from 2 main parts: Chrome recovery system and effluent treatment.

Figure 13. **Awash tannery – ETP** (source: author's picture, 2013)

Chrome Recovery

All of the exhaust chrome liquors are segregated from tanning drums, coarse, bar-screened, and then fed into a collection sump. They are then fine-screened using a wage wire screen and delivered in to a mixing-settling tank where the pH is raise to pH 8.5 using a mixture of magnesium-oxide and calcium hydro-oxide. After a two hours stirring, the chrome precipitates are allowed to settle. The supernatant is discharged to the effluent treatment plant and the chrome sludge is pumped to a reaction vessel where it is acidified by using sulphuric acid. The final pH of the regenerated chrome liquor is pH 3.2 -3.4, basicity 33%, and the chrome content 10% Cr2O3. This recycled liquid is used for tanning, with new 33% basic chrome added to make up the required chrome offer (ELICO, 2014).

Effluent Treatment

One of the most sensitive areas in the tanning industry is the treatment aspect of effluents and water. Sulphide containing liquors are maintained separately from the other wastewaters. After screening, these sulphides liquors are delivered into a concrete sump for aeration with manganese sulphate to remove sulphides. After that, liquors are mixed with the main effluent in a balancing tank. This mixed effluent is chemically dosed with aluminium sulphate and polyelectrolyte and then fed into a primary clarification unit. The settled sludge is pumped from the base into a sludge thickening sump where it is dosed with lime to increase the viscosity, then dewatered using a pair of conventional filter presses. Conveyor belts are located beneath both presses so that the dewatered cake can be delivered into hoppers for disposal. The supernatant from primary settling is checked for COD, BOD, SS, chromium, sulphur and discharged into the adjacent river (ELICO, 2014).

3. Aims of the thesis and statement of the problem

Tannery processes cover series of chemical reactions and mechanical processes conducted in water media generating wastewaters that are usually discharged in to rivers, other water bodies or by drainage to the land. Purifying the effluent wastewaters before discharge to reduce the environmental adverse impacts usually received no adequate attention and action. The purifying processes also bring additional costs. Tannery processes including the clean technological applications, pollution-free chemical substitution, recycling, and waste treatment options, are often inefficiently managed and overprice, due to lack of know-how and knowledge. The environmental policy compliance and implementation problems related to the tannery wastewater management manifesting itself also a significant policy gap. This gap needs to be enforced to ensure sustainable improvement of the sector.

Objectives

This case study was focus on proposition and design of suitable water purification system based on the data which has been obtained from Awash tannery in Addis Ababa and also gain from our own water samples.

Main objective:

The main goal of this case study is to propose a basic water purification unit system to reduce water pollution load with consideration of specific local conditions and international effluents standards.

Specific objective:

Specific objective is to analyse and evaluate the current water pollution caused by Awash tannery and point out the main pollutants and their impacts.

Second specific objective is to propose an advanced water purification unit to reduce water pollution load with consideration of specific local condition and international standards.

4. Methodology

Sequential steps of our methodology started with exploiting of secondary data sources. The literature review was built on scientific articles from databases such as Science Direct or Web of Science as well as on UN handbooks connected with leather processing and water issues. The second step of our methodology was the observation and the sampling in the field (Awash tannery, Addis Ababa), where the primary data were obtained. The third step was analysis of primary data based on scientific researches, my own knowledge and international emission standards. The final step was designing of water purification unit based on the previous findings.

4.1. Place of description

For the purpose of this case study Ethiopia as priority country for cooperation and development of the Czech Republic was chosen. We were looking for suitable subjects with high economic, environmental, international and ecological impact, where adoption of future ecologic strategies in water treatment sector was expected. In consideration of these prerequisites, Awash tannery, as the second biggest producer of Ethiopian hides and skins[8], taking dominant position in the leather sector, was chosen. Awash tannery, as the member of ELICO's corporation, is situated in the south part of Addis Ababa called Bole (see figure 12 and figure 13). The factory itself is the part of an industrial park, directly connected to Little Akaki river system.

[8]ELICO industry (Abyssinia Tannery and Awash Tannery) produces approximately 15,500 sheep and goat skin per day and around 1,050 bovine hides per day, which represents the biggest production in Ethiopia. Awash tannery itself can produce up to 8,000 skins and 1,050 hides per day, which represents the second biggest production after Ethiopia tannery with production 12,000 skins per day and 1200 hides per day (UNIDO via LIDI, 2012).

Figure 14. **Map of Awash tannery location within the city** (source: Google maps, 2014)

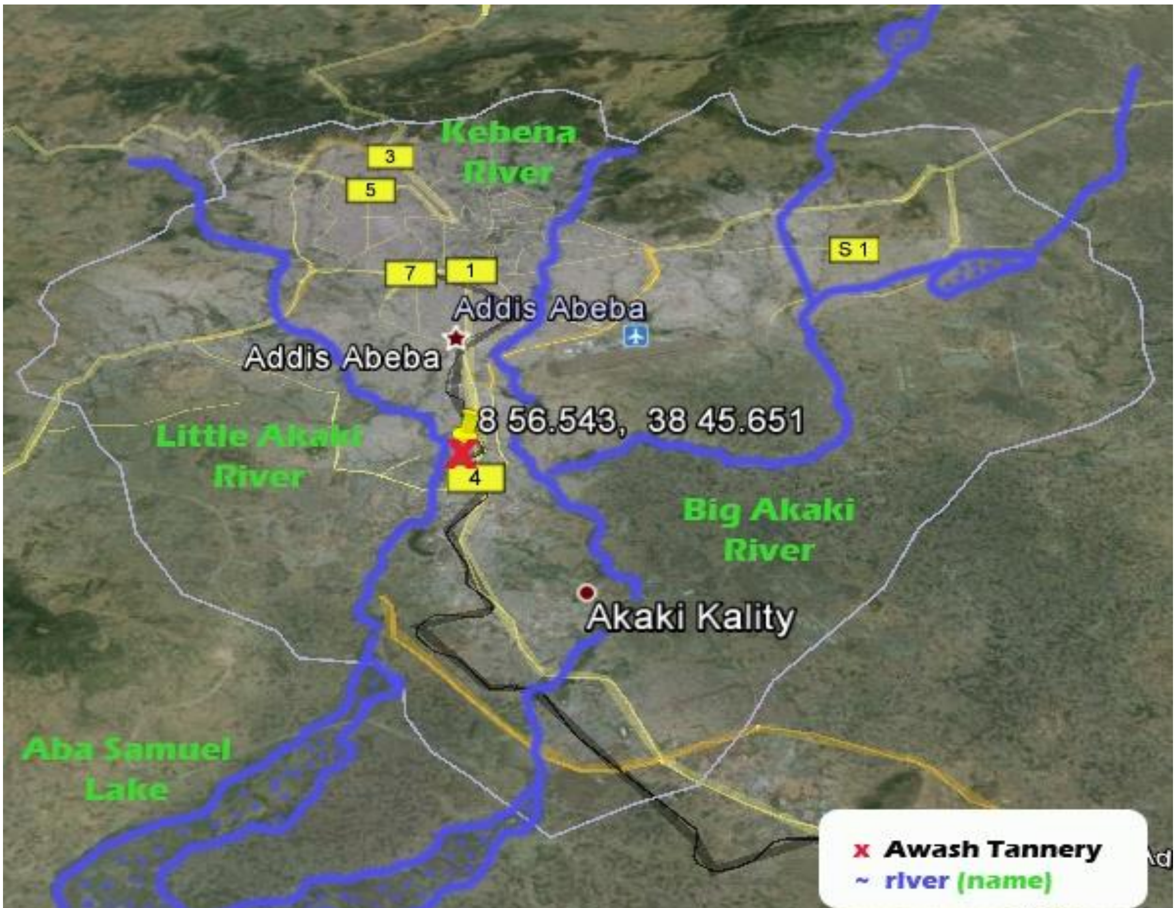

Figure 15. **Map of Awash tannery location including water bodies** (source: author's compilation by using Google Earth application)

4.2. Data collection

Data for this case study were obtained in the place of origin of Awash tannery - Ethiopia. The visitation of Addis Ababa, the capital city of Ethiopia, was realized in November 2013[9] together with supervisor of this thesis doc. Ing. Vladimir Krepl CSc.. The purpose of this research journey among other was to contact Awash tannery, obtain data and water samples for this case study. After a several days it become clear that reach this task is not easy. We had to overcome a few administrations processes with representative of ELICO industry and underlined that our research will be used only for academic purposes. After a few meetings and declarations we got permission to visit Awash tannery and take water samples. Nevertheless, we were not allowed to take almost any documentation about special machinery and process techniques which could enrich our data sets. Company representatives were afraid of leakage of sensitive information and know how, especially technical specifies about ETP.

On the other hand we were allowed to take water samples, which were sampled with cooperation of Awash tannery employee. Samples were obtained from inlet and outlet of ETP. We got two 1.5 litre plastic bottles with mix wastewater samples necessary for further analyses. We also obtained results of analyzed samples by certificated laboratory direct from chemical department of Awash tannery, which enriched our data sets, and other information.

4.3. Data analysis

Collected data were summarized and became main structure of this case study. Obtained effluent samples were analysed with cooperation of Ústav technologie vody a prostředí VŠCHT. Analyses we provided in laboratory with ASLAB certification, which allowed to scientific comparison between other certificated laboratories and guarantee rightness of results in the area of water chemistry. Other data such as skin and hide production values or water consumption numbers were calculated based on primary information obtained during observation stage in the factory. For further data processing were used knowledge of author based on studying scientific material and experts advices.

[9] Our research journey took place from October 28th to November 8th

4.4. Limitation of the case study

Due to the lack of technical information and specific processing parameters we compile our results only on basis of analyzed mix wastewater samples and data from certificated laboratory which we received from Awash tannery. Also the number of samples is very limited and for proper analysis is important to test these wastewaters for longer period of several days or weeks at specific time, because the composition of the samples during the day can be variable. This case study should provide example of possible solutions in the design process of water purification units. Other data obtain during observation stage are based on information provided by employee of Awash tannery and cannot be evaluate as exact data. In this case study we deal with those data as mean values for further calculation. Other limitations may appeared in relationship to work with incomplete data.

5. Results

5.1. Analysis of collected data

Analysis of water samples from Awash tannery show the level of contamination by various pollutants. Tables below evince through chosen parameters sample of mix wastewater after finishing all tanning processes and after ETP. Data obtained from Awash tannery (table 15, 16) show hazardous level almost all indicators while some of them reached alarming heights. For example level of COD, Sulphides or Cr^{3+} reaching very high concentration (compare with tables 18, 19) and discharging of these effluents to the surface waters could be life-threatening (see chapter 7.2). Differences between results from years 2006 and 2012 are obvious. Some pollutants, such as Cr^{3+}, meet effluent standards in 2006 and exceed them multiple times in 2012 while other ones deviate on both sides (up or down) to certain extent which could be more or less admissible (further analysis are placed below).

Table 15. Mix effluent analysis provide by Awash tannery 2012

Pollutant type	Unit	Inlet	Outlet
COD	mg O_2/L	2970	1547
pH	-	10.81	7.61
Temperature	°C	26.4	26.4
Colour	-	dark brown	less turbid
Odour	-	pungent	less punget
Total suspended solids	mg/L	6062	231
Cr^{3+}	mg/L	106.05	16.6
Total ammonia (nitrogen)	mg/L	62	136.13
Phosphate (P)	mg/L	0.02	0.016
Total solids	mg/L	14533	7865
Total dissolved solids	mg/L	7497	7438
CHLORIDE	mg/L	1513.7	3079.54
Sulphides	mg/L	1454.51	213.86
Sulphates	mg/L	839.1	589.38

Source (Awash tannery – documents)

Table 16. Mix effluent analysis Awash tannery 2006

Pollutant type	Unit	Inlet	Outlet
COD	mg/L	5300	1840
NH_3	mg/L	103.1	72.7
Nitrite as NO_2	mg/L	0.055	0.039
Nitrate as NO_3	mg/L	14	1.7
Total nitrogen as N	mg/L	180	90
PO_4	mg/L	20.5	4.94
Cr^{3+}	mg/L	1.2	0.94
H_2S	mg/L	141	3.5

Source (Bekele, 2007)

Data obtained from water samples tested in Czech Republic (table 17) show differences in concentration levels compare to data obtained from Awash tannery. Some indicators point a little differences (pH, TSS, COD) while others, for example Cr^{3+} or TDS, indicated completely different concentration.

Table 17. Mix effluent analysis – our water samples 2013

Pollutant type	Unit	Inlet	Outlet
Colour	-	white turbidity	white turbidity
pH	-	11.9	6.2
Conductivity	mS/m	1 007	1509
Total suspended solids	mg/l	4 150	600
Total dissolved solids	mg/l	7 245	12 885
Cr^{3+}	mg/l	0.052	0.231
Ni	mg/l	0.022	<0.005
Pb	mg/l	0.466	0.804
COD	mg O_2/l	5 290	3 990

Source (Results coming from our own water samples, see annex 3)

Those disparities are caused by several reasons. Firstly, the composition of effluents is little bit different every day, that is why also analysis from Awash tannery are not the same, and it depends on specific time, when samples are obtained. In our case, we don't know the specific time, when samples provided by Awash tannery were taken. Due to this fact, the concentration of some indicators could be dissimilar. Secondary, our samples were impact by long transport time (2 days) before they were analysed. This time factor is crucial for precise analysis. Due to the time delay between cull and testing itself cause by extreme distance between Czech Republic and Ethiopia, laboratory was not able to test all wanted parameters. On the other side, the data obtained for this case study are relevant and could be used for theoretical proposal purification units. In case of implementation, further measurements must be obtained (more information follow).

Table 18. International effluent discharge limits for surface water

Parameter	Unit	International standards[10]	
		Minimum	Maximum
COD	mg O_2/l	100	500
pH	-	5,5	9,5
Temperature	°C	25	45
Total suspended solids	mg/l	30	200
Cr^{3+}	mg/l	1	5
Total ammonia (nitrogen)	mg/l	2	100
CHLORIDE	mg/l	100	4000
Sulphides	mg/l	0,1	10
Sulphates	mg/l	500	2000

Source (UNIDO, 2000)

Table 19. Ethiopian and Czech effluent discharge limits for surface water

Parameter	Unit	Ethiopian emission limits	Czech emission limits (chrome tan.)	Czech emission limits (other tan.)
Temperature	°C	40	-	-
pH	-	6 - 9	-	-
BOD	mg/L	200 or >90% r.	50	100
COD	mg/L	500	500 or >80% r.	1000 or >70% r.
SS	mg/L	50	40	40
Total ammonia (N)	mg/L	30	80	100
Total nitrogen (N)	mg/L	60 or >80% r.	100	120
Total phosphorus (P)	mg/L	10 or >80% r.	-	-
Oils, Grease, Fats	mg/L	15	-	-
Chromium total Cr	mg/L	2	1	-
Chromium Cr (vi)	mg/L	0.1	-	-
Chloride (Cl)	mg/L	1000	-	-
Sulphide	mg/L	1	1.5	2
TDS	mg/L	-	5000	5000

Source (Sbírka zákonů České republiky, 23/2011 and CLRI, 2010 via Abebe 2011)

The comparison of the Czech and the Ethiopian standard emission limits denote differences among permissible values of pollutants on both sides. In some cases, the Czech standards are more strict than the Ethiopian ones (BSK, SS, Cr), in some cases, it is vice versa (ammonia, total nitrogen, sulphide), and in one case are values equal (COD).

[10] Limits are compiled on various national standard limits

This case study is working with wastewater analyses from 2006 (table 16), 2012 (table 15) which both were analysed in Ethiopia and from 2013 (table 17) which is our own analysis tested in the Czech Republic. Those analyses are based to wastewater samples taken from inlet of the ETP and from outlet of the ETP in each case. It allowed us to compare removal efficiency of the ETP and find out deficiencies, if there are any, in the ETP's cleaning processes.

The following tables were compiled to be able to compare the same pollutant types. The molar mass calculations were made to calculate chemical compound for accurate comparison. Example of calculation …

Pollutants in table 15, 16 and 17 were re-calculated to concentration of basic chemical element to due to comparison with standard limits and with comparison of each other. Also the ETP efficiency was calculate in percentage from a variation of inlet and outlet concentrations.

Table 20. Mix effluent analysis 2006 and its removal efficiency

Pollutant type	Influent (mg/L)	Effluent (mg/L)	Ethiopian emission limits (mg/L)	Czech emission limits (mg/L)	Removal efficiency (%)	Emission limit (%)
COD	5300	1840	500	500	65.28	> 80 (CZ)
$N\text{-}NH_3$	84.9	59.9	30	80	29.45	-
$N\text{-}NO_2^-$	0.017	0.012	-	-	29.41	-
$N\text{-}NO_3^-$	3.16	0.38	-	-	87.97	-
N_2	180 (176.2)	90 (120.6)	60	100	50 (31.56)	> 80 (ET)
$P\text{-}PO_4^{3-}$	6.69	1.61	10	-	75.9	> 80 (ET)
Cr^{3+}	1.2	0.94	2	-	21.67	-
S^{2-}	132.7	2.87	1	1,5	97.84	-

Note: red colour – exceeding standards for the limits values; green colour – values are in the limits norms
Source (Author's compilation and calculations from tables above)

Table 21. Mix effluent analysis 2012 and its removal efficiency

Pollutant type	Influent (mg/L)	Effluent (mg/L)	Ethiopian emission limits (mg/L)	Czech emission limits (mg/L)	Removal efficiency (%)	Emission limit (%)
pH	10.81 (-)	7.61 (-)	6-9 (-)	-	-	-
temperature	26.4 (°C)	26.4 (°C)	40 (°C)	-	-	-
COD	2970.72	1547.49	500	500	47.91	> 80 (CZ)
$N\text{-}NH_3$	62	136.13	30	80	-119.56	-
$P\text{-}PO_4^{3-}$	0.02	0.016	10	-	20	> 80 (ET)
Cr^{3+}	36.28	5.49	2	-	84.87	-
Cr^{6+}	-	0.2	0,1	-		-
S^{2-}	1454.51	213.86	1	1,5	85.3	-
TSS	6062	231	50	40	96.19	-
TS	14533	7865	-	-	45.88	-
TDS	7479	7438	-	5000	0.55	-
$S\text{-}SO_4^{2-}$	280.28	196.87	-	-	29.76	-
Cl^-	1513.7	3079.54	1000	-	-103.44	-

Note: red colour – exceeding standards of limit values; green colour – values are in the norms
Source (Author's compilation and calculations from tables above)

Table 22. Mix effluent analysis 2013 and its removal efficiency

Pollutant type	Influent (mg/L)	Effluent (mg/L)	Ethiopian emission limits (mg/L)	Czech emission limits (mg/L)	Removal efficiency (%)	Emission limit (%)
pH	11.9 (-)	6.2 (-)	6-9 (-)	-	-	-
COD	5290	3990	500	500	24.57	-
Cr	0.052	0.231	2	-	-344.23	-
TSS	4150	600	50	40	85.54	-
TDS	7245	12885	-	5000	-77.84	-
conductivity	1007	1509	-	-	-	-

Note: red colour – exceeding standards for the limit values; green colour – values are in the limit norms
Source (Author's compilation and calculations from tables above)

In table 17, we can notice increased concentrations of some pollutant compare to tables 15 and 16 and other evident deflections. This disproportions are caused by desorption of suspended solids, for example, during 2 days transportation of samples from Addis Ababa to Prague. Increasing of dissolved solids responds to increasing of conductivity. Other chemical reactions could take place during transportation stage too. Considering those malpractice we have to exclude 2013 analysis from further consideration and work. Nevertheless, those results may still show an outline for roughly comparison.

Tables 15, 16, (17) show that most of the pollutants are exceeding standard emission's limits. By values comparison analyses 2006 and 2012, we discovered different results which supposed to be approximately the same. It could be explain by additional modification on the ETP after analysis from 2006 or not working one or more removal stage of ETP. Table 23 shows comparison of removal efficiency for equal pollutants between years 2006 and 2012 which show us interesting results.

Table 23. Comparison of removal efficiency from 2006 and 2013

Pollutant type	Removal efficiency (%)	
	2006	2013
COD	65.28	47.91
$N\text{-}NH_3$	29.45	-119.56
$P\text{-}PO_4^3$	75.9	20
Cr^{3+}	21.67	84.87
S^{2-}	97.84	85.3

Source (Author's compilation and calculations from tables 19 and 20)

Removal efficiency surprisingly degreased almost at all the monitoring pollutants except Cr^{3+}, probably due to the improvement of chromium recovery unit. It means that additional adjustments on the ETP were not appropriate or part of ETP is really not working. Another surprising fact was that water consumption increased from average 487 m^3 per day in 2006 to average 1000 m^3 per day in 2012 (Bekele, 2007, observation data). Those findings we compared with skin and hide production for the same years and inlet pollution by COD (see table 24).

Table 24. Parameter comparison between 2006 and 2013

Parameter	2006	2013	Alteration (%)
Water consumption (L /day)	487.3	1 000	105.2
Skin and hide production per day (m^2)	5005.1	5597.4	11.8
Influent COD (mg/L)	5 300	2 970	-44

Source (Author's compilation and calculations from tables 14, 19 and 20)

From table 24 followed these facts: While skin and hide production increased only 11.8 %, water consumption increased steeply by 105.2 % and COD went down by 44 %. Rise in skin and hide production is really low compare to rise in water consumption, but degrease in COD parameter confirm our findings. Lower CODs could be explained by increasing in water consumption during manufacturing processes (more water - less concentration) which also could indicate with lowering removal efficiency.

For further consideration we calculated how many m^3 of water were needed for 1 ton of skin and hide production.

Inputs:

Weight of raw skin app. – 3.5 kg (1 piece)
Skin production per day A - 2006 – 6000 pc. and B - 2012 – 8000 pc.

Weight of raw hide app. – 25 kg (1 piece)
Hide production per day 2006 – 1050 pc. and 2012 – 1050 pc.

Water consumption per day A – 487.3 l and B – 1000 l

…………………………………………………………………………………

A total – 47 250 kg

B total – 54 250 kg

……………………

Water consumption: A – 10.3 m^3 (2006) per ton of raw skin and hide

B – 18.4 m3 (2012) per ton of raw skin and hide

Generally 15-50 m^3 of water are used per raw ton of skin or hide (see chapter 5.4). From our calculation followed that water management in Awash tannery is very well managed and there is no obvious water wasting.

Our findings show that the biggest problem of Awash tannery could be in load of COD, SS and ammonia nitrogen which highly exceed emission standards. From this reasons, we focus during designing of purification unit with emphasis to reducing above mention emissions.

5.2. Environmental effect of the main pollutants emerging in Awash tannery effluents

Tanning wastewaters discharged directly into a water body has negative effects on aquatic life and the subsequent uses of these waters. Despite the fact that, the rivers have capacity to assimilate some organic load according to the cycles of the elements in the biosphere, such as carbon, nitrogen, phosphorus, sulphur. This phenomenon is known as self-water purification of the rivers. The specific components that cause problems to the water bodies are mostly ammonia, chlorides, heavy metals (chromium), sulphates, sulphides and the organic load (BOD, COD) (SWITCH, 2011), (UNIDO, 2000). The effects that contamination by organic matter produces in the river are aesthetic, foul odours, the death of superior aquatic life, the transmission of diseases due to the high concentration of bacteria linked to the organic matter, such as coliforms, E coli etc. Also inorganic nutrients (in excess amounts) lead to the phenomenon of eutrophication also known as excessive plant growth (Chapra, 1997 via SWITCH, 2011).

Other contaminants like heavy metals cannot be assimilated by the environment. These metals accumulate in the ecosystems, in sediments, plants or animals. This type of contaminants can have dangerous effect on the health of whole communities if the water resource downstream from untreated discharges is consumed (Santos, 2010 via SWITCH, 2011).

Organic matter – Oxygen demand (BOD, COD)

Many effluent components are broken down by bacterial action into simpler components. Oxygen is required for both the survival of these (aerobic) bacteria and the breakdown of the components. Depending on effluent composition, this breakdown can be quite rapid or may take a very long time. If effluent with a high oxygen demand is discharged directly into surface water, the sensitive balance maintained in the water becomes overloaded (BULJAN and KRAL, 2011).In water bodies start deoxygenating process which cause foul odours and death to aquatic fauna (COTANCE, 2002 via SWITCH, 2011).The outcome is an environment populated by anaerobic bacteria (which are not oxygen-dependent) leading to toxic water conditions, which could lead to the annihilation of entire species (UNIDO, 2000 and European Commission, 2003 via SWITCH, 2011).

In our case the values of COD are 1547 (table 15) respectively 1840 (table 16) or eventually 3990 (table 17) mg(O_2)/l, which more than 3 times exceed Czech, Ethiopian and also international maximum limits for discharging effluents to the surface waters (see table 18 and 19). These concentrations lead to environmental impact discussed in paragraph above.

Nitrogen

Several components of effluents from tanneries contain mostly nitrogen in form of ammonia. In concentrations of 0.01 - 0.1 mg/l, NH_3 is toxic to fish. The concentration of this compound depends on factors like temperature and the pH. The exposure to ammonia by water ingestion is estimated in 0.36 mg/day for a person drinking 2 l/day (UNIDO, 2000 and European Commission, 2003 via SWITCH, 2011).

The concentration of ammonia in our case is 59.9 mg/l and 136.1 mg/l. If we have a look on Czech and Ethiopian standards provided above, we noticed that different limits for discharge ammonia to surface water range between 2 to 100 mg/l. Despite this fact, the amount of ammonia in effluent is quite high.

Sulphides

Toxicity of sulphides could compare to hydrogen cyanide. Even a low level of exposure to the gas induces headaches and nausea, as well as possible damage to the eyes. At higher levels could lead to the death. Hydrogen sulphide gas is fairly soluble. When absorbed, weak acids can form and cause corrosion of pipes and other metal component in sewers. If are sulphides discharged to surface water, even low concentrations pose toxicological hazards.
Sulphides can be oxidised into non-toxic compounds by certain bacteria in rivers. However, this creates oxygen demand which can harm aquatic life (UNIDO, 2000 and BULJAN and KRAL, 2011).

Values of sulphides from our data set show concentration 213.9 mg/l, which is extremely high. In comparison with international discharge standards, where range between minimum and maximum limits is set from 0.1 to 10 mg/l. Problem of sulphides in tannery wastewater is one of the biggest challenges for treatment plan.

pH

Municipal and common treatment plants prefer discharges to be more alkaline as it reduces the corrosive effect. Also alkaline pH due to the atmospheric CO_2 formed in biological processes that occur in surface water lower the pH value to neutral. Metals tend to remain insoluble and more inert, and hydrogen sulphide evolution is minimized. If the surface water pH is too far either way from the pH range 6.5 - 7.5, sensitive fish and plant life are endanger (UNIDO, 2000 and SWITCH, 2011).

According to the international standards for pH value, limits are set to range between 5.5 and 9.5. Findings from our data sets show value 7.6 respectively 6.2 which mean that pH value is balanced.

Chromium

Metal compounds are not biodegradable and they are present in tannery effluents usually in two forms as Cr^{3+} and Cr^{6+}. Trivalent chromium comes to the effluent mostly from the chrome tanning process. If chrome discharges are excessive, the chromium might remain in the solution. Even in low concentrations, it has a toxic effect upon daphnia, thus disrupting the food chain for fish life and possibly inhibiting photosynthesis (UNIDO, 2000). Hexavalent chromium is toxic to fish life since they swiftly penetrate cell walls. They are mainly absorbed through the gills and the effect is accumulative. By oxidation could be hexavalent chromium transfer to trivalent. However, tannery effluents are unlikely to contain chromium in this form (BULJAN and KRAL, 2011).

From our data sets we received 3 unequal concentration of Cr^{3+}. Table 15 shows chromium level 16.6 mg/l which is really high and represent limits exceeding between 3 to 16 times. Table 16 shows values 0.94 mg/l which meet Ethiopian and Czech standards. On the other side, we have results from table 17 which indicated concentration 0.052 mg/l which meeting even EPA water standards for drink water (EPA, 2013).

Sulphates

Sulphates are compounds derived mostly from the use of Sulphuric Acid. These compounds cannot be removed completely from the solutions by chemicals, certain biological conditions are used to remove and to bind them to certain microorganisms (UNIDO, 2000).
Effects of Sulphates on human health are given by its temporary laxative effect at high doses. Infants, the elderly or handicapped are sensitive to high doses of Sulphates in drinking water (greater than 500 mg/L) (EPA, 2003 via SWITCH, 2011).

Our findings show concentration of sulphates 589.4 mg/l. This fact fit to international standards which show range for discharge limits from 500 to 2000 mg/l. This concentration in tannery effluents is moderate.

Chlorides

Chlorides are introduced into tannery effluents usually as sodium chloride. They are highly soluble and stable and they are not affected by effluent treatment and nature, that means that the burden remain on the environment. Increased salt content in groundwater, especially in areas of high industrial density, is now becoming a serious environmental hazard (BULJAN and KRAL, 2011). Chlorides are long standing in water bodies and its concentration is only reduced by longitudinal dispersion and dilution processes (Santos, 2010 via SWITCH, 2011). Chlorides inhibit plants, bacteria and fish. High concentration can lead to the break-downs in the cell structure. If water is use for irrigation purposes chlorides can re-enter the eco-system and may finally end up in the ground waters (BULJAN and KRAL, 2011).

Our data for chlorides shows the concentration 3079.5 mg/l which supposed to be in the norm of international standards according to some countries. These limits are various between 100 mg/l in western countries to 4000 mg/l in developing countries. Nevertheless Ethiopian standards are strict about chlorides and permit values cannot exceed 1000mg/l. This fact means that our effluent is exceeding those standards more than 3 times.

Suspended solids

The suspended solids are components of wastewaters, where are defined as the quantity of insoluble matter contained in the effluents. These insoluble materials cause a variety of problems when discharged from tanneries. There are two basic types of suspended solids: Semi-colloidal solids and Solids with a rapid settling rate (settleable solids). Majority of settleable solids settle within 5 to 10 minutes. Some of them require more than an hour to settle down. If the wastewaters are discharged into surface water, the rate of flow determines the distance the material is carried before settling on the river beds. Even a thin layer of settled sludge can create a blanket that deprives part of the river or lake bed of oxygen. Aquatic life and plant dies and process of decomposition starts. Semi-colloidal solids are very fine solids that are not settling out from an effluent. They can be removed from effluent by filtering processions. Semi-colloidal solids not cause directly sludge problems. They are broken down over period of time by bacterial digestion and they create solids, which can settle down (UNIDO, 2000).

Our data sets show values of total suspended solids 231 mg/l (table 15) respectively 600 mg/l (table 17). International limits present allowed values between 30 – 200 mg/l. Despite those levels of our results, suitable purification unit could reduce those levels of pollution to acceptable values.

5.3. Proposal of water purification units

The results clearly show that pollutant indicators exceed the local emission standards and further purification is needed (see tables 20, 21, 22). In our case, the primary treatment itself is not efficient enough to meet given environmental standards. The biological treatment, due to high organic load, is necessary.

There are a variety of secondary (biological) treatment processes. Each of them has many modifications. Nowadays, the most common processes are:

Conventional activated sludge processes

Anaerobic treatment processes

Constructed wetlands and ponds processes

Sequences batch reactor processes

Each of the processes has pros and cons. Operational and initial costs along with space are three main factors that often determine which technique is appropriate. Additionally it need to be consider maintenance, reliability, and effectiveness of the treatment system. For proposal of our water purification system were consider also factors direct line with tropical and subtropical area such as weather, land availability and suitability of technical demands.

Based on those factors, ponds and lagoons, and activated sludge systems were chosen as possible methods suitable to tropical conditions. This proposition wants to take into account mostly specific conditions apply in developing world.

5.3.1. Variant A – stabilization ponds system

Waste stabilization ponds (WSPs) are regarded as often method for the treatment of wastewater in many part of the world. Simplicity in design, construction, operation plus cost effectiveness, low maintenance and energy requirements with easily adaptation for upgrading and high efficiency are the cornerstones of these systems.

WSP's are usually designed up to three stages in series, depending on the organic load of the inputs and effluent quality objectives. Usually, classical WSPs consist of an anaerobic pond, following primary or secondary facultative ponds. If further pathogen reduction is necessary, maturation ponds will be introduced to provide tertiary treatment (ERTAS, PONCE, 2005).

Many techniques have been introduced to improve the wastewater quality:

Integrated facultative ponds	Aerated ponds/lagoons
Mechanical aeration	High-rate algal ponds
Anaerobic digestion	Rock filters
Chemical treatment and biological additives	Maturation ponds and constructed wetlands
Schaffer modular Reclamation and reuse system	Advanced integrated wastewater pond system

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Basic description

WSPs are usually large, man-made water bodies, where different types of wastewater or industrial wastewater are treated by natural processes with cooperation of solar light, algae, microorganism and wind. Technical adjustments for intensification of natural processes are usually adopted. There usually three different types of ponds (sometime fourth is added), anaerobic, facultative and aerobic linked in series for improved treatment. Each of them has different treatment and design characteristic. WSPs are low cost for operations and maintenance and have high BOD and pathogens removal. Large surface areas and experts design are required. Effluent is usually appropriate for agriculture reusing and in some of advanced WSPs could be discharge directly to surface water (EAWAG, 2014)

Advanced Integrated Wastewater Ponds System (AIWPS)

A typical AIWPS facility consists of a minimum of four ponds in series. These are Advanced Facultative Ponds (AFP), Secondary Facultative Ponds or Algal High Rate Ponds (HRP), Algae Settling Ponds (ASP) and Maturation Ponds (MP).

AFP

The term facultative implies that waters near the surface are aerobic and anaerobic near the bottom. Methane fermentation is the main mechanism for BOD removal. Conventionally designed and other treatment processes tend to integrate carbon and generate sludge.

HPR

The secondary unit of a conventional wastewater pond system is typically another facultative pond. Much greater treatment is attained by using an algal high rate pond. HRP is much shallower than a facultative pond, but requires a much shorter retention time and produces much more oxygen. The cultivation of algae is optimized by paddle-wheel mixed HRPs. The carbon is transformed and exported by biological assimilation of microalgae grow in the HRP's. HRP's are designed to promote the symbiosis between microalgae and aerobic bacteria. They are utilizing the major metabolic products of the other. One of the unique contributions of algae grown in HRP's is their daily elevation of pH in the pond. A pH of 9.2 for 24 hours is known to provide a 100% kill of E. coli.

ASP

The HRP should be followed by an Algae Settling Pond (ASP) which is a method of removing algae from the effluent. Algae which settle tend to hibernate and thus do not immediately decompose or produce nuisance. If the effluent goes for crop irrigation, algae may not to be removed.

Maturation Pond

If the effluent from an AIWPS passed through the AFP-HRP-ASP sequence, it could be used for agricultural or landscape irrigation. Storage for a minimum of 10 to 15 days in a deep maturation pond will provide adequate die away of pathogenic bacteria of human origin (ERTAS, PONCE, 2005 and RAMADAN, PONCE, 2003).

The main biochemical reaction in the AIWPS

Photosynthesis: $CO_2 + H_2O \text{ --> } CH_2O + O_2$

Aerobic oxidation: $CH_2O + O_2 \text{ --> } CO_2 + H_2O$

Organic acid formation: $2CH_2O \text{ --> } CH_3COOH$

Methanogenesis: $CH_3COOH \text{ --> } CH_4 + CO_2$

$CO_2 + 4H_2 \text{ --> } CH_4 + 2H_2$ (Hetetrophic nitrification: Fixed N --> NO3-)

Denitrification: $2NO_3^- + 3CH_2O \text{ --> } N_2 + 3CO_2 + 3H_2O$

Carbonate and bicarbonate dissociation: $2HCO_3^- \text{ --> } CO_3^{-2} + H_2O \text{ --> } CO_2$

$CO_3^{-2} + H_2O \text{ --> } 2OH^- + CO_2$

Solution

Secondary treatment plant was designed for Awash tannery with proposed method of Advanced Integrated Wastewater Ponds System (see figure 16).

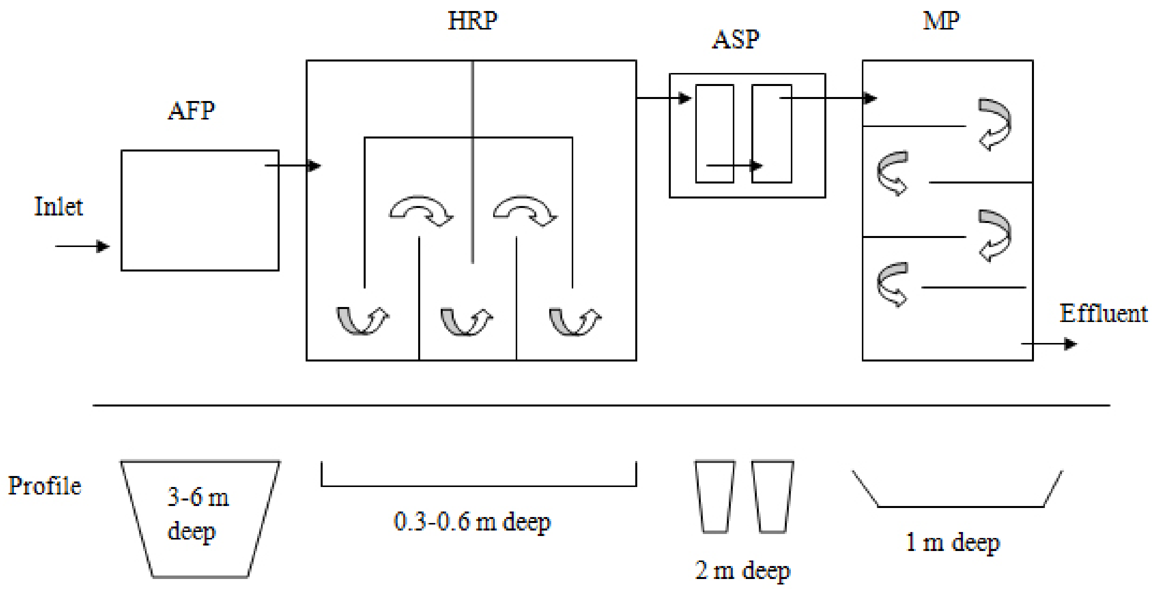

Figure 16. **Simplified diagram of secondary treatment unit A** (source: author's compilation based on RAMADAN, PONCE 2003)

Table 25. Removal performances of the AIWPS for tannery wastewater

Parameter	Raw tannery ef. (mg/L)	HST (mg/L)	AFP (mg/L)	SFP (mg/L)	MP (mg/L)	Overall rem. (%)
SS	5,071	418	339	279	386	92
BOD	3,58	2,225	250	85	50	99
COD	11,157	4,544	669	463	364	97
NH_3-N	152	135	156	58	20	87
Ortho P	12	9	8	7	7	42
SO_4^{-2}	840	624	115	150	155	82
Cr^{+3}	46	13	0.66	0.33	0.31	99

Source: (ERTAS, PONCE 2005 via TADESSE, GREEN, PUHAKKA 2004)

Table 26. Expected results of treatment unit A

Parameter	Overall rem. (%)	Data 2006 ml/L	Expect. results ml/L	Data 2012 ml/L	Expect. results ml/L
SS (TSS)	92-99			231	18.5-2.3
BOD	99				
COD	93-97	1840	128.8-55.2	1547.5	108.3-46.4
NH_3-N	87-99	59.9	7.3-0.6	136.13	17.7-1.4
SO_4^{-2}	82			196,9	35.4
Cr^{+3}	99	0,94	0.0094	5.5	0.0549

Note: red colour – exceeding standards for the limit values; green colour – values are in the limit norms
Source: (Author's compilation based on tables 21, 22 and 25)

Based on our findings, using AIWPS technology is also suitable for wastewater treatment of tanning industry. Table 26 shows that all followed pollution indicators may, by using this technology, fulfil Czech and also Ethiopian effluent standards for discharging effluent to open water bodies. This method has been successfully operating for the last four decades in California. The treatment method has very important advantages such as very low energy and land requirements. Because of its high coliform bacteria removal efficiency, effluent of AIWPS may be used for irrigation purposes. If high values of TDS and Cl^- don't degrease during purification process, removal filters or other purification systems, such as carbon filtration or reverse osmosis have to be applied before discharging.

5.3.2. Variant B – activated sludge system

Activated sludge process (AS) belong to the secondary treatment. AS primary removes dissolved organic solids as well as settleable and non-settleable suspended solids. It is a biological process that utilizes microorganisms to convert organic and certain inorganic matter from wastewater into cell mass. The activated sludge itself consists of a concentration of microorganisms and sludge particles that are naturally found in raw or settled wastewater. These organisms are cultivated in aeration tanks, where they received dissolved oxygen and food from the wastewater. The term “activated” comes from the fact that the particles are full of moving bacteria, fungi, and protozoa. The activated sludge is then separated from the liquid by clarification. The settled sludge is either returned or wasted. Activated sludge is commonly used as a wastewater treatment process due to an effective treatment process and it provides a high degree of treatment (WUTAP, 2007).

The principle role which microorganisms have in the activated sludge process is to convert dissolved and particulate organic matter (BOD) into cell mass. In a conventional activated sludge process, microorganisms use oxygen to break down organic matter (food) for their growth and survival. Over the time food (BOD) decreases with a resultant increase in cell mass (MLSS concentration). Organic matter stabilization process can be summarized as:

Inert matter + organic matter + oxygen + nutrients + micro-organisms $\longrightarrow$

$\longrightarrow$ new micro-organisms + CO2 + H2O + additional inert matter

The activated sludge wastewater treatment process must operate under proper environmental conditions to keep growing population of healthy microorganisms. The operator must monitor the activated sludge process to ensure the right environmental conditions are being provided for the microorganisms and for ETP efficiency (WUTAP, 2007 and BULJAN and KRAL, 2011).

Many techniques of AS have been introduced to improve the wastewater quality:

Conventional activated sludge	Oxidation ditch
Extended aeration activated sludge	Deep shaft
Contact stabilization	Surface-aerated basin
Package plants	Other

Extended aeration activated sludge

The extended aeration mode of operation is often used in smaller package-type plants and uses conventional plug flow patterns for complete oxidation. It is modification of activated sludge process. Extended aeration is typically a very stable activated sludge processes, due to the light loading (low F:M) that these system's operate under. In extended aeration, the low F:M ratios are made possible by the use of larger aeration basins which also provides for over 15 hours of hydraulic retention times (HRT). Sludge ages that are commonly greater than 10 days, usually 15-30 days. Although the process is stable and easy to operate, it is common for extended aeration systems to discharge higher effluent suspended solids than found under conventional loadings. This results in a highly treated effluent, and less WAS produced The oxidation ditch is a variation of the extended aeration process (WUTAP, 2007).

Extended aeration processes generally operate within the following ranges:

Detention time in aeration basin = 12-24 hrs. ƒ

MLSS in aeration basin = 2000-5000 mg/L ƒ

System SRT = > 10 days ƒ

System F:M Ratio = 0.05 – 0.15 : 1 ƒ

RAS pumping rate = 50-150% (of plant influent flow)

Solution

Secondary treatment plant was designed for Awash tannery with proposed method of extended aeration. It consists of aeration tank, clarifier unit and sludge recirculation pump (see figure 17 below).

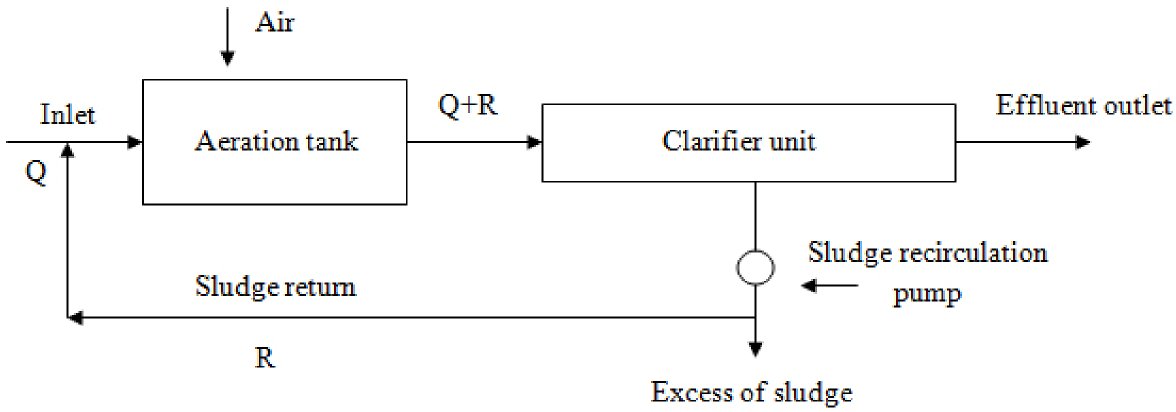

Figure 17. **Simplified diagram of secondary treatment unit B** (source: author's compilation based on Buljan, Kral, 2011)

Table 27. Purification efficiency during primary and secondary stage for Awash tannery

Parameter	Removal efficiency (%)		
	Primary Treatment		Combined treatment expected
year	2006	2012	
COD	65.28	47.91	87-93
$N\text{-}NH_3$	29.45	-119.56	80-90
Cr^{3+}	21.67	84.87	99
S^{2-}	97.84	85.3	99

Source: (Author's compilation via BULJAN, KRAL 2011)

Table 28. Expected results of treatment unit B

Parameter	Overall rem. (%)	Data 2006 ml/L	Expect. results ml/L	Data 2012 ml/L	Expect. Results ml/L
SS	95-98			231	11.6-4.6
BOD	97-99				
COD	87-93	1840	239.2-128.8	1547.5	201.2-108.3
NH_3-N	80-90	59.9	12-6	136.1	27.2-13.6
Cr^{+3}	99	0.9	0.0094	5.5	0.055

Source: (Author's compilation based on tables 21, 22 and 27)

Based on our findings, using activated sludge process with the method of extended aeration it may be suitable for wastewater treatment of tanning industry. Table 28 shows that all followed pollution indicators may, by using this technology, fulfil Czech and also Ethiopian effluent standards for discharging effluent to open water bodies. This method is common worldwide as one of the best practises for secondary wastewater treatment. The limitation for using effluent for irrigation, after this method, is smaller reduction of coliform bacteria and other microorganism. Additional disinfection processes may be applied. If high values of TDS and Cl^- don't degrease during purification process, removal filters or other purification systems, such as carbon filtration or reverse osmosis have to be applied before discharging to surface water bodies.

5.3.3. Comparison of both variant

There are numerous of purification systems with thousand of possible modifications. Each of them has advantages and disadvantages. It depends on specific case if the special characteristic of purification unit turns in advantage or disadvantage. In most of the cases are borders clear and their comparison may show valuable information for further solution during decision-making phase.

Variant A

AIWSP

Advantages

- Able to treat high loads of industrial and domestic wastewater
- Effluent may be used for irrigation
- Algae growing may be harvested and used as fertiliser or animal feed
- BOD, TSS and pathogen removal are similar or higher to activated sludge systems at relatively low-costs
- Resistant to organic and hydraulic shock loads
- High nutrient removal if combined with aquaculture
- Relatively low operational cost

Disadvantages

- Design, construction and maintenance need expert skills
- Energy source is required for operation
- Relatively high investment costs
- If the effluent is reused, salinity needs to be monitored
- Not always appropriate for colder climates
- Sludge requires proper removal and treatment

Variant B

EAAS

Advantages

- Most popular biological treatment process
- Ability to produce a high quality effluent
- BOD5 removal is typically high
- Stability, the ease of installation and operation of systems
- Relatively low construction operating and maintenance costs
- The low sludge yield and the odourless operation.
- Land area required for setting up the plant is minimal.
- Resistance to incoming shock load.
- Sludge is partially digested within air tank
- Extended aeration can be easily adapted to provide for nitrification and denitrification

Disadvantages

- Higher consumption of oxygen
- Retention time in final clarifier twice that of conventional system
- Compared with other wastewater natural treatment systems and land based systems this process consumes more power and has a higher cost of energy requirements
- In colder regions the process is susceptible to freezing
- Certain nuisance factors associated with this process are the odour produced when treating sludge and the noise from the blower
- This process requires a higher quality of skill for operational and maintenance roles
- re-use water is required in the future, filtration is needed at an additional cost

Comparison these proposed purification unit systems shows similarities in treatment efficiency which in both cases may reach over 90%. AIWSP has better pathogen removal but demand usually longer solid retention time than EAAS and may require more space. Both variant are suitable for developing countries where suitable temperatures occur during a whole year. On the other hand, both variant demand expert skills during design and operational phases. Also investment costs are quite high.

Those proposed variant fit to our case study, because Awash tannery is relatively modern factory with skills employees and enough investment capital for wastewater treatment. Isolated communities in developing countries may focus on lower technical solution of secondary treatment such as facultative lagooning and ponds which are easy to maintenance, have low investment capital and no expert skills are required.

6. Discussion

Final results found out evidence that Awash tannery effluent wastewater do not fulfil Ethiopian, either Czech effluent standards limit for discharging wastewater to open water bodies. Awash tannery uses primary ETP which must be upgraded to at least, according to our suggestions, secondary (biological) stage unit. The same suggestions have been promoted by Durai and Rajasimman who concluded *"that physical/chemical processes combined with biological processes is better option for treatment of tannery wastewater"* (DURAI, RAJASIMMAN, 2011).

Secondary treatment stage is based on decomposition of suspended and dissolved organic matter by microorganism. Our suggestion works with recommendation of aerobic, secondary treatment processes, but anaerobic and facultative processes are also available. Tare, Gupta and Bose found out that aerobic processes such as ASP-based plant were superior in all respects compare to UASB process-based plants. (TARE, GUPTA, BOSE, 2003). On the other hand, Durai and Rajasimman discovered that *"review shows that all aerobic processes have a similar of COD removal, but the highest COD removal efficiency at a high organic loading rate was observed in anaerobic reactor UASB"* (DURAI, RAJASIMMAN, 2011).

In our case, we proposed purification units with consider local condition of developing state. On the one hand, we wanted to propose basic treatment for particular local condition fitting to developing world. On the other hand, we wanted to propose adequate solution with consideration of Awash tannery modernization and abundant of professional skills. From those reasons we decided to apply basic, aerated units with modern modifications AIWPS and EAAS.

Developing countries are suitable to adopt WSPs systems which could be later upgraded to higher removal efficiency. WSPs are basically unsophisticated AIWPSs systems which need more space but less professional skills for maintenance and operation, and less or non electric energy. *"Because of the low capital and particularly low O&M costs it is a good option for decentralised treatments in developing coutries. In addition, it is one of the few low-cost natural processes, which provides good treatment of pathodens"* (TITLLEY et al., 2014).

7. Conclusion

The overall objectives were to proposed two purification unit (basic and advanced) and evaluated current water pollution caused by Awash tannery effluents. The case study was working with primary data from Awash tannery, with our own wastewater samples and with secondary data from scientific sources.

The case study brought wide perspective on tanning industry in Ethiopia with worldwide context. Connection between leather industry and ecological burden was discussed with focus on effluent wastewater and its impact on habitat.

Evaluation of samples and chemical analysis show exceeding of local standards limits for effluent wastewater and necessity of proposal advanced treatment system. The secondary stage of purifying processes was proposed based on aeration, biological methods.

Recommended units EAAS and AIWPS are modified low standard processes which may suite to local conditions of developing countries. Comparison of both units was performed and advantages and disadvantages were evaluated.

Ethiopia has actually 23 tannery operation units which only 9 of them are using some kind of treatment methods. This fact brought huge environmental burden to habitat and cause numerous problems connected to water quality.

Implementation of low standard treatment processes such as WSP may radically degreased load pollution with relatively low cost. Ethiopian authorities must enforce using of treatment units to all subjects in all industries within the country.

Correct management with wastewater and other waste is crucial step to sustainable development.

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Other sources

Awash tannery- internal documents (water test – see annex 1 and 2)

Water samples results (see annex 3)

Google Earth application (http://www.google.com/intl/cs/earth/)

Annexes

Annex 1

Inlet indicators from Awash tannery – 2012

S/No	Type of test	Unit	Test Result	Uncertainty	Test method	Standard Requ.	Remark
1.	Chemical Oxygen demand(COD)	mg o_2/L	2970.72	± 8.5	APHA 5220-COD B.		Accredited test
2.	PH	-	10.81	-	APHA 4500-H^+B		
3.	Temperature	°C	26.4	-	APHA 2550 B.		
4	Appearance/ Color	-	dark gray	-	APHA 2120 B		
5	Odour	-	Pungent	-	APHA 2150 B		
6	Total Suspended Solids	mg/L	6062	-	APHA 2540-D		
7	Chromium trivalent as Cr_2O_3	mg/L	106.05	-	SLC 208		
8	Total Ammonia (Nitrogen)	mg/L	62.0	-	APHA-4500-NH_3		
9	Phosphate (P)	mg/L	0.02	-	APHA-4500, P-C		
10	Total solids	mg/L	14533		APHA-2540-B		
11	Total dissolved solids	mg/L	7479		APHA-2540-C		
12	Chloride	mg/L	1513.70		APHA-4500-Cl^-_B		
14	Sulphide	mg/L	1454.51		SLC-202		
14	Sulphate	mg/L	839.1		APHA-4500.SO_4^{-2}		

Annex 2

Outlet indicators from Awash tannery ETP - 2012

S/No	Type of test	Unit	Test Result	Uncertainty	Test method	Standard Requ.	Remark
1.	Chemical Oxygen demand(COD)	mg o_2/L	1547.49	± 8.5	APHA 5220-COD B.		Accredited test
2.	PH	-	7.61	-	APHA 4500-H^+B		
3.	Temperature	°C	26.4	-	APHA 2550 B.		
4	Appearance/ Color	-	Less turbid	-	APHA 2120 B		
5	Odour	-	LessPungent	-	APHA 2150 B		
6	Total Suspended Solids	mg/L	231	-	APHA 2540-D		
7	Chromium trivalent as Cr_2O_3	mg/L	16.06	-	SLC 208		
8	Total Ammonia (Nitrogen)	mg/L	136.13	-	APHA-4500-NH_3		
9	Chromium Six Content	mg/L	0.2	-	INTERNAL		
10	Phosphate (P)	mg/L	0.016	-	APHA-4500, P-C		
11	Total solids	mg/L	7865		APHA-2540-B		
12	Total dissolved solids	mg/L	7438		APHA-2540-C		
13	Chloride	mg/L	3079.54		APHA-4500-Cl^-_B		
14	Sulphide	mg/L	213.86		SLC-202		
15	Sulphate	mg/L	589.38		APHA-4500.SO_4^{-2}		

Annex 3

Protocol about water analises from Awash tannery ETP – 2013

Ústav technologie vody a prostředí VŠCHT, Technická 5, 166 28 Praha 6

Protokol o zkoušce

Číslo: N159/13

Datum přijetí vzorků: 12.11.2013

Datum provedení zkoušky: 12. až 13.11.2013

Datum vyhotovení protokolu: 18.11.2013

ukazatel	**Vstup**	**Výstup**
vzhled, barva	**bílý zákal**	
pH	**11,9**	**6,2**
konduktivita (mS/m)	**1 007**	**1 509**
solnost – NL (mg/l)	**4 150**	**600**
rozpuštěné látky (mg/l)	**7 245**	**12 885**
chrom (mg/l)	**0,052**	**0,231**
nikl (mg/l)	**0,022**	**< 0,005**
olovo (mg/l)	**0,466**	**0,804**
CHSKCr (mg/l)	**5 290**	**3 990**

Laboratoř má osvědčení ASLAB o správnosti výsledků v rámci mezilaboratorního porovnávání zkoušek v oblasti chemie vody.

VYSOKÁ ŠKOLA
CHEMICKO-TECHNOLOGICKÁ V PRAZE
Ústav technologie vody a prostředí
Technická 5, 166 28 Praha 6
217/1

Doc. Ing. Nina Strnadová, CSc.

Annex 4

Provisional standards for industrial pollution control in Ethiopia (EPA, 2003)

Tannery Effluent Standard

Emission Limit Values for Discharges to Water

Constituent Group or Parameter	Emission Limit Value (mg/l)
Temperature	40 °C
pH	6 – 9 pH units
BOD_5 at 20□C	>90% Removal or 200 mg/l
COD	500
Suspended Solids	50
Total Ammonia (as N)	30
Total Nitrogen (as N)	>80% Removal or 60 mg/l
Total Phosphorus (as P)	>80% Removal or 10 mg/l
Oils, Fats, and Grease	15
Mineral Oil (Interceptor)	20
Chromium (as total Cr)	2
Chromium (as Cr VI)	0.1
Chloride (as Cl)	1000
Sulphide (as S)	1
Phenols	1

Annex 5

Inlet and outlet indicators from Awash tannery ETP – 2006 (Bekele, 2007)

Pollutant type	Unit	Influent result	Effluent result	% Removal efficiency
COD	mg/lt	5,300	1,840	65.28
NH_3	mg/lt	103.1	72.7	29.49
Nitrite as NO_2	mg/lt	0.055	0.039	41.82
Nitrate as NO_3	mg/lt	14	1.7	87.86
Total Nitrogen as N	mg/lt	180	90	50.00
H_2S	mg/lt	141	3.05	97.84
PO_4	mg/lt	20.5	4.94	75.90
Cr^{3+}	mg/lt	1.2	0.94	18.33