Impact of Floriculture Effluents on the Quality of Farmland Soils: A Case Study of Holeta Area, Oromia Regional State, Ethiopia

Gemeda Kebebew

A Thesis Submitted to

The Department of Plant Biology and Biodiversity Management

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management)

Addis Ababa University

Addis Ababa, Ethiopia

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This is to certify that the thesis prepared by Gemeda Kebebew Keneni, entitled: *The Impact of Effluents from Flower Industries in Holeta on the Quality of Farmland Soil* and submitted in partial fulfillment of the Requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Some floriculture industries located at Holeta town discharge untreated effluents into the surrounding environment. As a result excessive fertilizer and pesticide residues from the farm are deteriorating the soil. Therefore, this study was proposed with the objective of assessing the impact of effluents from floriculture industries on soil quality. We selected two study sites near the floriculture industry at Holeta town. The first site used as a control was selected from the effluent free area around the farm whereas, the second site set along the effluent flow. A total of 30 samples (15 from each) were tested for their physicochemical characteristics such as soil texture, cation exchange capacity (CEC), exchangeable bases and micronutrient parameters. The data were analyzed using SAS software to see if there were significant differences between the control and impaired sites at 5% level of significance. Soil texture, pH, CEC, exchangeable bases (K, Ca, Mg) showed significant differences ($P<0.05$) between the control and impaired sites. On the other hand OC, TN, Na and micronutrients (Cu, Zn, Fe and Mn) showed insignificant difference. There is a significant raise in pH, K, Ca and Mg and significant decrease in CEC in effluent affected areas which indicate the quality of farmland soil around the floriculture industry has been affected. Hence, actions should be taken before the precious soil turn out to be seriously polluted. Environmental audit and waste water management could be possible solutions to minimize the direct discharge of fertilizer rich effluents into the soil and the river.

Key words: Effluent, Soil quality, Farmland soils

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LIST OF ACRONYMS (ABBREVIATIONS)

AAS	Atomic Absorption Spectrophotometer
CEC	Cation Exchange Capacity
DEC	Department of Environment and Conservation
EHPEA	Ethiopian Horticultural Producers and Exporters Association
ENA	Ethiopian News Agency
FAO	Food and Agricultural organization of the United Nations
m.a.s.l	meters above sea level
OC	Organic Carbon
OM	Organic Matter
pH	Potential of Hydrogen
SAS	Statistical Analysis System
SEPA	Scottish Environment Protection Agency
SJWEH	Scandinavian Journal of Work, Environment and Health
SPSS	Statistical Package for the Social Sciences
TN	Total Nitrogen
USD	United State Dollars
USEPA	United States Environmental Protection Agency

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CHAPTER ONE

1. Introduction

1.1 Background

The expansion of flower industries in Ethiopia has been generating income opportunities both to the country and individuals since the time of its introduction. However, there are visible challenges regarding with improper handling of its byproducts. Holeta is one of the many towns where the industries are being expanded. Researchers have been conducted to investigate the impact on environment due to the improper management of these particular industries. Misganaw (2007) in his thesis in the study of "Assessment of the Ecological Impacts of Floriculture Industries Using Physico-Chemical Parameters and Benthic Macro-invertebrates Metric Index along Wedecha River, Debrezeit, Ethiopia" indicated that floriculture, like other agricultural industries, exacts an environmental toll, though making substantial contributions in the generation of foreign exchange, employment for workers, increasing revenue, and contribution to rural stability through provision of jobs, incomes, public services and amenities to villages surrounding flower farms. It has also contribution to the development of other commercial activities in areas adjacent to the flower projects (building blocks, restaurant, farming, etc.) and reduces rural-urban migration. However, the externality of floriculture industries is huge; pesticides travel an average distance of 1,500 miles, adding significantly to global warming and pollution.

Although industrial processes are desirable, at the same time, the serious and irreversible damage done to the environment through their apparently innocuous discharges of effluents are unquantifiable. Despite the treatment being employed by some industries, it is still impossible to remove all undesirable properties from effluents. The discharge of poorly treated effluents can cause severe and even irreparable damage to receiving waters and land environments. If not properly managed, contaminants such as phosphorus, nitrogen, heavy metals, suspended solids, and those with high oxygen demand can cause undesirable changes in both aquatic ecosystems and land vegetation (Department of Environment and Conservation/DEC, 2004). Effluents are wastes produced from industries and they vary depending on human activities that produce them. Production of these wastes is an integral part of industrial activities but unfortunately our inability to anticipate or predict the types and magnitude of undesired consequences of the unbridled effluents in our environment, coupled with the growth of industrialization have resulted in massive and destructive operations in our ecosystems.

Mineral forms of nitrogen are readily transformed into other mineral forms. Some mineral forms such as nitrate, nitrite and ammonia can be taken up by plants. Nitrate is also readily leached to groundwater. High concentrations of nitrate make waters unsuitable for stock and domestic water supplies, or can nourish unwanted plants and algae. N_2 and NH_3 can be lost to the atmosphere in gaseous form. It is estimated that between 15% (cool climates) and 25% (warm climates) of applied nitrogen in the form of ammonia (DEC, 2004) can be lost to the atmosphere, with up to 50% volatilised under optimal conditions (e.g. fine spray irrigation in hot and low humidity climates).

Floriculture industries use high and large quantities of fertilizers and pesticides. These fertiliser and pesticide application may lead to soil acidification, eutrophication and the buildup of pesticide residues, thereby impacting soil quality. These pressures can also result in water pollution through, for example, the run-off of nitrate and phosphorus to surface waters and the potential contamination of private drinking water supplies with pesticides (SEPA, 2001).

Soil can immobilize many pollutants, effectively acting as a buffer against pollution of water and air. However, this ability is finite, depending on soil properties and processes and must be carefully managed to protect the environment. When conditions which affect this immobilising ability change, for example increasing acidification or changes in land use, the soil can turn into a pollutant source itself, an effect sometimes described as a chemical time bomb (SEPA, 2001). The evidence could indicate the necessity of pre-treatmement when one considers the case of Holeta for the discharge of effluents may affect the surrounding soil quality.

1.2 Statement of the Problem

In Ethiopia, the economic advantage of the floriculture industry has overshadowed social and environmental sacrifices of the sector. There are different perceptions with regard to the socio-economic and environmental impacts of the sector in the country. Some government officials believed that the environmental and the social effect of the sector are very insignificant and should not be considered. Other environmental and social concerned bodies believed that the country is losing much more than the government expected.

Despite the fact that huge socio-economic advantages and considerable incentives are given, in Ethiopia the internationally known social and environmental disadvantages of the sector are vague. According to Frank and Cruz (2001) even if the floriculture industry were taken as a solution for economic development and gained in the generation of employment during the last 30 years in developing countries, these advantages of the industry are at the expense of social and environmental disadvantage.

Inappropriate choice of cultivation methods and a wide range use of chemicals and fertilizers have negative impacts on soil and water condition. Too much use, or misuse, of herbicides and pesticides can threaten human, animal and plant life. Moreover, the industry has also created land holding problems.

There is little research work done about the environmental and social impacts of the sector while the floriculture industry is blooming in the country. Thus, this study aims to address the problem by emphasizing on the impact of the effluents on the quality of farm soils in Holeta.

1.3 Significance of the Study

This research is expected to contribute to the existing understanding of the industry in Ethiopia floriculture industry on the environment aspect at Holeta. Especially, the study tries to explore the situation of farmland soils surrounding the industry.

This study can increase the awareness about problems that floriculture farm effluents pose on soil. How the industry affects the environment will give an insight into whether the floriculture industry in Holeta is operating in a sustainable manner or not. The findings of the study may encourage concerned bodies and farm owners to be more conscious of the issue and it can initiate the formation of a National Code of Conduct that governs waste disposal conditions at floriculture farms and the environment.

1.4 Objectives

General Objective

The major objective is to study the impact of effluents released from floriculture industries on the physical and chemical characteristics of soil.

Specific Objective(s)

- To characterize the effluent free and effluent affected soils around flower industries in Holeta in terms of physico-chemical properties and heavy metal element contents.

CHAPTER TWO

2. Literature Review

2.1 Evolution of the Ethiopian Flower Industry

In recent decades, the global demand for cut flowers has grown considerably. This growth in market demands and its diversification value has attracted increasing numbers of developing countries to the global fresh flower trade. These reasons seem to make Ethiopia come in to the picture of this business. But some people say that Ethiopia gives attention for this sector because the European production cost skyrocketed. European cut flower growers (especially Netherlands) have been looking to other continuities for more affordable conditions as experienced by other East African countries like Kenya, Tanzania and Uganda (Tadele, 2009).

Floriculture development in Ethiopia started thirty two years ago for commercial purposes in the Derge regime. The first fresh cut flowers production was commenced in 1981 /82 crop season. The Horticulture development corporations were established where the government was responsible both for regulation and production even for marketing of horticultural products including flowers. During that time the production and export of cut flowers were only aimed at foreign exchange earnings in Ethiopia and was not well planned (Ethiopian Horticultural Strategy, 2007).

As a result of this, the industry was one of the highly subsidized sub-sectors during the Derg regime (Habte, 2001). Floriculture was started to show modest increase in 1990s by 2-3 % from the agricultural output of the country. In 2001 it contributed $ 4.7 million to the country's foreign currency earnings. But it was not as such significant enough to say it was important sector to develop the country's economy. In five years the total export earnings increased at least five times that figure.

Realizing the government's attention and friendly climatic condition, investors were attracted. By February 2006, of the 70 operational flower farm (50 % of the investors were known to be nationals, 37 % are foreign and the balance 13 % is joint venture) enterprises already existed in Ethiopia, quickly followed by new enterprises (Tewodros, 2010). The industry covered 2,031 hectares of land up to March 2007. Of this land, 840.58 hectares was covered with greenhouse and the rest were covered by land flowers up to June 2007 (ENA, 2007; Hortiflora magazine, 2007; Trade and Industry Ministry, 2006).

Among the resources which make Ethiopia favorable for floriculture development is water and irrigable land resources which the country has and the abundant flower needs in the country. Ethiopia has 122 billion cubic meter surface water, 2.6 billion cubic meter ground water, 12 river basins, 18 natural lakes including the rift valley lakes and a potential of 3.7 million hectares irrigable land. About 80 – 90 percent of these resources are located in the west and south west of the country where close to 40 percent of the Ethiopian population lives and 10 – 20 percent of these resources are located in the east and central part where most of the population has settled. But the above principal production sites are located within the low resource available and highly populated areas (Ethiopian Horticultural Strategy, 2007).

Most of the Floriculture farms are largely confined around the vicinity of Addis Ababa. Most farms are located in West of Addis Ababa particularly located in Menagesha, Holeta, Sebeta and Addis Alem while the rest are more or less evenly distributed in the Rift Valley and the Awash River Basin systems (Nancy, 2006). The fact of the matter is that Ethiopia is still in the beginning stages of floriculture industry and there are a number of challenges that must be resolved to continue the development of the sector with the present rapid speed. Among the challenges include social and environmental impacts of the sector which can create pressure on the sustainability and market acceptability of flower industries.

According to recommendation given on the "Development strategy for the export oriented horticulture in Ethiopia" based on the stakeholders discussions at the workshop on February 9th, 2007, Ethiopia needs development of a conducive legislative framework and pesticide registration system which is felt under responsibility of Government especially Ministry of Trade and Industry and Ministry of Agriculture and Rural Development as well as development of a Code of Conduct at sectoral level to demonstrate compliance with general standards (environment, workers' welfare, etc) with responsibilities of Ethiopian Horticultural Producers and Exporters Association (Tadele, 2009).

Thereafter, the Ethiopian Horticultural Producers and Exporters Association (EHPEA) initiated the development of an Ethiopian Code of Practice on sustainable flower cultivation. This initiative responds to a request of the EHPEA members to develop a sector broad tool to respond in an effective way to the growing demand by various stakeholders for corporate social responsible farm management. This initiative has been one of the strategic actions of EHPEA for 2006 and 2007, and is supported by the Netherlands throughout the Dutch Ethiopian horticulture partnership (Misganaw, 2007).

Due to suitable weather conditions, altitude, favorable market in the rest of the world and domestic enabling environment for investors, the number of new farms is increasing and the existing farms are expanding and consequently the volume of cut flower production is increasing. The production of cut flower is destined entirely for export. The production system is capital and technology intensive, and production mainly takes place under green houses (Worku, 2010). The number of firms increased sharply, rising from 10 firms in 2004 to 81 firms by the end of 2008 (Table 1). Prior to 2004, the sector only generated USD 3.7 million. By 2008, this increased to nearly USD 100 million, and the sector became among the four top foreign exchange earning commodities for the country (Gebreyesus and Iizuka, 2010; Table 2).

Table 1 Major statistics of floriculture development in Ethiopia

Year	Number of Farms	Cultivated Area (hektar)	Number of Export Stems	Export Value (USD)
2001/02	-	-	-	305000
2002/03	-	-	16000000	2900000
2003/04	-	-	32000000	5500000
2004/05	30	150	83000000	12700000
2005/06	69	345	186,000,000	26900000
2006/07	80	645	1,114,000,000	113,000,000

Source: Ministry of Trade & Industry (Oct 2006)

Dashes (-) indicate there was no recorded data.

Table 2 Export performance 2004-08

Year	Weight	Value Ethiopia Birr	Ave. $ to Birr	Value (USD)	% Change Value	% Change in Vol.
2004	202,877.00	7,088,619.03	7.70	921,198.05	0	0
2005	3,527,667.55	101,476,738.84	8.10	12,527,992.45	1260%	1639%
2006	9,137,082.87	321,547,395.14	8.50	37,829,105.31	202%	159%
2007	18,235,012.20	787,440,383.79	9.03	87,202,700.31	131%	100%
2008	25,470,434.33	1,197,976,217.48	9.57	125,156,837.53	44%	40%

Source: - (Worku, 2010)

The sector's contribution to export revenue and employment generation has been progressively increasing over the last few years. So far, 27-30,000 workers are employed by the sector of which 60 per cent are women. As far as export revenue is concerned, in the first half of 2007, about 50 million US dollars was generated. Ethiopia exports up to 700-800 tons of flowers and fruits and vegetables in one week of which flower constitutes the most part (ENA, 2007; Trade and Industry Ministry, 2006).

Despite the industry's significant contribution to the national economy, social and environmental problems may exist, almost in the same way as occurred in Colombia and Ecuador. Use of various chemicals by the industries may cause damage to the environment and flower growers use a large amount of water, which is resulting in the shrinking of surface and underground water. Companies such as Rose Ethiopia and Garad Flowers are some examples causing shrinkage of water (Aklilu, 2006; Trade and industry Minster, 2006).

Absence of safety measures at places of work may cause health problems to the employees. In this respect, there are concerns that hazardous and toxic chemicals could be used in the flower farms. Floriculture farms use a lot of fertilizers and pesticides. In relation to this, the use by employees of protective apparel should be compulsory, and disposal of chemicals has to be seen widely (Aklilu, 2006).

2.2. Environmental Impact of the Floriculture Activities

With the expansion of any new industry in general and floriculture in particular, there is a growing concern as to its adverse effect on the national environment. With the same concept the situation of Holeta under study is considered to investigate the impact of effluents on the nearby soil quality. Under this section information from the previously conducted researches will be discussed focusing on fertilizers and pesticides impacts.

2.2.1 Fertilizers

Fertilizers are significant pollution threats because of their high solubility and the frequent application of large volumes of irrigation water (Thrupp and Lori Ann, 1998). Some environmentalists are of the opinion that the environment is unique and irreplaceable and therefore no "price" can or should be assigned to it. This argument is typically used against policies that trade off environmental objectives against economic interests. The viable course of action thus seems to be minimizing the adverse impact of floriculture on the environment.

Although much criticism has been forwarded against chemical fertilizers by different individuals, the insistence to their use continues. This is for the high productivity in their uses. But, the use of these chemicals can impact on soil quality through changes in nutrient turnover rates, organic matter decomposition rates and the buildup of pesticide residues in soil, which may in turn be transferred to the human food chain as indicated by (SEPA, 2001). Nitrogen in fertilizer for instance can produce nitrates, which can be washed away from fields by rain or irrigation, eventually finding their way to water bodies and soil. Ensuing impacts on the water environment include the leaching of nutrients and pesticides to surface and ground waters. In addition, the use of nitrogen fertilizers can result in elevated emission of the greenhouse gas nitrous oxide from soil (SEPA, 2001).

a) Impacts on Human Health

Chemical fertilizers cause diseases such as skin rush respiratory problems and may lead to death when there is a direct contact with food based on its concentration. Diseases such as Methemoglobinemia, Japanese encephalitis (JE), cancer etc. as reported by Getu (2009) have been noted due to use of chemical fertilizers. With the same token he cited as research demonstrates that "on rare occasions, nitrates have caused infants to become ill or die of Methemoglobinemia (more commonly known as blue-baby syndrome)." It occurs when the excess nitrates that remain in the soil move into the ground water and when this water is used for drinking by human beings as a result of which the nitrite interferes with the oxygen carrying capacity of the blood. Cattle are also exposed to many diseases when they graze on fields with high content of chemical fertilizers.

b) Effects on Soil

The intensive usage of fertilizers and chemical as well as the waste disposal of cut flowers can result in the depletion of the soil. This is because they have different character and react differently. The different types and amount of chemicals exposes the soil to loss its natural fertility by changing its texture, acidic value and fertility as pointed out by Tadele (2009). With similar evidence, SEPA (2001) indicated that the use of these chemicals can impact soil quality through changes in nutrient turnover rates, organic matter decomposition rates and the buildup of pesticide residues in soil, which may in turn be transferred to the human food chain after citing its importance in agriculture that its intensification since the Second World War has resulted in large increases in crop yields mainly due to increased reliance on inorganic fertilizers and pesticides.

Researches have been conducted to reduce the environmental impact of inorganic fertilizers. (Marecos do Monte *et al.*, 1989) pointed out that commercial fertilizers could be replaced by industrial wastewater. Nonetheless, continued wastewater irrigation can change soil properties, e.g. pH, nutrient concentration (Russell *et al.*, 1988). These changes might be a threat to sustainability of long term land use. On the other hand, application of wastewater has been reported to significantly increase crop yields, (Russell et al., 1988). Use of wastewater also brings about changes in the soil moisture contents, adding nutrients and organic matter, which may further induce favorable changes in soil properties, tree growth and tree nutrient uptake. Schipper *et al.* (1996) revealed that wastewater application was attributed with the addition of nutrients into the soil rather than additional water loading. Significant effects of soil properties, tree biomass production and nutrient uptake has been reported when Eucalyptus short-rotation forests were applied with slaughter house wastewater irrigation (Guo, 1998). Contrary to that, increased concentrations of heavy metals through wastewater irrigation may also negatively influence crop growth by interfering with metabolic processes thereby inhibiting growth that may sometimes leading to mortality in plants (Syed Fazal ur Rehman Shah, 2009).

Generally, a growing crop does not take up all the nutrient ions in the fertilizer applied to the soil. This is because soil contains enough nitrogen fixing bacteria, which fix sufficient atmospheric nitrogen to supply the needs of the growing plants. But continued use of chemical fertilizers may destroy these nitrogen-fixing bacteria and many other micro- and macro- organisms in the soil. In addition, acids in chemical fertilizers, such as sulfuric acid and hydrochloric acid, which tend to increase the acidity of the soil, reduce the soil's beneficial organism population and interfere with plant growth.

c) Effects on Aquatic Life

There are many fertilizers, which leak through the soil to the ground water or ditches and streams, thus causing water pollution. In a process known as eutrophication, fertilizer washed from fields into surface waters stimulates algae growth, which blocks sunlight needed by aquatic vegetation putting their survival at stake. This loss in vegetation disrupts the food chain, leading to the death of economically important aquatic life. Moreover, this causes depletion of oxygen found in the water thus degrading the quality and usability of the water (Ferrey, 2004).

d) Water Logging and Salinization

Naturally, some water seeps into the ground from irrigation ditches and canals. In this water logging, the seepage can cause the subsoil water table to rise to the root zone of crops, killing them. The problem can be compounded by salinization, which occurs when water logging brings harmful salts to the surface. Some plants, e.g. tomatoes, have very low tolerance for salt making growth nearly impossible in saline soil. Salinization occurs because salt is left behind as irrigation water evaporates (Getu, 2009), or from leaking of salt and minerals from the soil due to water use for agriculture (Ferrey, 2004).

Salts are usually most damaging to young plants but not necessarily at the time of germination, although high salt concentration can slow seed germination by several days or completely inhibit it. Because soluble salts move readily with water, evaporation moves salts to the soil surface where they accumulate and make the soil surface harden as a result delaying germination. Kumar *et al.* (2010) reported that germination percentage of wheat became lower than that of the control in effluent irrigated soil.

2.2.2 Pesticides

Pesticides (which include herbicides, insecticides, fungicides and more) can contaminate organisms, soil, water, turf, and other vegetation. It is estimated that less than 0.1 percent of the applied pesticide reaches the target pest, leaving 99.9 percent as a pollutant in the environment, including the soil, air, and water, or on nearby vegetation Pimentel (1995). The adverse effect of pesticide use includes degrading water and soil quality, effect on non-targeted lives like soil organisms, aquatic life, human beings, insects, cattle etc, air pollution, and increase of pesticide resistance by targeted pests. This finding indicates the same result with the result obtained by SEPA (2001).

In countries like United States, flower imports are not inspected for pesticide residues because they are not edible; however, since flowers are considered as an agricultural product, they must be pest- free when imported. As a result, trade regulations in countries like the U.S. and Japan actually promote use of highly toxic fumigant methyl bromide, also, a potent ozone depleter, for some flower exports (Restrepo, 2002). According to Maharaj *et al.* (1995) rose producers in Ecuador use an average of six fungicides, four insecticides, and three nematicides (nematode poisons), along with several herbicides. Some of the toxic insecticides and nematicides, including methyl parathion, terbufose, and aldicarb are restricted heavily in the united states because of the health hazard they pose. According to Meer and Vander (1997) methyl bromide, an ozone depleter and a categoryl acute toxin, is heavily used and is among the most dangerous toxic substances known. There exists a wide array of other pesticides with known health risks.

Several classes of organic compounds can be found in effluents, including insecticides. Organochlorine (OC) pesticides (such as dieldrin, heptachlor and chlordane) and polychlorinated biphenyls (PCBs) are known to persist in the environment. The rate of decay of the organochlorines can vary from place to place, because organic compounds are affected by climate and soil characteristics. Organophosphorus and carbamate insecticides tend to be more readily broken down (hydrolysed) and are less persistent than OC pesticides. Trace concentrations of these chemicals may be found in effluent from municipal sewage treatment plants and they can be present in effluent from other industries. Many species of wildlife are sensitive to insecticide concentrations that have little or no effect on crops or other plants. One of the major concerns about insecticides in effluent irrigation, therefore, is the contamination of surface and groundwater, and the possible adverse effect on wildlife or soil biosystems that use this water (Department of Environment and Conservation/DEC, 2004).

a) Water

Pesticides can move from the site of application via drift, volatilization, leaking, and runoff. Pesticides, including herbicides, can and do leak to contaminate ground water. Once ground water is polluted with toxic chemicals, it may take many years, a huge expense and a complex process for the contamination to be cleaned up. As a result, the contamination (by pesticides) of ground and surface water, which supplies the greatest part of drinking water, is a serious problem worldwide (Pimentel,2001). When pesticides contaminate water, they can be harmful to the fish and other marine or freshwater animals that live there (Getu, 2010). In Costa Rica, as stated by Misganew (2007) pesticide residues are directly discharged into waterways, pesticide equipment is washed into streams and rivers, and runoff is allowed to enter, aquifer recharge areas.

b) Soil Organisms

Soil is a dynamic living system with a variety of micro- and macro- floral and faunal species including *bacteria, actinomycetes, fungi, nematodes, arthropods, crustaceans and earthworms* (Anonymous, 1999). These flora and fauna play a primary role in the degradation of plant and animal residues and other organic matter in the environment as well as in nitrogen fixation, nitrification and the release of nutrients from soil minerals (Doetsch and Cook, 1974; Frankenberger *et al*, 1991). Anything that affects their activities in turn affects the function of soils in crop production, and in the global carbon and nitrogen cycles (Silver and Riley, 2001).

Soil is a heterogeneous environment, in both time and space, and microbial activity is concentrated at localized sites on and around organic residues. The decomposer communities undergo succession as organic and inorganic residues are changed. Agricultural irrigation with industrial wastewater is a common practice in arid and semiarid regions and it is used as a readily available and inexpensive option to fresh water. Addition of such a mixed bag of compounds causes significant shift in the structure and function of a microbial community, which in turn may influence viability of soil for agriculture. The structural organization of soil particles provides a spatially heterogeneous habitat for microorganisms characterized by different substrates, nutrients, oxygen concentrations and water contents as well as variable pH values (Sessitsch *et al.*, 2001). Soil bacteria degrade organic matter and promote soil moisture retention and fertility, which are important for arid ecosystem productivity and stability (Kuske *et al.*, 2002). A change in soil microbial diversity or a shift from bacterial to fungal population has also been reported in metal contaminated soils. Oved *et al.* (2001) reported that irrigation with wastewater altered ammonia oxidizing bacterial (AOB) population in soil and *Nitrosospira* and *Nitrosomonas* species became dominant. Sarnaik & Kanekar (1995) reported alteration and reduction in number of *Pseudomonas* species from soil samples collected from the premises of a dye factory in India. Excess of soluble salts in water result in low crop yields, and if sodium is in excess, soil deterioration occurs as well. Baath (1989) reported that soils with high cation exchange capacity and more organic matter are known to bind metals and make them less available to microorganisms.

c) Pesticide Resistance

The extensive use of pesticides has resulted in the development of pesticide resistance in many insect pests, plant pathogens, weeds, and rats (Pimentel & Lehman, 1993; Kaushik, 2004). Worldwide, more than 500 insect and mite species, more than 150 plant pathogen species, and more than 275 species of weeds have become resistant to herbicides. The estimated cost of pesticide resistance in pests in the United States, for example, is estimated to reach $1.4 billion annually as indicated by Getu (2010).

d) Non-Target Organisms

The effect of pesticide on non-target organisms is also immense. It has been reported that about ten million non-target organisms including thousands of domestic animals are poisoned each year throughout the world. Moreover, it destroys the population of natural enemies, whose destruction and lack of biological control in agriculture, result in food loss due to pests which can increase by as much as fifty-eight percent. Pesticide use also has an adverse effect on the pollination process as honey and wild bees are vital for pollination of about one-third of fruits, vegetables, and other crops worldwide (Pimentel, *et al.*, 1997). Wild birds and mammals are also hurt by the application of pesticides (Pimentel, *et al.*, 1991). The ethical issue that arises at this juncture is the extent to which it is justifiable to destroy thousands of species for the purpose of killing the "harmful" few.

e) Air Pollution

Many pesticides can volatilize (that is, they can evaporate from the soil and foliage, move away from the area of application, and contaminate the environment (Glotfelty and

Schomburg, 1989). As much as 80-90 percent of applied pesticides can be volatilized within a few days of application (Majewski, and Capel, 1995). Research conducted in the US shows the availability of pesticide residues in air. Accounting for all of these effects, a conservative estimate of the total damage to the environment and public health caused by pesticides is about $9 billion each year (Pimentel, 1995). Research is not available to show how much of this impact is contributed by the floriculture sector, but it is obvious that the sector usually uses more fertilizer than conventional farming.

Air pollution caused by flower industry has given rise to various conflicts with the neighboring communities. The pesticides applied in the greenhouses travels an average distance of 1,500 miles, adding significantly to global warming and air pollution (Anonymous, 2003). Fertilizers do pose the same result. For instance, some fertilizers, like urea, spread in the fields with the help of sprayers and the ammonia therein react with the water present in the air causing the formation of ammonia oxide, and hence air pollution.

2.3. Pesticides and Occupational Hazards

In any institutions training is recommended when workers first start their jobs for the well-being of their institution as well as for themselves. The workers, for instance, rarely know the health hazards of the chemicals they are handling in the case of floriculture industries. (Megara and John, 1999) in their study entitled "the rose industry exception for early entry into pesticide treated greenhouses" indicated that showers are rarely provided for workers, who end up washing their work clothes. On the other hand, the US EPA recommends that workers remain outside the greenhouses for between 24 and 48 hours after fumigation. Nevertheless, workers in Madrid said often they would return after 20 minutes, and resume their jobs with the pesticide-drenched flowers, while the acrid smell of chemicals hung in the air. Sometimes other workers would not leave the greenhouse at all when fumigators were spraying which is the risk to the workers.

Some fungicides used, such as Mancozeb and Captan are suspected carcinogens, and such herbicides as paraquat, are extremely toxic through any route of exposure, whether absorbed through the skin, inhaled, or somehow ingested. These chemicals are dangerous, let alone when they are coupled with the method of usage and the conditions in which they are utilized. Many of these substances are applied daily in warm, poorly ventilated greenhouses, where high levels of toxic vapours can accumulate and where contact to these pesticide residues is close to impossible to avoid by workers. According to Sandra (2000), flower greenhouses in Morels state Mexico, applied 36 different chemicals, including the persistent organochlorines, DDt, aldrin, and dieldrin (Table 3).

Misganew (2007) stated that workers exposure in greenhouses where up to 127 different chemicals are used in enclosed spaces increasing risk of exposure through the skin and by inhalation. It can cause cancer, birth defects and other reproductive illnesses, and neurological disease in humans. A study of fern and flower workers in Costa Rica found that over 50% of workers had at least one symptom of pesticide poisoning, such as headache, dizziness, nausea, diarrhea, skin eruptions (skin lesion) and blurred vision. With similar results, Restrepo (1990) and David (2002) arrived at a conclusion that nearly 60%

of the workers in Ecuador manifested the above symptoms including nervous system problems because many insecticides that kill insects by interfering with nerve function could have similar nervous effects on man. Indications of genetic damage (genotoxic effects on markers of DNA) were also found in studies of workers exposed to organochlorines in greenhouses in Mexico (David, 2002; SJWEH, 2000).

2. 4. Intensive Water Use

Floriculture industries use large amount of water for their production is throughout the year. This could be revealed by the work of David (2002) who reported that after intensive water use by floriculture, the water table has dropped under the savanna surrounding Bogota. There are water shortages in the towns and villages in most floriculture areas because flower production requires its use in large quantities (USEPA, 1990). "Flower farmers in Colombia don't realize that the intensive use of the soil, the water and the intensive and excessive use of chemicals is going to convert the Savannah of Bogota into a sterile land" (USEPA. 1997).

Tadele (2009) indicated that fishermen and local residents living on the shores of Lake Naivasha in Kenya made alarming announcements to show the water level of the lake has been dropping for the past several years, fish stocks declining and chemicals polluting the lake. The blame for this situation has been put on the flower industry around the lake. This conclusion was arrived from the number of large flower farms (approximately 30), mainly producing cut flowers for the European markets, situated around the lake and had a heavy effect on the lake's biodiversity.

2.5. Crop Protection Agents

With the same objective for fertilizers and pesticides the use of crop protection agents in floriculture generally is high, especially in roses. For instance, in the Netherlands producers of roses use on average 68 kg active ingredients per ha (Hengsdijk and Jansen, 2006b). The Netherlands has a very strict admission policy for crop protection agents and most toxic agents are not any longer permitted.

Table 3 Pesticides used in Colombian flowers, indicating WHO classification.

Pesticides	**Levels of toxicity**
Insecticides	
Aldicarb	Ia
Cypermethrin	II
Deltamethrin	II
Dichlorvos	Ib
Endosulfan	II
fenvalerate	II
Lambada cyhalothrin	II
Malathion	III
methamidophos	Ib
mevinphos	Ia
Fungicides	
Acephate	II

Benomyl	III
Captan	III
chiorothalonil	III
Copper hydroxide	III
Copper oxychloride	III
Mancozeb	III
Methyl bromide fumigant	Ia

Ia= extremely hazardous Ib= highly hazardous II= moderately Hazardous III=slightly hazardous (Meer and Vander, 1997)

CHAPTER THREE

3. Materials and Methods

3.1 Study Area

Holeta is one of the towns in the Oromia Special Zone Surrounding Finfinne located in central part of the country 29 km away from Addis Ababa towards West direction. It has a latitude and longitude of 9°3′N 38°30′E and 9.05°N 38.5°E coordinates respectively, and an altitude of 2391 meters above sea level (http://www.2flowers.com/Ethiopia).

3.1.1 Climate

Holeta is characterized by humid tropical climate and heavy precipitation from July to September having an annual mean rainfall of 85.95 mm. The small rainy season occurs from November to January, while the main rainy season occurs from July to September with a dry season from October to February. The average annual temperature of the surrounding area is 13.2^{0}C with a mean maximum of 20.23^{0}C and mean minimum of 6.17 ^{0}C (Figure 2).

3.1.2 Soils of the study area

Soil under the study area is characterized by: deep, well-drained, red soils this type of soil is called Humic Nitisols and shallow Chromatic Luvisols, clay loam in texture, occupy many of the steeper slopes. Lower, gentler slopes are often characterized by deeper clay Vertic Cambisols which are well drained and easy to work, but poor in organic matter and nitrogen. Deep, clay Eutric Vertisols occur in the lowlands. These are subject to water logging and are generally difficult to work (Figure 1).

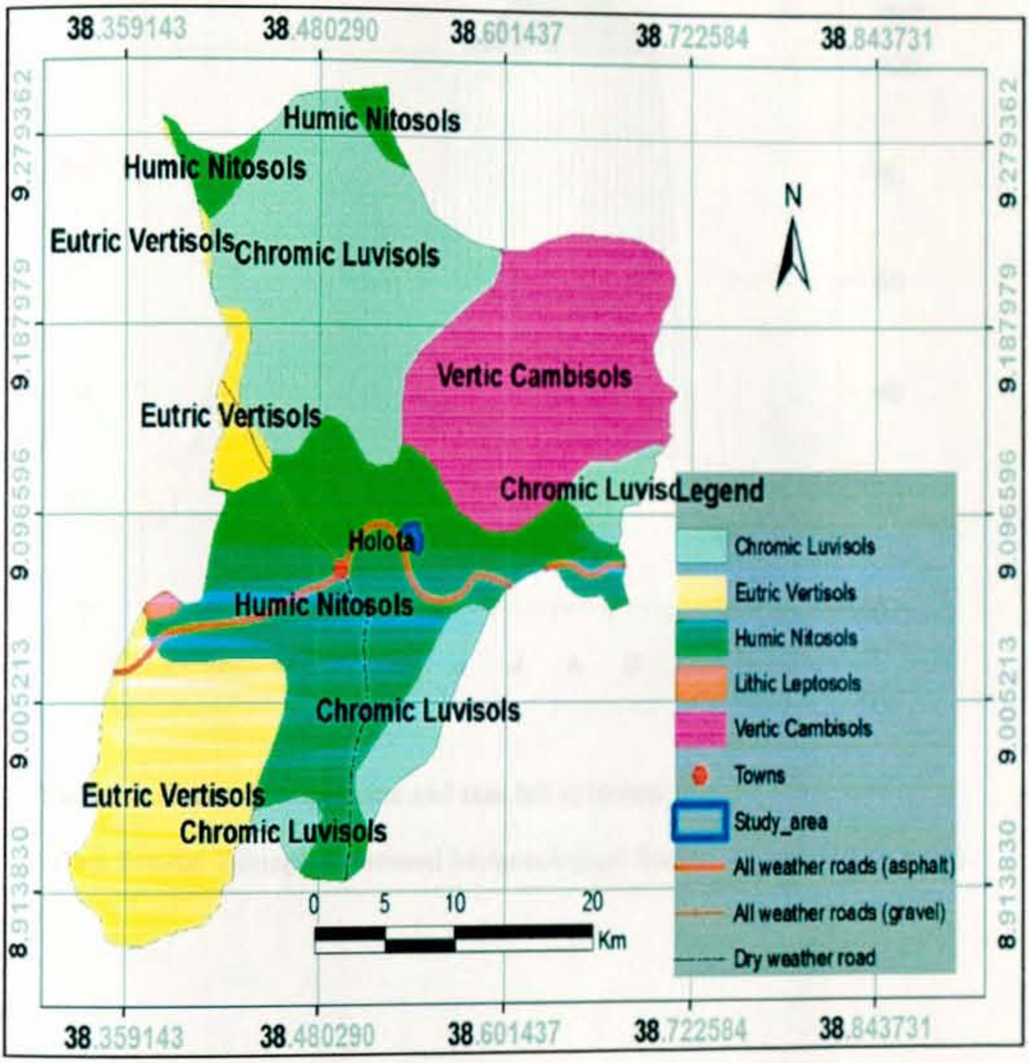


Figure 1: Map of soil types at Holeta

Source: Borgal et al., 1980

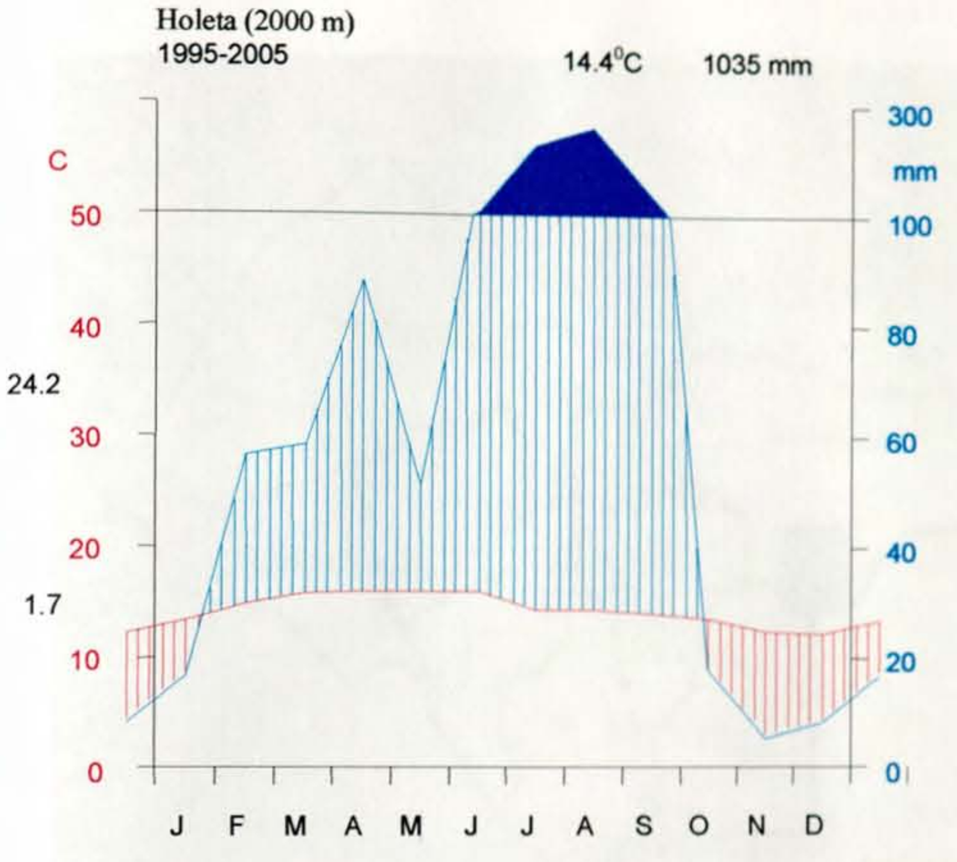


Figure 2: Annual temperature and rain fall at Holeta

Data Source: Ethiopian National Meteorological Station Agency (1995-2005).

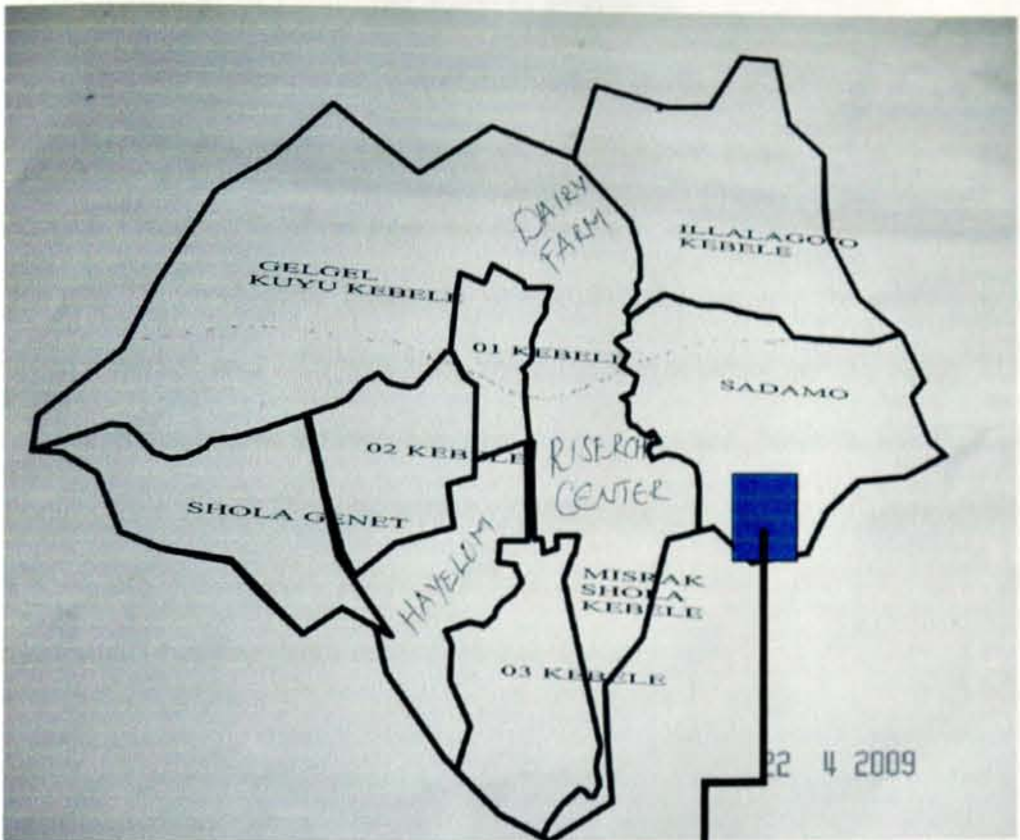
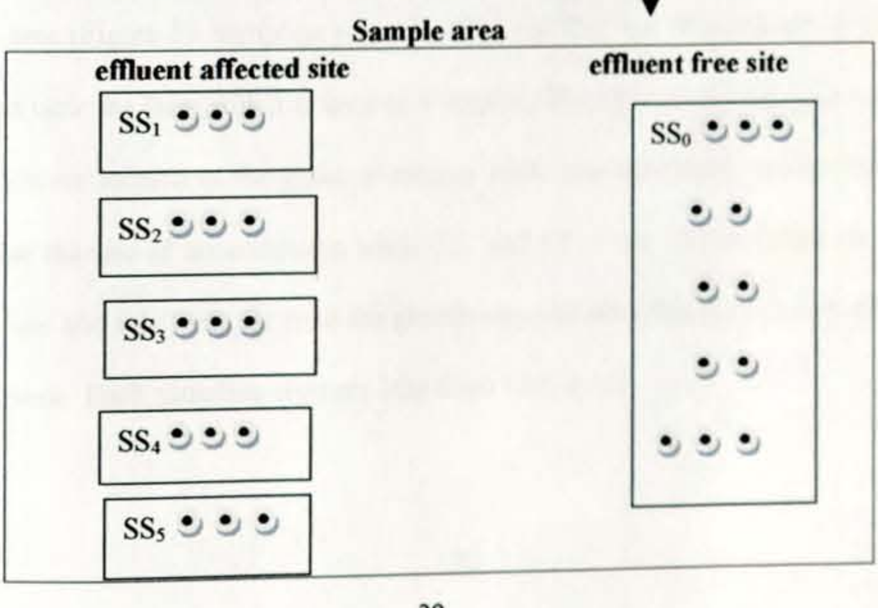


Figure 3 Map of Holeta Town Administration

Source: Holeta town administration Asset Management Plan, 2009.



3.2 Materials

3.2.1 Assessment of Pollutant Sources at Holeta

A reconnaissance survey has been conducted around the flower industries to identify the management of effluent disposal. There are 18 functional flower industries in Holeta (Annex 1). The majority of the farms already put waste water management techniques in to practice. However, some farms like Oromia Wonder discharge their effluents into temporary storage area after which the waste water is released into the nearby Holeta River. The River is used for irrigation after a certain distance. Based on the site survey, five points were chosen along the temporary storage site and one as a control to assess the status of physicochemical parameters such as soil texture, pH, TN, OC, CEC, concentration of exchangeable bases and micronutrients.

3.2.2. Sampling

Soil samples at a depth of 15cm of the top soil were collected cross sectionally using an auger from five major locations and three at each site as well as fifteen samples from the control area (Figure 2). Sampling was done from the first site (SS_0) chosen at a location of free area near the farm which is used as a control. The effluent affected sites such as SS_1 and SS_2 were located at the point of release above the temporary storage site. SS_3 was chosen at the site of accumulation while SS_4 and SS_5 were chosen below the temporary storage site and relatively far from the greenhouse and after this the released effluent joins Holeta river. Each sampling sites are 10m from each other.

One composite soil sample was then prepared from the fifteen samples for each site. The soil samples collected from representative fields were then air-dried, mixed well and sieved using 2 mm sieve for the analysis of selected soil physical and chemical properties.

3.4 Methods

Soil samples were analysed for physical and chemical characteristics at Holeta Agricultural Research Center Soil and Plant Research Laboratory. The physical parameters determined were soil texture and pH. Chemical parameters determined were Total Nitrogen, Cation Exchange Capacity, and Organic Carbon. Metals such as Na, K, Ca and Mg as well as heavy metals such as Cu, Zn, Fe and Mn were also determined. Standard laboratory procedures were followed in the analysis of the selected physicochemical properties considered in this study.

3.4.1 Analysis of Soil Physical Properties

Soil particle size distribution was determined by the Bouycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 1992) after removing OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$).

3.4.2 Analysis of Soil Chemical Properties

The soil pH was potentio-metrically measured in the supernatant suspension of a 1: 2 soil to water ratio using the glass electrode in VWR Scientific Model 2000 pH meter (Rayment and Higginson, 1992) while the Organic carbon was determined using Walkley-Black oxidation method (Allison, 1965). Total nitrogen was determined by the micro-

Kjeldahl digestion, distillation and titration method by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4).

Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0 to avoid CEC variability that may happen due to differences in soil pH. Exchangeable Ca and Mg in the extracts were analysed using atomic absorption spectrophotometer (AAS), while Na and K were analysed by flame photometer (Chapman, 1965). Cation exchange capacity was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Percentage base saturation (PBS) was calculated by dividing the sum of the charge equivalents of the base-forming cations (Ca, Mg, Na and K) by the CEC of the soil and multiplying by 100. Available micronutrients (Fe, Cu, Zn and Mn) were extracted by Diethylenetriamine pentaacetic acid (DTPA) and all these micronutrients were measured by atomic absorption spectrophotometer.

3.4.3 Data Analysis /Statistical Analysis

The data collected for this study were analyzed using SAS (Statistical Analysis System, version 15.0) for variation in soil texture, total nitrogen, organic carbon, cation echange capacity, exchangeable bases and micronutrient concentrations between the control and impaired sites. The Analysis of Variance procedure was applied to test the mean differences at 5% level of significance.

CHAPTER FOUR

4. Results

The result of the current soil analysis (Table 4) indicated increment in clay and sand content and a decrease in content of silt in effluent affected sites (measured in %). Similarly, the results of pH, K, Ca, Mg and heavy metals (Cu, Zn, Fe and Mn) indicate an increase in effluent affected areas while OC, CEC and TN showed a decrease (OC, CEC , TN and exchangeable bases were measured in meq/100g soil while heavy metals in ppm). The Tukey's HSD Multiple Comparisons result also confirms there is much significant difference between each parameter under study and others in effluent affected areas than the free sites.

Table 4 Average values and Standard Error of effluent free and effluent affected sites

Parameter	Effluent Free Site		Effluent Affected Site	
	Mean	Std. Error	Mean	Std. Error
pH	6.14	.13	7.05	.11
clay	54.75	.68	57.03	1.35
sand	7.13	1.88	10.20	.47
silt	39.32	1.57	27.62	.98
TN	.34	.02	.33	.04
CEC	5.67	.15	4.90	.10
OC	4.31	.29	3.03	.37
Na	2.55	.09	2.49	.20
K	1.89	.17	2.09	.08
Ca	1.66	.16	2.34	.06
Mg	4.84	.08	5.01	.04
Cu	.52	.01	.53	.003
Zn	2.31	.17	2.69	.13
Fe	16.54	.13	16.73	.06
Mn	2.39	.16	2.74	.14
Total	10.02	1.03	9.65	.97

CHAPTER FIVE

5. Discussion, Conclusion and Recommendation

5.1 Discussion

The change in the soil texture is an indication that untreated effluents released from floriculture industries affect the soil quality by changing soils particle size distribution. Soil texture (or particle size distribution) is a stable soil characteristic that influences the physical and chemical properties of the soil.

The increase in the results of effluent affected site confirms the disturbance of soil pH. An increase in soil pH may be due to the presence of salts applied in the effluent. The change in soils pH affects the availability of minerals, macro and microorganisms that are important for the normal functioning of soil for most plant nutrients are available in moderately acidic media (5.6 – 6.5). Tadele (2009) and Misganaw (2007) independently reported similar changes in the chemical properties of the water after being supplied with effluents. Untreated effluents released into the surrounding environment affect soil and water by altering pH.

The reduction in OC of the data is an indicative for the deterioration of soil quality. Even if there in a slight decrease in the percentage of total nitrogen, it didn't significantly affect the soil. This insignificant difference might be from the use of nitrogen fertilizers by the floriculture industries. On the other hand, the decrease in Cation Exchange Capacity (CEC) in effluent affected site shows the soil surrounding the floriculture industry is likely to be leached away because cations retained electrostatically are easily exchangeable with cations in the soil solution so a soil with a higher CEC has a greater capacity to maintain adequate quantities of Ca^{2+}, Mg^{2+} and K^{+} than a soil with a low CEC.

It is widely known that soil physico-chemical properties for instance pH, contents of clay minerals and organic matter etc determine that bioavailability and mobility of metals in soils. Thus, the higher the cation exchange capacity (CEC) of the soil, the greater the sorption and immobilization of the metals. In acidic soils, due to competition of H^{+} for binding sites on the colloidal components of the soil, metal desorption and release into solution is stimulated. Therefore, soil pH not only affects metal bioavailability but also metal uptake into roots. Soil pH is an important factor controlling the bioavailability of nutrients and metal elements to plants (Bose and Bhattacharyya, 2008).

The results of K, Ca and Mg in the data indicate their usage by the floriculture industry because calcium and potassium are essential fertilizer elements. However, the value for soil Na did not show any significant change among treatment means. Rani et al, 2007) indicated that alkaline soils tend to have Ca, Mg and K in high concentrations. With the same result soil samples from effluent released area showed a similar pattern with regard to Ca, Mg and K. Effluent irrigation generally adds significant quantities of salts to the soil environment, such as sulphates, phosphates, bicarbonates, chlorides of the cations sodium, calcium, potassium and magnesium.

In general, the concentration of most exchangeable bases increased in effluent applied areas with varying extent and proportion except for Na. The increase in their concentrations is due to high concentrations of the cations in the effluent. They stimulate the growth at lower concentration but inhibit at higher concentration.

The result of micronutrients in the study clearly demonstrates that soil adjacent to the flowing floriculture effluent experiences change in physiochemical parameters. These elevated concentrations can be attributed to high content of metal ions discharged into the wastewater and thus accumulated in the soil.

5.2Conclusion and Recommendation

5.2.1 Conclusion

Floriculture activities produce different types of waste ranging from liquid to solid, hazardous to non-hazardous, and in effect require safe waste disposal and differentiated treatment. Empty chemical containers (fertilizers, pesticides) and their washing waters and obsolete chemicals are the major spheres of concern in addition to which other agricultural wastes such as cut off crop parts, unused soil, and waste water are generated in the sector. Hazardous wastes are those which contain hazardous substance(s) in a quantity liable to cause death, injury or impairment to living beings, pollution of waters, or an unacceptable impact on the environment if not properly treated, handled or disposed of. It is believed that toxic/hazardous wastes have an adverse effect on the environment and human health. These include increased exposure to cancer, and children born near toxic waste sites can be physically deformed or have developmental disabilities. There are different types of waste disposal mechanisms including landfill, incineration, anaerobic digestion and recycling. Unfortunately, they are unevenly implemented partially because of the cost involved. Recycling of waste is also a means whereby organic waste breaks down over a few weeks into mulch which can be used as soil fertiliser.

Floriculture industries located at Holeta have been creating much needed employment opportunities to the local people which mainly depend on smallholder agriculture; it has been also helping the country to generate foreign exchange. However, these industries located in the area are using a broad range of fertilizers and pesticides; the farm effluent discharged by some farms in to the nearby soil led to deterioration of the soil quality and surface water.

In this study, the results of Physicochemical, soil texture, exchangeable bases and micronutrient parameters analyzed at the impaired sites were compared with effluent free samples which showed significant difference in the majority of physicochemical, soil texture, exchangeable bases but insiginificantly different for micronutrients. Although the soil and water quality of Holeta is still acceptable for different purposes under the current condition, the high levels of fertilizer residues in the farm effluent is promoting growth of algae in water and affecting the soil quality.

In general because of the activities of the flower farm on the soil, the farmland soil quality may be seriously deteriorated and agricultural products will decline near the flower industries. Unless immediate measures are taken, the farmland soil will be heavily polluted and become unfit for the variety of purposes being used before.

5.2.2 Recommendations

Based on results of this study and experience of other countries producing floriculture products, the following recommendations were drawn to sustain the floriculture industries with its minimum environmental impacts:

Fertilizer management: providing nutrients in the right quantities at the right time helps to reduce excessive amounts of nutrients entering in to the soil.

Waste water treatment: Effluents loaded with fertilizer and pesticide residues should be treated before discharging to the surrounding soil.

Waste Water recycling: This method also helps to reduce excessive abstraction of soil in addition to protecting the soil from being polluted.

Many pesticides are harmful to soil organisms and some are dangerous to humans as well. Integrated Pest Management should be used to minimize intensive pesticide application by floriculture industries. It is an effective and economical management strategy for controlling crop pests, helps to protect the environment and human health. The firm should undertake environmental audit about the inputs and discharges in to and out of the farm.

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Annexes

Annex 1. List of Flower Farms at Holeta

S.N.	Company Name	Product Type	Area Coverage in m^2
1	Top Flower	Roses	243,000
2	"A" Flower	Roses	185,000
3	Rose Ethiopia Plc.	Roses	220,400
4	Ethio Agri-CEFT	Roses	285,000
5	Metrolux Plc.	Roses, Summer plants and Lilies	211,600
6	Dire Highland Flower Plc.I	Roses	280,000
7	Garad Plc.	Rose	280,000
8	Arsi Flower Plc.	Roses	268,500
9	Holeta Rose Plc.	Rose	224,500
10	Joe Flowers Plc.	Rose	103,000
11	FIYORI Ethiopia Pvt.Ltd.Co	Rose	279,400
12	Agre Flora Flower	Roses	222,000
13	Ethio Dream Plc.	Roses	211,700
14	Ethiopian Medous Plc.	Roses	1,070,000
15	Oromia Wonder Plc.	Roses	150,000
16	Euro Flora Plc.	Roses	211,758
17	Aklom Fer.KAF Rose Plc.	Roses	165,600
18	Dandi Boru Plc.	Apple	182,700
19	Star Flora Plc.	Strawberry	176,000

Annex 2. Fertilizers in use in Ethiopian Floriculture industries

Item no.	Fertilizer
1	Calcium Nitrate
2	Potassium Sulphate
3	Borax
4	Magnesium sulphate
5	MAP
6	Phosphoric acid
7	Potassium Nitrate
8	Zinc sulphate
9	Magnesium Nitrate
10	Nitric Acid
11	Sulpharic Acid
12	Manganese sulphate
13	Copper sulphate
14	Ammonium sulphate
15	Sulphric Dust
16	MKP
17	Sodium Molybedate
18	Calcium Hypochlorite
19	Fe EDDHA6%
20	DAP
21	Aluminum Sulphate
22	UREA

Annex 3. Some of the Chemicals Used in Ethiopian Floriculture Industries

No	Product name	Active Ingredient
1	Apollo	Keofentazin
2	Dynamic	Abemectin
	Zoro	
3	Knocout	clofortazine
	Akramactin	
4	Aviramic	
5	Floramite	Binfenazation
	Pegaseus	Difenthinron
	Abalon	
6	Tosha	
7	Polythrin	
8	oxymitrin	oxymethrin
9	mercure	Difenthinron
10	Nissron	Hexythiaon
11	mitac	
12	Tedion	
13	striker	
	miteclean	
	Cascade	
14	Dynamite	
15	Aligator	

16	Impulse	
17	Stroby	
18	collis	
19	Rubigan	
20	Bellice	Boscalid + Pyracolstrobin
21	Soncozeb	25%Azoxy strobin
22	Switch	Cyprodiml + Fludiox
23	Nuster	Imidacloprut
24	Folicure	tebuconazole
25	manic	Mancozeb
26	mavric	Tufluvalinat
27	prova	
28	Meletatox	Dofemoraph Acetate

Annex 4. Images showing the study sites and pollution of the surrounding soil

Plate 1. Cattles grazing near the effluent affected area

Plate 2. Eutrophication of water near the greenhouse at Holeta

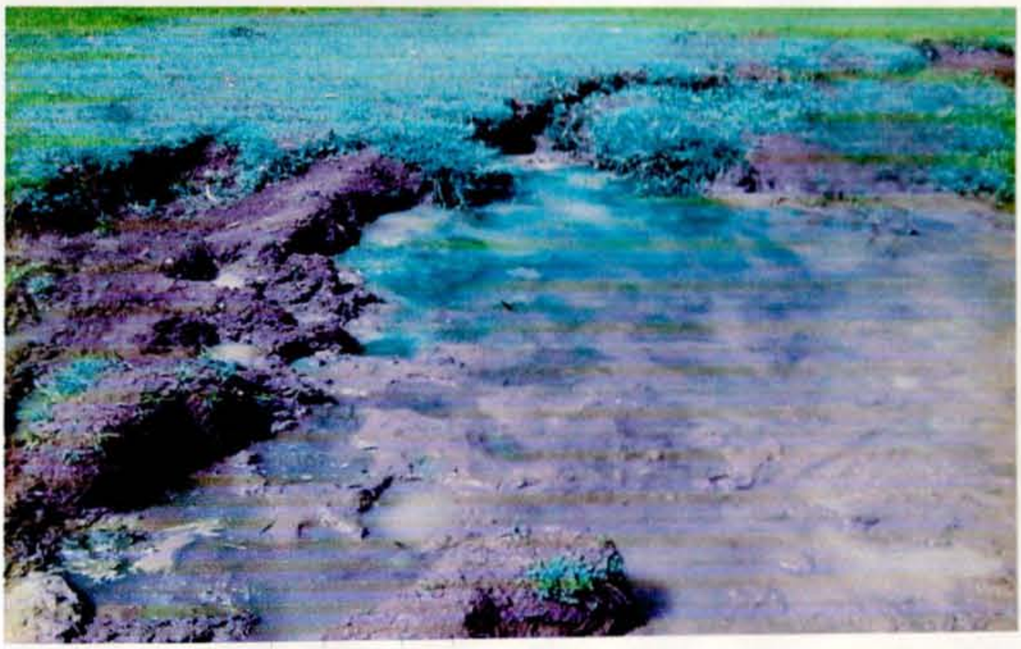
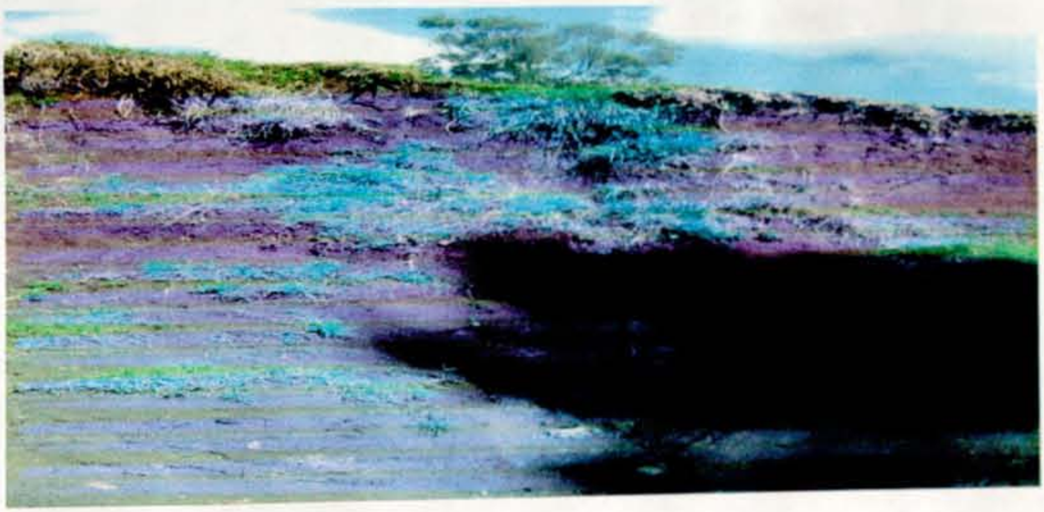


Plate 3. Open temporary storage of effluent near the floriculture industry

Plate 4. Effluent affected waste flowing to Holeta River



Annex 5 (a) Tukey HSD Multiple Comparisons

		Effluent free site			Effluent affected site		
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.
pH	clay	-48.60667(*)	.95013	.000	-49.97933(*)	.65836	.000
	sand	-.98467	.95013	.999	-3.14533(*)	.65836	.000
	silt	-33.18067(*)	.95013	.000	-20.56867(*)	.65836	.000
	TN	5.80133(*)	.95013	.000	6.72133(*)	.65836	.000
	CEC	.47533	.95013	1.000	2.15133(*)	.65836	.001
	OC	1.82733	.95013	.839	4.01867(*)	.65836	.000
	Na	3.59000(*)	.95013	.016	4.55800(*)	.65836	.000
	K	4.24400(*)	.95013	.001	4.95667(*)	.65836	.000
	Ca	4.48000(*)	.95013	.000	4.71733(*)	.65836	.000
	Mg	1.29733	.95013	.989	2.04933(*)	.65836	.002
	Cu	5.62400(*)	.95013	.000	6.52533(*)	.65836	.000
	Zn	3.83600(*)	.95013	.006	4.35733(*)	.65836	.000
	Fe	-10.39400(*)	.95013	.000	-9.67667(*)	.65836	.000
	Mn	3.75000(*)	.95013	.009	4.31800(*)	.65836	.000
clay	sand	47.62200(*)	.95013	.000	46.83400(*)	.65836	.000
	silt	15.42600(*)	.95013	.000	29.41067(*)	.65836	.000
	TN	54.40800(*)	.95013	.000	56.70067(*)	.65836	.000
	CEC	49.08200(*)	.95013	.000	52.13067(*)	.65836	.000
	OC	50.43400(*)	.95013	.000	53.99800(*)	.65836	.000
	Na	52.19667(*)	.95013	.000	54.53733(*)	.65836	.000
	K	52.85067(*)	.95013	.000	54.93600(*)	.65836	.000
	Ca	53.08667(*)	.95013	.000	54.69667(*)	.65836	.000
	Mg	49.90400(*)	.95013	.000	52.02867(*)	.65836	.000
	Cu	54.23067(*)	.95013	.000	56.50467(*)	.65836	.000
	Zn	52.44267(*)	.95013	.000	54.33667(*)	.65836	.000
	Fe	38.21267(*)	.95013	.000	40.30267(*)	.65836	.000
	Mn	52.35667(*)	.95013	.000	54.29733(*)	.65836	.000

Annex 5 (b) Tukey HSD Multiple Comparisons

		Effluent free site			Effluent affected site		
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.
sand	silt	-32.19600(*)	.95013	.000	-17.42333(*)	.65836	.000
	TN	6.78600(*)	.95013	.000	9.86667(*)	.65836	.000
	CEC	1.46000	.95013	.969	5.29667(*)	.65836	.000
	OC	2.81200	.95013	.179	7.16400(*)	.65836	.000
	Na	4.57467(*)	.95013	.000	7.70333(*)	.65836	.000
	K	5.22867(*)	.95013	.000	8.10200(*)	.65836	.000
	Ca	5.46467(*)	.95013	.000	7.86267(*)	.65836	.000
	Mg	2.28200	.95013	.516	5.19467(*)	.65836	.000
	Cu	6.60867(*)	.95013	.000	9.67067(*)	.65836	.000
	Zn	4.82067(*)	.95013	.000	7.50267(*)	.65836	.000
	Fe	-9.40933(*)	.95013	.000	-6.53133(*)	.65836	.000
	Mn	4.73467(*)	.95013	.000	7.46333(*)	.65836	.000
silt	TN	38.98200(*)	.95013	.000	27.29000(*)	.65836	.000
	CEC	33.65600(*)	.95013	.000	22.72000(*)	.65836	.000
	OC	35.00800(*)	.95013	.000	24.58733(*)	.65836	.000
	Na	36.77067(*)	.95013	.000	25.12667(*)	.65836	.000
	K	37.42467(*)	.95013	.000	25.52533(*)	.65836	.000
	Ca	37.66067(*)	.95013	.000	25.28600(*)	.65836	.000
	Mg	34.47800(*)	.95013	.000	22.61800(*)	.65836	.000
	Cu	38.80467(*)	.95013	.000	27.09400(*)	.65836	.000
	Zn	37.01667(*)	.95013	.000	24.92600(*)	.65836	.000
	Fe	22.78667(*)	.95013	.000	10.89200(*)	.65836	.000
	Mn	36.93067(*)	.95013	.000	24.88667(*)	.65836	.000

Annex 5 (c) Tukey HSD Multiple Comparisons

		Effluent free site			Effluent affected site		
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.
TN	CEC	-5.32600(*)	.95013	.000	-4.57000(*)	.65836	.000
	OC	-3.97400(*)	.95013	.004	-2.70267(*)	.65836	.000
	Na	-2.21133	.95013	.571	-2.16333(*)	.65836	.001
	K	-1.55733	.95013	.948	-1.76467(*)	.65836	.008
	Ca	-1.32133	.95013	.987	-2.00400(*)	.65836	.003
	Mg	-4.50400(*)	.95013	.000	-4.67200(*)	.65836	.000
	Cu	-.17733	.95013	1.000	-.19600	.65836	.766
	Zn	-1.96533	.95013	.754	-2.36400(*)	.65836	.000
	Fe	-16.19533(*)	.95013	.000	-16.39800(*)	.65836	.000
	Mn	-2.05133	.95013	.693	-2.40333(*)	.65836	.000
CEC	OC	1.35200	.95013	.984	1.86733(*)	.65836	.005
	Na	3.11467	.95013	.078	2.40667(*)	.65836	.000
	K	3.76867(*)	.95013	.008	2.80533(*)	.65836	.000
	Ca	4.00467(*)	.95013	.003	2.56600(*)	.65836	.000
	Mg	.82200	.95013	1.000	-.10200	.65836	.877
	Cu	5.14867(*)	.95013	.000	4.37400(*)	.65836	.000
	Zn	3.36067(*)	.95013	.036	2.20600(*)	.65836	.001
	Fe	-10.86933(*)	.95013	.000	-11.82800(*)	.65836	.000
	Mn	3.27467(*)	.95013	.048	2.16667(*)	.65836	.001
OC	Na	1.76267	.95013	.872	.53933	.65836	.414
	K	2.41667	.95013	.415	.93800	.65836	.156
	Ca	2.65267	.95013	.260	.69867	.65836	.290
	Mg	-.53000	.95013	1.000	-1.96933(*)	.65836	.003
	Cu	3.79667(*)	.95013	.008	2.50667(*)	.65836	.000
	Zn	2.00867	.95013	.724	.33867	.65836	.608
	Fe	-12.22133(*)	.95013	.000	-13.69533(*)	.65836	.000
	Mn	1.92267	.95013	.782	.29933	.65836	.650

Annex 5 (d) Tukey HSD Multiple Comparisons

		Effluent free site			Effluent affected site		
(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.
Na	K	.65400	.95013	1.000	.39867	.65836	.545
	Ca	.89000	.95013	1.000	.15933	.65836	.809
	Mg	-2.29267	.95013	.508	-2.50867(*)	.65836	.000
	Cu	2.03400	.95013	.706	1.96733(*)	.65836	.003
	Zn	.24600	.95013	1.000	-.20067	.65836	.761
	Fe	-13.98400(*)	.95013	.000	-14.23467(*)	.65836	.000
	Mn	.16000	.95013	1.000	-.24000	.65836	.716
K	Ca	.23600	.95013	1.000	-.23933	.65836	.717
	Mg	-2.94667	.95013	.126	-2.90733(*)	.65836	.000
	Cu	1.38000	.95013	.981	1.56867(*)	.65836	.018
	Zn	-.40800	.95013	1.000	-.59933	.65836	.364
	Fe	-14.63800(*)	.95013	.000	-14.63333(*)	.65836	.000
	Mn	-.49400	.95013	1.000	-.63867	.65836	.333
Ca	Mg	-3.18267	.95013	.064	-2.66800(*)	.65836	.000
	Cu	1.14400	.95013	.997	1.80800(*)	.65836	.007
	Zn	-.64400	.95013	1.000	-.36000	.65836	.585
	Fe	-14.87400(*)	.95013	.000	-14.39400(*)	.65836	.000
	Mn	-.73000	.95013	1.000	-.39933	.65836	.545
Mg	Cu	4.32667(*)	.95013	.001	4.47600(*)	.65836	.000
	Zn	2.53867	.95013	.330	2.30800(*)	.65836	.001
	Fe	-11.69133(*)	.95013	.000	-11.72600(*)	.65836	.000
	Mn	2.45267	.95013	.389	2.26867(*)	.65836	.001
Cu	Zn	-1.78800	.95013	.860	-2.16800(*)	.65836	.001
	Fe	-16.01800(*)	.95013	.000	-16.20200(*)	.65836	.000
	Mn	-1.87400	.95013	.812	-2.20733(*)	.65836	.001
Zn	Fe	-14.23000(*)	.95013	.000	-14.03400(*)	.65836	.000
	Mn	-.08600	.95013	1.000	-.03933	.65836	.952
Fe	Mn	14.14400(*)	.95013	.000	13.99467(*)	.65836	.000

* The mean difference is significant at the .05 level.