IMPACTS OF SUGAR MILL'S EFFLUENT ON SOIL AND PLANTS SEED GERMINATION

(MS Thesis)

By

Muhammad Musaa Khan

Supervisor

Dr Islamud Din

DEPARTMENT OF ENVIRONMENTAL SCIENCE

FACULTY OF BASIC AND APPLIED SCIENCES

INTERNATIONAL ISLAMIC UNIVERSITY ISLAMABAD

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- Seeds

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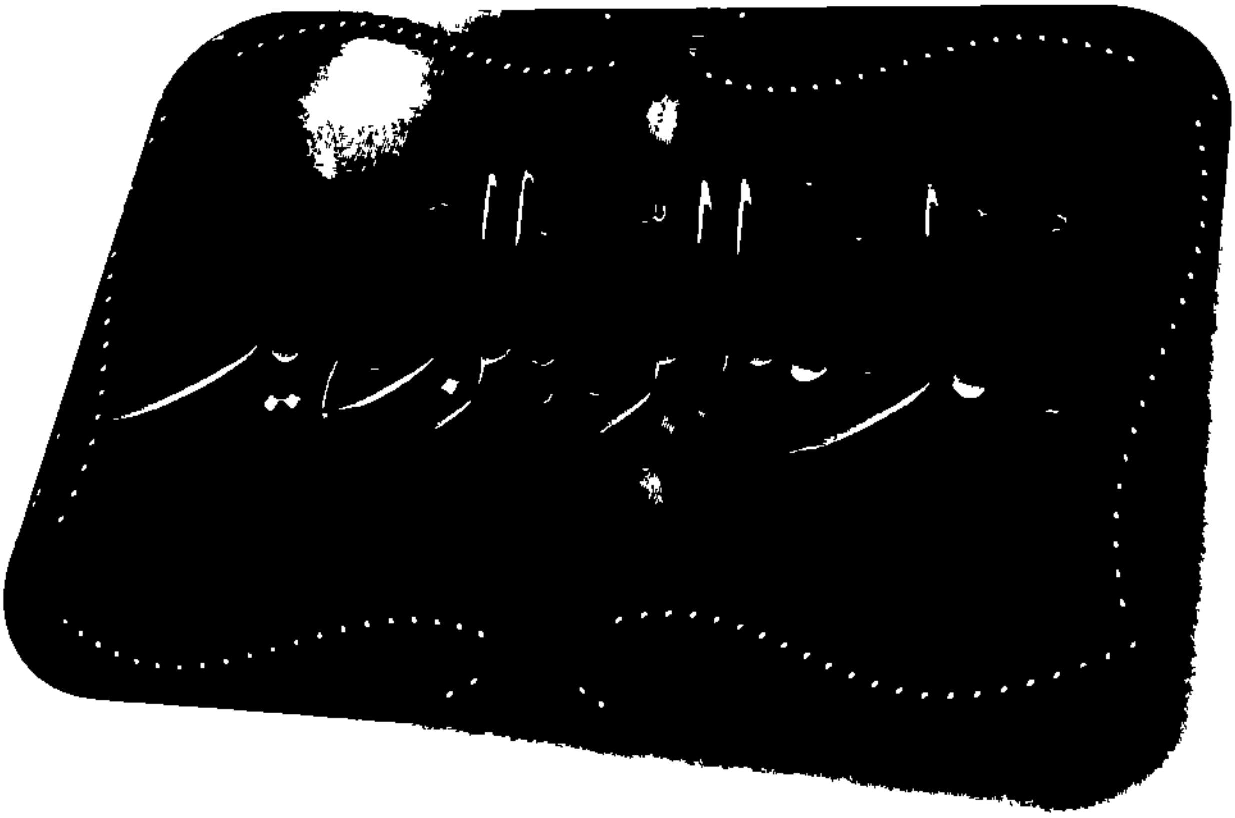

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Muhammad Musaa Khan

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

Father & Mother,

Whose affection, love, encouragement and prays of day and night make me able to get such success and honor,

*Also to all hard working and respected **Teachers***

DECLARATION

I hereby declare that the work presented in this thesis is my own effort, except where otherwise acknowledged and that the thesis is my own composition No part of the thesis has been previously presented for any other degree

Date ______________

Muhammad Musaa Khan

Signature ____________

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometer
APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DDRMP	District Disaster and Risk Management Plan
DO	Dissolve Oxygen
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
KP	Khyber Pakhtunkhwa
NARC	National Agricultural Research Center
NEQS	National Environmental Quality Standards
NTU	Nephelometric Turbidity Unit
Pak EPA	Pakistan Environmental Protection Agency
PCRWR	Pakistan Council of Research in Water Resource
PSQCA	Pakistan Standards and Quality Control Authority
SME	Sugar Mill Effluent
TDS	Total Dissolved Solid
TSS	Total Suspended Solids
UNO	United Nation Organization
USEPA	United State Environmental Protection Agency
WHO	World Health Organization
WWF	World Wildlife Fund for Nature

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ABSTRACT

The present study was carried out to assess the physico-chemical analysis of sugar mill effluent and its impact on soil and seed germination of okra and tomato plants Total 12 samples of sugar mill effluents were collected from different points Similarly 12 soil samples were collected from the fields irrigated with sugar mills effluents in radius of 500 meters and at a depth of 8 inches All the analysis for both the effluents and soil were performed according to the Standard Methods Mean values of the selected parameters in the effluents were of pH 6 67, total suspended solids (366 mg/L), total dissolved solids (5248 mg/L), biological oxygen demand (475 mg/L), chemical oxygen demand (2662 mg/L), electrical conductivity (3865 μS/m), temperature (55 °C), turbidity (118 NTU), dissolved oxygen (1 8 mg/L), sodium (163 mg/L), calcium (160 mg/L), magnesium (63 mg/L), chlorine (535 mg/L) and bicarbonates (332 mg/L) With respect to heavy metals the value differ iron (1 45 mg/L), zinc (1 51 mg/L), lead (0 18 mg/L), cadmium (0 21 mg/L), copper (0 52 mg/L) and chromium (0 17 mg/L) Most of the parameters mean values were greater than the WHO permissible limits The results of soil samples analysis indicated that mean values of all the parameters were in permissible limits Seeds of okra (*Abelmoschus esculentus*) and tomato (*Solanum lycopersicum*) showed maximum germination (95% and 90% respectively) at control condition While at 10% concentration, seed germinated 95% and 90% respectively At 25% concentration okra showed 90% seed germination concentration while 70% tomato seeds germinated Okra plant is more vassal as compare to tomato with respect to effluent concentration Sugar mill effluents are good for vegetation if diluted before irrigation Crops and soil fertility could be increased by applying environment friendly techniques during effluent discharge

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Water is the basic requirement of life on this earth Only 3% of total water on earth makes fresh water, of which a small portion (0 01%) is available for human consumption (Hinrichsen & Tocio, 2002) This small quantity of freshwater is also under stress due to increased population, urbanization, industrial and agricultural use of water Many nations of the world especially, in South Asia, Africa and Middle East will be under pressure due to water scarcity in the upcoming future The countries which are under developed, problem is worse and dangerous due to lack of suitable management and oversight of government, absence of professionals and experts and economic limitation (Kahlown, & Aslam, 2005, Abdullah 2013)

Water is definitely the absolute natural resource that exists along the earth, without which life could not be possible Water is essential for growth and it is the basic right of all living things Regardless of this, human beings use water for their own needs, pollute and spoil water resources Nearly 1 5 billion people have no access to drinking water globally and every year minimum 5 million people die due to water related diseases (Javaid *et al* , 2008, Appa *et al* , 2007) Definitely, water is the most obligatory requirement not just for life provisions but for the economic and industrial development too (Joshi *et al* , 1954, Chhonkar *et al* , 2000)

Throughout the world and particularly in developing countries, water bodies were considered boundless dumping ground for wastes of every kind, such as garbage, domestic waste, industrial effluents, raw sewage, electronic waste nuclear waste and oil spills and a lot more The quality of water is thoroughly associated with the water usage, water resources, to the state of economic development and industrial growth (Hasan & Deininger, 2010, Dash, 2012)

Naturally, the environment was very clean, which comprises on atmosphere, animal and plants In the past, the needs of human beings were limited only to food, habitat and clothes Air was clean and fresh, water was pure and serene and land was fertile (Azizullah *et al*, 2011, Misra, *et al*, 1991) Due to human's luxurious life and other needs nature was disturbed and relation between human being and environment totally changed, polluting the air we breathe, water we use, the food we eat and the working place (Rajesh *et al*, 2014 ,ASP, 2005-06)

In rural areas almost 90% of population is attached with agriculture About more than 50% labor force is engaged in this sector In agriculture a large quantity of water is used in every kind of production in the field and its consumption will remain to take over water need (Ahmed *et al*, 2007, Rahman *et al*, 2013) Water usage can be allocated into three categories i e, domestic consumption, commercial or industrial use and irrigation (NWP 2004, Butt *et al*, 2005, Adriano, 2001) Farming is largely bent on a canal irrigation system, but due to the negligence of authorities and management of respective department, it is not efficient in supplying water to fulfill the crop production requirement (Haran *et al*, 2002)

In Pakistan, sewage is dispose of in two ways, one is direct application for irrigation of vegetables and crops fields, while the other is direct discharge into fresh water bodies like rivers or lakes (Dhurani *et al*, 2004) Sewage water is the mixture of organic, inorganic chemicals and heavy metals It creates severe problems of salinity hardness, and change of acidity and basicity and in the end reduction in agriculture production (Butt *et al*, 2005 Arif, 1994, Hashmi *et al*, 2009) In Pakistan, unluckily, most of the industries pay no attention to the regulation and supervision of industrial wastewater Farmers are also interested to use this untreated wastewater due to nutrient richness (Butt *et al*, 2005, Yadav & Pathak 2012)

Environmental contamination has been known as one of the major problems of the world The problem has come into touch due to industrial development and urbanization (Barman *et al*, 2000, Kisku *et al*, 2000) Sugarcane (*Saccharum officinarum L*) is a vital profitable crop of the tropical and subtropical nations It produces about 70% of the world's sugar and 30% is from sugar beet and some other sources (Yadav & Solomon, 2006, Yaduvanshi & Yadav, 1990) Sugar industry is periodic in nature and functions only for 4-6 months in the season (Kolhe *et al*, 2011) The industrial development and change of manufacturing methods have given rise to an increase in the quantity of wastewater discharge into the environment which causes water pollution (Manisankar *et al*, 2003, Bharati *et al* 2014)

Brazil is at the top in the production of sugar cane The following five major manufacturers, are China, India, Thailand, Pakistan and Mexico Pakistan, with respect to sugarcane production is at a 5^{th} position worldwide (Wiedenfeld & Enciso, 2008, Qureshi *et al*, 2015) In this industry sugar cane is used as their new material along with a number of chemicals added during the working process to increase the value of output produced as an end product During the processing large quantity of water is used and as a result sugar mills discharge large amount of wastewater The effluent from mill house is normally mixed with different chemicals used during processing (Hsieh *et al*, 1995, Kohli & Power, 2011)

Sugarcane itself contain about 70-80 % water as an effect large amount of waste water is generated during its crushing and processing in the industry (Sanjay 2005, Trivedy,1998) About 0 73 m^3 (730L) of water is generated by every single ton of sugarcane processed The related environmental issues are disposal of effluent, molasses and air pollution (Guven *et al*, 2009, Mancera *et al*, 2010) Such type of wastewater contains high content of organic materials and as a result has high biological oxygen demand (BOD) In sugarcane processing, the typical levels of

BOD are 1700–6600 mg/L in the untreated effluent, the chemical oxygen demand (COD) is from 2300 to 8000 mg/L and the total suspended solids (TSS) are up to 5000 mg/L (ADB, 1994, Kumar *et al*, 2011, Jadhav *et al*, 2013) All chemicals are washed away with the wastewater discharged Thus effluents consist of all types of chemicals which contain toxic heavy metals Many processes have been developed to treat this effluent such as electrochemical oxidation, bio-sorption (Lara *et al*, 2010), membranes separation (Hinkova *et al*, 2002), and biochemical oxidation (Prasad *et al*, 2006) Effluents moves along with heavy metals and reach in shallow water table by leaching processes and contaminants may disperse in a wide range of the region Contamination of soils of close areas occurs when the effluents or polluted water comes under contact of soil (Afzal *et al*, 2000) The regular contact of polluted water with soil makes the soils sodic and alters the physico-chemical characteristics texture and profile of soil stratum (Bharati & Kumar, 2012) These effluents are used by farmers unscientifically for irrigation and due to this exercise the growth, health and yield of the soil is reduced To fulfill the water needs farmers use these effluents Contaminants such as chloride (Cl^{1-}) sulphates (SO_4^{2-}), phosphates (PO_4^{3-}), magnesium (Mg) and NO^{3-} are discharged with the effluent which creates a nuisance due to physical appearance, odor and taste (Baruah *et al* 1993) As it is a common practice to use sugar industry effluent for irrigation, therefore, with regards to public health and crop production, it is essential to identify how crops in the field respond when they are irrigated or exposed to industrial wastewater For this purpose, working has been done from different department and from institutions to explore the effect on seed germination of different crops such as wheat, maize, pine, rice and green gram Seed germination is a very important stage that confirms reproduction and controls the refinements of plant populations, that is why, it is very critical to identify effect during germination stage (Doke *et al* 2011 Yadav *et al*, 2014)

1.2 SUGAR INDUSTRY IN THE WORLD

Almost over 110 countries produce sugar worldwide Study showed that 70% of the total world production is used domestically and 30% is sold in the world market Sugar cane is the harvest which is developed in tropical and sub-tropical zone perennially (Reddy *et al*, 1999) Brazil occupies a leading position with respect to area by raising sugarcane on an area of 25 10 million hectares, followed by India, China, Cuba and Pakistan in 4 42, 1 43, 1 05 and 1 09 million hectares, respectively In the half of 20th century world average crop was about 42 6 tons cane per hectare and top countries were Brazil, India, China, Thailand, Philippines and Guatemala with production of 38 8, 32 2, 35 3 17 6, 18 7 and 37 7 t/ha respectively (ADB,1994, WHO, 2004)

During 2002, Brazil, India, China, Thailand, Philippines and Guatemala did much energy to increase their production to 71 0, 67 4, 64 8, 93 6 70 6 and 94 0 t/ha respectively, hence on average they increase of 66 1 t/ha (PARB, 2008)

1.3 SUGARCANE PRODUCTION IN PAKISTAN

Pakistan is at 5th and 8th number in the world by cane cultivation and sugar production respectively In Pakistan, in 2007-08, sugar cane was produced on 1 25 million hectares, out of which Punjab province contributed 67 % by area, whereas Sindh and KP shared 25 % and 8 % area respectively The total cane production was 63 9 million tones of which Punjab, Sindh and KP shared 63 %, 29 % and 7 % respectively The median output of the rural area is about 51 6 tones cane for each hectare Sindh province maximum yield of cane was (60 9 t/ha) and almost equal production of Punjab (48 72 t/ha) and KP (45 72 t/ha) (Rehman *et al*, 2013) Sugarcane production in Baluchistan province is almost zero only 41000 tons from 800 hectares The climatic condition of the Sindh is more suitable for sugar cane production as compared to other areas of the country Production is low due to the irrelevant pressure of needs and supported methods of cane cultivation (PARB, 2008, Akber & Khawaja, 2006)

The following Table shows the sugarcane production in three provinces of Pakistan

Table 1 Production with respect to area of cane in Pakistan during Years 1950- 2008

Province	Area (ha)		% Increase	Yield (t/ha)		% Increase
	1950	2008		1950	2008	
Pakistan	219 3	1241 3	466 0	35 8	51 49	43 83
Sindh	8 1	308 8	3712 3	33 7	60 86	80 59
Punjab	170 0	827 2	386 5	37 7	48 72	28 89
KP	41 3	104 8	153 75	28 2	45 72	62 13

Source: Cane and sugar production, (PARB, 2008)

Typically sugar mills operate more than 150 days in the year 30, 45 and 07 sugar mills are operating in Sindh, Punjab and Khyber Pakhtunkhwa respectively In Pakistan sugar industry is the 2nd leading agro based industry after textile containing 82 sugar mills (PSMA, 2009)

In Pakistan, sugarcane is grown on about 1 1 million hectares and provides raw material for 86 sugar mills Furthermore sugar cane and sugar is used in the production of ethanol, fuel ethanol, paper bags, chipboard work, and pressed mud used as organic fertilizer Since 2011, sugar production has increased due to more area Sugar recovery data analysis showed that sucrose innards have enlarged by more than 15 % over the last 10 years (PSMA, 2014, Agarwal *et al*, 1995)

1.4 SUGAR MILL EFFLUENTS (SME)

Great concern has been raised regarding environmental contamination as a side event of rapid industrialization and subsequent urbanization (Chaurasia & Tiwari, 2012) The disposal of wastewater from industry into rivers, lakes or streams may disperse over a huge area (Chatterjee *et al*, 2010, Chaurasia & Tiwari, 2011) The flora and fauna near the water bodies are affected directly or indirectly by polluted water However effluents containing various types of metallic and non-metallic elements act as nutrients but at the higher concentrations may be toxic to seed germination and affecting vegetable growth (Avasn *et al* 2001, Akbar & Khwaja 2006)

During the production of sugar huge amount of untreated or partially treated wastewater is discharged onto the surface nearby the industry or water bodies (Nath *et al*, 2007, Barman *et al*, 2000) This is common phenomenon that once the wastewater mixed with water course, it liberates the bad odour within few days On the other hand, the effluents came out from these industries having a large number of pollution Sugarcane mills generate 1000L of wastewater from 1000 kg of sugar cane crushed Effluent from sugar mill if discharged without proper treatment creates pollution problems in aquatic as well as terrestrial environment (Kumar & Srikantaswamy, 2015)

Water consumed in sugar manufacturing can be classified in to two classes,

- External Water (Cold Water)
- Internal Water

1.4.1 Sources of Effluents

The following is the classification of the wastewater generated in different process in the industry

a) Mill House

The effluent consists of water used for cleaning the floor of mill house which is responsible to be changed by spills This clearing up operation will prevent growth of bacteria on the juice-covered floor Water used for cooling of mills also added to effluents from this source

b) Boiling House Waste Water

The wastewater from boiling house comes through leakage of pumps, pipelines and the washing of various units such as evaporators, juice heaters, clarification, pans crystal and centrifugation etc The cooling water from numerous pumps also added to water

c) Waste Water from Boiler Blow-down

The water used in boiler contains soluble and insoluble solids like salts of calcium (Ca), magnesium (Mg) and sodium (Na), fatty salts etc These salts get concentrated after generation stream from the original water These solids have to be released time to time to save the boiler being covered up by scales

d) Excess Condensate water

The excess condensate does not normally contain any pollutant and is used as boiler feed water and the washing operations Sometimes it gets contaminated with juice due to entrainment of carryover solids with the vapors being condensed, in that case if goes into the wastewater drain

e) Condenser cooling water

Condenser cooling water is re-circulated again unless it gets contaminated with juice, which is possible due to defective entrainment separators faulty operation beyond the design rate of evaporation etc if gets contaminated the water should go into the drain invisibly This volume of water is also increased by additional condensing of vapors from the boiling juice in the pan

f) Soda and Acid Wastes

Caustic soda and hydrochloric acid are used for cleaning of the heat exchangers and evaporator in order to remove the formation of deposits or scales on the surface of the tubing

Most of the sugar industries let this valuable chemical go into drains The soda and acid wash contribute huge amounts of organic and inorganic contaminations and may cause shock loads to wastewater treatment (Kumar & Srikantaswamy, 2015)

1.4.2 Volume of the Effluent

Volume of effluent varies from industry to industry depending on the crushing volume of mill, consistency and controlling of water conductor of working machinery etc (Vaithiyanathan *et al*., 2014)

1.4.3 Effects of Effluents

The effluent that is generated from the industry, if used directly for irrigation then it will disturb the soil fertility as well as affect the growth of plant and seeds germination (Ramkrishan *et al*., 2001) The SME reduce the rate of seed germination of paddy crops These effluents also distress the soil Bacteria and fungi which maintain the soil fertility will be in danger by the highly toxic chemicals releases from sugar industry (Shivappa *et al*., 2007) The SME having highly toxic chemicals and heavy metals, affect aquatic flora and fauna (Qureshi *et al*., 2015, Doke *et al*., 2011) It hinders germination of seeds growth, enzymatic activities, uptake and distribution of micro and macro-nutrients in plant tissues, transpiration rate and relationship of water and plants, and many other interior or exterior activities (Yildirim *et al*., 2006, Jauybon, 2012)

1.5 PROBLEM STATEMENT

Sugar industry is one of the most significant industrial sectors of Pakistan It is not only provides raw material to the agriculture as fertilizer and many other sectors, but as well offer the livelihood to the local citizens It likewise, provides the electricity to the nearby villages Major types of production in the sugar industry are sugar, alcohol, biogas, fertilizer, mud etc Different stages involve during the processing of sugar from crushing of sugar cane to packing and storing of sugar Effluents of sugar industry are openly flowing into the field and soil may affect soil productivity During all these processes, the industry uses large amount of water for cooling and mixing Sugar cane also carries large quantity of water in it These effluents are used for irrigation of crops and vegetables as water and fertilizer. The use of SME may cause many problems to the soil and plants as well This study dealt with the effect of SME on the seeds germination of two selected plants as well as impacts on soil.

1.6 OBJECTIVES OF THE STUDY

- To assess physico-chemical properties of SME
- To assess heavy metals in soil due to SME
- To investigate the effects of SME on soil and plants seeds germination

CHAPTER 2

LITERATURE REVIEW

A study conducted to evaluate the physico-chemical characteristics of sugar industry effluent and some of the parameters were above the permissible limits of Indian irrigation water standards. Effects of different concentrations of SME on seed germination, seedling growth and biochemical characteristics of green gram and maize were studied (Badgujar, 2012).

Qureshi *et al.*, (2015) studied physico-chemical characteristic of sugar mill and measured pollution contribution by sugar mill industries to the coastal district of Badin. The results indicated that all studied parameters were within the defined limits of NEQS of Pakistan for municipal and industrial effluents except two parameters mercury and COD. Chaurasia & Tiwari (2012) reported the physico-chemical analysis of effluents released from Saraya sugar factory and distillery. The result showed it unsafe to be used for agricultural purposes.

Rebecca *et al.*, (2014) examined heavy metals like arsenic, cadmium (Cd), copper (Cu), lead (Pb), mercury, zinc, chromium in sugar mills effluents and detected in all the samples. Result recommended that effluent should be treated and discharge within permissible range.

Noel and Rajan (2015) studied effluent effect on seed germination and early growth of okra. The results showed that physico-chemical parameters of effluents were above the permissible limits. Germination of seeds was examined with different concentration. There was inverse relation between the percentage of seed germination and seedling growth and concentration of effluent. The maximum growth rate was at 25 % concentration while at increased concentrations the growth rate decreased till it reached zero at 100 % concentration.

Madhu, *et al*, (2015) study the effect of SME on growth, yield and soil properties of Ratoon Cane in Cauvery Command area The results showed that growth was significantly reduced when irrigated with concentrated SME Soil properties were also different from the standards and exceeded the values as the concentration of the effluent increased

The study was conducted by Adhikary (2014) to examine the physico-chemical parameters of soil with different percentage of dilution of SME and its impact on biochemical parameters of the tomato plant The results showed that the physico-chemical parameters of soil at different dilution of effluent were increased and decreased over control soil Among biochemical parameters, 25 % effluent in soil noticed highest chlorophyll, protein and carbohydrate content in leave of 25 days old tomato plant over control followed by 50 %, 10 %, 75 %, 5 % and 100 % The results showed the effects of effluent and indicated that plants growth could be increased if proper care is done before use in agriculture and economical and environmentally safe strategy to utilize the sugar industry effluent as organic fertilizer to improve soil health and crop system

Daulta *et al*, (2014) carried out a study on the effect of SME on physico-chemical properties of soil collected from different location of selected area Results showed that SME affected various soil parameters such as organic carbon electrical conductivity (EC), sulphur (S) and potassium (K) These effluents up to certain limits improve the soil properties but too much of these effluents decline soil property and the soil becomes toxic Therefore SME should be treated properly otherwise it affects soil fertility as well as plants growth

Rais and Sheoran, (2015) carried out treatment of SME The low pH, EC, and chemical elements present in sugarcane effluent may cause changes in the physico-chemical properties of soils, rivers, and lakes with frequent discharges over a long period of time, and also have adverse effects on agricultural soils

Yadav and Renu, (2014) investigated the effect of sugar mill on physico-chemical characteristics of groundwater of surrounding area Results of analysis indicated that the pH, EC, BOD, temperature and COD were above BIS limits for drinking water Hence results showed that effluent should be diluted and properly discharge so that it did not affect the nearby ground water and productive soil

Ranjitsinh and Dipak, (2014) reported the effect of SME on soil as well as on ground water The results revealed the high values of Ca, Na, Cl^{-1}, SO_4^{2-}, nitrates and hardness in the samples which were located downstream suggested that SME was the source of soil and groundwater pollution Results suggested that water quality management, an important issue for the sustenance of human civilization must become a major priority The effluent should be treated within the industry

Goli and Sahu, (2014) studied the effects of SMI on fertility of soil and crops The work focused on the effects of wastewater on the seed germination of *Triticum aestivum, Arachis hypogea* and *Vigna radiate* crops The investigation was carried out with different concentration of effluent for seed germination, root length shoot length, fresh weight and dry weight of crops The growth rate and the root shoot length were decreased as the percentage concentration increased

Kumar and Chopra, (2010) studied the influence of SME on physico-chemical characteristics of soil The influence of SME (viz 0 5, 10 25, 50, 75 and 100 ml/kg soil) along with control (Bore-well water, BWW) on the physical and chemical properties of soil revealed that various concentrations of the effluents showed effect on it and caused toxicity The enrichment factor (Ef) of various micronutrients in the soil was recorded in order of Cr>Pb>Cd>Cu>Zn after irrigation with SME The maximum concentration found in soil was of Cr

Hussain *et al*, (2013) analyzed the effect of SME on growth and anti-oxidative potential of maize seedling Higher concentrations of SME decreased the growth, the low concentration (25%) of SME was very effective in increasing the growth of both maize cultivars when compared with control The better growth of maize plants irrigated with SME (25%) suggested that diluted SME could be used for irrigation in nutrients deprived environments

Nath *et al*, (2007) conducted an experiment on SME to specify its effects on seed germination and seedling growth in different selected vegetables The seed germination and seedling growth were significantly reduced with increase in concentration of the effluent Based on the data of selective crops barley was found to be highly tolerant as the 25 % and 50% dilution levels of combined effluents It showed no changes in germination, while seedling growth was increased in lower dilution levels of combined effluent as compared to control Almost every kind of vegetable were affected and reduced number of germination as concentration increased

Siddique *et al*, (2012) carried out a comparative study of treated and untreated effluent of SME The high level of COD, BOD, TSS, TDS and low contents of DO were found in untreated SME The impacts of treated and untreated SME on seed germination of certain cereal crops were also studied It was found that untreated effluents reduce the germination of cereal crops This study showed that treated effluents of sugar industry are not highly polluted and they satisfy the BIS Indian standards and it can be used for irrigation purposes The effluent with no treatment cause serious effect on soil productivity and plants growth

Doke *et al*, (2011) studied the physico-chemical parameters of sugar effluents and its effect on seed germination of *Vigna angularis, Vigna cyclindrical* and *Sorghum cernum* Germination percentages and germination values were decreased with increase in concentrations of effluent in all the seeds tested

Tabriz *et al*, (2012) studied SME and its impact on soil properties The wastewater elevated the EC and reduced the pH of soil It however improved soil fertility by improving the phosphorous (P), K, S and organic matter contents It also elevated the porosity and reduced the bulk density of soil The soil-water content at field capacity and the saturated hydraulic conductivity increased due to the effects of wastewater

Nagaraju *et al*, (2009) assessed the impact of sugar industry effluents on soil Some core samples were collected from the selected sites The experimental results indicated that most of the physico-chemical properties were significantly higher in the test sample than in the control Growth rate decreased from control to effluent and as concentration increased

Ayyasamy *et al*, (2008) determined the impacts of sugar factory effluent on aquatic plant Effluent parameter found above the permissible limits of Indian irrigation water standard The effluent was divided into different concentration percentages and its effects were increased with increase in concentration Experiment was carried out using the aquatic plants water hyacinth and water lettuce Higher concentration (above 60%) of the effluent affected the plant growth Diluted effluent (up to 10- 60%) favoured seedling growth

Kaur *et al*, (2010) reported the study of industrial effluents The results showed that values exceeded the NEQS and also affected microbial community due to the high BOD and COD values

Saini & Pant, (2014) examined the physico-chemical parameters of SME and its impact on the germination and growth patterns of wheat and maize It was found that concentration of 25 % and 50 % has stimulatory effects on germination rate and further increase in concentration (beyond 50%) showed inhibitory effects on germination percentage and initial growth of wheat (*Triticum aestivum*) and maize (*Zea mays L*) The growth rate decreased with respect to concentration

Kumar *et al*, (2011) carried out a study on the sugar mill press mud composite for some heavy metal contents and their bio-availability The results revealed that concentration of heavy metals were in safe limits as the recommended reference values Further, it was suggested that press mud compost does not showed heavy metal pollution, besides a good source of soil elements and organic matter to the agricultural land

Ajmal & Khan (1983) studied the effects of SME on soil and crop plants Due to these effluents the nutrients of the soil has been disturbed The greatest disturbance has been observed in the K concentration of soil when effluent was used for irrigation Germination in the water-irrigated soil was 100 % whereas it ranged between 99 % and 91% in other concentrations of the effluent The water irrigated soil and the soil irrigated with 25 % effluent were found most suitable for germination It is suggested that the SME can be used for irrigation after dilution

Doke *et al*, (2011) examined waste water effluents from a sugar industry and determined the effects of various concentrations of effluent on seed germination, germination speed, peak value and the germination value of varieties of seeds The results indicated the high inorganic and organic content with an acidic load Germination percentages and germination values decreased with increasing concentration of effluent in all the seeds tested The more concentrated the effluent the less is the germination

Vanitha and Rao, (2014) examined physico-chemical analysis of effluents released from sugar mill The results showed that the SME contained TSS, dissolve solids, BOD, COD, Cl^{-1}, SO_4^{2-}, nitrates, calcium (Ca) and Mg exceed than the permissible limits The continuous use of the effluents for irrigation negatively affected the crops The results showed that the effluent is unsafe for domestic and agriculture purposes and should be recycled and utilized only for industrial purposes

CHAPTER 3

MATERIALS AND METHODS

3.1 SAMPLING STRATEGY

Sartaj sugar mill located in District Jhang Punjab Pakistan was selected for samples collection The study area was surveyed before samples collection to identify sampling points The effluents (SME) were collected from outlet of the sugar mill Pre-cleaned, acid washed, plastic bottles of 2 liters capacity were used to collect wastewater samples Then these were stored below 4 °C Four effluent sample sites were selected to collect in triplicate Every sample was analyzed for physico-chemical parameters and for the assessment of heavy metals The samples were collected in January In the heavy metals samples 50% HNO_3 were used to bring the pH < 2 All of the samples were transported to PCRWR lab for analysis and were analyzed according to the Standard Methods (APHA, 2005, Yadav *et al*, 2014) Moreover for the seed germination 80 liter composite effluents samples were collected in four container having the capacity of 20 liters each (Awasare *et al*, 2015)

3.2 SOIL SAMPLING

Soil samples were collected from the fields where SME was used as irrigation water Four different sites were selected for soil samples collection where effluent was used to irrigate vegetables The complex soil surface samples (at 0-30 cm depth) were collected in clean polythene air tight bags Each bag contained 2-3 kg of soil sample and transported to the soil laboratory NARC, Pakistan for further analysis

CHAPTER 4

RESULTS AND DISCUSSION

Numerous physico-chemical parameters were examined to evaluate the quality and characteristics of the collected effluent as well as soil samples according to WHO guidelines and NEQS of waste water

4.1. PHYSICO-CHEMICAL ANALYSIS

Results of SME analyses for pH, EC, DO Ca Na are summaries in Table 2

Table 2 Physico-chemical parameters of the SME samples

Parameter	S1	S2	S3	S4	Standards*
Temp °C	57	70	42	50	40
Color	Dark yellow	Yellow	Dark Brown	Yellow	
EC (µS/m)	3387	4760	4122	3190	1000
Turbidity (NTU)	125	116	122	110	25
pH	8 1	5 54	7 6	5 8	6-9
DO (mg/L)	1 18	1 35	1 55	3 23	4 5-8
TSS (mg/L)	410 66	373 33	413 33	268 33	150
TDS (mg/L)	4846	5233 33	5570	5342	3500
BOD (mg/L)	487	717	366	331	80/200
COD (mg/L)	1491	1400	3712	4047	150
HCO_3 (mg/L)	302	417 7	310 7	297 33	440
Na (mg/L)	167	165	160 33	161	200
Ca (mg/L)	169	169	138 33	162	200
Mg (mg/L)	57	52	74	70	100
K (mg/L)	45 33	42 7	32 33	42 33	N/A
Cl (mg/L)	413	435	863	428	1000
P (mg/L)	8 85	9 29	7 28	7 33	N/A

- **Source** (Khan at al 2003 WWF-Pakistan 2007 Badgujar 2012)

4.1.1 Heavy Metals in Effluents

Heavy metals were analyzed in SME samples and the values are given in Table 3

Table 3 Concentration of heavy metals (mg/L) in SME

Parameters	S1	S2	S3	S4	Standards*
Fe	1 99	2 03	0 82	0 98	2 0
Zn	2 12	1 46	1 4	1 09	5 0
Cd	0 16	0 05	0 42	0 19	0 10
Cu	0 16	0 17	0 15	1 6	1 00
Cr	0 19	0 12	0 21	0 15	1 0
Pb	0 206	0 20	0 13	ND	0 20-0 50

- **Source** (Khan at al 2003 Badgujar 2012)

4.1.2 Metals analysis in Soil

As different literature studies showed that effluent are used for irrigation Different crops and vegetables are watered by effluent which affects soil characteristics Soil was also analyzed for some metal contents and the results are shown in Table 4

Table 4 Concentration (mg/kg) of metals in sugar effluent irrigated soil

Parameters	S01	S02	S03	S04	Standards*
Fe	20 85	21 2	20 52	21 63	N/A
Zn	10 86	9 45	11 09	11 42	600-1100
Cd	0 063	0 302	0 079	0 075	0 43
Cu	2 34	1 72	2 11	2 16	200-270
Cr	0 332	0 261	0 344	0 342	11
Pb	1 42	1 62	1 64	1 51	200
K	2858	1441	2558	2655	N/A
P	78 24	82 6	83 57	78 94	N/A

- **Source** (Sharma *et al* , 2007, Hassan *et al* 2012)

4.2. BASIC STATISTICS OF SELECTED PARAMETERS IN SME

Basic tools of statistics such as mean value, standard deviation, minimum and maximum (range) of tested parameters in all the effluent samples collected from the selected sites of district Jhang are presented in Table 5

Table 5 Basic descriptive statistics of analyzed parameters

Parameters	N	Minimum	Maximum	Std Deviation
pH	4	5 53	8 1	1 28
TSS	4	268 33	413 33	67 89
TDS	4	4846 66	5570	302 11
BOD	4	330 66	716 66	174 49
COD	4	1400	4046 66	1412 02
EC	4	3190	4760	719 18
Tep	4	42 33	69 33	11 49
DO	4	1 18	3 23	0 95
Turbidity	4	110 66	124 66	6 33
Na	4	160 33	167	3 18
Ca	4	138 33	169 00	14 45637
Mg	4	52 00	73 66	10 31482
K	4	32 33	45 33	5 71509
Cl	4	413 33	863 33	219 02568
HCO_3	4	297 33	417 66	57 43115
P	4	7 28	9 29	1 03494
Valid N	4			

The results of examined parameter in the SME samples are described as follows:

4.2.1. The pH value

Acidic or basic nature of the pH of a solution normally range from 6-9 gave protection for the aquatic life Figure 1 shows the pH values of analyzed of SME samples The pH values of some of the samples were lower than the minimum permissible level (6-9) and were acidic in nature The lower pH value may cause of deterioration of water quality Extreme changes in pH (acidity and alkalinity) can exert stress condition or put an end to aquatic life The maximum mean pH value was 8 10 and the minimum pH was recorded as 5 53 It shows the acidic nature of effluent and may cause negative effects on nearby soil and water used for the crops irrigation (GOB, 1997) The effluents must be diluted before draining into field or water bodies (FAO, 1985, Keshavarzi et al., 2015)

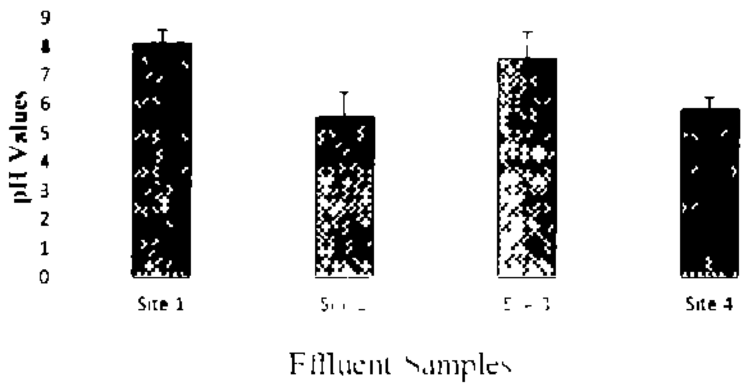

Figure 1 pH of the selected SME samples

4.2.2. Total Suspended Solids (TSS)

The highest value of TSS was recorded as (413 33 mg/L) while minimum value was recorded as (268 mg/L) All values were above the permissible limits of NEQS (150 mg/L) The suspended solids may increase the value of turbidity and penetration of sun light could not be possible High TSS values are visually not favorable It may cause sludge in the water and settling down at the bottom also create a blanket that may be harmful to fish and other flora and fauna TSS may also cause depletion of oxygen supplies at the bottom and cause the production of fowl smelling and lethal gases such as methane, carbon monoxide, ammonia and hydrogen sulfide The TSS value can be decreased by dilution and by mixing properly the effluent before discharge from the sugar mill (Agale, 2013)

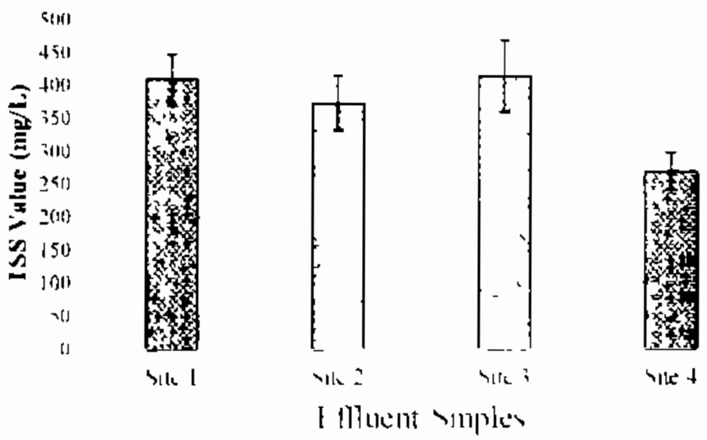

Figure 2 TSS value of the selected SME samples

4.2.3. Total Dissolved Solids (TDS)

The maximum TDS value recorded was (5570 mg/L) while the minimum value was (4846 7 mg/L) TDS values for all the samples were above the safe limits set in the NEQS (3500 mg/L) TDS are associated to the total mineral contents (i e , salts, metals and carbonates) of the water which are left after evaporation of water The more TDS indicates the more possibility of contamination Higher concentration of TDS shows high values of dissolved ions which may make water more corrosive (Kaur et al , 2010) The high TDS values may attribute towards the turbidity of effluent

4 2 4. Electrical Conductivity (EC)

The EC of examined samples was ranged from 3190 µS m to 4760 µS/m All samples have EC above the safe limit set under NEQS (1000 µS m) (Figure 4) The number of total dissolved solid and ions present in water could be measured by identifying EC EC increases as the total dissolved content of effluent increases (Yasin at al , 2012) These effluents if used for irrigation purposes will affect soil fertility and plants growth, therefore, the SME should be diluted and properly monitored before discharge

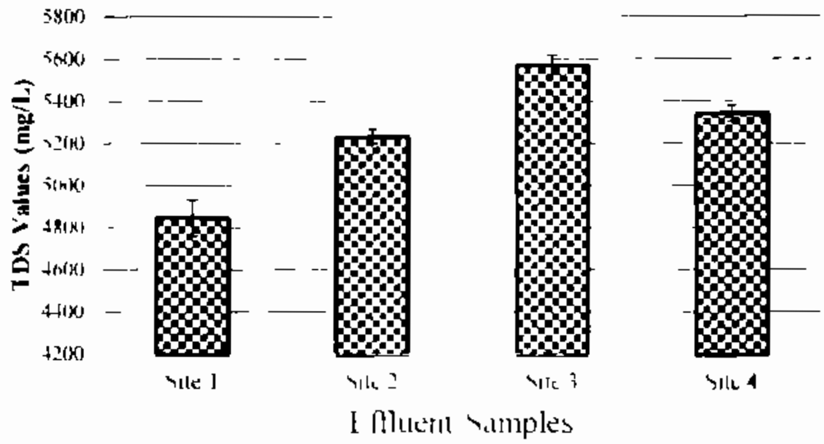

Figure 3 TDS value of the selected SME samples

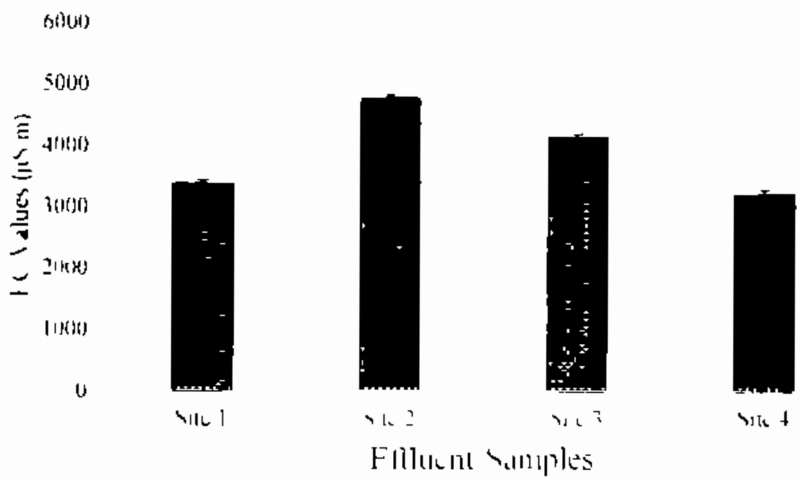

Figure 4 EC value of the selected SME samples

4.2.15. Concentration of Bicarbonates (HCO_3)

The analyzed samples show different concentrations of bicarbonates The maximum value was 417 66 mg/L, while the minimum value was 297 mg/L No limit has been set for HCO_3 by Pak-EPA and WHO for industrial effluents

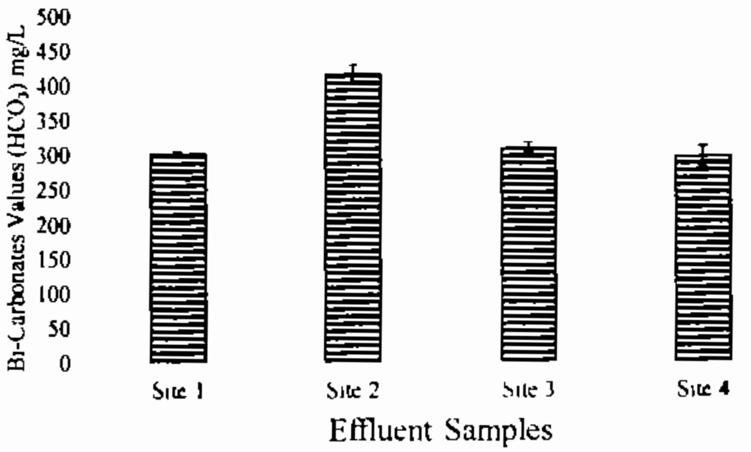

Figure 15 Bicarbonate values in the selected SME samples

4.3. BASIC STATISTICS FOR HEAVY METALS IN SME

The standard deviation, mean, maximum and minimum values of heavy metals such as iron (Fe), zinc (Zn), cadmium (Cd), copper (Cu), chromium (Cr) and lead (Pb) in all effluent samples collected from selected site of District Jhang are presented in Table 6

Table 6 Basic descriptive statistics of analyzed parameter of heavy metals

	N	Minimum	Maximum	Std. Deviation
Fe	4	1 43	2 03	0 28937
Zn	4	1 09	2 12	0 43308
Cd	4	0 05	0 20	0 06160
Cu	4	0 15	1 60	0 72072
Cr	4	0 12	0 21	0 04031
Pb	4	0 00	0 20	0 09430
Valid N	4			

dissolved solid and ions present in water could be measured by identifying EC. EC increases as the total dissolved content of effluent increases (Yasin at al., 2012). These effluents if used for irrigation purposes will affect soil fertility and plants growth, therefore, the SME should be diluted and properly monitored before discharge.

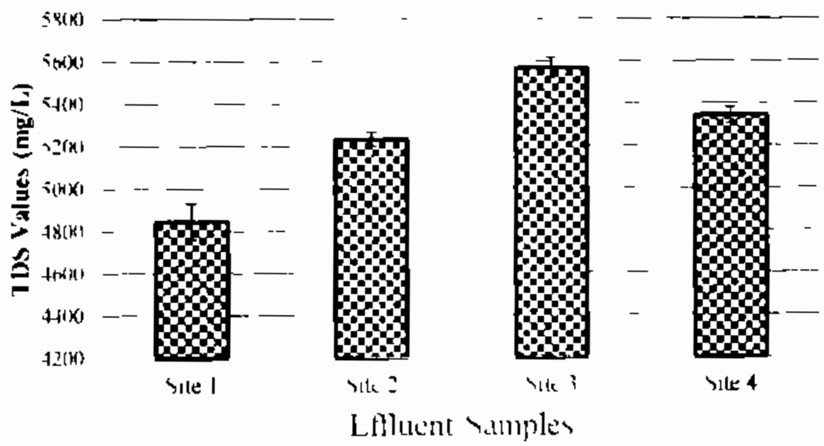

Figure 3 TDS value of the selected SME samples

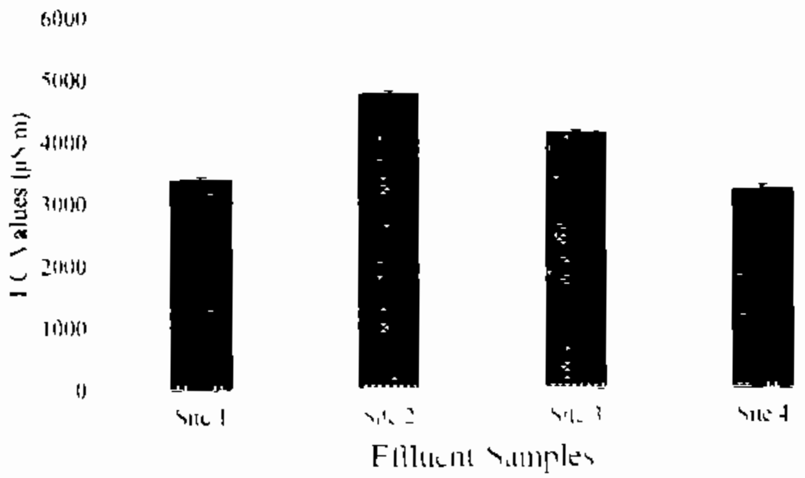

Figure 4 EC value of the selected SME samples

4.2.5. Dissolved Oxygen (DO)

The minimum DO value recorded was 1 18 mg/L while the maximum value was 3 23 mg/L DO is one of the very important parameters in water quality assessment It tells about the physico-chemical and biological processes taking place in a water body Most of the aquatic life depends on the dissolved oxygen (DO) contents The suggested value of DO for normal drinking water is 8 mg/L Increase in temperature may cause the DO level fall DO is an indicator which shows that how much oxygen is depleted in a water body (WHO, 2004) The results indicated lower concentration of DO in the effluent which may decrease the level DO in a water body when discharged with treatment and may cause death of many aquatic organisms as well as negatively affect soil fertility

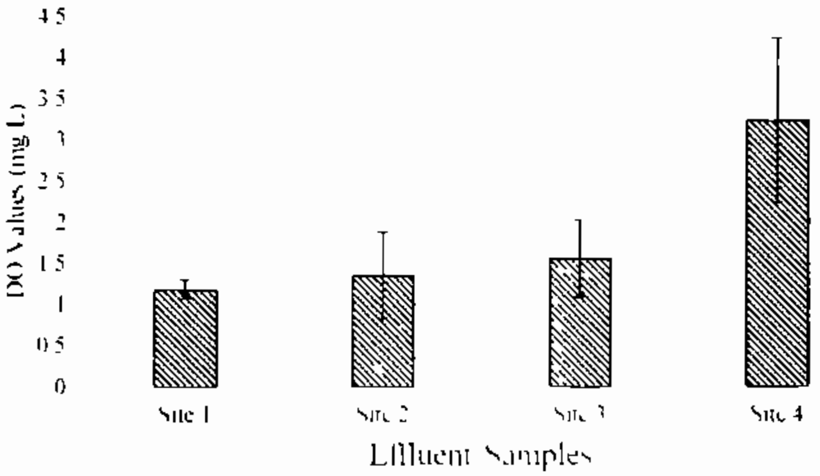

Figure 5 DO value of the selected SME samples

4.2.6. Turbidity

The turbidity level in all the analyzed samples were found beyond the permissible limit (25 NTU) recommended by the NEQS and WHO The minimum value recorded was 110 66 NTU while the maximum value was 124 66 NTU Turbidity could be defined as an appearance of optical property that causes light scattered and absorbed instead of transmitted in straight lines through water. It can be due to the presence of silt particles, organic matters and microorganism. Drinking water turbidity indicates the presence of bacteria and other pathogens while in effluents indicate the impurities which may alter the soil properties and affect flora and fauna. The presence of high turbidity level in water act as a cover for microbiological organism and can increase their growth. Increase the turbidity may increase the population of coliform bacteria.

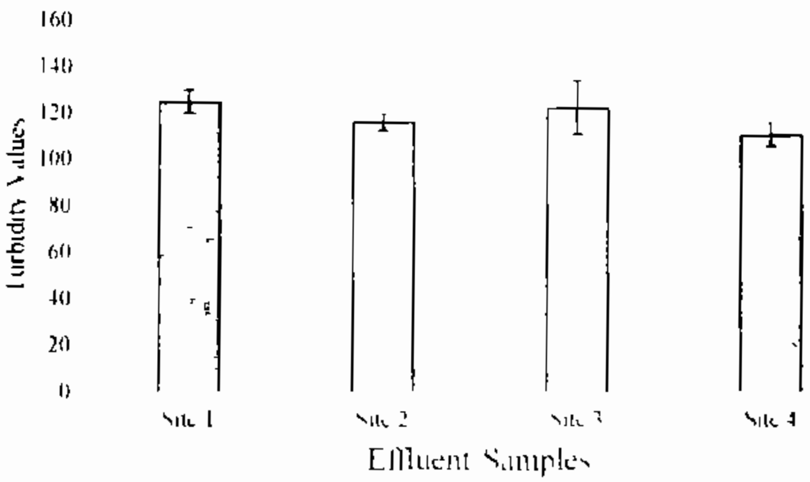

Figure 6 Turbidity value of the selected SME samples

4.2.7. Temperature

The temperature values of the samples indicated that temperature was beyond the permissible limit set by the NEQS and WHO (40 C*). Higher values of temperature affect the aquatic life. Temperature variability affect soil and plants growth (Solomon, 2005).

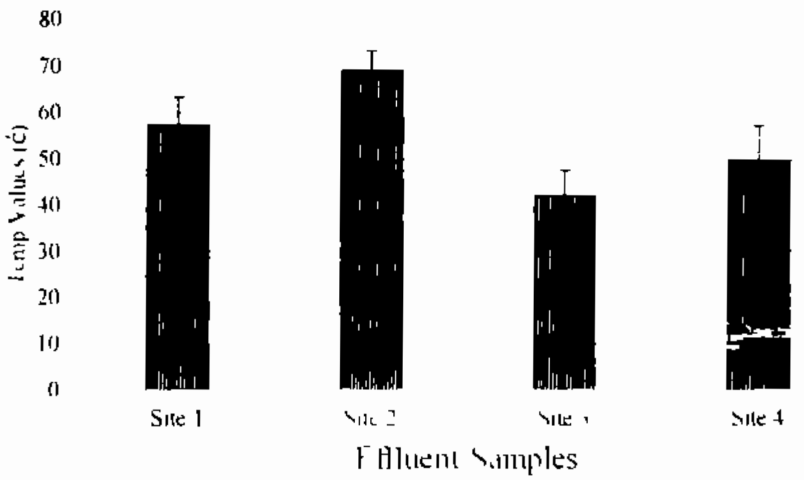

Figure 7 Temperature value of the selected SME samples

4.2.8. Biological Oxygen Demand (BOD)

The BOD_5 values of SME samples were ranged from 330 7 mg/L to 716 66 mg/L It was found that all the samples had higher BOD values than the NEQS value (200 mg/L) The higher BOD values may be attributed to the leakage of molasses and sugar contents on the mill floor and are washed away with the effluents and thus increase the level of BOD (Chhonkar *et al* , 2000)

BOD is the amount of oxygen required by microorganism to stabilize biodegradable organic matter in wastewater under aerobic conditions Therefore, decreased DO value is correlated with the degree of BOD Other physical or chemical parameters such as temperature, pH, etc can also affect BOD values Oxidation and decomposition of organic waste by microorganisms produce high level of BOD As the quantity of organic matter increases, more dissolved oxygen will be needed and as a result BOD will be higher BOD is a significant parameter that indicates the level of water pollution due to organic waste

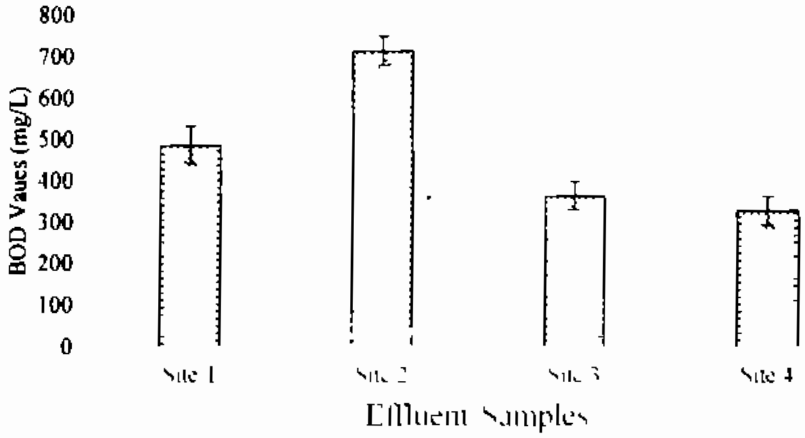

Figure 8 BOD value of the selected SME samples

4.2.9. Chemical Oxygen Demand (COD)

The highest value of COD was 4046 mg/L while minimum value was 1400 mg/L COD values of all the samples were above the permissible limit (150 mg/L) set under the NEQS as well as WHO The SME is used for different purposes such as irrigation, fish farming ponds and animals drinking directly High COD deteriorate water quality and may harm aquatic life and decrease soil fertility Therefore, SME must not be discharged into environment without proper treatment

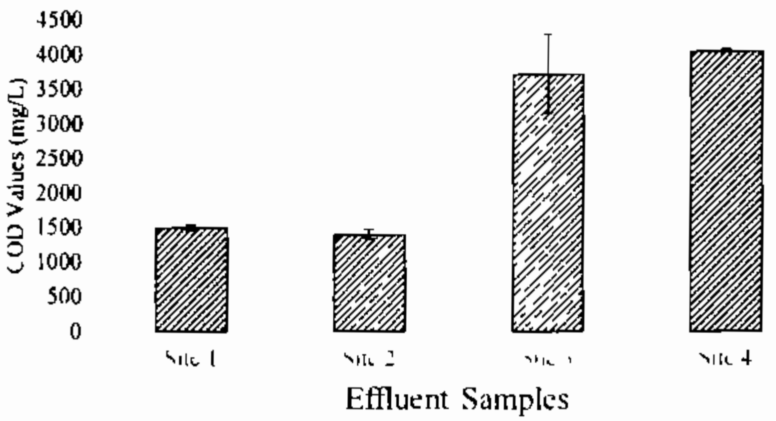

Figure 9 COD value of the selected SME samples

4.2.10. Concentration of Sodium (Na)

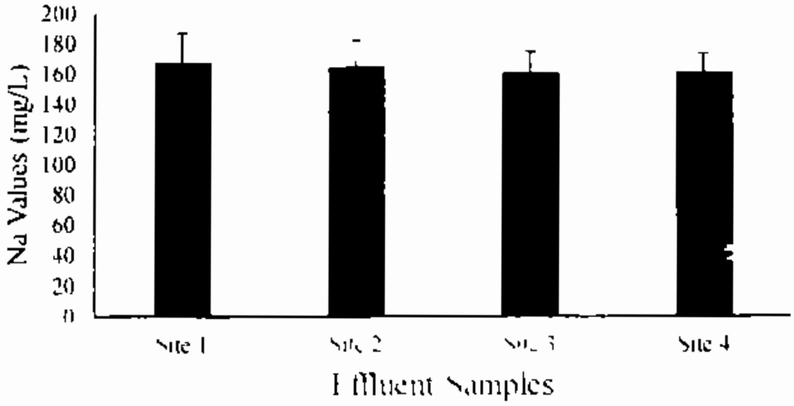

Figure 10 Sodium value of the selected SME samples

SME samples contained Na^{1+} in the range of 160 33 mg/L-167 mg/L and all the values were under the WHO safe limit (200mg/L) High level of Na^{1+} is considered harmful for aquatic life and soil Higher concentrations of Na^{1+} in drinking water may cause heart and kidneys problems, blood pressure and vomiting (WHO 2004)

4.2.11. Concentration of Calcium (Ca)

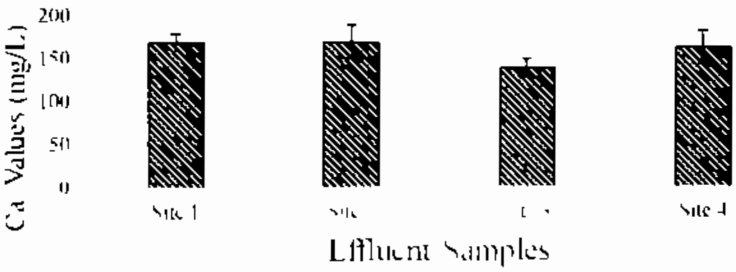

Figure 11 Calcium value of the selected SME samples

Results showed that minimum concentration of Ca was 138 33 mg/L and maximum was 169 mg/L For Ca in waste effluent no limit has been set under NEQS and WHO However, Pakistan Standard and Quality Control Authority (PSQCA) laboratory have the limit of 200 mg/L and accordingly Ca values in all samples were under the prescribed limit

4.2.12. Concentration of Magnesium (Mg^{+2})

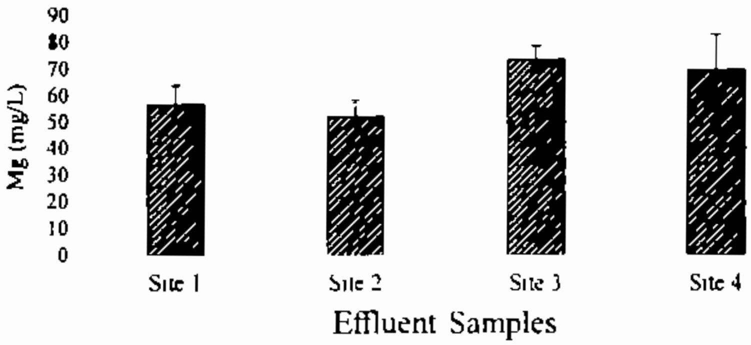

Figure 12 Magnesium value of the selected SME samples

The maximum and minimum values of Mg were 73 mg/L and 52 mg/L respectively There is no such recognized limit for Mg level available in WHO guidelines or Pak-EPA permissible levels The approved limit of Mg contents mentioned in PSQCA limits is 100 mg/L and the level of Mg in the analyzed samples was below the PSQCA permissible limit

4.2.13. Concentration of Potassium (K)

The maximum content of the K was 45 mg/L and the minimum was 32 mg/L as per analysis The average content was 38 mg/L There is no NEQS limit regarding K for drinking or for effluent of the industries From the WHO standard the safe limit for K is 12 mg/L for drinking water The value of K in the SME could be reduced by treating effluents before discharge in the environment (Sankar 2014 Akpor *et al*., 2014)

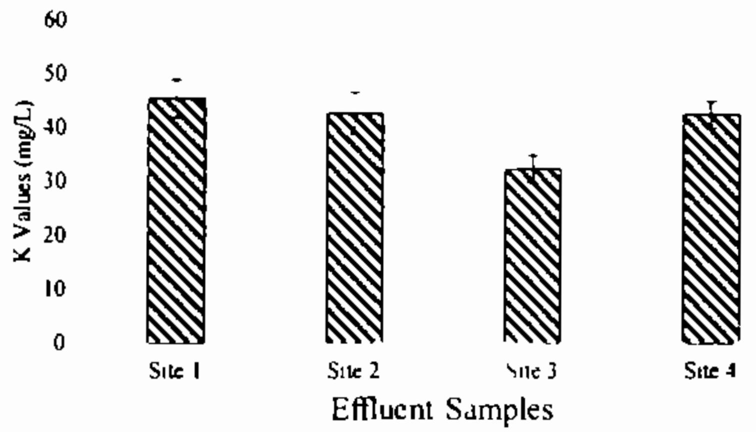

Figure 13 Potassium (K) value of the selected SME samples

4.2 14. Concentration of Chloride (Cl^{-1})

Cl^{-1} values in all the samples were below the safe limit of NEQS (1000 mg/L) The minimum value was 413 33 while the maximum was 863 33 mg/L Cl^{-1} ion should be at minimum level as it causes salinity and hardness Cl^{-1} ion mostly exists in natural water and help in dissolving other deposits coming from industries sewage etc (Badgujar, 2012, Pandey & Sony, 1994)

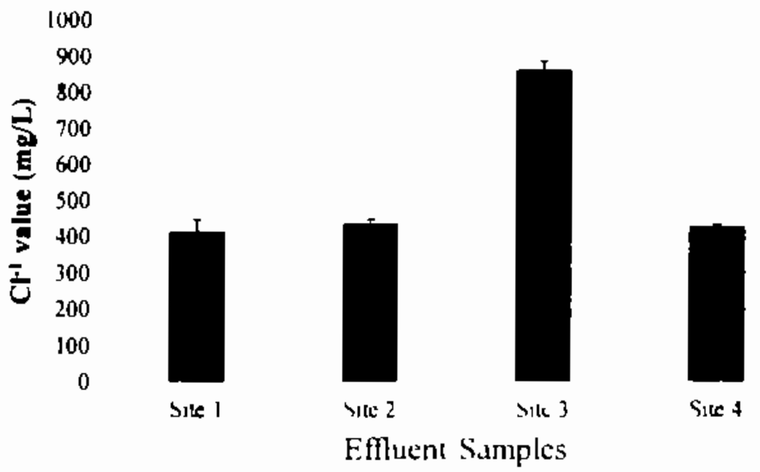

Figure 14 Chloride value of the selected SME samples

4 2.15. Concentration of Bicarbonates (HCO_3)

The analyzed samples show different concentrations of bicarbonates The maximum value was 417 66 mg/L, while the minimum value was 297 mg/L No limit has been set for HCO_3 by Pak-EPA and WHO for industrial effluents

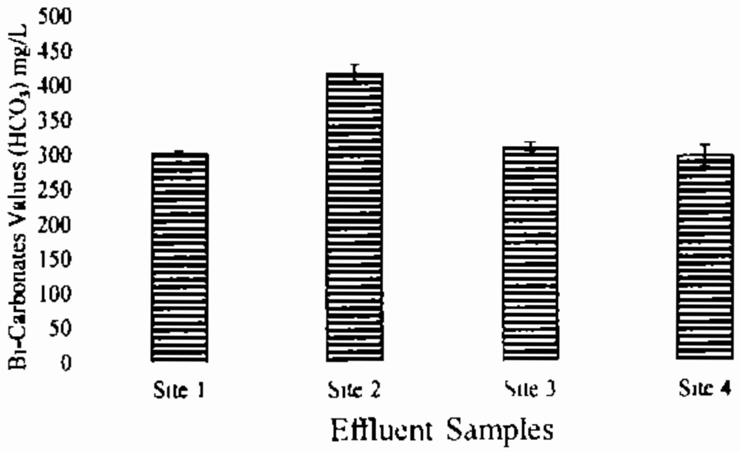

Figure 15 Bicarbonate values in the selected SME samples

4.3. BASIC STATISTICS FOR HEAVY METALS IN SME

The standard deviation, mean, maximum and minimum values of heavy metals such as iron (Fe), zinc (Zn), cadmium (Cd), copper (Cu), chromium (Cr) and lead (Pb) in all effluent samples collected from selected site of District Jhang are presented in Table 6

Table 6 Basic descriptive statistics of analyzed parameter of heavy metals

	N	Minimum	Maximum	Std Deviation
Fe	4	1 43	2 03	0 28937
Zn	4	1 09	2 12	0 43308
Cd	4	0 05	0 20	0 06160
Cu	4	0 15	1 60	0 72072
Cr	4	0 12	0 21	0 04031
Pb	4	0 00	0 20	0 09430
Valid N	4			

The untreated effluent discharged is mostly used for irrigated of crops and vegetables These effluents also carry trace elements (especially heavy metals) in it which have negative effects on aquatic life and soil Heavy metals are non-degradable and toxic in nature and are discharged into the environment with the untreated effluent by the industries (Lokhande *et al*, 2011)

4.3.1. Concentration of Iron (Fe)

The maximum value of Fe found in the sample was 2 03 mg/L and the minimum was 1 43 mg/L Fe values in some of the samples were higher than the permissible limit of NEQS (2 mg/L) (Khan *et al*, 2003) This higher concentration of Fe may be cause pathogenic microbial growth in the SME and other water bodies as well as soil

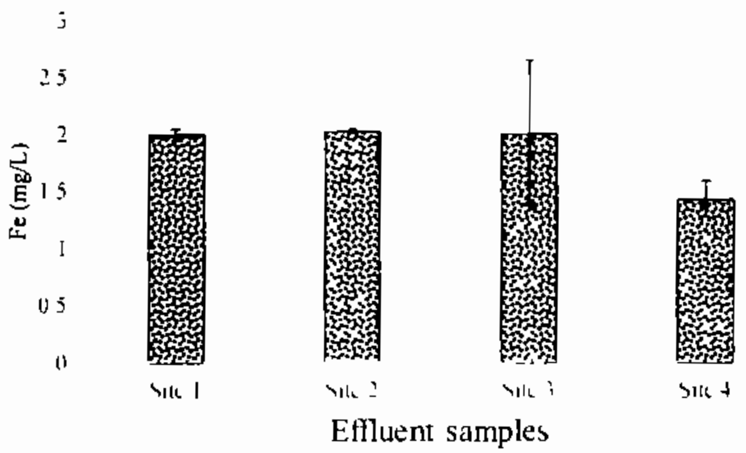

Figure 16 Iron metal in selected sample of SME

4.3.2. Concentration of Zinc (Zn)

In the analyzed samples of SME the maximum and minimum values of Zn were 2 12 mg/L and 1 09 mg/L respectively Zn values in all samples were within the NEQS permissible levels (5 0 mg/L) Absorption of higher amounts of Zn causes necrosis, chlorosis and also affects plants growth (Agarwal *et al* 1995)

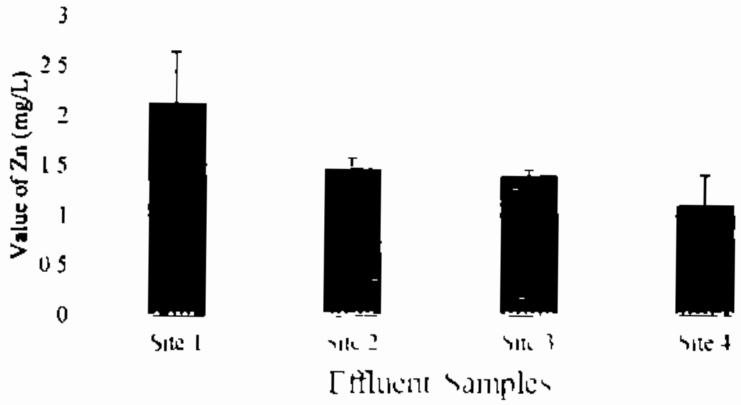

Figure 17 Zinc metal in selected sample of SME

4.3.3. Concentration of Cadmium (Cd)

Cd was not detected in all the samples The minimum detectable limit of Cd was 0 05 mg/L for the AAS The US-EPA set a maximum contaminant level for Cd at 5 mg/L The limited value is 0 1 mg/L in NEQS The maximum value was 0 2 mg/L detected in the selected samples The average value was 0 125 mg/L These values were not in the safe limit and may cause harm to the environment Cd is a supplementary component and affects metabolic activities in plants and can bio-accumulate in aquatic organisms and enters the food chain (Adriano, 2001)

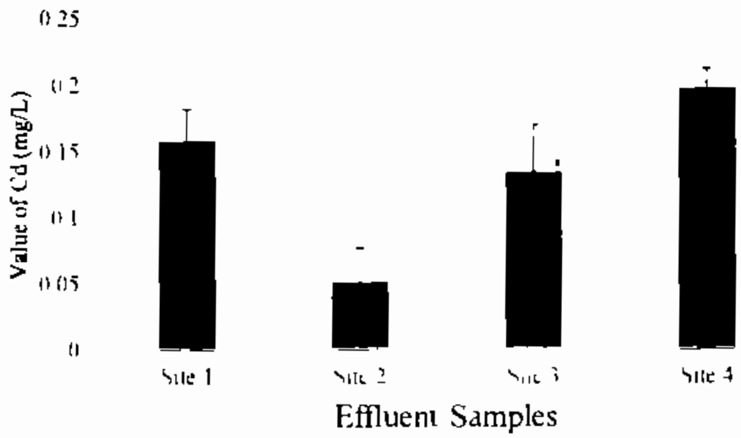

Figure 18 Cadmium metal in selected sample of SME

4.3.4. Concentration of Copper (Cu)

The results showed that only site 4 samples contained Cu values higher than the permissible limits of NEQS (1 0 mg/L) for wastewater Cu is a micro nutrient and essential for all living organism but higher concentrations of Cu making water unpleasant to drink and may damage in liver Even though the effect of low Cu toxicity in human is rear, aquatic life are possibly at risk from Cu exposures (Adriano, 2001) A medication must be obligatory for Cu levels in the effluent of industry where high levels of metal in effluent It should be noted that to most fishes, invertebrates and aquatic plants as compare to other metal Cu is highly lethal except mercury It influence on the growth and reproduction rate of plants and animals The chronic level of Cu is 0 02–0 2 mg/L (Moore & Ramamoorthy, 2012)

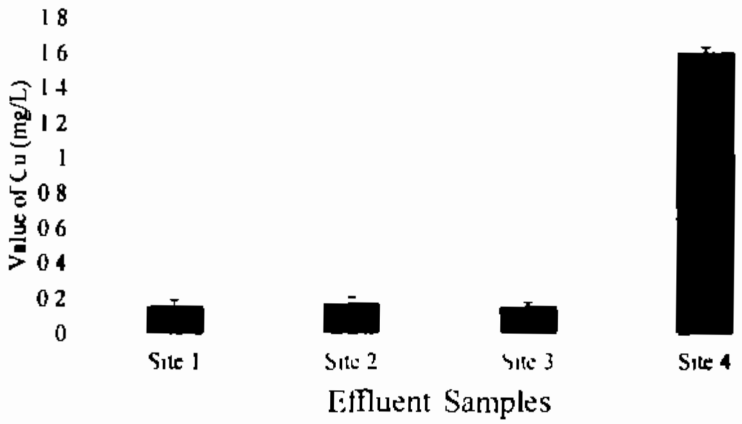

Figure 19 Copper metal in selected sample of SME

Aquatic plants absorb three times more Cu than plants on dry lands Extreme Cu levels can cause damage to roots, by attacking the cell membrane and destroying the normal membrane structure, inhibit root growth and formation of numerous short, brownish secondary roots Cu becomes toxic for organisms when the rate of absorption is greater than the rate of excretion As Cu is readily collected by plants and animals, it is very important to reduce its level in the watercourse (Lokhande *et al* 2011)

4.3.5. Concentration of Chromium (Cr)

The maximum value of Cr was 0.21 mg/L in the analyzed samples and was below the permissible limit set under NEQS (1.0 mg/L). Its toxicity is not considerably acute for fishes and invertebrate. At higher temperature, Cr is generally more toxic and a known human's carcinogen. The toxic effect of Cr on plants shown as the roots remain small and the leaves narrow with reddish brown stains and small necrotic spots.

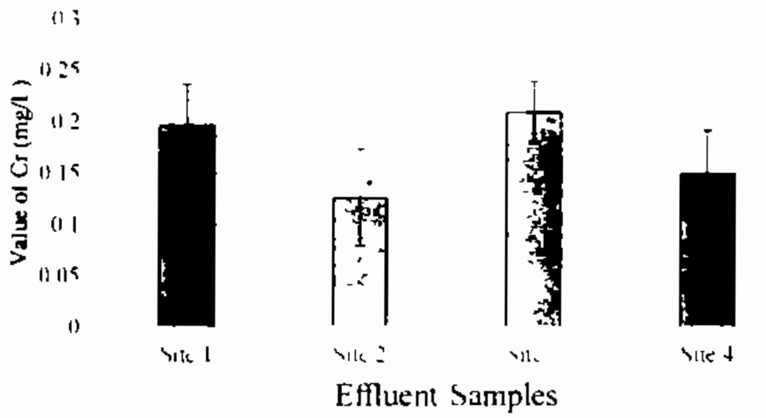

Figure 20 Chromium metal in selected sample of SME

4.3.6. Concentration of Lead (Pb)

The concentrations of Pb in all the samples were within the NEQS limit (0.5 mg/L). Pb is a toxic element that stores in the skeletal body. The toxic effects of Pb to fish drops with increasing water hardness and dissolved oxygen. Although Pb is estimated to have low phyto-toxicity because of its strong attraction to organic matter, under certain environmental conditions e.g., pH change, it may become moveable (Muwanga & Barifaijo 2006).

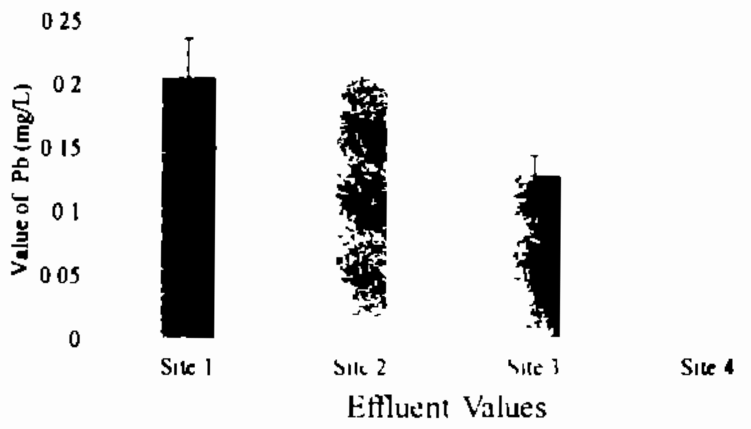

Figure 21 Lead metal in selected sample of SME

4.4. BASIC DESCRIPTIVE STATISTICS OF HEAVY METALS IN SOIL

Untreated or partially treated wastewater containing heavy metals when discharged into water bodies or used for irrigation purposes cause different health and environmental problems (Deshmukh, 2014) The heavy metals pose threat to the soil and plants and with bio-accumulation and bio-magnification through plants to animals and then humans leading to severe harmful effects (Saidi, 2010) It has been reported that consumption of toxic metals in vegetables and corn products accumulate in kidneys and cause damage to it Some studies have also linked skeletal damage (osteoporosis) in humans to heavy metals, such as high levels of selenium (Abdullah, 2013, Gill & Tateju, 2010)

The presence of high levels of heavy metals in a soil could also lead to the interruption of plants growth, nutrients uptake, physiological and metabolic activities chlorosis, and harm to root tips, reduced water and nutrients uptake and damage to enzymes (Akpor *et al*, 2014)

Following Table shows analyzed parameters in soil samples collected from agricultural fields irrigated with SME

Table 7 Statistical analysis of soil irrigated by SME

Parameters (mg/L)	N	Minimum	Maximum	Std. Deviation
Iron	4	20 52	21 63	47603
Zinc	4	9 45	11 42	86766
Cd	4	06	63	28018
Cu	4	1 72	2 34	26107
Chromium	4	26	34	03944
Pb	4	1 42	1 63	09950
Potasium	4	1441 00	2858 00	637 04997
Phosphorus	4	78 00	83 56	2 89201
Valid N	4			

4.4.1 Concentration of iron in soil

Four sample sites were analyzed and the maximum value was 21 63 mg/kg while the minimum value was 20 52 mg/kg and all the values were within the permissible limits

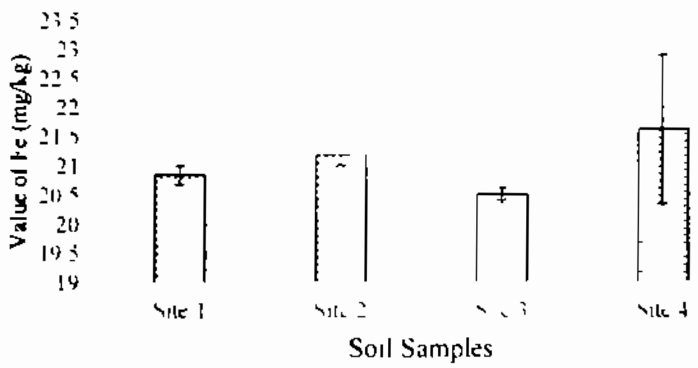

Figure 22 Concentration of Iron metal in selected samples of soil

4.4.2. Concentration of zinc in soil

The concentration of Zn in the soil samples was ranged from 9 45 mg/kg to 11 42 mg/kg and all values were within the permissible limit of WHO for irrigation water Zn is one of the important trace elements that play very important role in the physiological and metabolic processes of many organisms

4.6. ONE SAMPLE T-TEST FOR PHYSICO-CHEMICAL PARAMETERS

The average value of pH for SME (6 5) was within the permissible limit (6-9) The values of TSS, TDS, BOD, COD, EC, temperature and turbidity were significantly higher (p<0 05) than their standard values The DO of SME was significantly lower (p<0 05) than its prescribed standard value The color of SME ranged from yellow to dark brown The concentration of Na, Ca, Mg, Cl and HCO_3 were significantly lower (p<0 05) than their standard values

Table 11 One sample t-test for physico-chemical Parameters of SME

Parameters	t	Df	Sig (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
PH	10 58	3	0 002	6 75	4 72	8 78
TSS	10 79	3	0 002	366 41	258 38	474 44
TDS	34 74	3	0 00	5247 99	4767 28	5728 72
BOD	5 45	3	0 012	475 08	197 42	752 73
COD	3 77	3	0 033	2662 50	415 65	4909 34
EC	10 75	3	0 002	3864 75	2720 37	5009 13
Tep	9 53	3	0 002	54 75	36 47	73 03
DO	3 84	3	0 031	1 82	0 31	3 33
Turbidity	37 40	3	0 00	118 42	108 34	128 49
Na	102 55	3	0 00	163 08	158 02	168 14
Ca	22 05	3	0 00	159 42	136 41	182 42
Mg	12 21	3	0 001	62 99	46 58	79 41
K	14 23	3	0 001	40 66	31 57	49 76
Cl	4 89	3	0 016	535 08	186 56	883 60
HCO_3	11 56	3	0 001	331 92	240 53	423 30
P	15 82	3	0 001	8 19	6 54	9 83

- Such plants should be introduced which could grow well in such effluents and the plants could be used in industry
- Regular monitoring is necessary be done by the industry and by law enforcement institution
- In-house treatment plant should be installed by the industry
- Existing laws should be implemented in true spirit
- Farmers should be educated about the proper use of the effluents
- Awareness programs should be conducted by the NGOs and Pak-EPA to encourage investor for investment in environment friendly technologies

Table 7 Statistical analysis of soil irrigated by SME

Parameters (mg/L)	N	Minimum	Maximum	Std. Deviation
Iron	4	20 52	21 63	47603
Zinc	4	9 45	11 42	86766
Cd	4	06	63	28018
Cu	4	1 72	2 34	26107
Chromium	4	26	34	03944
Pb	4	1 42	1 63	09950
Potasium	4	1441 00	2858 00	637 04997
Phosphorus	4	78 00	83 56	2 89201
Valid N	4			

4.4.1. Concentration of iron in soil

Four sample sites were analyzed and the maximum value was 21 63 mg/kg while the minimum value was 20 52 mg/kg and all the values were within the permissible limits

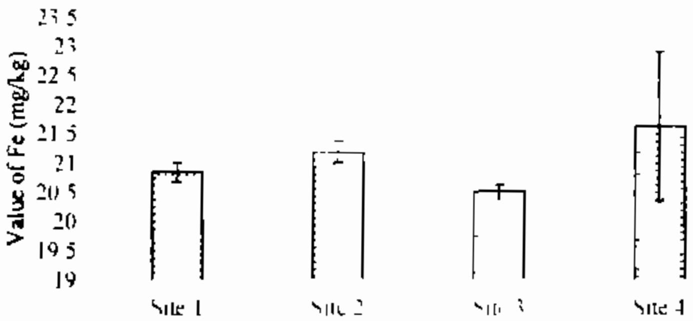

Figure 22 Concentration of Iron metal in selected samples of soil

4.4.2. Concentration of zinc in soil

The concentration of Zn in the soil samples was ranged from 9 45 mg/kg to 11 42 mg/kg and all values were within the permissible limit of WHO for irrigation water Zn is one of the important trace elements that play very important role in the physiological and metabolic processes of many organisms

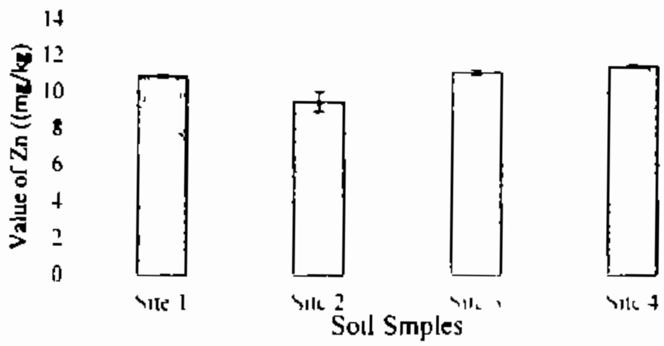

Figure 23 Concentration of zinc metal in selected samples of soil

4.4.3. Concentration of cadmium in Soil

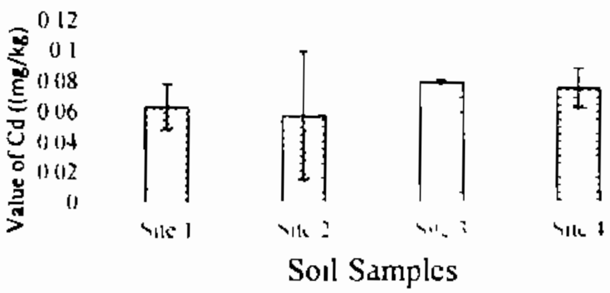

Figure 24 Concentration of cadmium metal in selected samples of soil

Maximum value of Cd recorded was 0 63 mg/kg while minimum value was 0 06 mg/kg respectively

4 4.4. Concentration of copper in soil

The maximum value of analyzed sample was 2 34 mg/kg and all the samples were within the safe limit

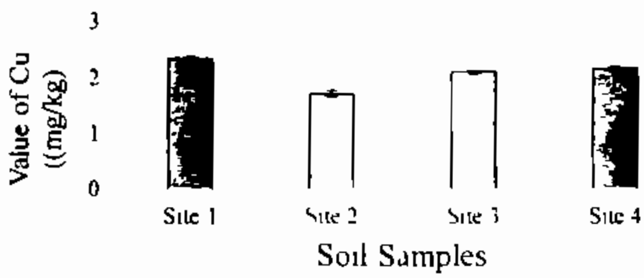

Figure 25 Concentration of copper metal in selected samples of soil

4.4.5. Concentration of chromium in soil

The values of Cr in all the analyzed samples were ranged from 0 26 mg/kg and 0 34 mg/kg and all were below the permissible limit

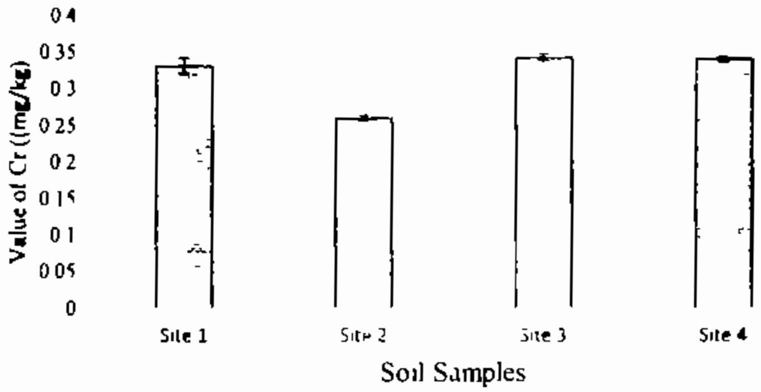

Figure 26 Concentration of chromium metal in selected samples of soil

4.4.6. Concentration of lead in soil

The results showed that the maximum value of Pb in soil sample was recorded as 1 63 mg/kg while minimum value was 1 42 mg/kg It accumulates with time in bones, aorta, liver, spleen and kidneys It is mostly ingested through food (65%), water (20%) and air (15%) and thus enter the human body

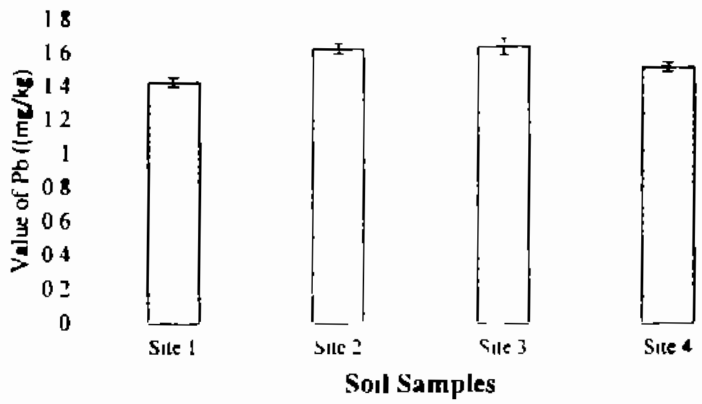

Figure 27 Concentration of lead metal in selected samples of soil

4.5. PLANTS MORPHOLOGY

Application of industrial wastewater for irrigation of agricultural lands is becoming a common practice (Ayyasamy *et al*., 2008, Kumar and Chopra, 2012) Most of the crops give greater yields when irrigated with wastewater and decrease the demand for chemical fertilizers hence save the total costs of farmers (Ezhilvannan *et al*, 2011) Following calculation shows the collected and observed germination percentages of okra (*Abelmoschus esculentus* L) and white potato (*Solanum tuberosum*)

4.5.1. Germination Percentage

Germination means the first appearance of the radicle by optical surveillance The germination percentage was calculated by using the following formula

$$\textit{Germination percentage} = \frac{\textit{Number of seeds germinated}}{\textit{Total number of seeds sown}} \times 100$$

Table 8 Effect of SME on seed germination percentage of okra and tomato plants

Effluent concentration (%)	Seed germination percentage (%)		Time of germination (Hour)	
Vegetable	Okra	Tomato	Okra	Tomato
Control	95	90	24	24
5	95	85	24	24
10	95	90	24	24
25	90	70	24	24
50	60	40	48	48
75	22	10	48	48
100	00	00	48	48

The values in Table 8 show that when the SME concentration increased the plants germination percentage decreased The maximum germination of plants was with control effluents (okra 95 % and potato 90%) and the minimum germination was for 100 % SME concentration Up to 25 % effluent concentration maximum germination of plants was observed while above that limit plants germination decreased and at 100% SME the germination of seeds was zero

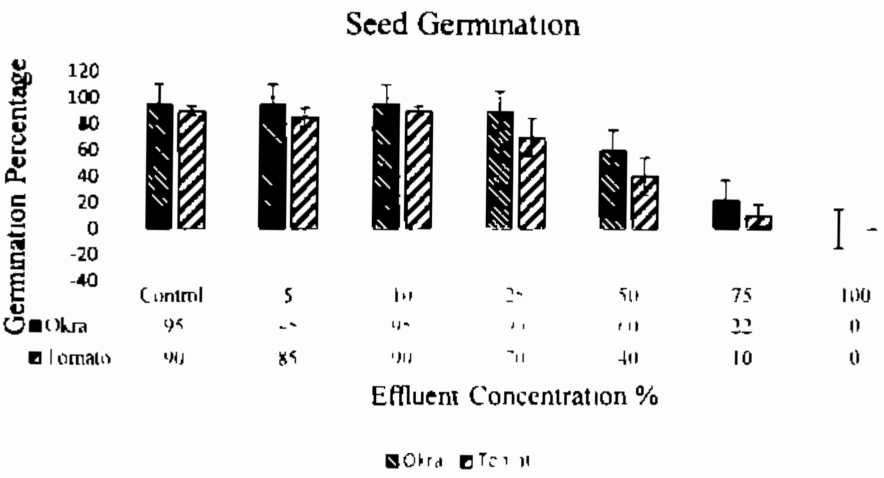

Figure 28 Percentage germination of Okra and Tomato plants

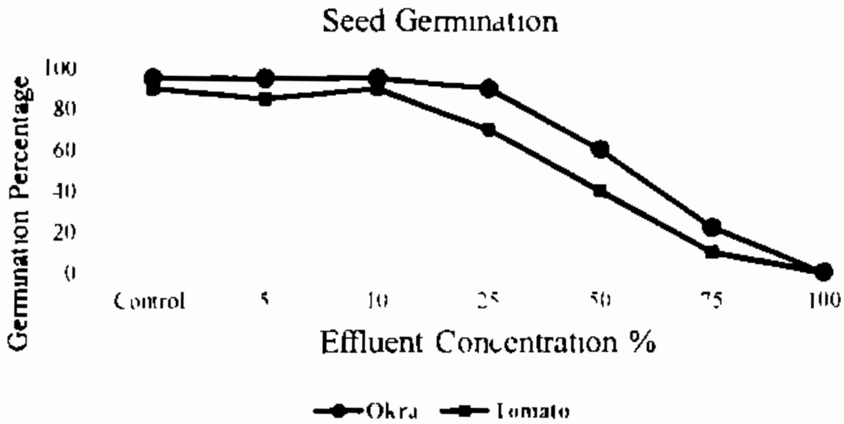

Figure 29 Okra and tomato seed germination and effluent uptake

4.5.2. Physiological Parameters of the Plants

The root length and fresh and dry weight of the selected plants were determined by the Lenin *et al*, (2014) method

a) Root and shoot lengths

The root and shoot lengths of the plants was measured at 40th day of germination The shoot length was measured from the part which was above the soil while the root was measured from the part which was inside the soil

b) Fresh and dry weights

Garden fresh okra and tomato plants were taken and weighed Then were dried in an oven at 80°C for 24 hours The dry weight of plants samples were measured by using high accuracy electrical balance The following Table indicates the measured value of the selected plants physiological parameter

Table 9 Root and shoot length of okra and tomato grown in different concentrations of SME

Effluent concentration (%)	Okra		Tomato	
	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)
Control	33 5±1 64	33 8±1 5	33±1 41	33±2 54
5%	35±1 12	34±1 67	33±1 32	41±2 95
10%	30±1 30	32±1 76	29±1 85	43±3 22
25%	33 2±2 59	32±1 78	30±2 07	47±2 84
50%	29±2 01	32±2 30	30±2 15	35±2 o5
75%	33 5±2 5	31±2 51	28±3 21	34±2 30
100%	00±00	00±00	00±00	00±00

Values are mean ± standard error

The results showed that maximum plants growth was observed for control and from 5% to 25% SME concentrations Higher concentrations of SME used for irrigation decreased the growth of plants

Table 10 Fresh and dry weight of okra and tomato grown at different concentrations of SME

Effluent concentration (%)	Okra		Tomato	
	Fresh weight (gm)	Dry weight (gm)	Fresh weight (gm)	Dry weight (gm)
Control	30±4 98	3±0 54	42±2 56	6±0 96
5%	37±3 7	3±0 62	37±2 58	5±1 09
10%	40±2 45	10±2 17	27±3 58	9±1 54
25%	38±1 42	7±1 15	29±2 48	6±0 84
50%	27±1 31	3±0 43	23±1 20	3±1 45
75%	38±2 05	8±1 12	23±1 73	6±0 70
100%	00±00	00±00	00±00	00±00

Values are mean ± standard error

4.6. ONE SAMPLE T-TEST FOR PHYSICO-CHEMICAL PARAMETERS

The average value of pH for SME (6 5) was within the permissible limit (6-9) The values of TSS, TDS, BOD, COD, EC, temperature and turbidity were significantly higher ($p<0\ 05$) than their standard values The DO of SME was significantly lower ($p<0\ 05$) than its prescribed standard value The color of SME ranged from yellow to dark brown The concentration of Na, Ca, Mg, Cl and HCO_3 were significantly lower ($p<0\ 05$) than their standard values

Table 11 One sample t-test for physico-chemical Parameters of SME

Parameters	t	Df	Sig (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
PH	10 58	3	0 002	6 75	4 72	8 78
TSS	10 79	3	0 002	366 41	258 38	474 44
TDS	34 74	3	0 00	5247 99	4767 28	5728 72
BOD	5 45	3	0 012	475 08	197 42	752 73
COD	3 77	3	0 033	2662 50	415 65	4909 34
EC	10 75	3	0 002	3864 75	2720 37	5009 13
Tep	9 53	3	0 002	54 75	36 47	73 03
DO	3 84	3	0 031	1 82	0 31	3 33
Turbidity	37 40	3	0 00	118 42	108 34	128 49
Na	102 55	3	0 00	163 08	158 02	168 14
Ca	22 05	3	0 00	159 42	136 41	182 42
Mg	12 21	3	0 001	62 99	46 58	79 41
K	14 23	3	0 001	40 66	31 57	49 76
Cl	4 89	3	0 016	535 08	186 56	883 60
HCO_3	11 56	3	0 001	331 92	240 53	423 30
P	15 82	3	0 001	8 19	6 54	9 83

4 1.1 One Sample t-test for Heavy Metals

The concentrations of Fe, Zn and Pb in SME were significantly lower (p<0 05) than their standard values while concentrations of Cd, Cu and Cr in SME were significantly higher (p<0 05) than their permissible limits

Table 12 Heavy metals one sample t-test

Parameters	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Fe	12 880	3	0 001	1 86350	1 4030	2 3240
Zn	6 988	3	0 006	1 51325	0 8241	2 2024
Cd	4 345	3	0 023	0 13383	0 0358	0 2318
Cu	1 440	3	0 245	0 51900	-0 6278	1 6658
Cr	8 310	3	0 004	0 16750	0 1034	0 2316
Pb	2 810	3	0 067	0 13250	-0 0175	0 2825

4 1 2 Independent t-test.

The concentrations of Fe, Zn, Cu, Cr and Pb in SME irrigated soils were significantly higher (p<0 05) than their concentrations in SME The concentration of Cd in SME irrigated soil did not showed a significant difference (p=0 09) than its concentrations in SME

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

It was interesting to find out that the seedling growth was lower in control than the effluent concentrations Seed germination percentage was higher for okra than tomato at the SME concentrations of 5 %, 10 %, 25 % and 50 % The TSS, TDS COD, BOD, turbidity, Na, Mg, Ca and Cl^{-1} levels in SME were higher than the permissible limits The pH value was in acidic range The concentrations of Cu, Fe and Cd in SME were above the limit The SME concentrations of 5 %-10 % and 25 % showed better results (almost 90%) for seeds germination At 75% and above concentrations of SME seeds germination and plants growth rate was almost zero Concentrated SME can have negative impacts on plants and vegetable growth rate as well as on soil productivity

5.2 RECOMMENDATIONS

With regards to the present study recommendations are given as under,

- The mills effluent should be treated before discharge into the environment by removing suspended solid and correcting the pH value
- Waste water generated from sugar canes and sugar processing should be diluted and treated separately
- Coordination between institutions and industries should be strengthened to carry on research and development activities with the objectives to convert nutrient rich effluents into fertilizers to be used in agriculture

- Such plants should be introduced which could grow well in such effluents and the plants could be used in industry
- Regular monitoring is necessary be done by the industry and by law enforcement institution
- In-house treatment plant should be installed by the industry
- Existing laws should be implemented in true spirit
- Farmers should be educated about the proper use of the effluents
- Awareness programs should be conducted by the NGOs and Pak-EPA to encourage investor for investment in environment friendly technologies

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