EVALUATING THE IMPACT OF NALLA LAI CONTAMINATION ON DRINKING QUALITY OF GROUNDWATER IN RAWALPINDI

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DEDICATION

I would like to dedicate my thesis to my beloved parents.

DECLARATION

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

Date __________

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Shahid Ali Khan

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GW	Groundwater	v
WW	Wastewater	vi
EOPs	Emerging Organic Pollutants	2
WHO	World Health Organization	3
GDP	Gross Domestic Product	4
PCRWR	Pakistan Council of Research in Water Resources	4
WASA	Water and Sanitation Agency	6
NSDWQ	National Standard for Drinking Water Quality	7
Pak-EPA	Pakistan Environmental Protection Agency	9
COD	Chemical Oxygen Demand	9
BOD	Biological Oxygen Demand	9
$-SO_4$	Sulphate	9
Cl^-	Chloride	9
TSS	Total Suspended Solids	9
TS	Total Solids	9
MCL	Maximum Contaminants Level	10
EC	Electric Conductivity	10
TDS	Total Dissolved Solids	10
Na^+	Sodium	10
EU	European Union	12

USEPA	United States Environmental Protection Agency	12
pH	Potential Hydrogen	13
Ni	Nickel	13
Cd	Cadmium	13
Pb	Lead	13
Cr	Chromium	13
Cu	Cupper	13
Zn	Zinc	13
Fe	Iron	13
Mn	Manganese	13
MPN	Most Probable Number	15
KPK	Khyber Pakhtunkhwa	16
$-NO_3$	Nitrate	18
CO_2	Carbon dioxide	20
$-CaCO_3$	Calcium Carbonate	23
E.coli	Escherichia coli	23
WFP	Water Filtration Plant	25
GPS	Global Positioning System	31
GIS	Geographic Information System	34
DO	Dissolved Oxygen	37
APHA	American Public Health Association	38
CLEAN	Central Laboratory for Environmental Analysis and Networking	42
EDTA	Ethylenediaminetetraacetic acid	52

AAS	Atomic Absorption Spectrometer	64
NEQ'S	National Environmental Quality Standards	73
Ha	Hardness	90
K	Potassium	141
TCU	True Color Unit	142
µS/cm	Microsiemen/Centimeter	144
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ABSTRACT

This scientific research work was carried out in Rawalpindi to investigate the potential impact of Nalla Lai wastewater percolation and leaching factor which alters the groundwater chemistry of nearby tubewells, bore water, dug wells and springs. Total 19 physico-chemical and microbiological parameters were tested in field and laboratory. Interpolation technique like Inverse Distance weighted (IDW) method was used to delineate the highest and lowest groundwater contaminated zones. Microbial results of (7) groundwater samples showed positive result and contamination was detected in (26) samples. The results of physico-chemical parameters of (68) samples revealed that Cadmium and Iron values were exceeding the standard values of WHO, NSDWQ, 2010 and NEQS, 1997 in many wastewater and groundwater samples. The research work highlighted that Sample (1) of Industrial wastewater carrying high load of contaminants whereas sample (2), sample (28) and sample (35) are highly contaminated groundwater localities within 100 meter distance along both sites of Nalla where maximum level of percolation and leaching contaminants of Nalla Lai were detected. The analysed results of both surface wastewater of Nalla Lai and groundwater of tube wells, bore water, dug well and springs revealed that certain pollutants are significantly percolating from surface wastewater of Nalla Lai and contaminating the groundwater quality of Rawalpindi. There is a dire need to cope with the issue by responsible authorities to ensure public health by providing safe drinking water supply.

CHAPTER 1

INTRODUCTION

1.1 Introduction:

Water is paramount for the survival of both plants and animals (Vanloon and Duffy, 2005). Approximately 75% of the earth surface is covered by water bodies. The earth's 97.5% water is saline and only 2.5% is fresh water and 68.9% of the freshwater is locked in ice caps and glaciers and 29.9% of freshwater is found in sub surface. The surface water contains only 0.3% of the freshwater and it includes lakes and rivers whereas 0.9% of the freshwater exist in the form of humidity, fog and soil moisture (Ashraf, 2015).

Only fresh water resources are potable for drinking purpose and essential for good health. Existing small percent fresh water resource of the earth is rapidly polluting by different anthropogenic activities which includes open drainage of waste effluents and release of toxic industrial chemicals in environment which finally poses a variety of water related diseases (Soomro et al., 2011).

The two core sources of fresh water resources are surface (lakes, streams, rivers and sea) and groundwater (springs, dug wells and boreholes) (Momodu and Anyakora, 2010).

Groundwater contamination is a very noteworthy environmental concern of the time (Momodu and Anyakora, 2010). Regardless of its importance, water resource is not properly managed in earth (Fakayode, 2005). As compared to other water resources, groundwater can be less polluting by open discarding of waste (Saadia et al., 2008). Human population is suffering from disposal of waste effluents into water system (Atta et al., 2016).

Rapid increase in demography, construction of new town and extension of industries has considerably lessened the area for waste dumping and removal. The quantity of waste effluents are generating increasingly because of rapid industrial productions to meet higher living standards.

Discharging of industrial and domestic waste effluents into the surrounding environment can pollute both soil and groundwater quality (Das and Das, 2003).

Groundwater quality management and protection is a paramount concern in several countries (Cronin et al., 2003). Various researches have conducted to determine the fate of emerging organic pollutants in sub-surface through downward movement of wastewater and industrial effluents (Lapworth et al., 2012). The presence of emerging organic pollutants (EOPs) can be well examined and analysed in wastewater and surface water as compared to groundwater. Emerging organic pollutants major source is wastewater whereas surface water carries their maximum load (Pal et al., 2010).

Anthropogenic activities such as agriculture, industrial and municipality are responsible for discharging and recharging of contaminants into groundwater (Spear et al., 2003; Razo et al., 2004). The groundwater contamination can be resulting from leakage of sewage (Eiswirth et al., 1997). The primary source of groundwater contamination in Lahore is leakage of sewer lines and landfill sites where percolation of leachate and sewage contaminates the groundwater quality (Malik et al., 2014).

There are numerous probable sources of groundwater pollution in cities including point, non-point and linear sources. Point sources include industrial effluents, domestic sewage and storm overflow, non-point sources include construction work, agriculture activities and atmospheric deposition and linear sources are roads and sewer system (Byoung et al., 2005).

Water contamination is the paramount heath and environmental issue in Pakistan. The surface and ground water quality is polluted by microbial and a variety of toxic chemicals (Azizullah et al., 2011). The main sources of groundwater pollution in Pakistan are the discharging of waste effluents into water bodies by many industrial units including textile, fertilizers, pesticides, steel, dying chemicals, cement, leather etc (Tariq and Shah, 2006).

The groundwater quality deterioration resulting from leachate percolation mainly occurs during monsoon season and escalating the diseases related to groundwater contamination. Groundwater contamination occurs mostly in the vicinity of landfill and municipal waste disposal sites and increasing the chances of percolation in aquifers (Butt et al., 2012).

In developed countries 95% population having access to safe drinking water and 90% population has sufficient sanitation facility (Amin et al., 2012). Almost 50% groundwater used in cities is obtaining from wells, boreholes and springs. One fifty million population of Latin American's and greater than 1000 million Asian are depending on groundwater (Clarke et al., 1995). Approximately 2.3 billion population across the world is suffering from diseases related to polluted water (UNESCO, 2003). According to United Nations research report, about 2.5 billion population of developing world do not have appropriate sanitation facility and more than 780 million masses do not have access to safe drinking water (UNICEF and WHO, 2012). Therefore, 2.2 million deaths in a year are resulting from shortage of potable water and insufficient sanitation (WHO, 2000).

Among 122 nations of the world, Pakistan's position is 80th concerning drinking water quality. Sixty-four percent bacterial contaminations were reported in northern region of country (Diagnostic Survey, PCRWR, 2007).

Worldwide, approximately polluted drinking water and insufficient sanitation kill 1.6 million children below the age of (5) years and 84% of them are residing in villages (Aliya et al., 2014). Only 23.5 % of rural population and 30% of urban population of Pakistan have accessed to potable drinking water of international standards (Rosemann, 2005). The national statistical report revealed that overall 56% population of Pakistan having access to potable drinking water but this figure goes down to 45% in rural areas (Farooq et al., 2008).

Generally, microbiological organisms found in surface water bodies like reservoirs, rivers and lakes but do not present in groundwater until it is directly contaminated by surface water (Health Canada, 2006).

The drinking water quality in Pakistan is highly contaminated at the source level, distribution system and finally at consumer level with total coliform and fecal coliform across the country. The review of (7000) analysed water samples revealed that 58% samples were contaminated with total and fecal coliform bacteria. About 20-40 % diseases in the country are the result of polluted drinking water which reduces annual income loss of 25-58 billion rupees and 0.6-1.44 % of total GDP (Nabeela et al., 2014).

Every year around (250000) children in Pakistan die due to contaminated water. Around 30% diseases and 40% deaths occur due to poor drinking water quality (Haydar, 2009). Pakistan council of research in water resources (PCRWR) collected water samples from (32) cities and the analysed results found bacteriological contamination and many highly toxic elements (Sajjad and Malik, 2016).

A variety of researches have recorded diseases such as cholera, dysentery and typhoid are the result of drinking polluted water (Talibi and Ogundana, 2014).

Total coliform is the basic water quality test and indicator of sanitary condition of drinking water supply because it occurs in soil and water contaminated with human or animal waste. Total fecal coliform is its sub group and it acts as more accurate and perfect indicator of fecal contamination of warm blooded animals (New Hampshire Department of Environmental Services, 2010).

E.coli is most excellent indicator of fecal coliform and existence of probable pathogens in water (WHO, 1996). E.coli does not exist, grow or reproduce in the environment except in warm blooded animals. Therefore, its presence in drinking water shows more accurate indicator of probable pathogenic microrganisms presence in water (Odonkor and Ampofo, 2013).

In Pakistan 20-40 % hospital beds are occupied by the patients of waterborne diseases like diarrhea, hepatitis, typhoid, dysentery, cholera etc. One third of all deaths occur across the country owing to waterborne diseases (Pak-SECA, 2006).

Particularly heavy metals in drinking water can pose severe health risks as mentioned in published data (Watt et al., 2000). Heavy metals presence in drinking water can damage vital organs i.e. kidney, liver and central nervous system. They also cause abnormality in blood composition (Khan et al., 2011). The toxic heavy metals in groundwater contaminate its quality. Their toxicological impact in ecosystem and human health takes consideration at local, regional and global level (Ullah et al., 2009).

It is documented fact that polluted water and contaminated food are the two key sources of heavy metals accumulation in the bodies of human beings (Barman et al., 2000).

The present study attempts to assess the potential impact of Nalla Lai on physico-chemical and microbiological anomalies in groundwater of tubewells, boreholes, dug wells and springs water due to seepage and percolation from surface wastewater of Nalla Lai into groundwater in its vicinity.

Insufficient sanitation and industrial effluents are the main sources of pollution in many countries of the world (Yusuf, 2007). The perennial wastewater of Nalla can be more vulnerable to groundwater quality deterioration of nearby tube wells and boreholes. The underground lithological environment is the principal influencing factor of contaminant migration to groundwater (Rehman, 2008).

1.2 Problem Statement:

The population of Rawalpindi city is largely depending on groundwater as a drinking water source. About 60-70% population relies on groundwater by extracting it through tube wells and boreholes. Total (385) tube wells are installed throughout city according to Comprehensive Master Plan for Water Supply, WASAR (Water and Sanitation Agency, Rawalpindi). About 30-35 % population is depending on service water from Khanpur dam and Rawal dam.

Nalla Lai is historically natural rain water nalla but with the passage of time it turned into open sewer and carries 70% of the total sewage of the Rawalpindi (Muhammad, 2007). The households sewage of Islamabad is also drained in it without proper treatment in I-9 sewerage treatment plant. Rawalpindi city has only 30% proper sanitation system (Asian Development Bank, 2003). Nalla Lai is passing through the centre of the city and finally it falls in Soan river. It is connected with numerous drains along the way. Nalla Lai also carries industrial waste of I-9 and I-10 Islamabad and domestic and commercial solid waste of Rawalpindi.

Plastic bags and papers disposing into water bodies lessen the flow speed and escalating the groundwater contamination through percolation (Nasrullah et al., 2006). The wastewater of Nalla Lai and Korang river percolates downward and contaminate groundwater quality due to geographical environment and soil porosity and permeability (Islam et al., 2007). The research on (240) tube well of Rawalpindi revealed that (72) out of (240) tube wells were microbiologically contaminated (RWASA Water Quality Report, 2003). Similar kind of study was conducted in Rawalpindi city in the year 2007. The analysed results of (220) tubewells revealed that 50% samples showed bacterial contamination. The prime source of microbial contamination is percolation of Lai Nalla wastewater (Islam et al., 2007). Nalla Lai is potential threat to groundwater aquifers by continuously recharging through percolation and contaminating the groundwater quality.

1.3 Hypothesis:

Groundwater in the vicinity of Nalla Lai is more vulnerable to physico-chemical and microbial contamination due to percolation of polluted wastewater of Nalla which ultimately deteriorates the drinking water quality of tube wells and boreholes.

1.4 Objective of the Study:

Following are the objectives of current research study.

1. Characterization of surface wastewater in Nalla Lai and identification of vulnerable tube wells and boreholes which are being contaminated by Nalla Lai.
2. To compare the analyzed results with WHO (World Health Organization) and NSDWQ (National Standards for Drinking Water Quality) standards and provide guidelines for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review:

A scientific investigation on groundwater quality in Kalalanwala city of Punjab, Pakistan revealed that all groundwater samples were found in elevated concentration of Arsenic (As) when compared with WHO standard value for drinking water quality. Groundwater samples collected from deeper depth were free from fluoride concentration when analysed in laboratory. The presence of Sulphate ($-SO_4$), Arsenic (As) and Fluoride (F^-) concentration in rain water samples indicated that these contaminants were resulting from air pollution from coal combustion in brick factories of locality (Abida et al., 2007).

The research work conducted on groundwater quality assessment in Sialkot city, Pakistan. Twenty-five ground water samples were collected and analysed in laboratory. The analysed results showed that water samples were very turbid and Zinc, Fluoride and Lead concentration were exceeding the international standard values of World Health Organization (Rizwan et al., 2009).

The groundwater quality was analysed in Kanchanpur district, Nepal by collecting water samples from tube wells, hand pumps and water supply tap stands. The results revealed that Arsenic, Nitrate and Nitrite concentration were found in high concentration. Seventy percent analyzed samples were exceeding the permissible limit of (WHO) standards. The water quality was not potable for drinking purpose (Bohara, 2015).

A scientific research on heavy metals in drinking water was carried out in Patiala district, India. Total (100) water samples were collected from the study area. The results showed that Nickel and Aluminum concentration were exceeding in most samples. Both natural and anthropogenic activities were main sources of heavy metals contamination in groundwater (Sekhon and Singh, 2013).

Physico-chemical and microbial parameters of groundwater quality was assessed in southwest region of Nigeria. Water samples were collected from twelve dug wells. The prime objective of the study was to examine the seasonal variations and proximity of pollution from the source. The research proved that the contaminants were increasing in the period of rainy season and reducing with escalating distance from the waste dumps. The analysed results showed that total coliform colonies, Lead (Pb), Nitrate (-NO_3) and Cadmium (Cd) concentration were beyond the World Health Organization (WHO) standards for drinking water quality. The dug well water was not potable for drinking purpose without appropriate treatment (Adekunle et al., 2007).

The study was conducted to examine the effects of solid waste dumping site on water quality in capital city Islamabad, Pakistan. Both surface and groundwater samples were collected from ten different points near solid waste dumping site. The laboratory results showed that concentration of Cadmium and Iron were exceeding the permissible limit of WHO and Pak-EPA standards. The spatial distribution of contaminants showed that a variety of heavy metals were increasing towards southeast in the downward direction. Maximum correlation was found between Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), Cadmium (Cd) and Sulfate (-SO_4), Electric Conductivity (EC) and Chloride (Cl^-), Total Suspended Solids (TDS) and Total Solids (TS) which signifying that the groundwater around solid waste dumping site of sector H-12, Islamabad was to a certain extent not fit for drinking purpose without proper treatment (Qadir et al., 2015).

Physico-chemical and microbial parameters of drinking water quality were analysed from different water sources of Tiruchirappalli locality of south India. The overall results showed that Fluoride, total hardness, total alkalinity and total dissolved solids concentration were exceeding the WHO permissible limits (Pavendan et al., 2014).

The potential sources of chemical contamination in tube well water and associated health risk to local population was investigated in Mailsi area of Punjab, Pakistan. Total (44) groundwater samples were collected for laboratory analysis. The concentration of heavy metals like Iron, Arsenic, Lead, Cadmium and ions of Sodium, Bicarbonates and Sulfate were exceeding the WHO permissible limit. By applying statistical tools, the results revealed that both natural and anthropogenic activities were responsible for excessive Arsenic, Cadmium and other heavy metal contaminations in groundwater. Hence, immediate treatment and remedial measures of tube well water is mandatory in order to protect the health of citizens from emerging pollutants (Atta et al., 2016).

The study on groundwater quality was conducted in the vicinity of Lagos by collecting forty nine wells and bore water samples. Cadmium, Lead and Aluminum in groundwater were tested by using Atomic Absorption Spectrophotometer. The analyzed results showed that Cadmium was present in 38% water samples and 32.65% water samples contained Cadmium concentration which was exceeding the international standard value of WHO whereas Lead was detected in 60 % samples but 36.73% water samples having Lead concentration above the permissible limit. Aluminum was detected below the Maximum Contaminants Level (MCL) in all the tested samples. The study proved that heavy metals contamination in groundwater can pose a considerable health risk to human population because dug wells and bore water are the mere sources of drinking water in that particular area (Momodu and Anyak, 2010).

Impact of leachate percolation on groundwater quality was assessed by collecting groundwater samples from various points near solid waste landfill site. Different physico-chemical and microbial parameters were tested in field and laboratory. The results revealed that in 37.5% water samples Electrical conductivity (EC), Total dissolve solids (TDS) and Sodium (Na^+) concentration were exceeding the WHO standards. pH and Iron (Fe) concentration were above in 75% samples. Negative correlations were found between EC, TDS and Na correspondingly to remoteness from landfill area. High Enterobacteriaceae contamination was detected in the ground water samples. The least impact of leachate on groundwater quality was due to clay soil in the landfill area which reduces leachate percolation to a large extent. High concentration of Lead, Cadmium and Zinc in leachate and some physical contaminants in groundwater exhibit that in the absence of proper leachate collection mechanism the amassing leachate contaminants can percolate to groundwater which will pose a significant risk to ground water quality. It is concluded that the groundwater quality of the study area is not safe for drinking purpose. Therefore, engineering sanitary landfill site should be constructed to protect groundwater quality deterioration (Aderemi et al., 2011).

The impact of Gazipur landfill site on groundwater quality was investigated by collecting leachate samples from landfill site and groundwater samples from both landfill and neighboring areas. Physico-chemical and microbial parameters were tested to find the extent of leachate percolation on groundwater quality. Groundwater samples away from the landfill site and deeper water table were also analysed. High concentration of sulpfurdioxide (SO_2), Ammonium (NH^+), Phenol (C_6H_5OH), Iron (Fe), Zinc (Zn), Chloride (Cl^-), Nitrogen oxide (NO) and Chemical Oxygen Demand (COD) evidently signifying that groundwater quality was significantly contaminated by landfill leachate. Groundwater quality was safe in samples which were taken from deeper water table and samples which were collected away from waste dumping site. The microbial presence of total coliform and fecal coliform indicated that water quality was not fit for human consumption. The study explored that only anthropogenic activities are possible reasons of groundwater contamination in the study area. It is necessary to take some corrective actions to minimize leachate percolation in groundwater (Suman et al., 2006).

Different heavy metals in groundwater of an industrial city Kasur, Pakistan were analysed by using Atomic Absorption Spectrophotometry. Among the selected metals, Chromium (Cr), Lead (Pb) and Iron (Fe) concentration level were exceeding a number of folds than internationally recommended standard values of WHO, EU, Japan and US-EPA. Chromium level was 21-42 times higher than that of drinking water quality standard. Positive correlations were established between Sodium and Chromium, Sodium and Manganese, Manganese and Iron, Magnesium and Chromium, Lead and Potassium, Lead and Nickel. The anthropogenic source of heavy metals contamination in groundwater was tanning industry located in Kasur (Saadia et al., 2008).

The groundwater quality of Rawalpindi city was studied by collecting water samples from (220) tube wells in the year 2007.The analysed results of tube wells revealed that 50% samples showed bacterial contamination. The prime source of microbial contamination is percolation of Lai Nalla sewage water. Nalla Lai acts as an open sewer which carries 65% sewage of the city. Ensuring proper sanitation system and applying engineering techniques will become constraint in groundwater contamination (Islam et al., 2007).

Heavy metals in soil and groundwater were studied at vehicles mechanic countryside situated in Ibadan, Nigeria. Samples of soil and groundwater were analysed from control points and seven automobiles localities. Soil contamination was confirmed when soil samples were compared with control area samples. The values of Lead, Chromium and Cupper in soil samples were found in higher concentration in auto-mechanic place than control sites. Groundwater samples of dug wells were within the permissible limit, except the elevated concentration of Cupper (Cu) which was beyond the WHO standard value for drinking water (Adelekan and Abegunde, 2011).

The sewage leakage and groundwater contamination in urban areas needs serious attention to the masses and regulatory bodied in Germany. The hydrochemical analysis of groundwater quality showed that damaged and leaked sewer pipes in numerous cities were major source of Chloride, Sulphate and Nitrogenous pollutants into water table. Sewage leakage and different industrial effluents pose greater threat to contaminants percolation into groundwater (Eiswirth et al., 1997).

Water samples of bore wells and sewage water were collected for physico-chemical analysis from streets of Sanmugasikamani Nadar, Naivatti Nada and Thiruthangal region of Sivakasi. Nearly all physico-chemical parameters i.e. pH, Total dissolved solids, Total suspended solids, Total solids, Dissolved oxygen, Free CO_2, Total alkalinity, Acidity, Total hardness, Magnesium, Chlorides, Calcium and Salinity were below the permissible limit of Indian standard Institution (ISI). All analysed water samples were microbially contaminated with total coliform, fecal coliform and faecal streptococcal, as per WHO standards for drinking water quality. The microbial contamination was detected due to sewage percolation in bore well water. It is recommended to recycle the sewage water and use boil water for drinking purpose (Radha et al., 2007).

A research on industrial effluents percolation in groundwater was carried out in Gadoon Amazai Industrial area of Swabi in the month of April, 2004.Wastewater samples were collected for physico-chemical analysis from soap, oil, ghee, textile, chemical, marble and steel industries.

Groundwater samples were taken from three tube wells. All the selected physico-chemical parameters of groundwater i.e. pH, EC, Temp, TDS, TSS, BOD, Ni, Cd, Pb, Cr, Cu, Zn, Fe and Mn were within the permissible limit when compared with international standards of WHO and US-EPA. It is concluded that groundwater is safe for drinking purpose but preventive actions must be taken by keeping in the view of future perspective through installing wastewater treatment plants in industrial drains to protect groundwater quality in the near future (Nasrullah et al., 2006).

Selected heavy metals in the proximity of tannery effluents were assessed by collecting soil and groundwater samples from Multan, Pakistan. The samples were tested on Flame Atomic Absorption Spectrophotometer. The analysed results revealed that Chromium (Cr), Sodium (Na), Calcium (Ca), Potassium (K), Cadmium (Cd), Iron (Fe) and Magnesium (Mg) were found in high concentration according to WHO standards in both soil and groundwater samples. The heavy metals emerge in different steps of leather production such as liming, tanning and finishing stages. So, it is suggested to take preventive measures before discharge of tannery effluents in to water bodies (Saadia et al., 2010).

The effect of industrial effluents on underground water of Peshawar was investigated in March, 2003. Total (12) samples of groundwater and surface wastewater were collected from various points. Seven samples of wastewater effluents of industries were taken from pharmaceutical, steel, marble, beverages, matches and ghee industry. One sample was collected from central drainage of all the industries. Four drinking water samples were collected from tube wells in the locality of Industrial area. The pH value of wastewater effluent of Aluminum industry was elevated. TDS value in Pepsi Industry wastewater effluent sample was higher than National Environmental Quality Standard (NEQS). Biological oxygen demand (BOD) of all waste effluents was beyond the standard value. Cadmium (Cd), Iron (Fe), Chromium (Cr), Copper (Cu) and Zinc (Zn) values of wastewater Industrial effluents were below the permissible limit whereas some heavy metals i.e. Nickel (Ni), Manganese (Mn) and Lead (Pb) values were exceeding the standard values. In groundwater samples the concentration of Copper (Cu), Manganese (Mn), Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr) were beyond the permissible limit when compared with the standard values of US-EPA and WHO. The analysed results proved that wastewater effluents of various industries of Peshawar were contaminating the groundwater quality. It is mandatory to install wastewater treatment plant in an industrial area to cope with the situation (Tariq and Shah, 2006).

A monitoring of surface and groundwater quality was carried out in the locality of many chemical and pharmaceutical industries in Patancheru Industrial region of Hyderabad, India. Fifty-three sampling locations were selected and thirteen chemical parameters were analysed. The study explored that Barium (Ba), Strontium (Sr), Nickel (Ni), Cobalt (Co) and Chromium (Cr) in groundwater were originating from human activities and underground rocks whereas the concentration of Lead (Pb), Iron (Fe), Zinc (Zn), Manganese (Mn), Boron (B), Cobalt (Co) and Arsenic (As) in groundwater were resulting from anthropogenic activities. The statistical analysis showed that unprocessed industrial effluents were the main sources of groundwater contamination. It is therefore recommended to curb the situation by periodically monitoring of groundwater and ensuring preventive remedial measures (Aradhi et al., 2009).

Sargodha city drinking water quality was assessed by collecting two set of water samples before and after monsoon season. Total (12) drinking water samples were collected, one sample were taken from tube well water, three water samples were collected from surface water source points, eight samples were collected from households respectively. Six drinking water quality parameters were analysed i.e. pH, TDS, Hardness, Turbidity, Fecal coliform and Total coliform. The results were then compared with international standard values of WHO. Water testing results verified that all physico-chemical parameters were within the range except samples of New Satellite Town area. The bacteriological results confirmed that all drinking water samples were contaminated with fecal coliform and total coliform before and after monsoon season. Proper chlorination of network and storage tank is recommended before drinking water supply to public (Sajjad and Malik, 2016).

A study was carried out to examine the contaminants concentration in drinking water around the premises of Punjab University Hostel. Twelve sampling points were selected and eighteen samples were collected from the source point and tap stand level. Various physico-chemical and microbiological parameters of drinking water quality were analysed in laboratory. The results showed that Hardness, pH, Turbidity and TDS were within permissible limit whereas Arsenic (As) contamination in source water was beyond the permissible limit of WHO standard values. The Arsenic value was in between 24-32 μ gram/l in water sample. The bacterial contamination in two sampling points were ranging from 38-21 MPN/100 ml. The samples of cooler water were free from coliform contamination which depicted that drinking water filtration unit was working properly. The research work concluded that water quality at source level was not drinkable because of high concentration of toxic heavy metal Arsenic in drinking water. It is therefore needed preventive measures on urgent basis and conduct periodic monitoring of water quality to curb the situation (Naeem et al., 2015).

A research was conducted to assess the possible effects of soil pollution on groundwater quality in densely demographic district (Ghulam Muhammad Abad) Faisalabad, Pakistan. The sampling area was divided into six locations and overall (159) groundwater samples were taken from 90 ft deeper pumps. The results of physico-chemical parameters of groundwater quality showed that EC value in (8) samples and TDS values in (2) samples were below the permissible limit value of WHO while the remaining samples were exceeding the standard values of drinking water quality. Total solid (TS) values in all samples were elevated. The entire area had TSS value much higher than WHO standard value. Most of the samples were found with acidic pH. Total suspended solids (TSS) ranging from 3-2222 mg/L^{-1}. It is believed that TSS value in drinking water should be close to zero. The groundwater quality of the study area is not safe for human consumption. The groundwater might be contaminated due to improper sewerage system and industrial effluents. There is a dire need of bringing improvement in groundwater quality in district Ghulam Muhammad abad Faisalabad (Abdul et al., 2012).

A research study was conducted in 2000-2001 on surface and groundwater quality of two provinces i.e. Sindh and KPK. The aim of the study was to investigate different heavy metals like Copper (Cu), Lead (Pb), Zinc (Zn), Iron (Fe), Manganese (Mn), Chromium (Cr), Cadmium (Cd) and Nickel (Ni) originating from different industrial wastes and their repercussions on surface and groundwater quality. The surface water samples were collected from Bakhshoo Pul, Kabul River, Kalpani Drain, Naguman River and Airab drain of KPK province and Malir river of Sindh province. Groundwater samples of Sindh province were taken from Industrial locality of Karangi, Sindh province and Risalpur and Charsadda region of KPK province. Total (16) samples of surface water and (8) samples of groundwater were collected from KPK province whereas (8) samples of surface water and (4) samples of groundwater were collected from Sindh province. The results revealed that various surface and groundwater parameters of trace elements were within range and many parameters were beyond the standard values of WHO and US-EPA. Anthropogenic activities like industries are core sources of both surface and groundwater contamination by discharging their effluents and wastes into water bodies. Therefore, appropriate management of waste effluents practices can get rid from this dilemma (Midrar et al., 2005).

The review paper revealed that emerging industrial organic contaminants in groundwater can pose a noteworthy threat to human health and ecology. Micro-Nanogram/l concentration of EOP (Emerging Organic Pollutants) for example PPCPs (Pharmaceutical and Personal care Products), Sulfamethoxazole, Carbamazepine, Ibuprofen and Bisphenol are detected in groundwater worldwide. In near future, their threshold values, drinking water quality standards and environmental quality standards are expected to be established. A further study is required to evaluate their sources of origin, mobility mechanism in subsurface and fresh water bodies and their physico-chemical properties and fate is a new investigation area for researchers and scientists (Lapworth et al., 2012)

Research on wastewater effluents, discharging from pharmaceutical industries and their significant adverse impact on surface and groundwater quality was investigated in Hyderabad, India. Two water samples were collected from uncontaminated lakes, another sample was taken from carrier stream, six well water samples were collected from countrysite and wastewater samples were taken from integrated wastewater treatment plant of pharmaceutical industries. Twelve pharmaceutical compounds were analysed by using the technique of liquid chromatography-mass spectrometry instrument. The results showed that all samples of well water were polluted with emerging pharmaceutical contaminants like terbinafine, ciprofloxacin, citalopram, cetirizine and enoxacin and their concentration were elevated than 1 micro gram/l. The samples of waste effluent of treatment plant were extremely contaminated with cetirizine and ciprofloxacin whereas maximum concentration of norfloxacin, cetirizine and ciprofloxacin were detected in lake water samples. It is concluded that inadequate and poor wastewater treatment techniques of pharmaceutical drug effluents can pose a serious threat to surface and groundwater quality. The responsible authorities should take initiatives to cope with the issue (Jerker et al., 2009).

The effect of urban land use and land cover on groundwater quality was assessed by analysing ionic and isotopic contaminants from different zones in Seoul city, South Korea. The results showed high values of tritium in groundwater represents current recharge of groundwater in the study area. The increased ionic concentration in groundwater was due to contaminants recharge from neighboring sources. As TDS values were increasing when contaminants recharged and dissolved in water. The TDS values were increasing in ascending order i.e. forested area < agriculture land < residential area < traffic site < industrialized zone respectively. The overall results confirmed that major sources of groundwater pollution were due to a variety of contaminants originating from anthropogenic activities in urban settlements (Byoung et al., 2005).

A scientific research was conducted to investigate both shallow groundwater of bore wells and deep tube wells in an industrial region of Uttar Pradesh, India in 2004. Total (126) water samples were collected to analysed Nitrate, Nitrite, Ammonium, Organic Nitrogen and Kjeldahl- Nitrogen in groundwater aquifers. The results revealed that about 46% of bore water and 26% of tube wells water showed elevated concentration of Nitrate ($-NO_3$) as compared to Bureau of Indian Standards (BIS). Research revealed that industrial effluents were the point source of ($-NO_3$) contamination in groundwater quality. The water is not safe for drinking purpose and it can cause adverse health effects. Therefore, proper monitoring of groundwater in an industrial region of Uttar Pradesh is recommended to safeguard the health of citizens (Kunwar et al., 2006).

Variable based factor analysis (R-mode analysis) was carried out to assess the groundwater quality in agricultural locality of Yunnan city, China. The groundwater samples were collected from (46) springs of Nandong Underground River System. The factor analysis of the hydrochemical investigation revealed that Potassium, Chloride, Nitrate, Magnesium, Bicarbonate and Sulphate were resultant of anthropogenic activities (Fertilizers and waste effluents discharges) whereas pH, Bicarbonates, EC, Magnesium and Calcium in spring water were the results of underground lithology (Calcium Carbonate and Dolomite rocks). R-mode analysis helped to unveil the potential sources and processes affecting groundwater quality of springs (Yongjun et al., 2009)

The improper landfill techniques and sewage effluents discharging into water bodies pose a significant threat to aquifers in Lahore city, Pakistan. The study on TDS concentration in groundwater was assessed by analysing benchmark values of leachate, river and drainage water to identify the pollution level in groundwater. The laboratory results of groundwater quality showed that 36% groundwater samples have elevated values of TDS as compared to Pakistan Standard Quality Control Authority whereas 1.5% TDS values were elevated than WHO drinking water quality standards. Maximum concentration of TDS in groundwater indicated that water is not potable for human use. It is necessary to enforce rules and regulations, environmental law and develop further plans to protect recharge areas and prevent aquifers contamination (Akhtar and Zhonghua, 2013).

High concentration of Fluoride in groundwater of arid region Sri Lanka was a sole reason of dental disease in the locality. The concentration of Fluoride in groundwater was exceeding 5 mg/L^{-1} due to which dental Fluorosis was a common disease in the region. The situation was inversed in the wet region of Sri Lanka where the concentration of Fluoride in groundwater was deficient which leads to dental caries disease. The majority of population was facing the problem because they depend on contaminated water for drinking purpose and their health was dependent on groundwater quality. It is therefore necessary to take steps on urgent basis to treat groundwater and make potable for human consumption (Dissanayake, 1991).

Impact of anthropogenic and natural factors on hydrochemical parameters of groundwater quality was investigated in Taejon, South Korea in 1999. Water samples were collected from different zones of city i.e. parks, residential areas, schools, colleges, hotels, public and private organizations, public places and industrial locality. Groundwater samples were taken from (170) points. Total (89) drinking water samples were collected. Eight samples were taken from industrial water, (43) household water samples were collected, (2) samples were taken from agriculture water and (3) samples of geothermal water of hot springs were collected for physico-chemical analysis. The results of (170) groundwater samples showed that average water was little acidic in nature due to impact of urban land use and anthropogenic activities, EC values ranging from 65-1290 µ s/cm. The groundwater samples of green belts and inhabited areas showed low EC values whereas concentration of Calcium and Bicarbonate were dominant. In industrial zone the values of EC, Calcium, Chloride, Nitrate and Sulphate were found in high concentration. CO_2 and inorganic ions showed positive relationship in groundwater chemistry of locality. Factor analysis revealed that excess concentration of CO_2, Nitrate ($-NO_3$), Bicarbonate ($-HCO_3$), Magnesium (Mg), Sodium (Na), Sulphate ($-SO_4$), Chloride (Cl^-) and Calcium (Ca) in water were the results of anthropogenic and natural activities (Chan, 2001).

The contaminants in stormwater can percolate to groundwater through a variety of reasons including rapid movement of pollutants in unsaturated (vadose zone), high pollutants load in stormwater and greater soluble portion of contaminants presence in stormwater. Volatile organic compounds, pathogens, disinfectant byproducts, Zinc, 1,3-dichlorobenzene, Pyrene, Fluoranthene, Salt, Chloride and Nickel have higher groundwater pollution potential whereas Pesticides, Lead, Phenanthrene, Pentachlorophenol, bis (2-ethylhexyl) Phthalate, Benzo anthracene and Chromium have moderate groundwater contamination potential through infiltration. Nitrate in stormwater has low to moderate groundwater contamination potential but excess concentration of nitrate in stormwater can result in high groundwater contamination. The concentrations of contaminants are greater in automobiles and industrial locality as compared to residential zone. The metals can least percolate through infiltration if pretreatment of sedimentation occurs. Surface percolation strategies like swales, ponds, grass, dry wells and trenches can remove soil pollutants and lessen the groundwater contamination (Robert et al., 1999).

The research was conducted in Lagos city which is an industrial and densely populated locality of Nigeria. The prime objective of the study was to investigate physico-chemical groundwater chemistry of well water. Samples of well water of shallow aquifers were analysed and the results showed that 38.9 % Lead concentration, 50% TDS, 44.4% pH, 11.1 % Calcium and Sodium, 27.8% EC and 50% TDS values in the tested water samples were exceeding the permissible limit of WHO. It is concluded that the water is not potable for drinking purpose and can cause health problems. Therefore, Environmental protection agency of Lagos should reinforce waste disposal and sanitation law and take preventive procedures to curtail groundwater contamination (Yusuf, 2007).

The sewage irrigated field of citrus was studied in Israel to examine the percolation level of organic contaminants to water table from surface water infiltration and through vadose zone. Two control site samples were taken to compare the results of organic contaminants in water table. Total (10) samples were analysed. The results of sewage irrigated fields showed that biodegradable organic contaminants like Toluene and Phthalates were reached through 20 m deep vadose zone to groundwater. Pollutants concentration generally increased with depth. On the other hand, pollutants concentrations at the two control sites were decreasing significantly with depth of the unsaturated zone. The downward movements of organic contaminants were generally increasing with depth in sewage irrigated area while pollutants level was decreasing in vadose zone of control sites. It is concluded that sewage effluents irrigated fields across the world can pose a significant threat to groundwater quality (Ritter et al., 1993).

Natural concentration of Arsenic in groundwater depends on environmnental climatic conditions and earth's feature. Approximately (15000) Arsenic tests in United States showed that Arsenic in groundwater was < 1 μ gram/l whereas in ten percent results their concentration were exceeding 10 μ gram/l. In Western United States Arsenic in groundwater was exceeding 10 micro gram/l as compared to eastern half. The Arsenic concentration in groundwater of Atlantic Plain and Appalachian Highland were < 1 mico gram/l. Arsenic in groundwater chemistry of South Dakota, New England, Wisconsin, Minnesota, Michigan and Oklahoma were beyond 10 micro gram/l. Ironoxide is the general cause of prevalent Arsenic elevated level of >10 micro gram/l in groundwater. The mineral Sulfide is the main source and sink of Arsenic whereas high evaporation and geothermal process are also linked with elevated level of Arsenic in groundwater. The research proved that both natural and anthropogenic activities are responsible of high concentration level of Arsenic in groundwater (Alan et al., 2000).

The research on Fluoride concentration in groundwater of North Jordan revealed that its concentration varies from 0.009-0.055 mg/L^{-1}. Both Fluoride and Calcite in groundwater were found in low concentration while the elevated level of Bicarbonate ($-HCO_3$) and Nitrate ($-NO_3$) were reported in groundwater. The low concentration of Fluoride and Calcite in groundwater might be due to topographic location (Rukaha and Khalid, 2003).

Sewage effluents percolation and groundwater contamination through vadose zone was studied for a longer period of time in Israel. The sewage effluents chemical composition changes while passing vadose zone through cation exchange and adsorption of contaminants. Clay mineral can prevent the leachate and contaminants to certain extent to percolate downward. So, imperfect changes of sewage contaminants occurred in vadose zone due to limited competency of soil adsorption and absorption capacity results in inorganic contaminants of groundwater quality resemblance with recharged sewage water. In vadose zone the organic matter decomposes and form Carbon monoxide (CO) and Calcium carbonate ($CaCO_3$) mineral dissolution in groundwater. Both chemical and biological decomposition of organic material occurs in vadose zone. Therefore, unsaturated zone plays a vital role to control and curtail the sewage effluents to contaminate groundwater quality (Avner and Rami, 1996).

Seasonal variations in groundwater quality due to municipal waste dumping landfill site were assessed in Mehmood Bolti Landfill locality in Lahore, Pakistan. Groundwater samples were collected in both wet and dry seasons to evaluate physico-chemical and microbial contamination. The results showed that TDS, EC and Turbidity values were elevated in wet season as compared to dry season while hardness level was high in dry season when compared with WHO standards. Bacterial contamination of total coliform, fecal coliform, E.coli and species of Salmonella and Pseudomonas were shown more in wet season than dry season. In dry season the bacterial colonies were found in minimum number whereas the species of Salmonella were not detected. The results exposed that groundwater is not potable for drinking purpose and it can outbreak many diseases. Consequently, it is necessary to protect public health by introducing sanitary landfill technique and careful monitoring of groundwater (Butt et al., 2012).

The research on bacterial contamination of groundwater quality was carried out in (13) union councils of Mardan. To evaluate microbial groundwater quality (39) water samples were collected from tube wells, hand pumps and wells. Both qualitative and quantitative techniques were used to analyse fecal coliform and E.coli in groundwater. The qualitative analysis showed that 90% samples were contaminated with fecal coliform and 56% samples were polluted with E.coli. The results of quantitative analysis revealed that MPN (Most Probable Number) ranging from 1601-2400 in 28% water samples, 551-1600 and 210-550 in 20% water samples each, 40-200 in 18% water samples and below 40 in 13% water samples. The main reason of microbial contamination was percolation of contaminated water form adjacent sources. The research concluded that water quality is not safe for drinking purpose and it needs to be protected from pollution sources (Naeem et al., 2012).

Lahore city is solely depending on groundwater and the city is facing drinking water quality problems due to multi-dimensional reasons ranging from inadequate sanitation system, water scarcity due to less recharge and high water pollutions from point sources. The research was conducted to assess groundwater quality by analysing different water quality parameters like pH, TDS, Hardness, Alkalinity and Turbidity. The laboratory results showed that 61% of total region had out-standing water quality, 27% area was good quality, 9% region was reasonable and 3% area had low water quality when compared the values with WHO standards whereas according to PSQCA 5% region having out-standing water quality, 29% area was good quality, 34% region had reasonable quality and 32% area water was not potable. To curb groundwater contamination issue first identify and quantify the sewage entrance points into fresh water bodies and protect groundwater recharge area and restore the old recharges, enforce environmental law and introduce new policies, rules and regulations to protect groundwater quality and finally water quality monitoring on periodic bases can overcome the problem (Malik et al., 2014).

Assessment of microbial parameters of groundwater quality was carried out in Ekiti State of Nigeria to examine the potential sources of contamination. Total (73) groundwater samples were taken from wells to analyse pH, Temperature, Bacteria and Nitrate (NO_3). The depth of water table was detected through dipmeter. Both pH and temperature were measured by using potable multiparametrier meter. Nutrient agar medium was used to analyse living bacterial colonies and lactose medium was used to analyse coliform count in water samples. Nitrate concentration in groundwater samples were detected by using the instrument Spectronic 20. The analysed results showed that pH value were ranging from 6-8.9 with an average of 6.87, Nitrate concentration was 1.2-19 with an average of 6.86 mg/l in water samples whereas EC value was <1000 μ S/cm in all the tested samples. The bacterial results revealed that all the tested water samples showed positive results. Coliform colonies were 0-8 with an average of 2.15 cfu /100 ml whereas total bacteria calculated as 2-25 with an average of 9.42 cfu/100 ml in water samples. It is concluded that the analysed water samples having less mineral contents and it is bacteriologically contaminated due to improper waste management techniques and sanitation. The water is not potable for drinking purpose and it needs further treatment facility (Talibi and Ogundana, 2014).

The groundwater quality of Bilaspur city, India was investigated for microbial contamination. Ninety samples were collected from ten zones in three seasons i.e. summer, winter and rainy season. The samples were taken from hand pumps, bore wells and tap water. The results revealed that tap water samples showed high bacterial contamination whereas bore well samples were slightly polluted than hand pump water. The basic reason of bacterial contamination in groundwater was poor sanitation facilities (Shrivastava et al., 2014).

The investigation on microbial contamination in "Water Filtration Plants (WFPs) of Islamabad" was conducted in April-September 2012. Thirty-two WFPs were tested to examine bacterial contamination. The analysed results showed that E.coli and Fecal coliform were found in (8) water samples, total coliform was present in (13) water samples. It is concluded that more than half of the analysed water samples of "Water Filtration Plants" were free from bacterial contamination (Aliya et al., 2014).

The research was carried out to examine total coliform and fecal coliform in drinking water supply of Badin city, Pakistan. Eighteen sampling sites were selected across the city representing source water, distribution lines and consumption point. Water testing kit was used in the monitoring survey. The results revealed that TDS, EC and pH values were below the permissible limit while turbidity and residual chlorine values were beyond the WHO standard limits. Both total coliform and fecal coliform were found in all water samples which indicated that water was not safe for drinking purpose and it could cause major health risk (Aziz et al., 2013).

Water supply of southern Lahore city was assessed by "Water and Sanitation Agency" Lahore, Pakistan. Twelve water samples were collected from tube wells and household connection points. Two set of water samples were taken from each sampling point before and after monsoon season. Different parameters of water quality like pH, Hardness, TDS, total coliform and fecal coliform were analysed in laboratory. The results revealed that physico-chemical parameters were beyond the permissible limit of WHO at all source and household connection level. Likewise, no bacterial contamination was found at source level. The microbial contamination was found in 50-62.5 % household connections before monsoon season. The microbial contamination in water samples after monsoon season was 75%. The potential causes of microbial contamination in drinking water were leakage and rusted sewage lines proximal connection with the pipes of water supply. Proper disinfection of water supply is necessary to protect drinking water from bacterial contamination (Haydar et al., 2016).

The review paper highlighted that microbial contamination in drinking water quality is the basic cause of disease outbreaks in developing countries especially in Pakistan. High contamination in drinking water quality at source level, distribution lines and consumer level were reported which were exceeding the standard values of WHO. The research on (70000) microbial tests across the country revealed that 58% samples showed microbial contamination of total coliform and fecal coliform. About 20-40 % diseases in country are the result of contaminated drinking water, which reduces 25-58 billion rupees of national income per annum and 0.6-1.44 of GDP. Lack of enforcement of environmental law, inappropriate dumping system of both industrial and municipal waste incorporating with improper sanitation system, insufficient drinking water filtration plants and lack of chlorination practices in water filtration plants resulting in drinking water microbial contamination across the country. There is a dire need to curtail microbial contamination in drinking water to protect the health of citizens (Farhat et al., 2014).

CHAPTER 3

MATERIAL AND METHODS

3.1 Description of the study Area:

3.1.1 Location:

Rawalpindi city is located in Potohar Plateau. It is the fourth populous metropolitan area of Pakistan. It lies between the latitude of 33.5984° N and 73.0441° E. The city is socio-economically interlinked with capital territory Islamabad and both cities are collectively known as "twin cities". It is the centre of many industrial and commercial activities and a head quarter of Pakistan army. The city has major transportation points due to the presence of 'Benazir International Air Port' and a famous transport point for tourists visiting to historical places like Rohtas Fort, Havelia, taxila, Azad Kashmir and Gilgit-Baltistan.

It is located along the primitive business route among many countries including Europe, Persia and India. It remained a cultural gathering area and historically it was an assault route for Genghis Khan, Mughal conquerors, Alexander the Great and many others for thousands of years (Wikipedia, 2017).

The major environmental problems of the city are pollution of surface and ground water resources due to inappropriate solid waste dumping sites and improper sanitation (Nisar et al., 2008).

Nalla Lai is wastewater Nalla originating from Margalla hills Islamabad and it is given the name of Lai Nalla when it enters the Katarian pull, IJP road, an administrative boundary between Islamabad and Rawalpindi (Wikipedia, 2017). Its catchment area is 73.6 km and it has about 15 km length. The Nalla is passing through the centre of Rawalpindi city and many drains of the city are also connected with it and finally this Nalla falls in Soan river (Muhammad, 2007).

Figure 3.1.1: Location Map of Study Area.

3.1.2 Demographic:

Rawalpindi city has 5.4 million population. About 84% population is Punjabi, 9% are pashtun and 7% population is belonging to other tribes and ethnic groups. These ethnic groups are migrated from different provinces across the country (Wikipedia, 2017).

3.1.3 Climate:

Rawalpindi has humid subtropical and monsoonal climate. It is characterized by hot, humid summers and mild-cool winters. The heavy monsoon rainfall starts in the month of June and ends in September. Average annual rainfall is 1249 millimeters (49.2 in) and most of the rainfall occurs in the monsoon season but the recorded rainfall occurred in 2013 was 1952 mm (76.9 in) typically due to unusually wet monsoon season. The atmospheric temperature in June reaches to peak. The maximum temperature recorded in 1953 which was 48.3 °C whereas January is the coldest month and the temperature drops to -3.9 °C recorded in 17th January 1967. An average of 90 thunderstorms were experiencing in both Rawalpindi and Islamabad throughout the year. Most rainfall occurs due to thunderstorms and peak thunderstorms are observed in the month of August. The annual mean wind speed is around 10 km per hour at 14 m height. Rawalpindi city having extremely variable weather because of nearness to the foothills of Himalayas (Wikipedia, 2017)

3.1.4 Hydrology:

The Soan river and Kurang river are the main water reservoirs draining the city. The main tributaries of Soan river are Ling river and Lai Nallah whereas Gumreh Kas is draining Kurang river into westward direction. Wide-ranging forest in the headwater of both Soan river and Kurang river advantages in terms of qualitative and quantitative water supply (Sheikh et al., 1997).

3.1.5 Hydrogeology:

The elevation of water table decreases from 600 m at the foot of Margala hill (F-7 sector Islamabad) to 450 m in the vicinity of Soan river. The saturated zone of water is located 2-20 m below the surface (Ashraf and Hanif, 1980). Nalla Lai carries sewage of Rawalpindi city and increases contamination level of Soan river through draining its wastewater. The open dumping of solid waste threatens the quality of groundwater (Sheikh et al., 1997).

3.1.6 Geology:

Potohar region has a complex history of mountain formation, erosion cycle and alluvial- loessic deposition. In Margalla range limestone is characteristic rock which is gray and bluish white in color. The soil is clayey and of low productivity which is infertile in most southern and western part. Disintegration of sandstone, clay and shell had formed the soil in different places (Haye, 2005).

3.2 Preliminary Visit to Study Area:

A previsit of the study area was carried out to delineate the sampling boundary of research area and to select sampling points location within 100 meter distance along both sites of Nalla Lai from IJP road till Soan river. Similarly, control sampling points were also selected in the baseline survey. Global Positioning System (GPS) points of the selected sampling locations were recorded by using GPS Meter. GIS map of the sampling points was generated according to prerecorded GPS points.

Likewise, physical features of the study area were observed. The sanitary condition near Nalla Lai was alarming, households and commercial waste were being dumping on the banks of Nalla and different wastewater channels were also mixing with increasing length of Nalla. Community views proved that residential colonies near Nalla Lai are facing different health problems.

Figure 3.2: Sanitation Water Pipe Lines Mixing in Nalla Lai

Figure 3.2.1: Commercial and Domestic Solid Waste Dumping in Nalla Lai.

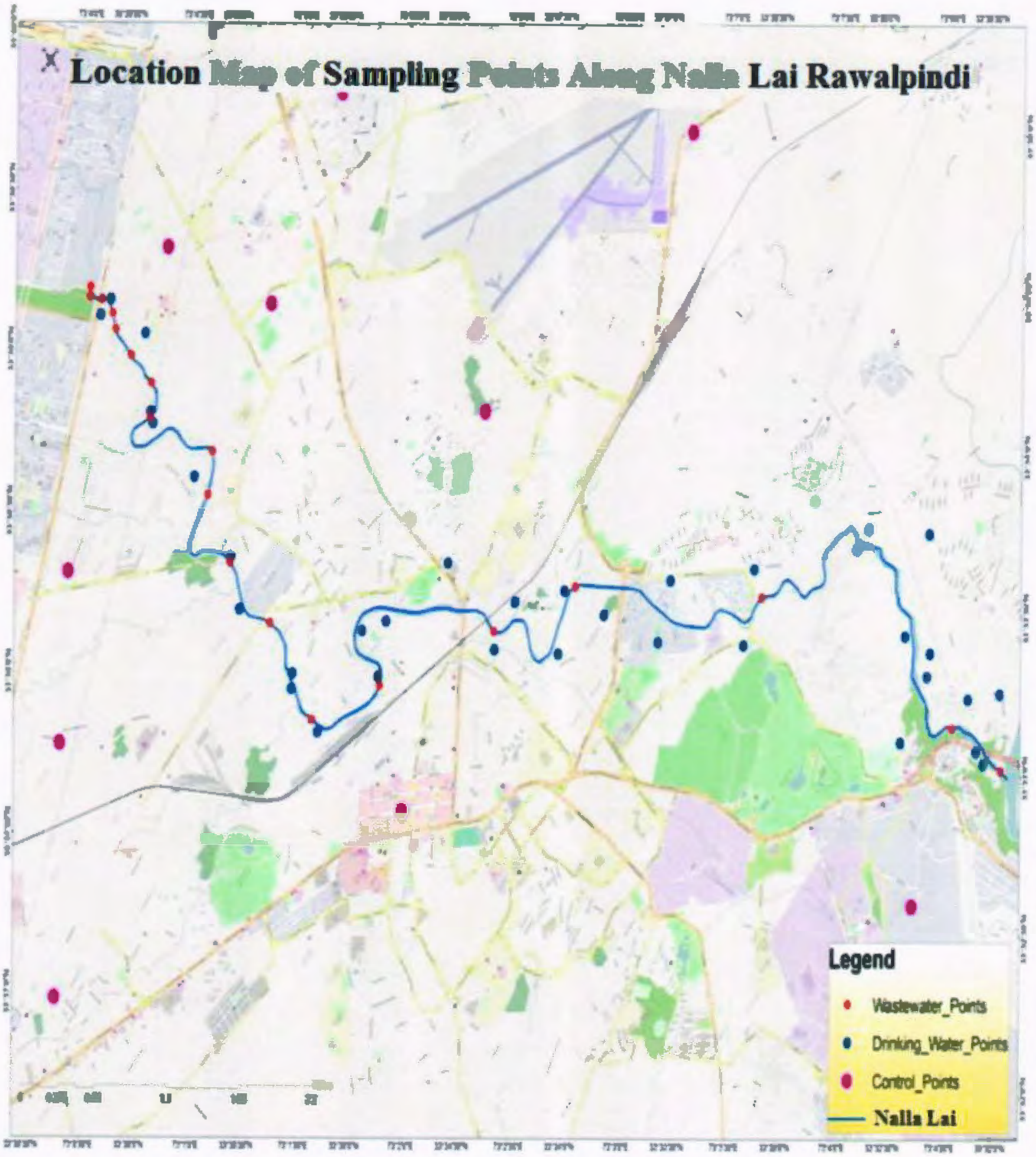


Figure 3.2.2: GIS Map of Sampling Points Location.

3.3 Preparation of Sampling Plan:

Before visit to water sampling in the study a weekly sampling plan was prepared for the effective implementation of sampling strategy. The sampling plan includes the following steps.

3.3.1 Preparation of a List of Pre Selected Sampling Points Location.

3.3.2 Requisition or Hiring of Transportation.

3.3.3 Selection of Sampling Day and Time.

3.3.4 Cleaning of Water Sampling Bottles.

3.3.5 Preparation of Preservative.

3.3.6 Ice Box.

3.3.7 Personal Protective Equipments (PPEs).

3.3.8 First aid Box.

3.3.10 Preparation of DO meter, pH meter and TDS Meter.

3.3.10 Note Book, Permanent Marker, and Ball point Pen.

3.3.11 Checklist.

3.3.1 Preparation of a List of Pre Selected Sampling Points Location:

A preselected sampling points location list helped to access the predetermine location easily. It was mandatory to mention in the sampling plan which helped to access the sampling points geographical location.

3.3.2 Requisition or Hiring of Transportation:

The requisition or hiring of transportation before field sampling was done to save time and effectively implement the sampling strategy.

3.3.3 Selection of Sampling Day and Time:

Sampling day and time in the sampling plan was properly mentioned to implement sampling strategy within the stipulated time period.

3.3.4 Cleaning of Water Sampling Bottles:

- Removed previously labeled information or tag on sampling bottles with Acetone.
- Washed sampling bottles thrice with liquid detergent in hot tap water.
- Opened the caps and inverted all sampling bottles and left for 24 hours to make them dry.

This process also cleans and removes the oil which sticks and adheres to the inner walls of sampling bottles or containers.

- After 24 hours the sampling bottles were rinsed thrice with distilled water, and left for few hours to make them dry and place in racks.

3.3.5 Preparation of Preservative:

Preservative was prepared in the laboratory before visit to field sampling because it preserves the chemical characteristics of water samples i.e. heavy metals.

Method of Preparation:

Took Nitric acid of analytical grade and added few drops of HNO_3 (Nitric acid) in 100 ml distilled until the pH become 2 pH. The preservative was kept safely in poly propylene bottle.

Note: Add acid in distilled water don't add distilled water in acid.

3.3.6 Ice Box:

Kept the ice box clean and washed with tap water and removed any type of contamination present in ice box and filled one third area of ice box with ice crystals which decreased the inner temperature of box containing water samples. Ice box acts as a preservative which preserved the water samples during transportation from field to laboratory.

3.3.7 Personal Protective Equipments (PPEs):

Personal protective equipments including gloves face mask and lab coat were prepared before field visit because these items were required for the sampling of drinking and especially wastewater sampling. Gloves and lab coat protect skin and clothes from damage and injury. Gloves protect skin during the process of preservative addition in water samples and from hazardous and toxic chemicals present in wastewater.

3.3.8 First aid Box:

First aid box including bandages and medicines are necessary in case of emergency. First aid box was prepared in laboratory before visit to field.

3.3.9 Prepared DO meter, pH meter and TDS Meter:

Properly calibrated and prepared the field testing kit in laboratory i.e. DO meter, pH meter and TDS meter.

3.3.10 Prepared Note Book, Permanent Marker, and Ball Pen:

Arranged the necessary stationary required in field including note book, permanent marker, ball point pen etc.

3.3.11 Checklist:

Prepared a checklist mentioning all the necessary items required in water sampling in field and marked all the items one by one just prior to field sampling visit.

3.4 Sample Collection:

Water sampling of the study area was divided into three categories.

3.4.1 Groundwater Sampling.

3.4.2 Wastewater Sampling.

3.4.3 Microbiological Groundwater Sampling.

3.4.1Groundwater Sampling:

Groundwater samples were collected by using grab sampling technique (Rahul, 2015) and following the internationally recognized sampling procedure "Standard methods for the examination of water and waste water" APHA (2012).

The water sampling was done in the month of September at least one week after rain fall. Groundwater samples of (17) tube wells, (29) boreholes, (1) dug well and (2) springs were collected by using sterilized polypropylene bottles pre-washed in hot tap water with detergent, water reagent and thrice rinsed with distilled water.

Total (49) ground water samples were collected from various distances along Nalla. The samples were collected at both source level and consumer level.

Total (36) groundwater samples were collected within 100 meter or nearest distance along both sites of Nalla. Among (36) samples, 19#samples of boreholes, 14#samples of tube wells, 1#sample of dug well and 2#samples of spring water were collected.

Total (13) control samples were taken from at least 1 km distance along both sites of Nalla. Among (13) control samples, (3) tube wells and (10) boreholes water samples were collected.

While starting sampling from IJP toward Soan river, (7) tube wells and (11) boreholes water samples were taken within 100 meter distance along left site of Nalla whereas (7) tube wells, (8) boreholes, (1) dug well and (2) springs water samples were collected within 100 meter distance along right site of Nalla Lai.

The water samples were collected after flushing the stagnant water of pipe for at least 5 minutes from tap stand, hand pump and borehole pipe. Used 1000 ml (1Litre) sampling bottle and collected water sample from each sampling point for the detection of non-metals whereas 500 ml sampling bottle was used and collected water sample from the same point for the analysis of heavy metals and added preservative of Nitric acid (-HNO_3) to bring pH of water sample less than 2 pH (pH <2). Nitric acid prevents metal contents by making nitric acid layer in water sample i.e. Iron nitrate, Cupper nitrate, Lead nitrate, Arsenic nitrate etc. The sampling bottles were fully filled with water and left 1 % space of the total volume of bottle for thermal expansion of sampling bottle during shipment.

The sampling bottles were properly tagged or labeled. The following information was mentioned in the sampling bottles:

- Sampling Number
- Sampling Date
- Sampling Time/ Hour
- Sampling Exact Location
- Sampling Source i.e. Ground or Surface water.
- Sampling Type i.e. Grab sampling or Composite sampling

The basic parameters of water like pH, Temperature, DO, TDS and EC were determined in field by following the standard analytical procedure. Finally the water samples were shifted to CLEAN laboratory of Pak-EPA and kept in refrigerator at 4 °C for futher analysis of selected chemical parameters.

Table 3.4.1: Groundwater Sampling Points Location Summery Table

S. No	Source of Water Sample	Location Area	Water Depth in Feet	Sampling Site of Nalla Lai	Sampling Point	Latitude	Longitude
1	Tube well	Kataria Mohallah	280	Left Site	Tap stand	33.64536	73.05399
2	Bore water	City Coloney- E-Block	250	Left Site	Hand Pump	33.64088	73.05494
3	Tube well	New Phakware	280	Left Site	Cooler	33.63559	73.05093
4	Tube well	Kashmir Coloney Mujahid Abad	260	Left Site	Cooler	33.62259	73.05012
5	Tube well	Ratta Mohin Pura	250	Left Site	Cooler	33.61174	73.0489
6	Bore water	Itehad Coloney	220	Left Site	Tap stand	33.60496	73.05538
7	Bore water	Aria Mohallah	250	Left Site	Water Cooler	33.60551	73.06661
8	Tube well	Dhoke Cherage Deen	270	Left Site	Tap stand	33.59826	73.06983
9	Tube well	Qazi Abad	260	Left Site	Tap stand	33.59504	73.07423
10	Tube well	Chaklal Scheem Askai 3	270	Left Site	Tap stand	33.58738	73.08297
11	Bore water	Askari 1	180	Left Site	Bottle	33.58149	73.09007
12	Bore water	Chaklal Scheem 3	170	Left Site	Cooler	33.58034	73.0983
13	Bore water	Dhoke Choderia	140	Left Site	Tap stand	33.57472	73.10104
14	Bore water	Dhoke Choderia	70	Left Site	Bottle	33.56981	73.10544
15	Bore water	Bostan Valley	120	Left Site	Inlet Pipe	33.56348	73.0993
16	Bore water	Near High Court Road	150	Left Site	Tap stand	33.5625	73.09787
17	Bore water	High Court Road Timber Market	140	Left Site	Tap stand	33.55815	73.09989
18	Bore water	High Court Road	120	Left Site	Tap stand	33.55595	73.10262
19	Tube well	Amin Abad Khayaban Sir Syed	240	Right Site	Bottle	33.64529	73.05241
20	Bore water	Dhoke Naju, Khayaban Sir syed	180	Right Site	Cooler	33.6364	73.05131
21	Bore water	Khayabanay Sir Syed B-4	150	Right Site	Tap stand	33.62961	73.05137
22	Bore water	Hazara Coloney	120	Right Site	Tap stand	33.61918	73.04811
23	Tube well	Ratta Imran Kachey Abaday	250	Right Site	Bucket	33.60672	73.04783
24	Bore water	Darya Abad Gawal Mandey	220	Right Site	Tap stand	33.60724	73.05884
25	Tube well	Mareed Choke	240	Right Site	Cooler	33.59739	73.06575
26	Bore water	Ghanda Street-6	120	Right Site	Tap stand	33.59072	73.07602
27	Tube well	Murree Bruraey, MT Area	250	Right Site	Tap stand	33.57832	73.08529
28	Dug well	Ghulistan Coloney line Numb-3	16	Right Site	Cooler	33.57458	73.09912
29	Bore water	Ghulistan Akbar Line Number- 7	180	Right Site	Bottle	33.56631	73.09827
30	Tube well	Al -Shafa Hospital Area	250	Right Site	Tap stand	33.56112	73.09243
31	Spring	Sua Adda		Right Site	Cooler	33.55356	73.0977
32	Spring	Sua Adda Darbar		Right Site	Pipe	33.55477	73.09779
33	Tube well	Serat Gunj	240	Right Site	Tap stand	33.60862	73.05649
34	Bore water	Mohellah Melad Nagar	110	Right Site	Pipe	33.61102	73.04804
35	Bore water	Ghanda Chichi Street Number-16	120	Right Site	Bottle	33.592207	73.070487
36	Tube well	IV Askari Tan	260	Right Site	Cooler	33.58511	73.07882
37	Tube well	Dhoke Paracha	280	Left Site	Bucket	33.6383	73.08251
38	Bore water	Kataria Mohallah	130	Left Site	Cooler	33.64362	73.06111
39	Bore water	National Market Umar Masjid	200	Left Site	Tap stand	33.63269	73.06622
40	Bore water	Chaudhery Dhoke Farman Ali	150	Left Site	Hand Pump	33.61053	73.07726
41	Bore water	Dhoke Raja Muhammad Khan	180	Left Site	Bottle	33.60913	73.10772
42	Tube well	Dhoke Kla Khan Hazara Coloney	300	Left Site	Tap stand	33.65048	73.09544
43	Bore water	Faizabad	170	Left Site	Tap stand	33.66186	73.08502
44	Bore water	Pakistan Town	140	Left Site	Tap stand	33.577299	73.148368

45	Bore water	Fauji Coloney Peerwadi	130	Right Site	Bucket	33.63334	73.03106
46	Bore water	Chak Madad khan	120	Right Site	Tap stand	33.62317	73.02208
47	Tube well	Ali Abad	260	Right Site	Tap stand	33.61405	73.00373
48	Bore water	Hattafri Haider Road Sadar	150	Right Site	Pipe	33.59606	73.05031
49	Bore water	Morga Dhoke Kalam	130	Right Site	Cooler	33.553338	73.087393

3.4.2 Wastewater Sampling:

Wastewater samples of Nalla Lai were collected by using composite sampling technique (Mohsin and Zaib, 2014) as per internationally recognized sampling procedure "Standard methods for the examination of water and waste water" American Public Health Association, 2012. The wastewater sampling of Nalla Lai was conducted in the month of October. Waste water samples were collected in pre-sterilized polypropylene bottles washed with hot tap water followed with detergent, water reagent and then thrice rinsed with distilled water.

Total (19) wastewater samples of Nalla Lai were collected from various distances. Sample#1 was collected from a wastewater nalla passing through 1-9 Industrial sectors Islamabad whereas sample# 2 was collected from a wastewater nalla passing through I-10 Industrial sector Islamabad. Sample#3 was collected from a junction point of 1-9 and I-10 industrial wastewater at the point of Kataria Bridge where the Nalla is properly named as Nalla Lai. The remaining 15#samples were collected from various distances along Nalla Lai from IJP road towards Soan River and finally sample#19 was collected at the end of Nalla Lai where it drains in Soan river.

The waste water samples were collected by using sampling stick, rop and a bucket. Put the sampling bucket mouth against the flow of Nalla water and the samples were taken from the midpoint of Nalla below 4-6 feet depth of water from the surface where maximum turbulence of wastewater exists. One litre wastewater was collected in a sampling bottle of 1000 ml (1 Litre) from each sampling point to detect non-metals whereas 500 ml wastewater sample was collected in 500 ml sampling bottle from the same point for the analysis of heavy metals and added preservative of Nitric acid (-HNO_3) to bring pH of wastewater sample less than 2 pH (pH <2). Nitric acid prevents metals degradation by making nitric acid layer in water sample i.e. Iron nitrate, Cupper nitrate, Lead nitrate, Arsenic nitrate etc.

The sampling bottles were properly tagged or labeled. The following information was mentioned in the sampling bottles:

- Sampling Number
- Sampling Date
- Sampling Time/ Hour
- Sampling Exact Location
- Sampling Source i.e. Ground or Surface water.
- Sampling Type i.e. Grab sampling or Composite Sampling

The basic parameters of wastewater samples like pH, Temperature, DO, TDS and EC were determined on site by following the standard analytical procedure and the samples were shifted to CLEAN laboratory of Pak-EPA and kept in refrigerator at 4 °C for futher analysis of selected chemical parameters.

Table 3.4.2: Wastewater Sampling Points Location Summery Table

S. No	Source of Sample	Location Area	Sampling Point	Latitude	Longitude
1	Nalla Passing through 1-9 Islamabad	Near Kataria pull	Nalla water	33.64751	73.05302
2	Nalla Passing through I-10 Islamabad	Near Kataria pull	Nalla water	33.64703	73.05248
3	Nalla Lai	junction point of sample 1 and sample 2	Nalla water	33.64598	73.0533
4	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.64442	73.05339
5	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.64336	73.05283
6	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.64078	73.05268
7	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.63781	73.05282
8	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.63608	73.05097
9	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.62951	73.05406
10	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.62759	73.05152
11	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.62237	73.04975
12	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.61606	73.04974
13	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.60778	73.04801
14	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.60434	73.05501
15	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.59833	73.06665
16	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.59438	73.07526
17	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.5794	73.08917
18	Nalla Lai	From various distance in Nalla Lai	Nalla water	33.55784	73.09714
19	Nalla Lai	End point Of Nalla Lai at Soan Adda	Nalla water	33.55185	73.09873

3.4.3 Microbiological Groundwater Sampling:

Microbial samples of groundwater were collected by using grabe sampling technique (Arifa et al., 2011) and following the internationally recognized sampling procedure "Standard methods for the examination of water and waste water" APHA (2012).

Total (33) samples were collected in the month of October from the study area. Twenty-eight samples out of (33) samples were collected within 100 meter or nearest distance along both sites of Nalla Lai. Among (28) samples, (15) boreholes, (10) tube wells, (1) dug well and (2) springs water samples were collected for microbial testing.

Four control samples were taken from at least 1 km distance along both sites of Nalla. Among (5) control samples, (2) tube wells water and (3) boreholes water samples were collected.

While starting microbial groundwater sampling from IJP toward Soan river, (7) tube wells and (10) boreholes water samples were taken within 100 meter distance along left site of Nalla whereas (4) tube wells, (5) boreholes, (1) dug well and (2) springs water samples were collected within 100 meter distance along right site of Nalla Lai.

During microbial sampling of groundwater the mouth of the tap stand was first ignited with a lighter to remove contamination. Then opened the tap stand and left for 5-10 minutes until the temperature of the water stabilized and flushed out the stagnant water of pipe. 50 ml water samples were collected in sterile container and leaved enough air space in sampling bottle and screwed the cap without touching in inner surface of the bottle and used aseptic method for maintaining samples integrity.

Table 3.4.3: Microbial Sampling Points Location summery Table

S. No	Source of Sample	Location Area	Water Depth in Feet	Sampling Site of Nalla Lai	Sampling Point	Latitude	Longitude
1	Tube well	Kataria Mohallah	280	Left Site	Pipe	33.64536	73.05399
2	Bore water	City Coloney- E-Block	250	Left Site	Hand Pump	33.64088	73.05494
3	Tube well	New Phakware	280	Left Site	Cooler	33.63559	73.05093
4	Tube well	Kashmir Coloney Mujahid Abad	260	Left Site	Cooler	33.62259	73.05012
5	Tube well	Ratta Mohin Pura	250	Left Site	Cooler	33.61174	73.0489
6	Bore water	Itehad Coloney	220	Left Site	Tap stand	33.60496	73.05538
7	Bore water	Aria Mohallah	250	Left Site	Inlet water	33.60551	73.06661
8	Tube well	Dhoke Cherage Deen	270	Left Site	Tap stand	33.59826	73.06983
9	Tube well	Qazi Abad	260	Left Site	Tap stand	33.59504	73.07423
10	Tube well	Chaklal Scheem Askai 3	270	Left Site	Tap stand	33.58738	73.08297
11	Bore water	Askari 1	180	Left Site	Inlet water	33.58149	73.09007
12	Bore water	Chaklala Scheem 3	170	Left Site	Inlet Pipe	33.58034	73.0983
13	Bore water	Dhoke Choderia	140	Left Site	Tap stand	33.57472	73.10104
14	Bore water	Dhoke Choderia	70	Left Site	Cane	33.56981	73.10544
15	Bore water	Bostan Valley	120	Left Site	Bottle	33.56348	73.0993
17	Bore water	High Court Road Timber Market	140	Left Site	Tap stand	33.55815	73.09989
18	Bore water	High Court Road	120	Left Site	Tap stand	33.55595	73.10262
19	Tube well	Amin Abad Khayaban Sir Syed	240	Right Site	Tap stand	33.64529	73.05241

22	Bore water	Hazara Coloney	120	Right Site	Tap stand	33.61918	73.04811
23	Tube well	Ratta Imran Kachey Abaday	250	Right Site	Bucket	33.60672	73.04783
24	Bore water	Darya Abad Gawal Mandey	220	Right Site	Tap stand	33.60724	73.05884
26	Bore water	Ghanda Street-6	120	Right Site	Tap stand	33.59072	73.07602
28	Dug well	Ghulistan Coloney line Numb-3	16	Right Site	Tap stand	33.57458	73.09912
31	Spring	Sua Adda		Right Site	Source water	33.55356	73.0977
32	Spring	Sua Adda Darbar		Right Site	Pipe	33.55477	73.09779
33	Tube well	Serat Gunj	240	Right Site	Tap stand	33.60862	73.05649
34	Bore water	Mohellah Melad Nagar	110	Right Site	Inlet water	33.61102	73.04804
35	Bore water	Ghanda Chichi Street Number-7	120	Right Site	Inlet water	33.592207	73.070487
37	Tube well	Dhoke Paracha	280	Left Site	Tap stand	33.6383	73.08251
40	Bore water	Chaudhery Dhoke Farman Ali	150	Left Site	Hand Pump	33.61053	73.07726
44	Bore water	Pakistan Town	140	Left Site	Inlet water	33.577299	73.148368
46	Bore water	Chak Madad khan	120	Right Site	Tap stand	33.62317	73.02208
47	Tube well	Ali Abad	260	Right Site	Tap stand	33.61405	73.00373

3.5 On Site or Field Analysis:

Some physico-chemical parameters like pH, TDS, Temperature, DO, EC and TDS were tested on the spot in field because their characteristics changes rapidly with time elapsed.

3.5.1 pH Analysis:

Instrument Name: pH Meter.

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 4500 H^+

Theoretical Principle of Method:

The measurement of pH is find out through the activity of H^+ ions by the potentiometric measurement by using a glass electrode and a reference electrode.

The Electromotive force (emf) created in the glass electrode system varies linearly with pH. This linear association is described by plotting the measured emf against the pH of different buffer solutions. The sample pH is determined by extrapolation.

pH Meter Calibration:

The pH instrument was calibrated by dipping the electrode in three standard buffer solutions i.e. buffer 4, buffer 7 and buffer 9.

Analytical Procedure:

- Rinsed pH meter electrode thrice with distilled water and tested the pH of distilled water for bench mark or for a calibration purpose.
- Took water sample in 500 ml beaker and dipped the pH electrode in water sample and pressed Ok button.
- pH value started blinking on the screen. Waited for few seconds till the value stabilized completely then noted the stabilized value of pH.

3.5.2 Temperature Analysis:

Instrument Name: Thermometer.

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 2550.

Theoretical Principle of Method:

The theoretical principle of method depends on the instrument used for the test of temperature. In thermometric instrument the filled mercury or alcohol expansion occurs by increasing temperature.

Analytical Procedure:

Rinsed the thermometer probe with distilled water and immersed into water sample. Allowed the thermometer reading until stabilize completely then noted the stabilized reading in °C.

3.5.3 DO Analysis:

Instrument Name: DO Meter.

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 4500-O

DO Meter Calibration:

DO meter can be calibrated in two ways.

1) Open Air Calibration
2) Zero Calibration: By Using Sodium Sulfide (Na_2S).

Analytical Procedure:

- Rinsed DO meter electrode thrice with distilled water and tested DO of distilled water for bench mark or for a calibration purpose.
- Took water sample in 500 ml beaker and dipped the DO electrode in water sample and pressed Ok button.
- The DO value started blinking on the screen. Waited for few minutes till the value stabilized completely then noted the stabilized value of DO in mg/L.

3.5.4 EC and TDS Analysis:

Instrument Name: TDS Meter.

Analytical Procedure:

Following are the procedural steps for the detecting of EC and TDS in drinking and wastewater samples.

- Took 500 ml pre-washed beaker and filled with water sample.

- On the TDS meter and dipped the electrode in water sample and pressed TDS button. The result of TDS in water sample was displayed on screen in mg/L$^-$. Similarly, pressed EC button of TDS meter the result of EC was displayed on screen in Microsiemen per centimeter.

3.6 Laboratory Analysis:

The chemical parameters of water and wastewater samples were analysed in laboratory by following the standard method prescribed by APHA, 2012.

3.6.1 Chloride Analysis:

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 4500 Cl^-.

Theoretical Principle of the Method:

Potassium chromate can indicate the end point of the silver nitrate titration of chloride in a neutral or slightly alkaline solution. Silver chloride is precipitated quantitatively before red silver chromate is formed.

Analytical Steps:

Chloride in water sample was analysed by preparing reagents in laboratory and following the standard analytical procedure.

i. Reagents Preparation

ii. Analytical Procedure

i. Reagents Preparation:

Following reagents were prepared in a laboratory for the analysis of Chlorides in drinking water samples.

a) Potassium Chromate (K_2CrO_4)

b) Silver Nitrate ($AgNO_3$)

c) Standard Sodium Chloride (NaCl)

a) Potassium Chromate (K_2CrO_4: (Indicator)

Apparatus and Chemicals:

- 12.5 gram of Potassium Chromate
- 50 ml Beaker
- Distilled Water
- Silver Nitrate
- 250 ml Volumetric Flask or Range flask
- Analytical Balance.

Procedure:

Dissolved 12.5 gram of Potassium Chromate in a little distilled water taken in 50 ml beaker and also added few drops of Silver Nitrate unless red precipitate formed. Left the solution stands for 12 hours and then diluted to 250 ml distilled water by using volumetric flask and tightly closed with cap.

b) Silver Nitrate ($AgNO_3$): (Titrant)

Apparatus and Chemicals:

- 1.2 gram Silver Nitrate
- 50 ml Beaker
- Distilled Water
- 500 ml Volumetric Flask or Range flask
- Analytical Balance.

Dissolved 1.2 gram of Silver Nitrate in a little distilled water taken in a 50 ml beaker and finally diluted to 500 ml distilled water by using volumetric flask or range flask and tightly closed with stopper.

c) Standard Sodium Chloride (NaCl): (Used as Standardization).

Apparatus and Chemicals:

- 0.824 gram Sodium Chloride
- 50 ml Beaker
- Distilled Water
- 500 ml Volumetric Flask or Range flask
- Analytical Balance.

Dissolved 0.824 gram of Sodium chloride in a little distilled water by using 50 ml beaker and diluted to 500 ml distilled water by using volumetric flask or range flask and closed with stopper.

ii. Analytical Procedure:

Method:

Argentometry titration method is used for the analysis of Chloride in drinking water.

Analytical Steps:

- Took 50 ml water sample in a titration flask and added few drops of Potassium chromate (Indicator) until the color of water sample changed to yellow.
- Fixed the burette with a stand and filled with titrant Silver Nitrate
- Noted the initial reading of titrant (Silver Nitrate) level in a burette.
- Placed the titration flask containing 50 ml water sample just below the vertical burette tube and on the stopper of burette slowly and adjusted it so that titrant (silver nitrate) drops fell

down slowly in a water sample and shook the titration flask simultaneously until the water sample color changed from yellow to raddish then off the stopper of burette. Noted the final reading of titrant level in burette to find the volume of titrant used for bringing the color of water sample from yellow to raddish. Then minus initial reading of titrant with final reading and noted the result. Repeated the titration process twice or thrice for one sample (to determine the difference of final and initial reading) and then taken the average of two or three results and noted the final value.

For example: (1) Final Reading 20 minus Initial Reading 25 = 5

(2) Final Reading 20 minus Initial Reading 13 =7

Average of two readings: 5+7 divided by 2= 6 ml

Formula:

$$\text{Chloride} = \frac{(A-B)*N*35*450}{\text{ml of sample}}$$

Where, A= Milliliter (ml) titrant for a sample

B= Milliliter (ml) titrant for blank

N= Normality (Silver Nitrate) 0.0141

35= Molecular weight of Chlorine

450= Factor (It deduct from regent or percentage purity).

Put the average value of titration in formula and found exact concentration value of Chloride in drinking water sample in mg/L.

3.6.2 Hardness Analysis:

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 2340 Hardness.

Theoretical Principle of the Method:

EDTA and its salts make a complex solution containing calcium and magnesium. The solution becomes wine red when Eriochrome Black T is added to the solution at pH 10.0 +- 0.1. EDTA has a strong affinity towards Ca^+ and Mg^+ ion. EDTA breaks the wine red complex into new blue colored complex which shows the end point of titration.

Analytical Steps:

Hardness of water sample can be analysed by the preparation of necessary reagents in laboratory and following the standard analytical procedure.

i. Reagents Preparation.

ii. Analytical Procedure.

i. Reagents Preparation:

Following are the necessary reagents prerequisite to prepared in laboratory before the analysis of Hardness parameter.

a) Ethylenediaminetetraacetic Acid (EDTA)

b) Buffer Solution

c) Eriochrome Black T (EDT)

a) Ethylenediaminetetraacetic Acid (EDTA): (Titrant)

First weighed 1.8615 gram of Ehtylenediaminetetraacetic acid in electronic balance then dissolved in 500 ml distilled water by using volumetric flask.

b) Buffer Solution:

- Weighed 6.76 gram of Ammonium chloride (NH_4Cl) in weighing balance.

- Weighed 0.5 gram of Dimagnesium salt of EDTA in electronic balance.
- Measured 57.2 ml Ammonium hydroxide (NH_4OH) in graduated cylinder.

Dissolved 6.76 gram of Ammonium chloride (NH_4Cl) in 57.2 ml Ammonium hydroxide (NH_4OH) and added 0.5 gram of Dimagnesium salt of EDTA and finally diluted in 100 ml of distilled water by using volumetric flask.

c) Eriochrome Black T (EDT): (Indicator)

Weighed 0.25 gram EDT and 2.25 gram of hydroxylamine hydrochloride and dissolved in 50 ml Ethyl Alcohol or Ethanol.

ii. Analytical Procedure:

- Took 50 ml water sample in a titration flask and added 2 ml buffer solution by using pipet.
- Added few drops of EDT (Indicator) in water sample to bring pink color.
- Fixed the burette with a stand and filled with titrant Ethylenediaminetetraacetic acid (EDTA).
- Noted initial reading of titrant (EDTA) level in burette.
- Placed the titration flask containing 50 ml water sample just below the vertical burette tube and on the stopper of burette slowly and adjusted it so that titrant (EDTA) drops fell down slowly into a water sample and shook the titration flask water sample simultaneously until the water sample color changed from pink to blue then off the stopper of burette. Noted the final reading of titrant level in burette to find the volume of titrant used for bringing the color of water sample from pink to blue. Then minus initial reading of titrant level with final reading and noted the result. Repeated the titration process twice or thrice for one sample and then taken average of two or three results and noted the final value. **For example:**

(1) Initial Reading 30 minus Final Reading 15 = 15

(2) Initial Reading 15 minus Final Reading 8 =7

(3) Initial Reading 8 minus Final Reading 2 = 6

Average of two readings: 15+7+6 divided by 3= 9.3

Formula:

Hardness= A*B*1000

ml of sample

Where, A=Sample-Blank (0.1)

B= Mg calcium carbonate equivalent to 1 ml EDTA (Normality= 1)

Put the value of titration in the formula and got result of hardness concentration in drinking water sample in mg/L⁻.

3.6.3 Sulphate Analysis:

Name of Instrument: UV/ Visible Spectrophotometer.

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 4500-SO4.

Theoretical Principle of the Method:

Sulfate (-SO_4) is precipitated in a Hydrochloride acid solution as Barium sulfate by the addition of Barium Chloride.

Principle of the Instrument:

- It is a single beam scanning instrument with spectral analysis software and it is equipped with a single monochromatic and a silicon photodiode detector and has a rage of 190 to 1100 nm and a band pass of 2 nm.

- Ultraviolet-Visible spectroscopy provides information about structure formulation and stability of material in a solution.
- It can analyzed both solids and liquids concentrations in parts per million (ppm).
- Absorption spectra are produced when ions or molecules absorb electromagnetic radiations in the visible or ultra violet regions. The absorption intensity is proportional to the number, type and location of color absorbing structure in the molecule.

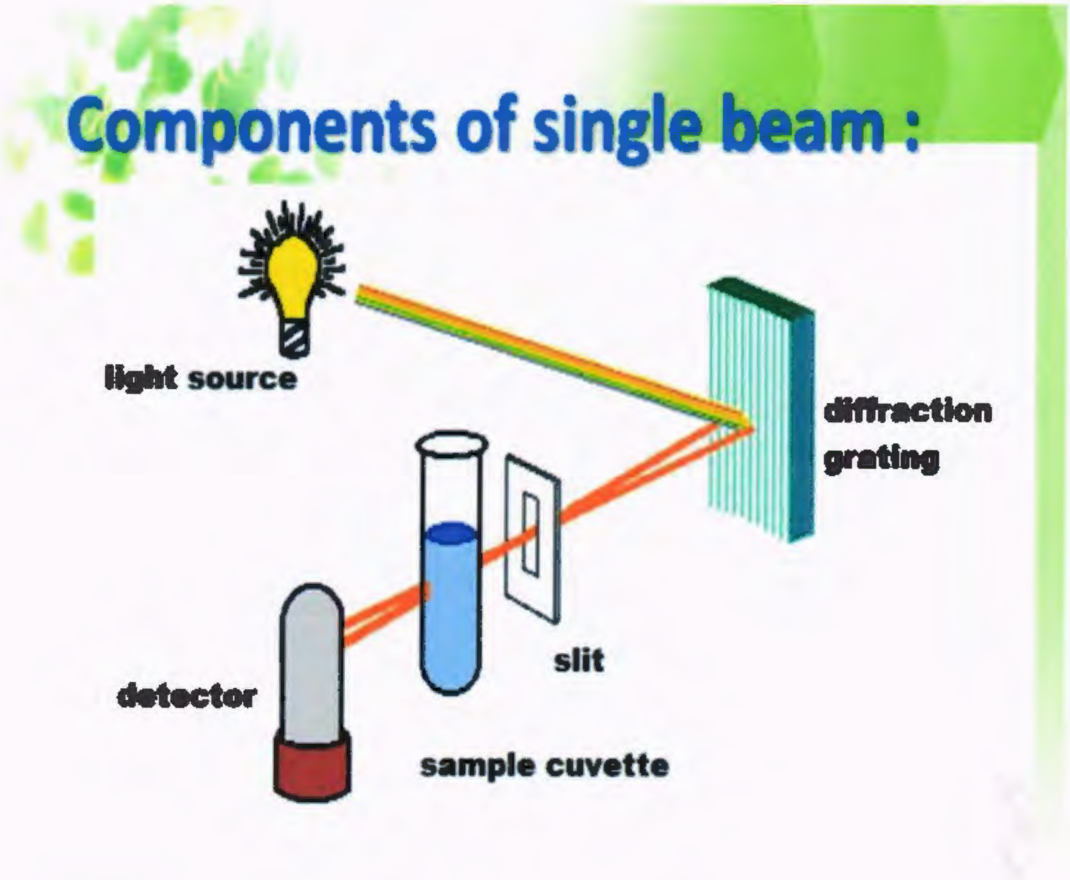


Figure: 3.6.3 Working Principle of UV Spectrophotometer.

Analytical Steps:

Sulphate in water sample can be analysed by preparing its requisite reagents and following the standard analytical procedure.

i. Reagents Preparation

ii. Analytical Procedure

i. Reagents Preparation:

The analysis of sulphate requires the following two necessary reagents to prepare in laboratory.

a) Buffer Reagent

b) Barium Chloride

a) Buffer Reagent:

- First weighed 15 gram Magnesium Chloride ($MgCl_2.6H_2O$), 2.5 gram Sodium Acetate ($CH_3COONaO_2$) and 0.5 gram of Potassium Nitrate (KNO_3)
- Dissolved 15 gram Magnesium Chloride, 2.5 gram Sodium Acetate and 0.5 gram of Potassium Nitrate in 10 ml Acetic acid (CH_3CHOOH) and diluted in 500 ml distilled water by using volumetric flask.

b) Barium Chloride:

Weighed 1 gram barium chloride by analytical balance.

ii. Analytical procedure:

Took 50 ml water sample and added 5 ml buffer reagent and dissolved 1 gram Barium Chloride. Left the sample for at least one hour for precipitate formation. Then analysed the sample in UV-VIS Spectrophotometer. Inserted the analysed values in excel sheet (formula) and got the accurate concentration result of sulphate in drinking water sample in mg/L^{-}.

3.6.4 Chemical Oxygen Demand (COD) Analysis:

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 5220.

Theoretical Principle of the Method:

Potassium dichromate solution act as an oxidizer which is refluxed with the water sample in an acidic medium and the oxygen reacted is measured by the back titration of residual potassium dichromate solution with a standard ammonium iron sulfate solution.

Analytical Steps:

Chemical Oxygen Demand (COD) of wastewater samples can be analysed by preparing the necessary reagents and following the standard analytical procedure.

i. Reagents Preparation

ii. Analytical Procedure

i. Reagents preparation:

Following were the required prerequisite reagents prepared in laboratory before the analysis of Chemical Oxygen Demand (COD).

a) Potassium Dichromate ($K_2Cr_2O_7$)

b) Sulfuric Acid (H_2SO_4) reagent

c) Mercuric Acid ($HgSO_4$)

d) Ferrous Ammonium Sulfate ($Fe\ (NH_4)_2(SO_4)_2.6H_2O$

e) Ferroin Indicator

a) Potassium Dichromate ($K_2Cr_2O_7$):

Weighed 12.25 gram of Potassium dichromate in analytical balance and dried in oven machine (to evaporate water vapors) then dissolved in 1000 ml distilled water.

b) Sulfuric Acid (H_2SO_4) Reagent:

Dissolved 5.5 gram of Silver Sulfate (Ag_2SO_4) in 1 liter Sulfuric acid (H_2SO_4) of analytical grade.

c) Mercuric Acid ($HgSO_4$):

Weighed 1 gram of Mercuric Sulfate in a weight machine.

d) Ferrous Ammonium Sulfate ($Fe\ (NH_4)_2(SO_4)_2\ {}_6H_2O$:

Dissolved 20 gram of Ferrous Ammonium Sulfate in little distilled water taken in 100 ml beaker and added 10 ml Sulfuric acid (H_2SO_4) of analytical grade and diluted to 500 ml distilled water by using volumetric flask.

e) Ferroin Indicator:

Dissolved 1.485 gram of 1, 10 Phenanthroline monohydrate and 0.695 gram of Ferrous Sulfate ($FeSO_4.7H_2O$) in 100 ml distilled water by using measuring cylinder

ii. Analytical Procedure:

- Took 50 ml wastewater sample in 250 ml Round Bottom Flasks.
- Added 5 ml Potassium dichromate (Oxidizing agent) and 15 ml sulfuric acid in wastewater samples.
- Added 1 gram of mercuric sulfate in wastewater samples and shook well and mixed thoroughly.
- Attached the round bottom flasks containing wastewater samples to the condenser in Draft Chamber and refluxed the mixtures for 2 hours.

- After two hours cooled the samples and washed the condenser with little distilled water.
- Started Titration of solutions with Ferrous Ammonium Sulfate (Titrant) using 3-5 drops of Ferroin indicator, color changed from blue green to raddish brown. Run the blank sample similarly.

Note: Blue green color appeared in wastewaters due to Ferroin indicator drops whereas radish brown color appeared after titration. Noted the final reading of titrant level in burette to find the volume of titrant used for bringing the color of wastewater sample from blue green to raddish brown. Then minus initial reading of titrant level with final reading and noted the value.

COD Formula:

$$\textbf{COD} = \frac{\textbf{(A-B)*C*8*100}}{\textbf{Vol of sample}}$$

Where, A= Blank

B=Sample

C=0.1 (Normality value of FAS)

Put the titration value of wastewater samples in COD formula and got exact concentration value of COD in wastewater sample in mg/L^{-}.

3.6.5 Biological Oxygen Demand (BOD) Analysis:

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 5210.

Theoretical Principle of the Procedure:

The BOD test measures the molecular oxygen utilized during the 5 days incubation period for the biochemical degradation of organic material and the oxygen used to oxidize the inorganic material such as sulfates and ferrous ions. It also measures the amount of oxygen used to oxidize reduced form of nitrogen unless their oxygen is prevalent by an inhibitor. The seeding and dilution provides an estimate of BOD at pH 6.5 to 7.5.

Analytical Steps:

Biological Oxygen Demand (BOD) of wastewater can be analysed by preparing the necessary reagents and following the standard analytical procedure.

i. Reagents Preparation

ii. Analytical Procedure

i. Reagents preparation:

Following were the prerequisite reagents prepared in laboratory before the analysis of Biological Oxygen Demand (BOD).

a) Phosphate Buffer Solution

b) Magnesium Sulfate Solution ($MgSO_4.7H_2O$).

c) Calcium Chloride Solution ($CaCl_2$)

d) Ferrous Chloride or Iron Chloride ($FeCl_3.6H_2O$).

e) Dilution Water

a) Phosphate Buffer solution:

First weighed the chemicals by analytical balance and then dissolved 8.5 gram of potassium dihydrogen phosphate (KH_2PO_4), 21.75 gram of dipotassium hydrogen phosphate (K_2HPO_4), 33.4 gram of disodium hydrogen phosphate (Na_2HPO_4) and 1.7 gram of Ammonium Chloride (NH_4Cl) in 500 milliliter (ml) distilled water and diluted in 1 liter with pH of buffer solution 7.2.

b) Magnesium Sulfate Solution ($MgSO_4.7H_2O$):

Dissolved 22.5 gram of magnesium sulfate solution in little distilled water and diluted to 1 litre distilled water by using volumetric cylinder.

c) Calcium Chloride Solution ($CaCl_2$):

Dissolved 27.5 gram anhydrous calcium chloride in a little distilled water and diluted to 1 litre distilled water

d) Ferrous Chloride or Iron Chloride ($FeCl_3.6H_2O$):

Dissolved 0.25 gram Ferric Chloride in a little distilled water and diluted in 1 litre distilled water.

e) Dilution Water:

Put 1 liter of each phosphate buffer, magnesium sulfate, calcium chloride and ferric chloride in 1 litre distilled water and then started aeration by using motor pump in order to dissolve maximum concentration of oxygen level in dilution water, and then stored it at 20 °C for at least one week. If dilution water is to be stored in incubator then add phosphate buffer solution just prior to using the dilution water.

ii. Analytical Procedure:

- Took BOD bottles and put 5 ml wastewater sample in each bottle.
- Filled the remaining space of BOD bottles with dilution water.
- Measured the initial dissolved oxygen (DO) of each sample by DO meter.
- Placed the stopper cap on each BOD bottle that no air incubated. Kept all BOD bottles at 20 °C in an incubator for 5 days.
- After five days measured the final DO value and also measured the DO of blank sample and put the values in BOD formula.

BOD Formula with Example:

Table 3.6.5: BOD Formula with Example

	Blank	Sample
Volume of sample (ml)	0	5
Volume of dilution water	300ml	294
Decimal fraction of sample....p		5/300=0.02
Initial DO (mg/L^{-1})= D1	6.20	6.39
Final DO (mg/L^{-1}) =D2	5.20	4.86
Db (blank)= D1-D2	6.20-5.20=1	
D3 = (D2(sample)+Db)	NA	4.86+1=5.86
Difference (D1(sample)-D3)	NA	6.39-5.86 = 0.53
BOD =Difference/p	NA	0.53/0.02= 26.5
BOD of imaginary sample is	26.5 Ans.	

3.6.6 Turbidity and Color Analysis:

Instrument Name: Water Analyzer.

Reference Method of Turbidity Analysis:

Standard methods for the examination of water and wastewater 22th edition, part 2130.

Theoretical Principle of the Method:

The principle of turbidity is based on light absorption and scattering by suspended or colloidal particles in water sample. Higher will be the turbidity of a sample higher will be scattering of light.

Analytical Procedure:

On the water analyzer instrument and opened the cap and put little water sample in a quartz cell and placed in the Water Analyzer instrument and pressed ok buton. The screen displayed results of both Color in TCU and Turbidity in NTU.

3.6.7 Heavy Metals Analysis:

Instrument Name: Atomic Absorption Spectrometer (AAS).

Gases Used in AAS: Acetylene, Nitrous oxide and Air.

Reference:

Standard methods for the examination of water and wastewater 22th edition, part 3110.

Theoretical Principle of Method:

The sample is aspirated in to a flame which atomizes the heavy metals present in the water sample. A beam of light with a particular wavelength is generated by a hollow cathode lamp and passes through a monochromator. The atomized heavy metals particles absorb the light which finally detects by the detector. The amount of light absorb by the energized particle, absorbance is calculated according to bear Lambert Law from which sample concentration can be calculated.

Working Principle of Instrument:

- The Perkin Elmer AAS Analyst 800 high-performance Atomic Absorption Spectrometer with Win Lab 32 for AA software features an automated motorized atomizer exchange that allows switching between flame and graphite furnace AA by a simple software command.

- The instrument is equipped with a high performance burner system, Total flow gas controls for flame AA and a Transversely Heated Graphite Furnace (THGA) with longitudinal Zeeman-effect background corrector.

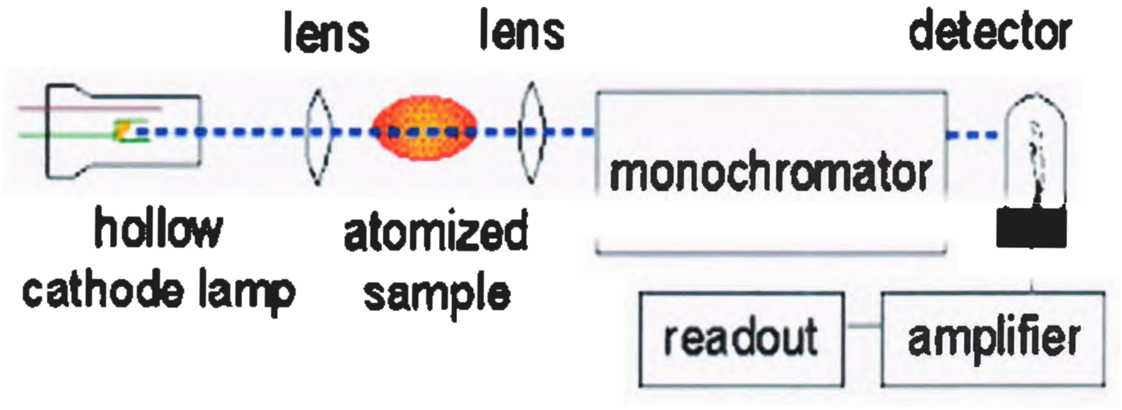


Figure 3.6.7: Working Principle of Atomic Absorption Spectrometer (AAS)

Analytical Procedure:

Preliminary Treatment of wastewater Samples:

The pretreatment of wastewater samples are required before analysis. The preliminary treatments of wastewater samples can be done in two steps.

a) Filtration of Wastewater Sample.

b) Digestion of Wastewater Sample.

a) Filtration of wastewater sample:

Apparatus:

- Filter Paper
- Filtration Assembly
- Suction Pump
- 500 ml Beakers

The vacuum filtration of wastewater sample was done through a porous filter membrane of 0.45 micro meter in size. It is a fast and effective filtration technique than gravity and hot filtration. First of all fixed the filter paper in filtration assembly and placed 500 ml prewashed empty beaker below the filtration assembly pipe. On the suction pump and created vacuum in inner portion of filter flask assembly. Took sample water in 500 ml pre-washed beaker and put in filtration assembly gradually. The sample water was filtered through the filter paper and passed through filtration assembly and finally stored in a 500 ml beaker which was placed below the filtration assembly.

b) Digestion of wastewater samples:

The digestion of wastewater samples was done before analysing in Atomic Absorption Spectrometer (ASS) through the following steps.

- Took 100 ml wastewater sample in a beaker or china dish and added 10 ml nitric acid (HNO3).
- Heated the sample on hot plate or water bath till the sample reached to 10 ml.
- Made up the volume of sample till 100 ml by adding distilled water.

Analytical Steps: Stock solution A= 1000 μ gram/ml

Ist make stock solution B of 10 ppm:

$$\frac{10*100}{1000} = 1$$

Where, 100 is volume of stock solution B

1000 is volume of stock solution A

1 is volume of stock solution A in ml to make 10 ppm stock solution B of 100 ml.

- Made at least three standards and one blank sample for results accuracy according to the standard vule of parameter set by WHO or NSDWQ, 2010.

For Example:

i. **Standard1** = 1 ppm $\frac{\mathbf{1*20}}{\mathbf{100}} = 0.2$

Where, 20 is volume of standard 1 100 is volume of stock solution B

0.2 is volume of stock solution B in ml to make 1 ppm “standard solution1” of 20 ml.

ii. **Standard 2** = 2 ppm $\frac{\mathbf{2*20}}{\mathbf{100}} = 0.4$

Where, 20 is volume of standard 2 100 is volume of stock solution B

0.4 is volume of stock solution B in ml to make 2 ppm “standard solution 2” of 20 ml.

iii. **Standard 3** = 3 ppm $\frac{\mathbf{3*20}}{\mathbf{100}} = 0.6$

Where, 20 is volume of standard 3 100 is volume of stock solution B

0.6 is volume of stock solution B in ml to make 3 ppm “standard solution 3” of 20 ml.

Analysis of Samples in Atomic Absorption Spectrometer:

Following the key steps to run the drinking and wastewater samples in AAS.

- Opened Air Pressure of Pump
- Opened the Instrument
- Opened Acetylene Gas
- Clicked the software and on the Flame and set the Lump to analyzed metal.
- Placed the blank sample first and dipped the nebulizer in it. The nebulizer sucked the blank sample towards flame. The graph on computer screen showed the calibration curve accuracy.
- Placed standard 1, 2 and 3 one by one and checked the calibration curve result.

- The calibration curve showed the correct result then placed the water samples one by one and dipped in nebulizer for analysis. The results of samples were displayed on computer screen in mg/L^{-1}.

3.6.8 E.Coli Analysis:

Reference:

(Aamir et al., 2015) and Standard methods for the examination of water and wastewater 22th edition, part 9225.

Analytical Procedure:

Following are the procedural steps of E.coli detection in drinking water samples.

- Took 50 ml water sample in sterile container and put blister pack with care and shaked well to dissolve the granules and did not touch the inner part of container.
- Put the container at room temperature for 48 hours.
- Checked the color of sample container after 48 hours. The color changed of Blue and Green showed bacterial contamination which indicated that water was not potable for drinking purpose and some sample showed yellow, off white, brownish or no change in color which meant water was fit for drinking purpose.

36	7.53	25	0	5.39	6.56	472	383	25.60	17.54	480	BDL	BDL	BDL	0.091	BDL	BDL	
37	7.54	22	0	5.63	6.34	332	272	13.9	12.21	452	BDL	BDL	BDL	0.089	BDL	0.018	+ve
38	7.28	23	0	5.36	5.23	445	366	20.4	18.7	464	BDL	BDL	BDL	0.091	BDL	BDL	
39	7.70	22	0	4.74	6.43	376	291	17.44	13.10	564	BDL	BDL	BDL	0.082	BDL	1.036	
40	7.47	23	0	5.94	5.31	387	301	18.09	10	480	0.016	BDL	BDL	0.149	BDL	0.785	+ve
41	7.64	21	0	6.56	6.08	373	288	14.21	8.43	524	0.021	BDL	BDL	0.164	BDL	0.250	
42	7.12	22	0	4.90	5.75	468	392	21.36	28	412	0.023	BDL	BDL	0.301	BDL	0.018	
43	7.29	22	0	5.26	5.15	327	275	15.07	10.7	628	0.036	BDL	BDL	0.120	BDL	1.337	
44	7.44	22	0	4.90	6.78	462	378	20.37	19.32	408	0.008	BDL	BDL	0.104	BDL	0.041	-ve
45	7.26	22	0	8.17	3.93	701	597	15.52	50	448	0.009	BDL	0.316	0.569	BDL	3.242	
46	7.19	23	0	5.31	5.49	524	435	22.19	24.20	576	0.007	BDL	BDL	0.098	BDL	0.051	-ve
47	7.19	23	0	4.43	5.17	605	503	37.17	36.2	844	0.021	BDL	BDL	0.161	BDL	0.010	+ve
48	7.02	21	0	5.21	5.75	653	535	27.86	43.74	788	BDL	BDL	BDL	0.170	BDL	6.195	
49	7.03	22	0	5.81	5.56	607	506	17.7	68.17	732	BDL	BDL	BDL	0.269	BDL	0.200	

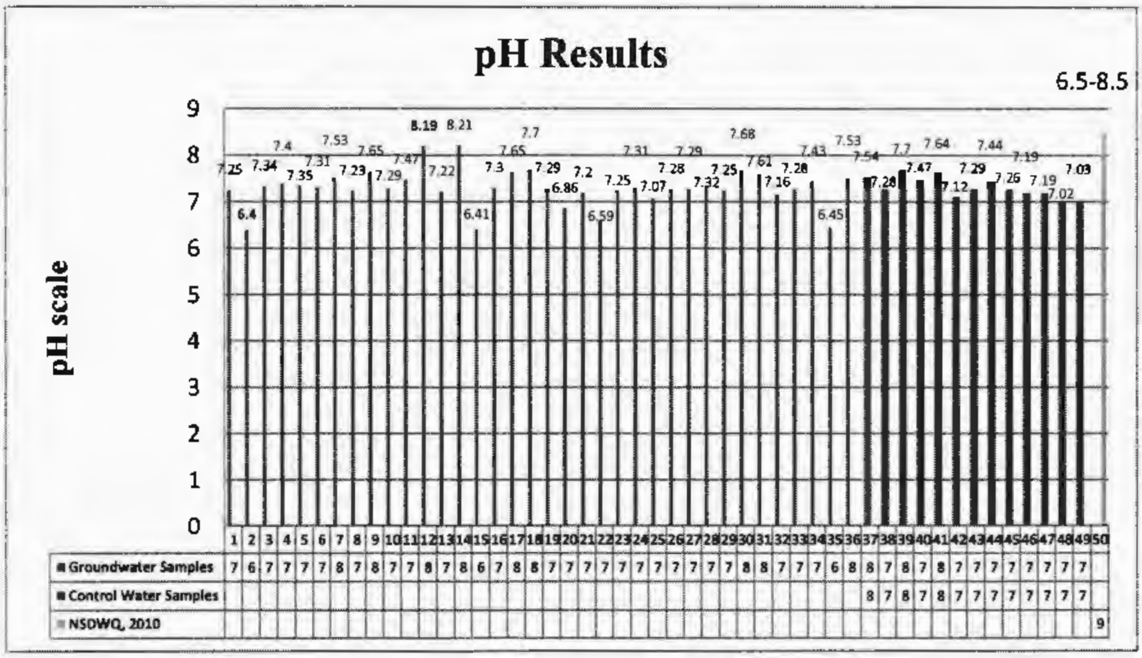
WASTE WATER PARAMETERS

S. No	pH 6-10 NEQS 1997	Temp 40 °C NEQS 1997	Turbidity NGVS	DO No Limit Listed	EC NGVS	-SO4 600 mg/$^{L-1}$ NEQS 1997	Cl- 1000 mg/$^{L-1}$ NEQS 1997	Cd 0.1 mg/$^{L-1}$ (NEQS 1997)	Cu 1 mg/$^{L-1}$ (NEQS 1997)	Fe 2 mg/$^{L-1}$ (NEQS 1997	Mn 1.5 mg/$^{L-1}$ NEQS 1997	Pb 0.5 mg/$^{L-1}$ (NEQS 1997)	Zn 5 mg/$^{L-1}$ (NEQS 1997)	BOD 80 mg/$^{L-1}$ (NEQS 1997)	COD 150 mg/$^{L-1}$ (NEQS 1997)
1	7.54	20	4547.34	0.94	1271	21.9	60	0.3	0.204	4.479	1.483	0.012	1.046	168	296
2	7.66	26	2625	2.05	1377	22.76	55.6	0.22	BDL	1.212	0.150	0.182	2.046	66	168
3	7.63	27	3113	1.03	1365	19.81	55.6	0.016	BDL	3.134	0.176	BDL	0.066	112	243
4	7.71	25	3689	0.33	1396	24.20	54.18	BDL	0.161	0.392	0.161	BDL	0.076	121	276
5	7.68	25	2057.11	0.74	1529	23.30	46.62	BDL	0.012	BDL	0.189	BDL	2.214	93	229
6	7.67	25	3635.84	0.15	1492	22.22	57.28	BDL	0.016	BDL	0.161	BDL	0.048	186	315
7	7.70	26	3645.65	0.24	1557	23.12	55.06	BDL	BDL	0.149	0.490	BDL	0.061	161	311
8	7.72	26	3359.74	0.16	1242	23.6	57.4	0.120	BDL	BDL	0.251	BDL	0.071	168	312
9	7.68	29	2313.49	0.26	1342	23.05	49.4	BDL	BDL	0.186	0.215	BDL	0.063	121	291
10	7.71	29	2111.69	1.04	1349	23.9	46.62	0.159	0.013	0.125	0.315	BDL	0.057	89	175
11	7.70	28	2543	0.65	1367	24.6	47.06	0.095	BDL	0.121	0.188	BDL	0.213	89	222
12	7.73	29	3030	0.63	1372	22.9	46.62	0.007	BDL	0.315	0.212	0.268	4.201	91	219
13	7.69	29	3343.74	0.35	1395	25.02	61.4	0.020	BDL	BDL	0.312	BDL	0.059	96	228
14	7.74	28	2981.84	0.81	1390	24.3	7.6	0.006	0.091	BDL	0.612	BDL	0.129	78	196
15	7.72	29	3399	1.14	1397	23.30	61.72	0.015	BDL	0.357	0.215	BDL	0.059	78	168
16	7.69	28	4215.73	0.69	1427	24.52	66.16	BDL	0.013	2.173	0.610	BDL	0.120	91	221
17	7.62	27	3186	0.26	1430	24.23	75.06	0.143	BDL	1.635	0.219	BDL	0.204	119	272
18	7.97	28	4155	2.96	1472	24.34	79.6	0.012	BDL	0.822	0.237	BDL	2.213	78	176
19	7.94	29	3390	2.67	1474	27.21	72.4	0.015	BDL	0.118	0.521	BDL	0.064	60	170

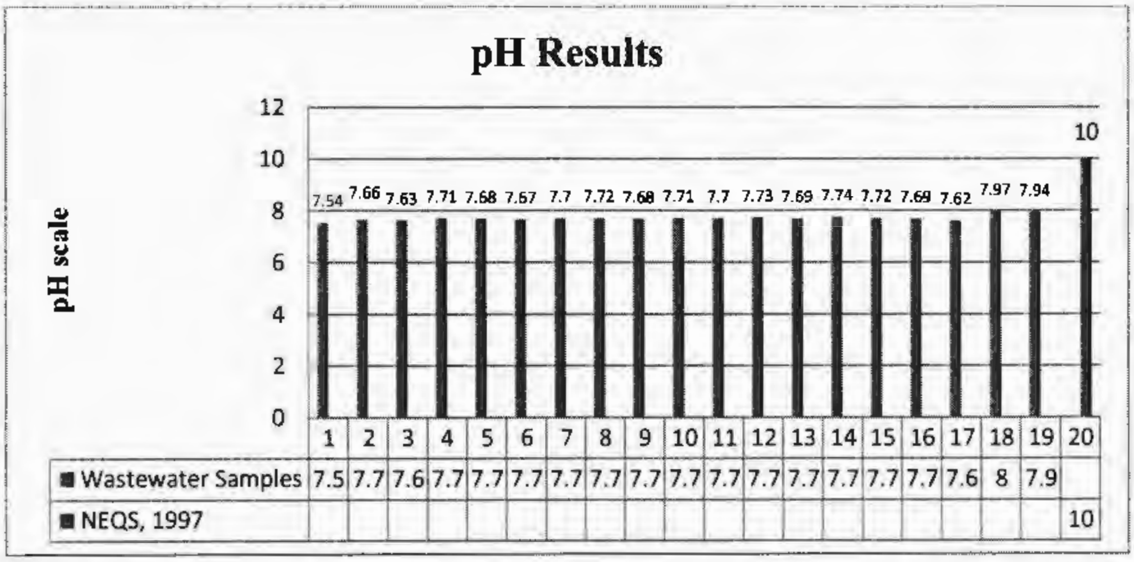
Table 4 B: Physico-Chemical and Microbial Results of Permissible Limit Value Crossed Groundwater Samples And High Concentration Zones Within 100 Meter Distance Along Both Sites of Nalla Lai

Parameters	Standard Values WHO, NSDWQ, 2010	Groundwater High Concentration Zones Within 100 Meter Distance From Nalla Lai			Permissible Limit Value Crossed of GW Samples Within 100 Meter Distance
Cadmium	0.01, 0.003mg/l	S#2 (B) 0.028 mg/l	S#16 (B) 0.021 mg/l	S#33 (T) 0.019 mg/l	S#23 Tube well (T) S#28 Bore water (B)
Iron	0.3 mg/l	S#2 (B) 4.757 mg/l	S# 35 (B) 2.933 mg/l	S#22 (B) 2.914 mg/l	S#28 (D), S#12 (B), S#32 (S), S#17 (B), S#10 (T), S#19 (T), S#11 (B)
Manganese	0.5 mg/l	S# 28 (D) 0.853 mg/l	S# 2 (B) 0.685 mg/l	S#34 (B) 0.629 mg/l	S#35 (B)
Zinc	5 mg/l	S#29 (B) 5.108 mg/l			
TDS	1000 mg/l	S#13 (B) 1007 mg/l			
pH	6.5-8.5	S#2 (B) 6.40	S#15 (B) 6.41	S#35(B) 6.45	
Color	15 TCU	S# 28 (D) 17.89 TCU			
Hardness	500 mg/l	S#26 (B) 1564 mg/l	S#12 (B) 1528 mg/l	S#21(B) 1144 mg/l	17 Bore water (B), 11 Tube wells (T), 1Spring (S), 1 Dug well (D)
E.Coli	0/100 ml	12 Bore water, 9 Tubewells, 2 Springs and 1 Dug well			

4.1 pH:



Graph 4.1: pH Variations in Groundwater Samples.



Graph 4.1.1: pH Variations in Wastewater Samples.

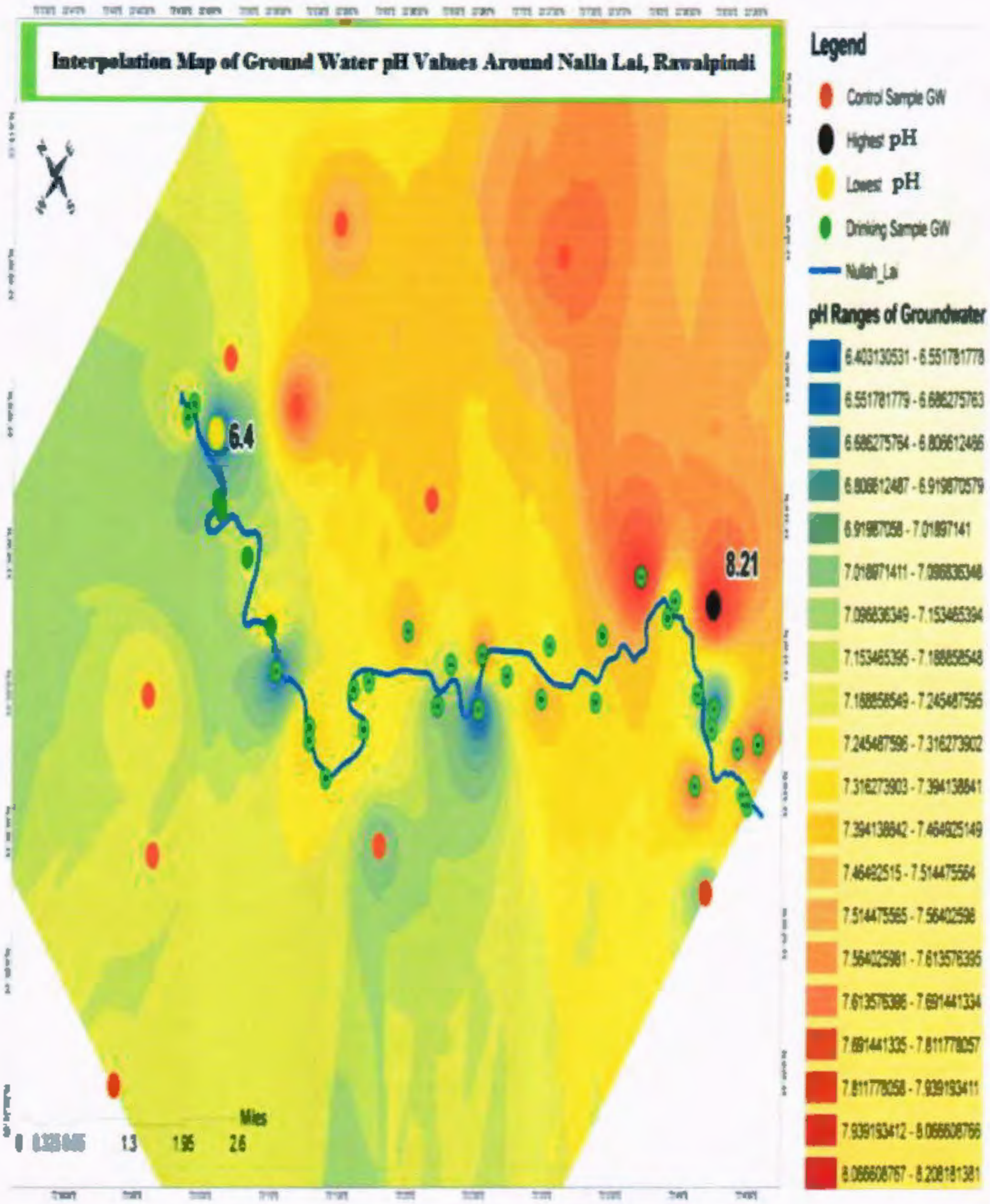


Figure 4.1: Interpolation Map Showing Highest and Lowest pH Location Points of Groundwater.

Table 4.1: Permissible Limit Value Crossed pH Sample of Groundwater

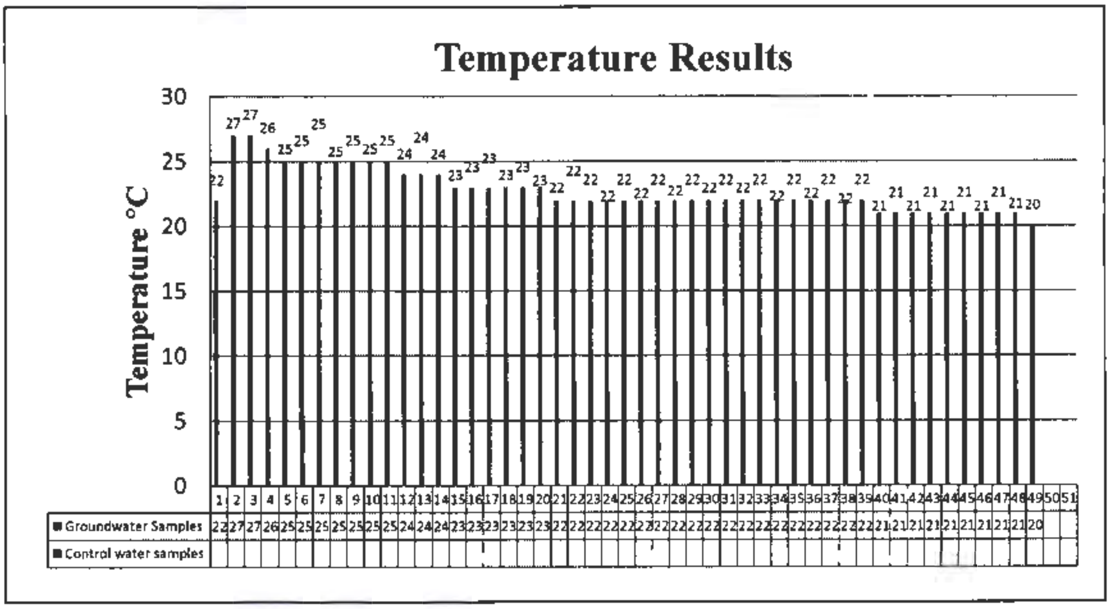
S.No	pH Concentration	Sample Number	Source of Water	Permissible Limit 6.5-8.5 NSDWQ, 2010
1	6.4	2	Hand pump Bore water	

pH stands for potential hydrogen. It determines the concentration of hydrogen ions in a solution. When pH level decreases metals solubility increases in water (JICA, 2005). It specifies the acidity and basicity of water. pH values ranging from 7-14 are alkaline or basic. pH values from 0-7 are acidic whereas 7 pH is neutral (Devendra et al., 2014).

The standard value for pH in drinking water is between the range of 6.5-8.5 (NSDWQ, 2010). The average value of pH in (49) groundwater samples was 7.30. Highest pH value in groundwater samples was 8.21 which was detected in sample#14 of bore water. Lowest pH value in groundwater samples was 6.4 which was observed in sample#2 of hand pump bore water. The lowest pH value was exceeding the drinking water quality standard.

The standard value for pH in wastewater is between the range of 6-10 (NEQS, 1997). The average pH value in (19) wastewater samples was 7.71. Highest pH value in wastewater samples was 7.97 which was analysed in sample#18 whereas lowest pH value in wastewater samples was 7.54 which was detected in sample#1.

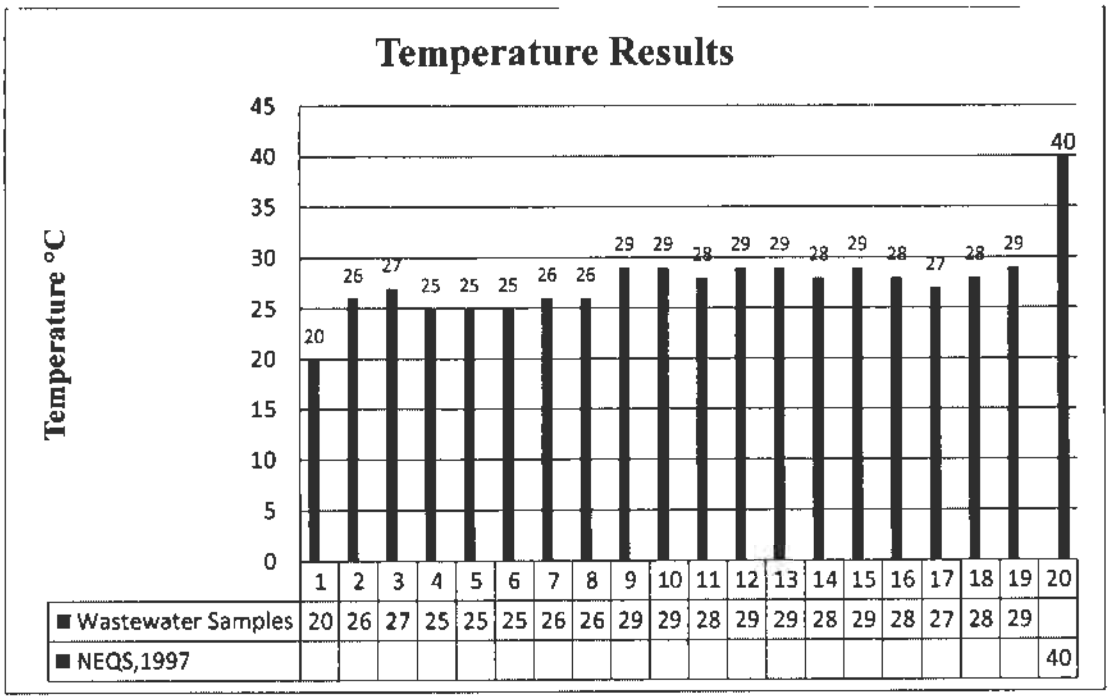
4.2 Temperature:



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
■ Groundwater Samples	22	27	27	26	25	25	25	25	25	25	25	24	24	24	23	23	23	23	23	23	22	22	22	22	22	22
■ Control water samples																										

	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
■ Groundwater Samples	22	22	22	22	22	22	22	22	22	22	22	22	22	21	21	21	21	21	21	21	21	21	20		
■ Control water samples																									

Graph 4.2: Temperature Variations in Groundwater Samples.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
■ Wastewater Samples	20	26	27	25	25	25	26	26	29	29	28	29	29	28	29	28	27	28	29	
■ NEQS,1997																				40

Graph 4.2.1: Temperature Variations in Wastewater Samples.

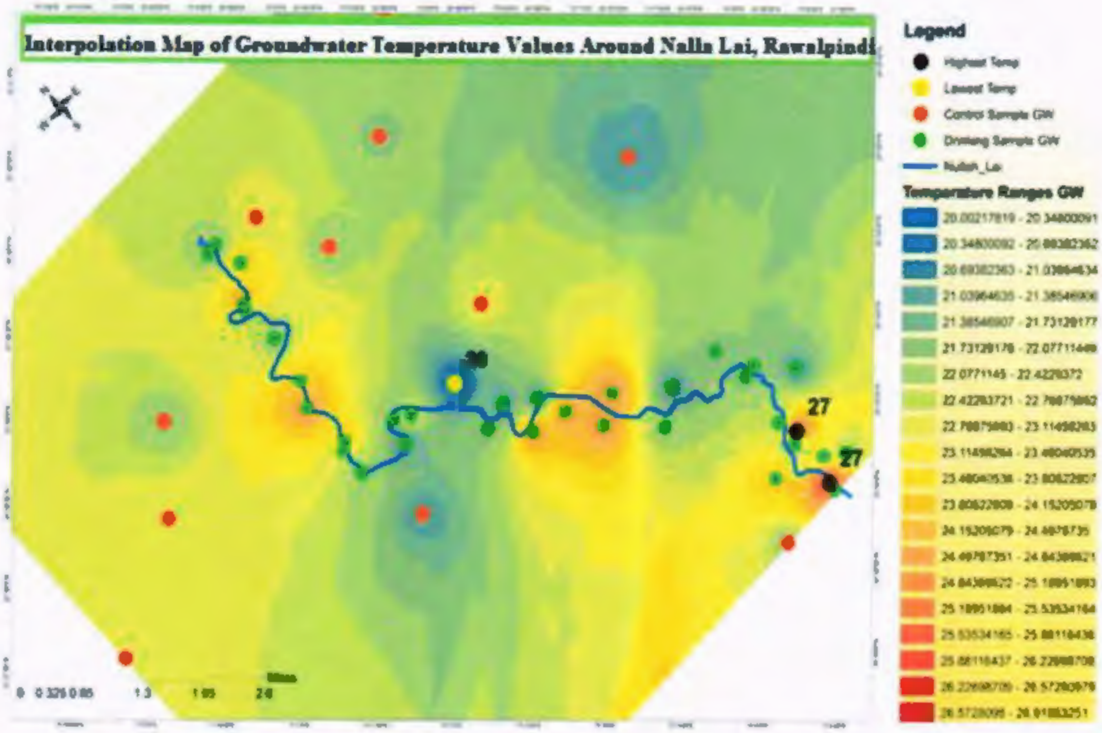
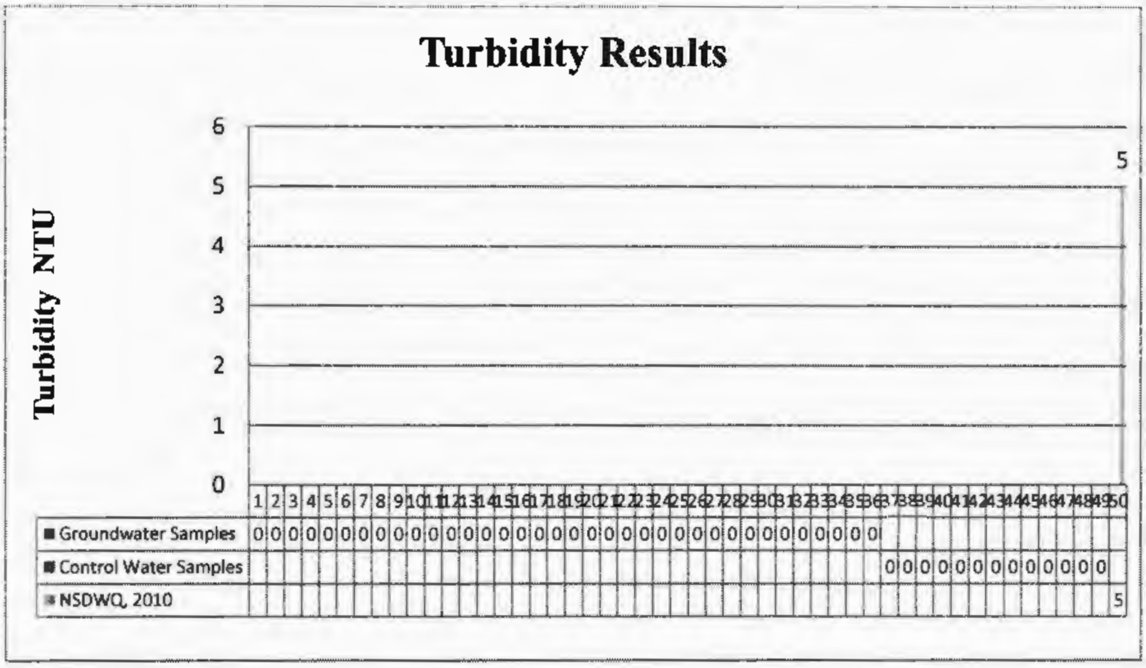


Figure 4.2: Interpolation Map Showing Highest and Lowest Temperature Location Points of Groundwater.

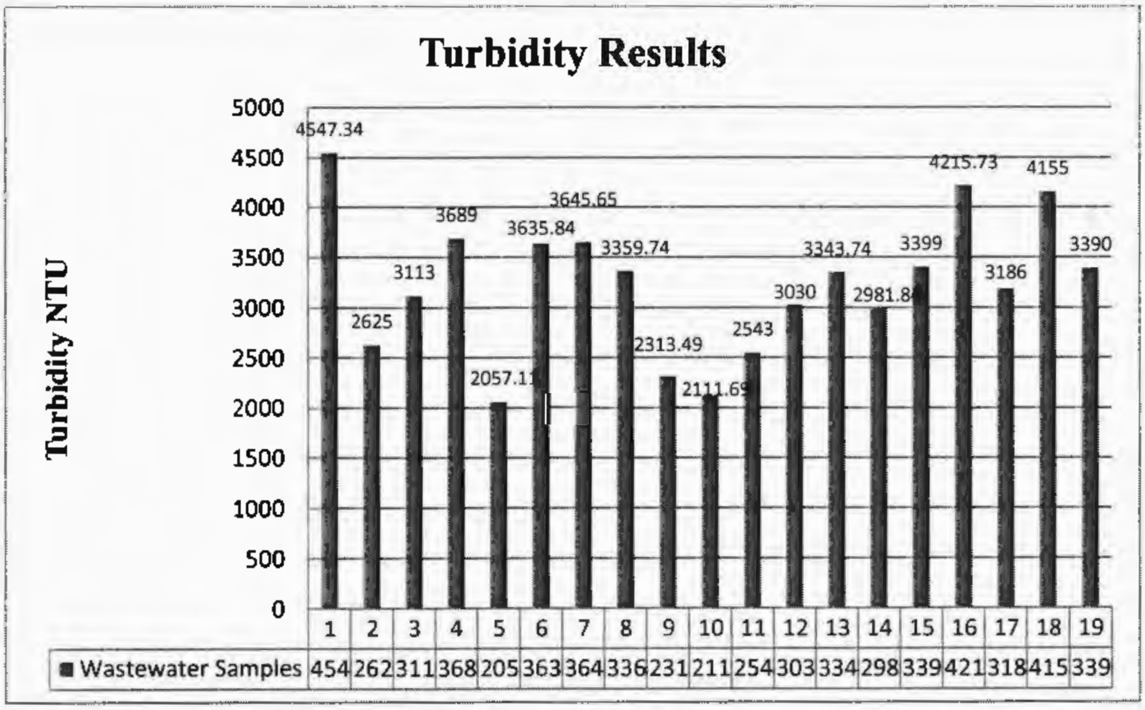
Temperature is a significant indicator of water quality in relation to the existence of aquatic life (Tariq et al., 2016). Air temperature has a slight effect on groundwater but key effect on surface water of low velocity (Kirten et al., 2016).

The average value of temperature in (49) groundwater samples was 22.73 °C. Highest value of temperature in groundwater samples was 27 °C which was analysed in sample#15 and sample#32. Lowest value of temperature in groundwater samples was 20 °C which was observed in sample#7. The standard value for temperature in wastewater is 40 °C (NEQS, 1997). The average value of temperature in (19) wastewater samples was 27 °C. Highest value of temperature in wastewater samples was 29 °C which was analysed in sample#9, sample#10, sample#12, sample#13, sample#15 and sample#19. Lowest temperature value in wastewater samples was 20 °C which was detected in sample#1.

4.3 Turbidity:



Graph 4.3: Turbidity Variations in Groundwater Samples.



Graph 4.3.1: Turbidity Variations in Wastewater Samples.

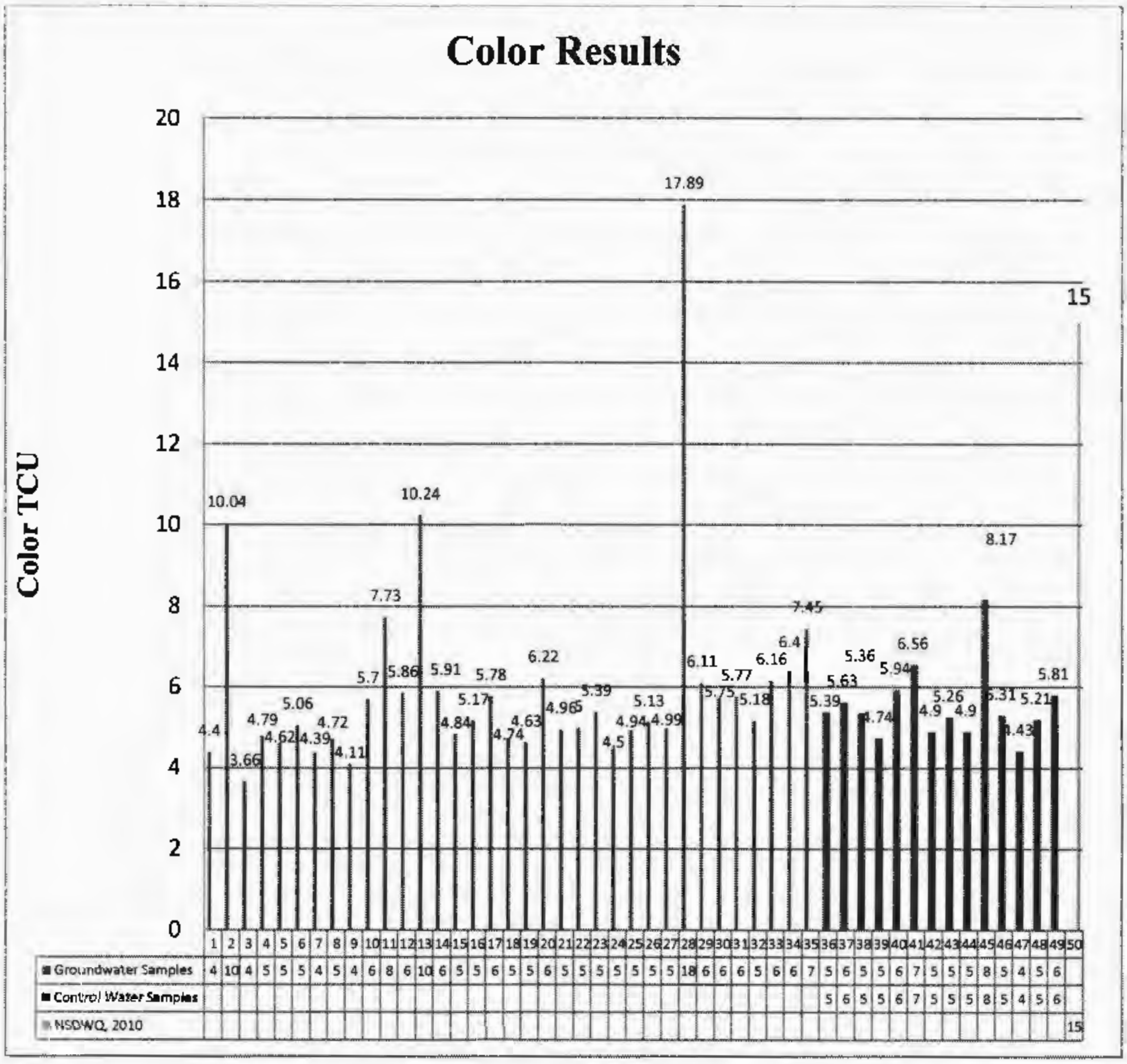
Turbidity relates to the cloudiness of water. High turbidity in water occurs due to different impurities like silt, wood ash, coal dust, microorganism or chemicals (Malik et al., 2014).

Turbidity occurs due to the presence of colloidal and very fine dispersions (Ratna and Deepti, 2012).

The standard value for Turbidity in drinking water is < 5 NTU (NSDWQ, 2010). Turbidity values of all (49) groundwater samples were zero.

The average value of turbidity in (19) wastewater samples was 3228.54 NTU. Highest value of turbidity in wastewater samples was 4547.34 NTU which was analysed in sample#1. Lowest value of turbidity in wastewater samples was 2057.11 NTU which was detected in sample#5.

4.4 Color:



Graph 4.4.: Color Variations in Groundwater Samples.

Table 4.4: Color Permissible Limit Value Crossed Sample of Groundwater

S.No	Color Value	Sample Number	Source of Water	Permissible Limit < 15 TCU NSDWQ, 2010
1	17.89	28	Dug well	

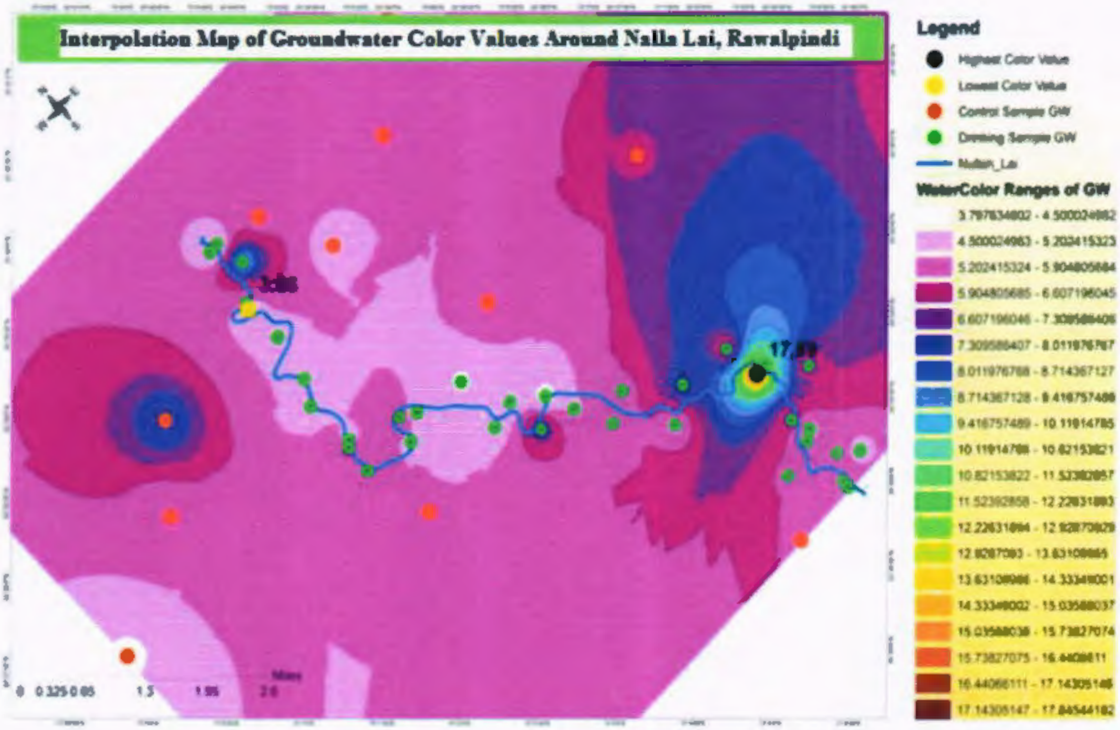
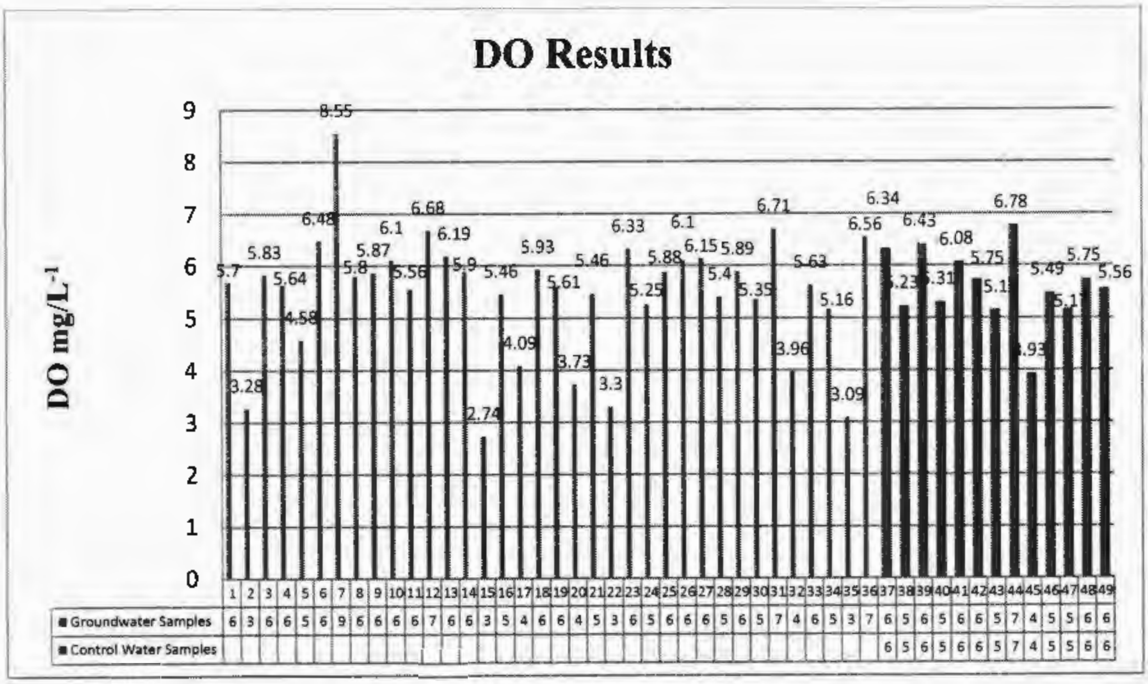


Figure 4.4: Interpolation Map Showing Highest and Lowest Color Location Points of Groundwater.

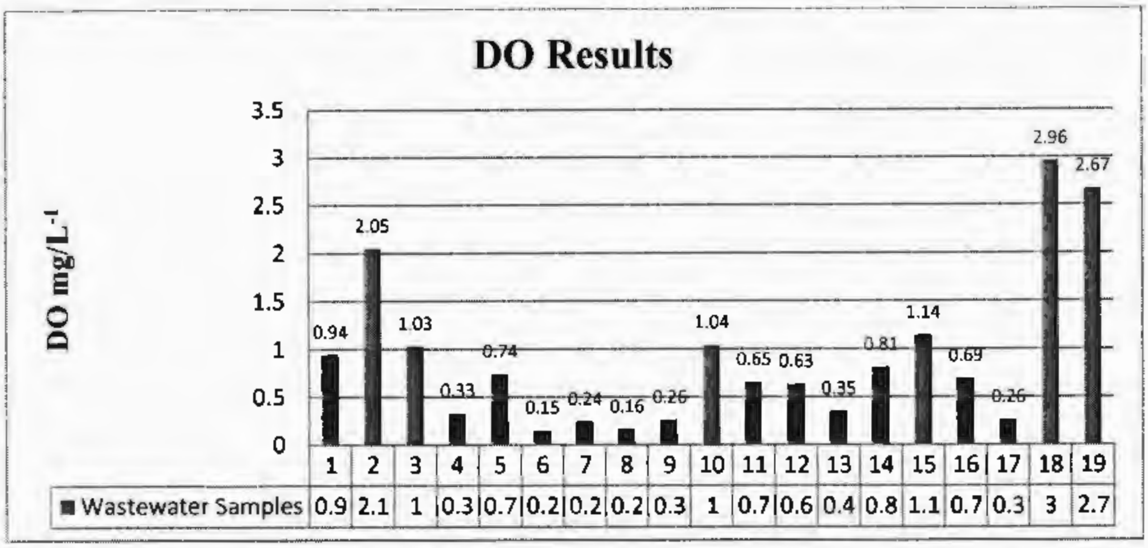
The color of water is very important for both domestic and industrial users and they generally prefer colorless water (Seema, 2015).

The standard value for Color in drinking water is <15 TCU (NSDWQ, 2010). The average value of color in (49) groundwater samples was 5.83 TCU. Highest value of color in groundwater samples was 17.89 TCU which was analysed in sample#28 of dug well water. The highest value was exceeding the standard value. Lowest value of color in groundwater samples was 3.66 TCU which was detected in sample#3.

4.5 Dissolved Oxygen (DO):



Graph 4.5: DO Variations in Groundwater Samples.



Graph 4.5.1: DO Variations in Wastewater Samples.

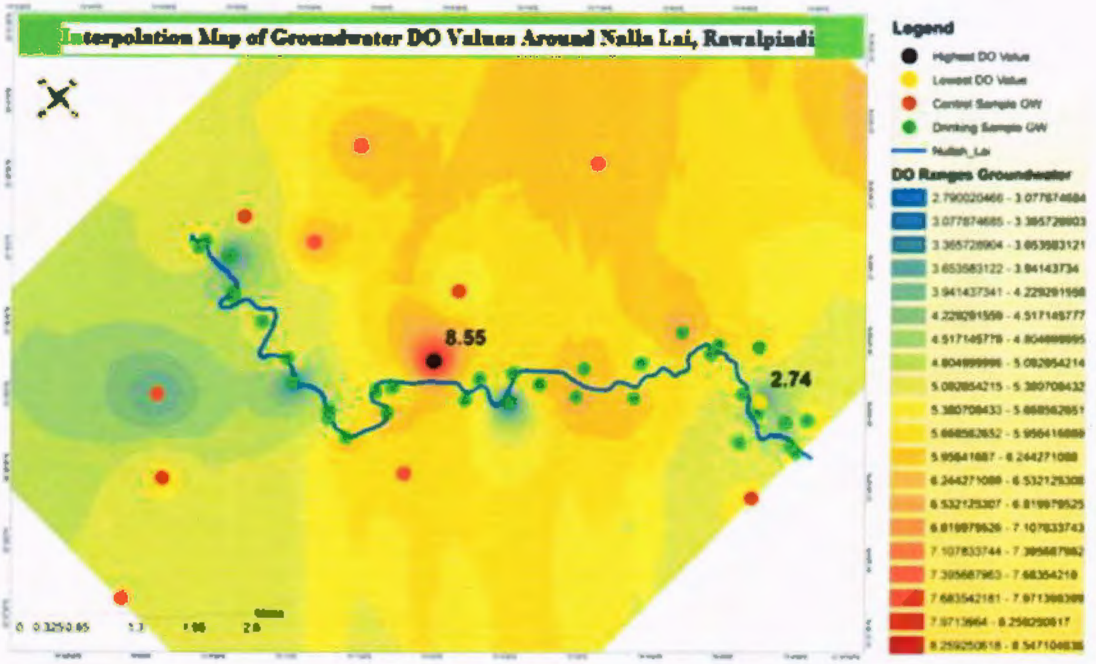


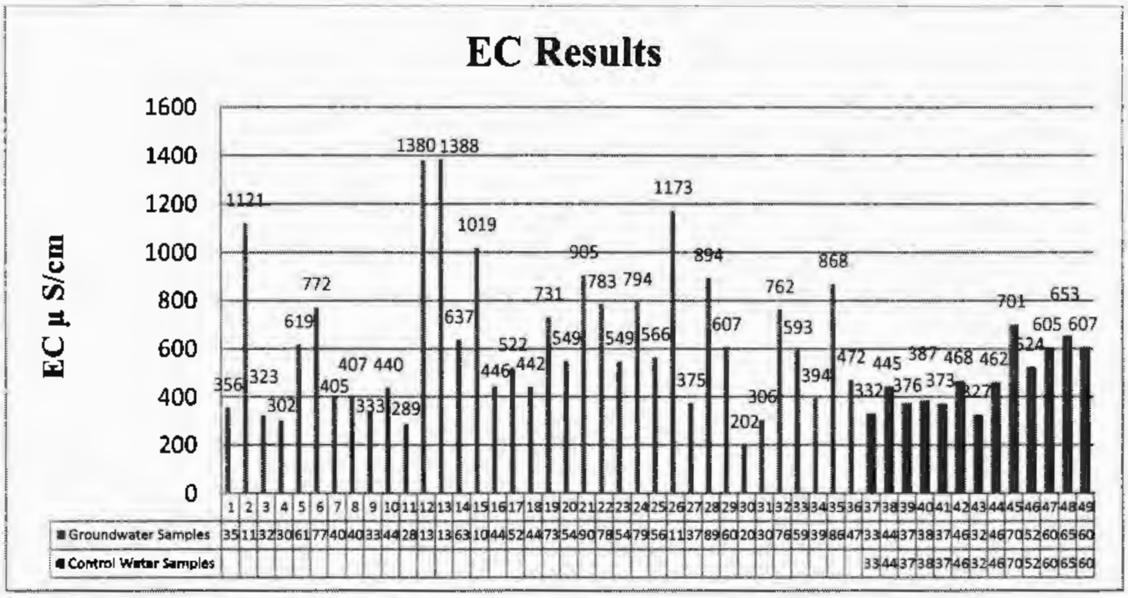
Figure 4.5: Interpolation Map Showing Highest and Lowest DO Location Points of Groundwater.

Dissolved oxygen is the amount of gaseous oxygen dissolved in water body through any source (Uday and Anil, 2016). Dissolved Oxygen is a significant indicator in the judgment of water quality. It reflects both physical and biological processes prevailing in water bodies. The DO level signifies the level of pollution intensity in water (Balamurugan et al., 2012).

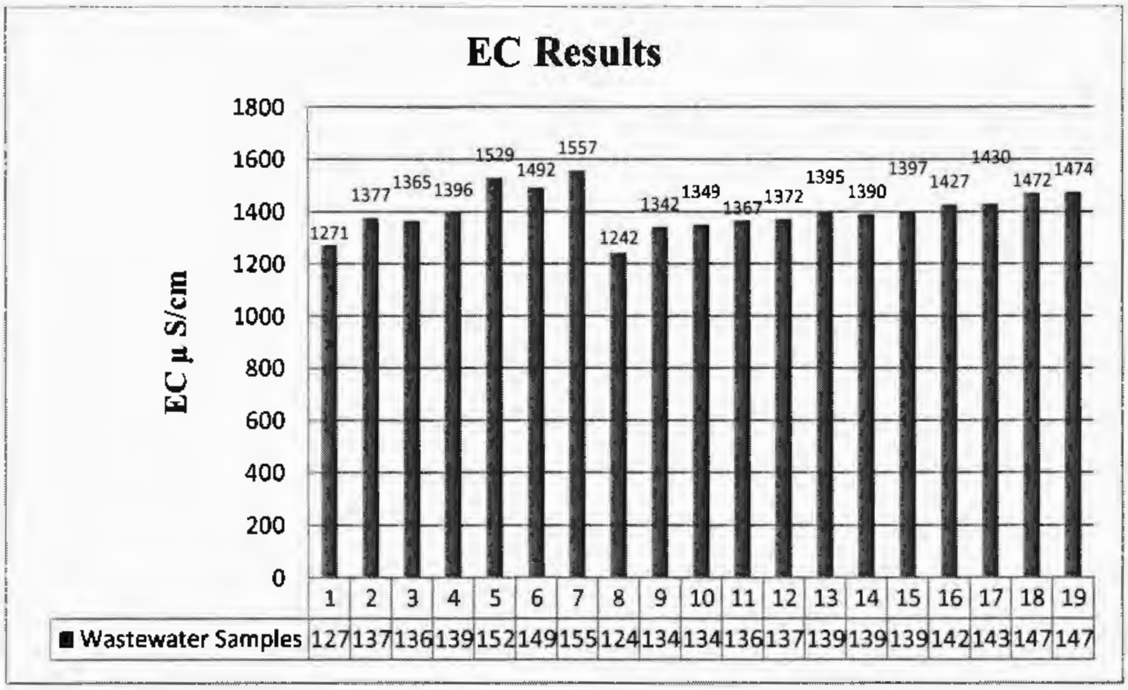
The average value of DO in (49) groundwater samples was 5.49 mg/L^{-1}. Highest value of DO in groundwater sample was 8.55 mg/L^{-1} which was analysed in sample#7 of bore water. Lowest value of DO in groundwater samples was 2.74 mg/L^{-1} which was observed in sample#15 of bore water.

The average value of DO in (19) wastewater samples was 0.9 mg/L^{-1}. Highest value of DO in wastewater samples was 2.96 mg/L^{-1} which was analysed in sample#18. Lowest value of DO in wastewater samples was 0.15 mg/L^{-1} which was detected in sample#6.

4.6 Electric Conductivity (EC):



Graph 4.6: EC Variations in Groundwater Samples.



Graph 4.6.1: EC Variations in Wastewater Samples.

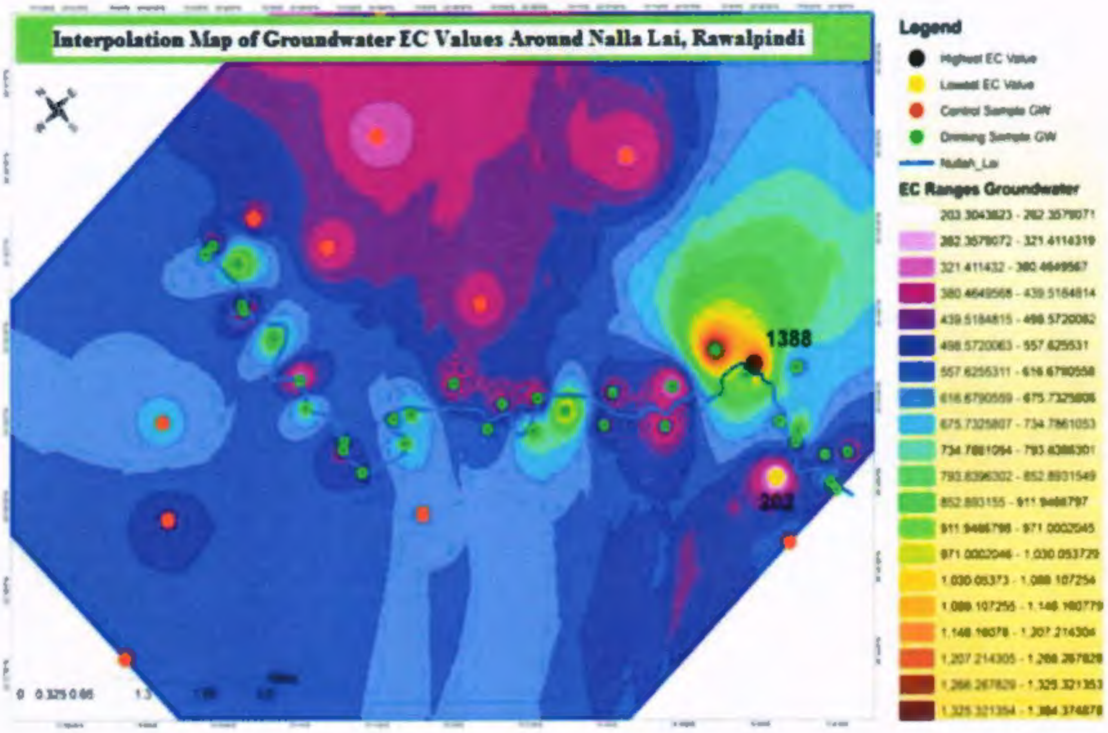
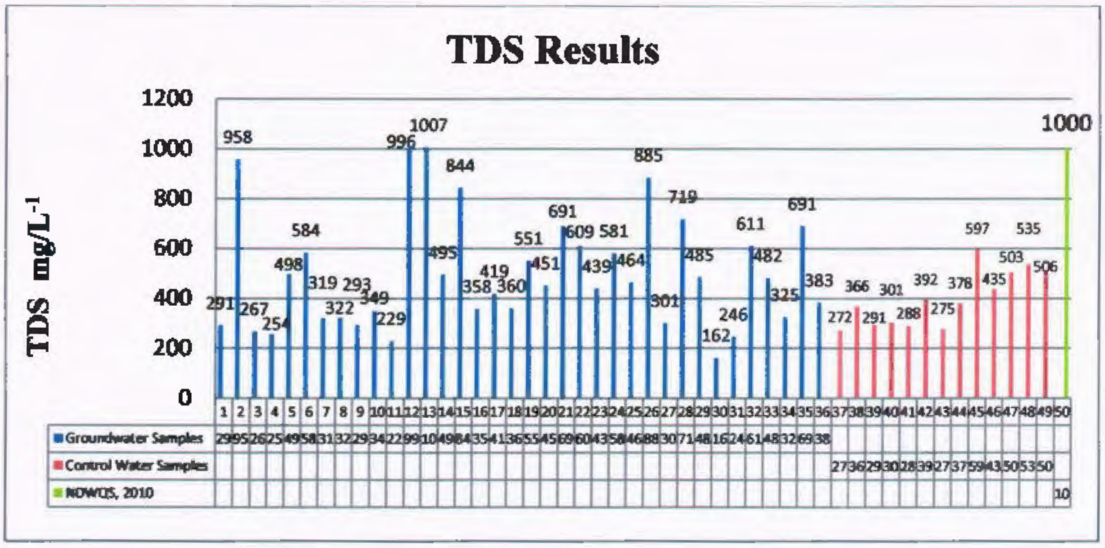


Figure 4.6: Interpolation Map Showing Highest and Lowest EC Location Points of Groundwater.

Electric Conductivity measures the ability of water to pass an electric current. EC level depends on the mobility of free ions (Nasrullah et al., 2006).

The average value of EC in (49) groundwater samples was 591.51 µ S/cm. Maximum value of EC in groundwater samples was 1388 µ S/cm which was analysed in sample#13 of bore water. Minimum value of EC in groundwater samples was 202 µ S/cm which was observed in sample#30. The average value of EC in (19) wastewater samples was 1402.32 µ S/cm. Maximum value of EC in wastewater samples was 1557 µ S/cm which was analysed in sample#7. Minimum EC value in wastewater samples was 1242 µ S/cm which was detected in sample#8.

4.7 Total Dissolved Solids (TDS):



Graph 4.7: TDS Variations in Groundwater Samples.

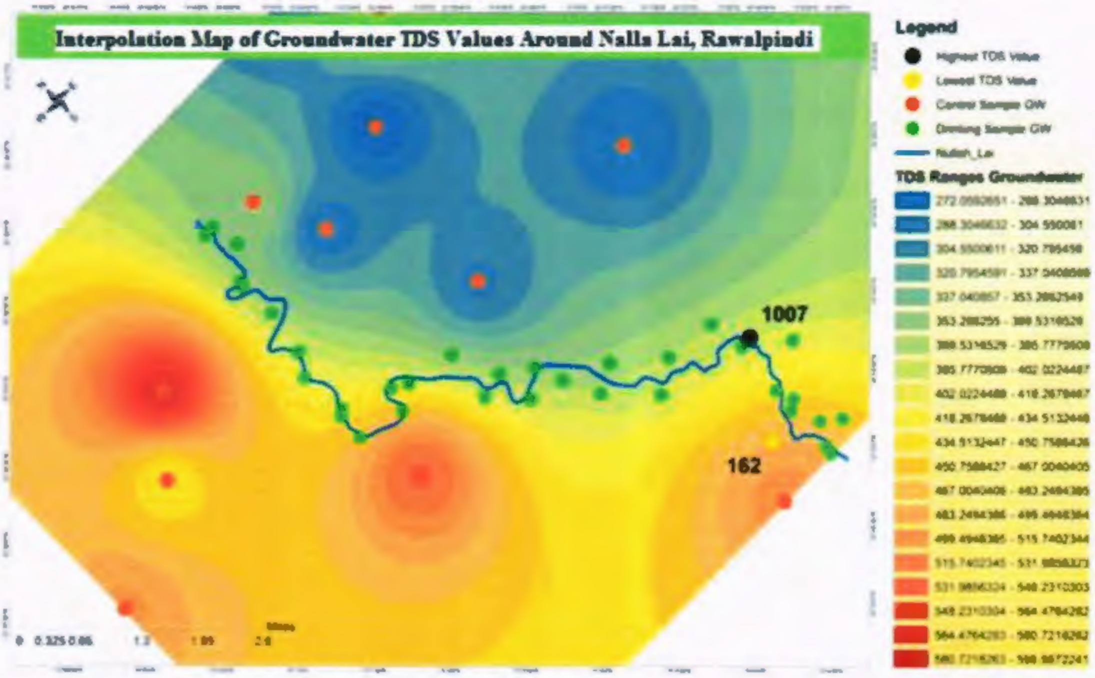


Figure 4.7: Interpolation Map Showing Highest and Lowest TDS Location Points of Groundwater

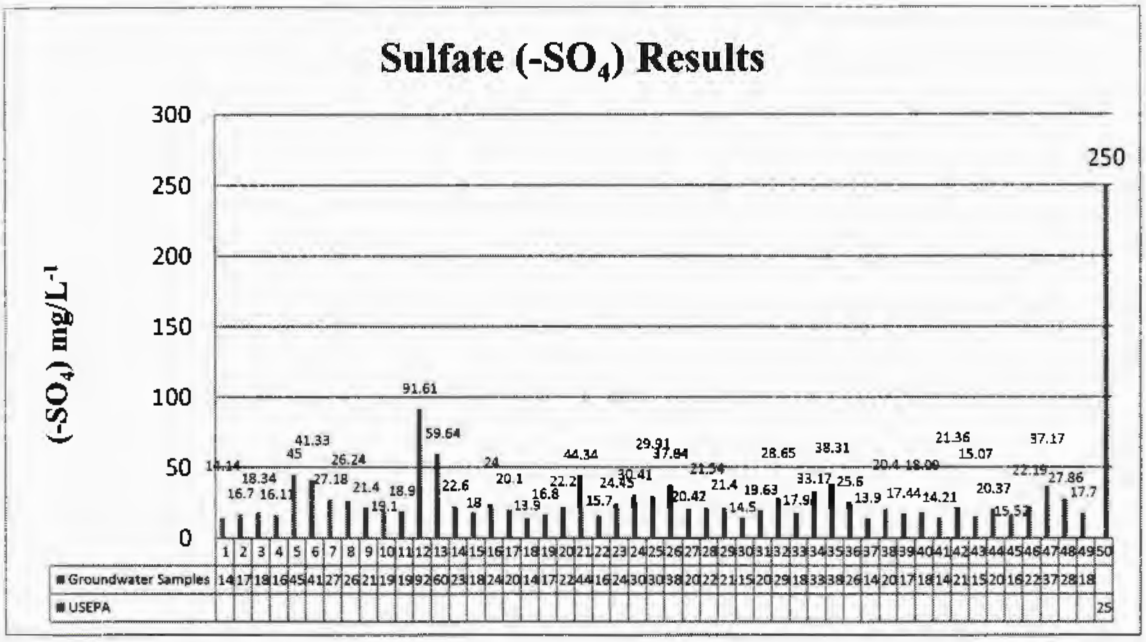
Table 4.7: TDS Permissible Limit Value Crossed Sample of Groundwater

S.No	TDS Concentration	Sample Number	Source of water	Permissible Limit < 1000 mg/ L^{-1} NSDWQ, 2010
1	1007	13	Bore water	

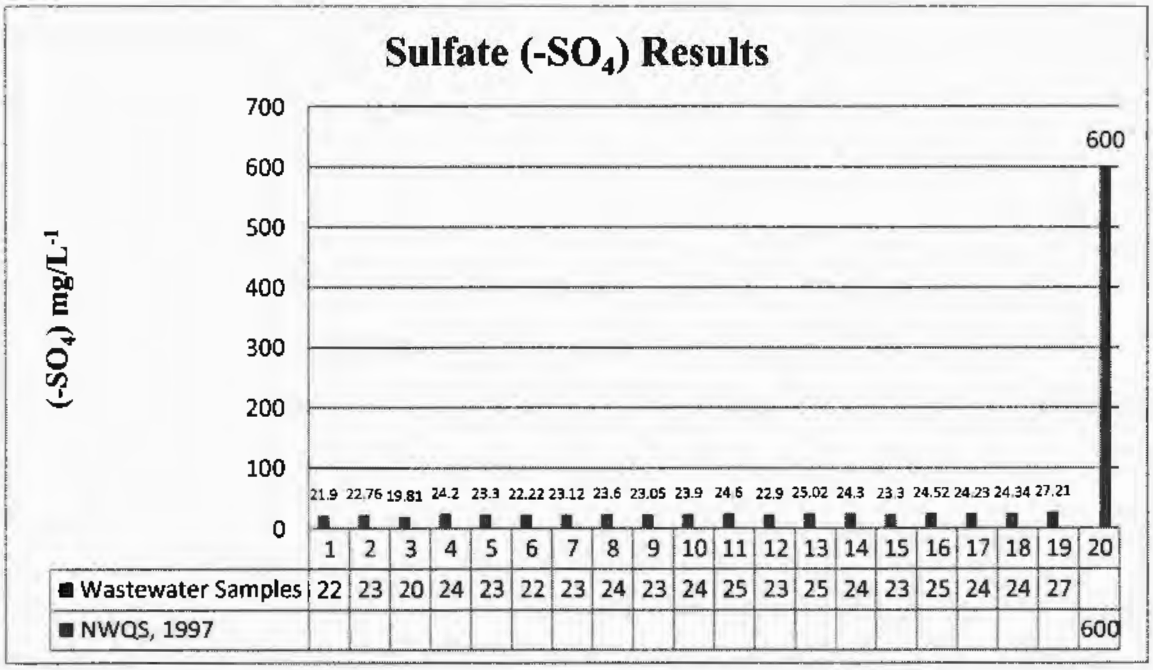
Total dissolved solids include minerals, salts or metals (Sagar, 2015) dissolved in water. TDS indicates water quality and salinity (Pande et al., 2015). It is the indicator of water suitability for different types of uses. High level of TDS affects water taste, hardness and corrosive property (Malik et al., 2014).

The standard value for TDS in drinking water is 1000 mg/L^{-1} (NSDWQ, 2010). The average value of TDS in (49) groundwater samples was 470.57 mg/L^{-1}. Maximum value of TDS in groundwater samples was 1007 mg/L^{-1} which was analysed in sample#13 of bore water. Minimum value of TDS in groundwater samples was 162 mg/L^{-1} which was detected in sample#30 of tube well water.

4.8 Sulfate (-SO₄):



Graph 4.8: (-SO₄) Variations in Groundwater Samples.



Graph 4.8.1: (-SO₄) Variations in Wastewater Samples.

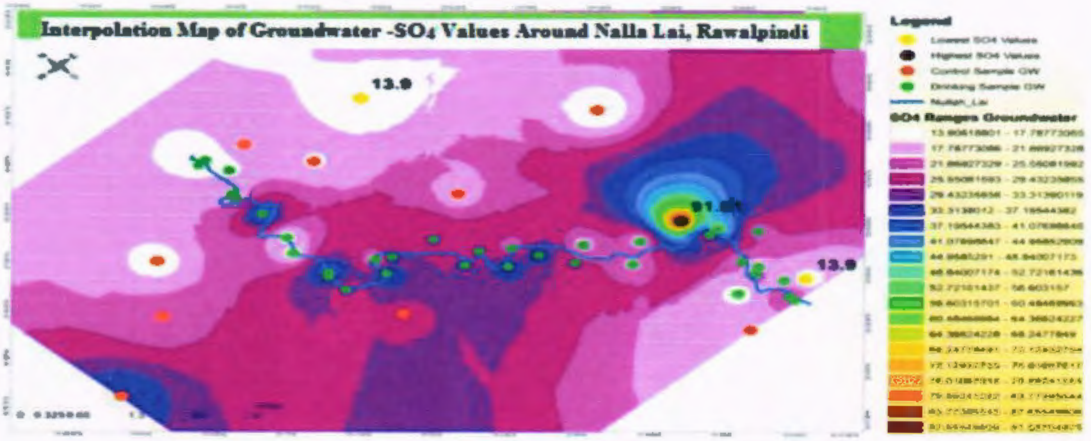


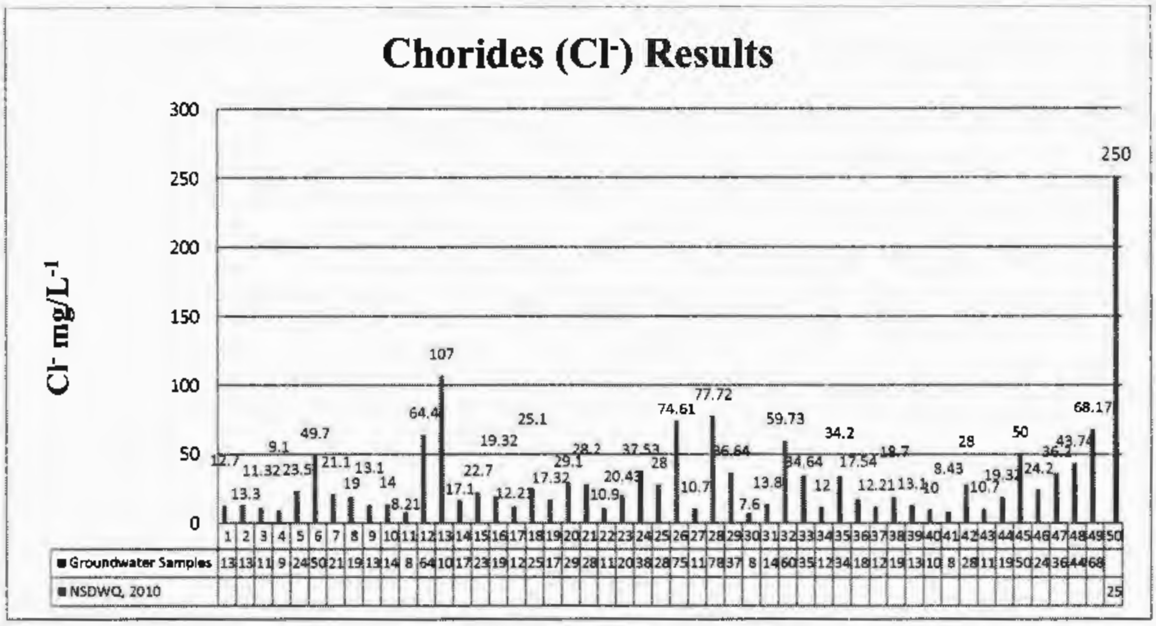
Figure 4.8: Interpolation Map Showing Highest and Lowest (-SO$_4$) Location Points of Groundwater.

Sulfate occurs largely in both natural and anthropogenic water supply (Miao et al., 2012). Natural sources of sulfate include deposits through atmosphere, sulfide mineral oxidation and sulfate mineral dissolution (Krouse and Mayer, 1999). Anthropogenic sources of sulfate include power plants, coal mines, metallurgical refineries and phosphate refineries (Seller and Canter, 1980). Both industrial and domestic discharges can increase its concentration level (Ratna and Deepti, 2012). High dose of sulfate ingestion can cause diarrhea in humans particularly in infants (EPA, 1999).

The standard value for Sulfate (-SO$_4$) in drinking water is 250 mg/L^{-1} (US EPA). The average value of Sulfate in (49) groundwater samples was 25.27 mg/L^{-1}. Maximum value of sulfate in groundwater samples was 91.61 mg/L^{-1} which was analysed in sample#12 of bore water. Minimum value of sulfate in groundwater samples was 13.9 mg/L^{-1} which was observed in sample#18 and sample#37.

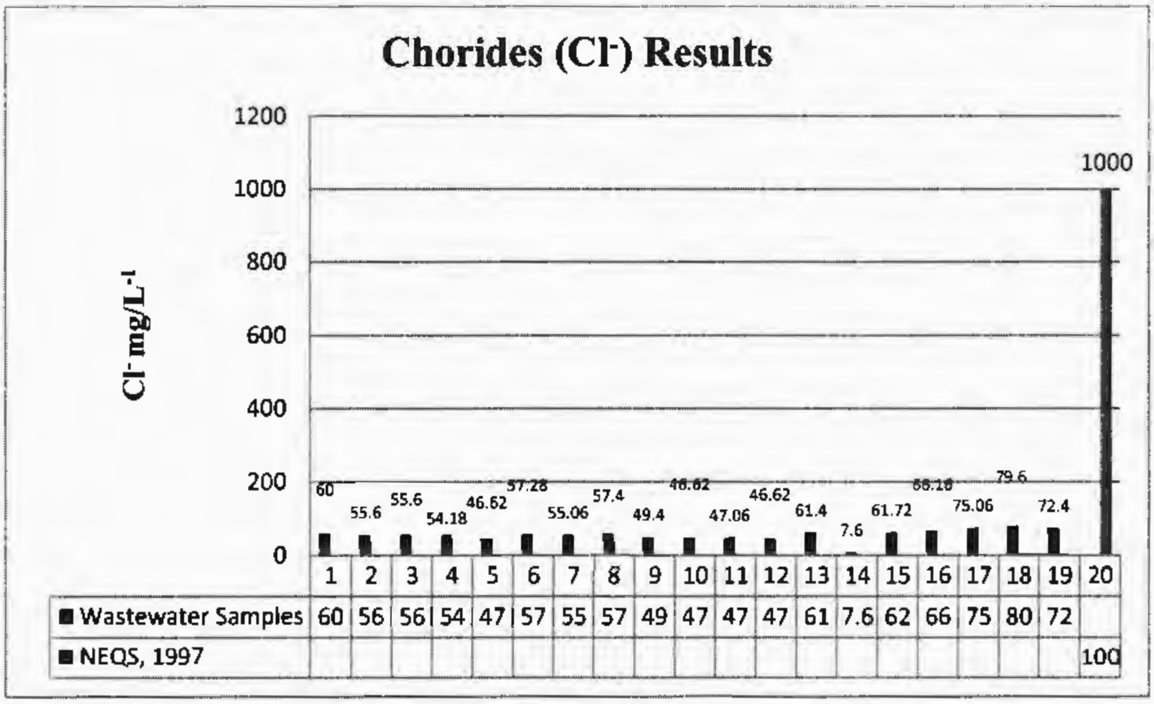
The standard value for Sulfate (-SO$_4$) in wastewater is 600 mg/L^{-1} (NEQS, 1997). The average value of sulfate in (19) wastewater samples was 23.59 mg/L^{-1}. Maximum value of sulfate in wastewater samples was 27.21 mg/L^{-1} which was analysed in sample#19. Minimum value of sulfate in wastewater samples was 19.81 mg/L^{-1} which was detected in sample#3.

4.9 Chloride (Cl^-):



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
■ Groundwater Samples	13	13	11	9	24	50	21	19	13	14	8	64	10	17	23	19	12	25	17	29	28	11	20	38	28	75	11	78	37	8	14	60	35	12	34	18	12	19	13	10	8	28	11	19	50	24	36	44	68	
■ NSDWQ, 2010																																																		25

Graph 4.9: Cl^- Variations in Groundwater Samples.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
■ Wastewater Samples	60	56	56	54	47	57	55	57	49	47	47	47	61	7.6	62	66	75	80	72	
■ NEQS, 1997																				100

Graph 4.9.1: Cl^- Variations in Wastewater Samples.

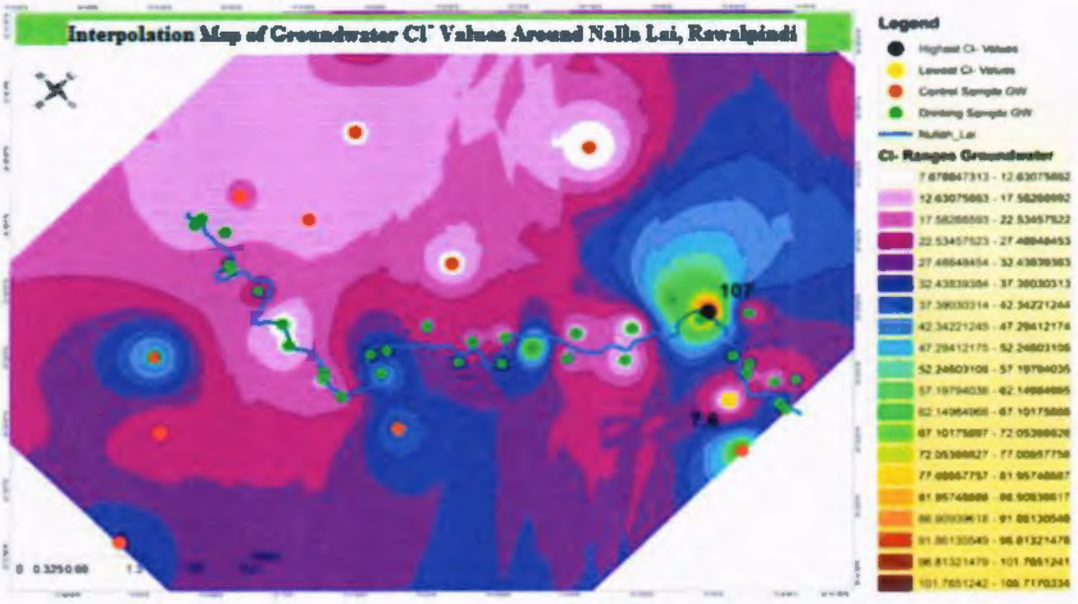


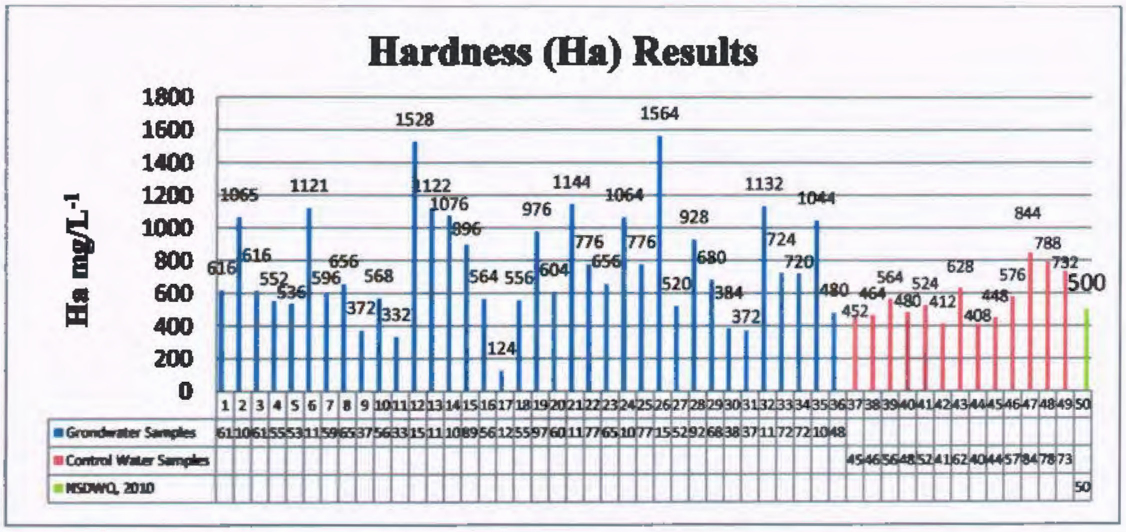
Figure 4.9: Interpolation Map Showing Highest and Lowest Cl^- Location Points of Groundwater.

Chloride occurs in natural water but both agricultural and industrial activities are responsible for its elevated level (Devendra, 2014). Chloride exists as anions in groundwater (Venkatesan, 2008). Its high concentration indicates heavy pollution due to inorganic fertilizers, landfill leachate, septic tank effluents etc (Sarada and Bhushavanthi, 2015; Balamuruganet et al., 2012).

The standard value for Chloride (Cl^-) in drinking water is 250 mg/ L^{-1} (NSDWQ, 2010). The average value of Chloride in (49) groundwater samples was 27.68 mg/L^{-1}. Maximum value of chloride in groundwater samples was 107 mg/L^{-1} which was analysed in sample#13 of bore water. Minimum value of chloride in groundwater samples was 7.6 mg/L^{-1} which was observed in sample#30.

The standard value for Chloride (Cl^-) in wastewater is 1000 mg/L^{-1} (NEQS, 1997). The average value of Chloride in (19) wastewater samples was 55.55 mg/L^{-1}. Maximum value of chloride in wastewater samples was 79.6 mg/L^{-1} which was analysed in sample#18. Minimum value of chloride in wastewater samples was 7.6 mg/ L^{-1} which was detected in sample#14.

4.10 Hardness (Ha):



Graph 4.10: Ha Variations in Groundwater Samples.

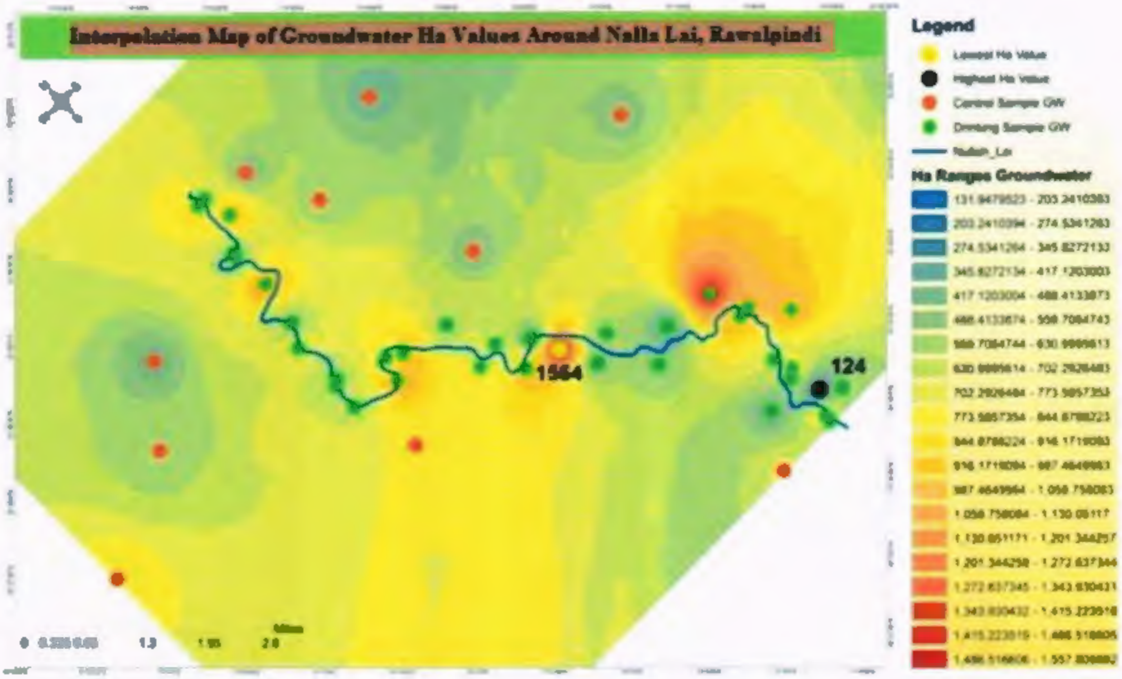


Figure 4.10: Interpolation Map Showing Highest and Lowest Ha Location Points of Groundwater.

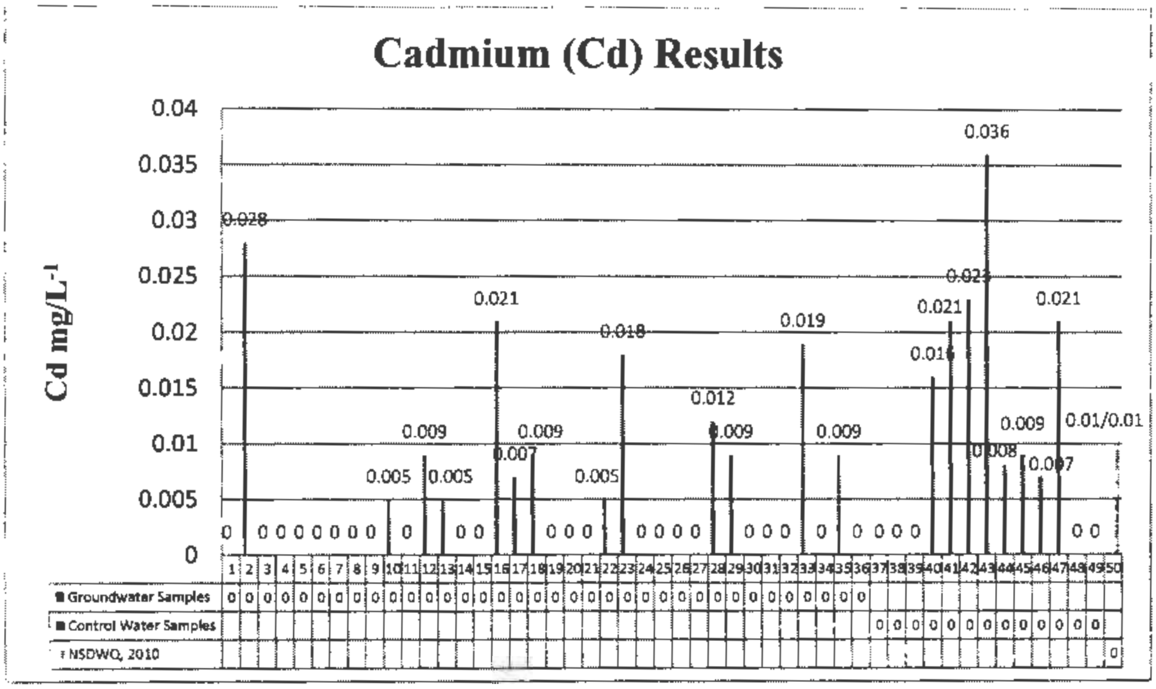
Table 4.10: Hardness Permissible Limit Crossed Values of Groundwater Samples

S.No	Hardness (Ha) Concentration	Sample Number	Source of Water	Permissible Limit <500 mg/L^{-1} NSDWQ, 2010
1	1564	26	Bore water	
2	1528	12	Bore water	
3	1144	21	Bore water	
4	1132	32	Spring	
5	1122	13	Bore water	
6	1121	6	Bore water	
7	1076	14	Bore water	
8	1065	2	Bore water	
9	1064	24	Bore water	
10	1044	35	Bore water	
11	976	19	Tube well	
12	928	28	Dug well	
13	896	15	Bore water	
14	844	47	Tube well	
15	788	48	Bore water	
16	776	22	Bore water	
17	776	25	Tube well	
18	732	49	Bore water	
19	724	33	Tube well	
20	720	34	Bore water	
21	680	29	Bore water	
22	656	8	Tube well	
23	656	23	Tube well	
24	628	43	Bore water	
25	616	1	Tube well	
26	616	3	Tube well	
27	604	20	Bore water	
28	596	7	Bore water	
29	576	46	Bore water	
30	568	10	Tube well	
31	564	16	Bore water	
32	564	39	Bore water	
33	556	18	Bore water	
34	552	4	Tube well	
35	536	5	Tube well	
36	524	41	Bore water	
37	520	27	Tube well	

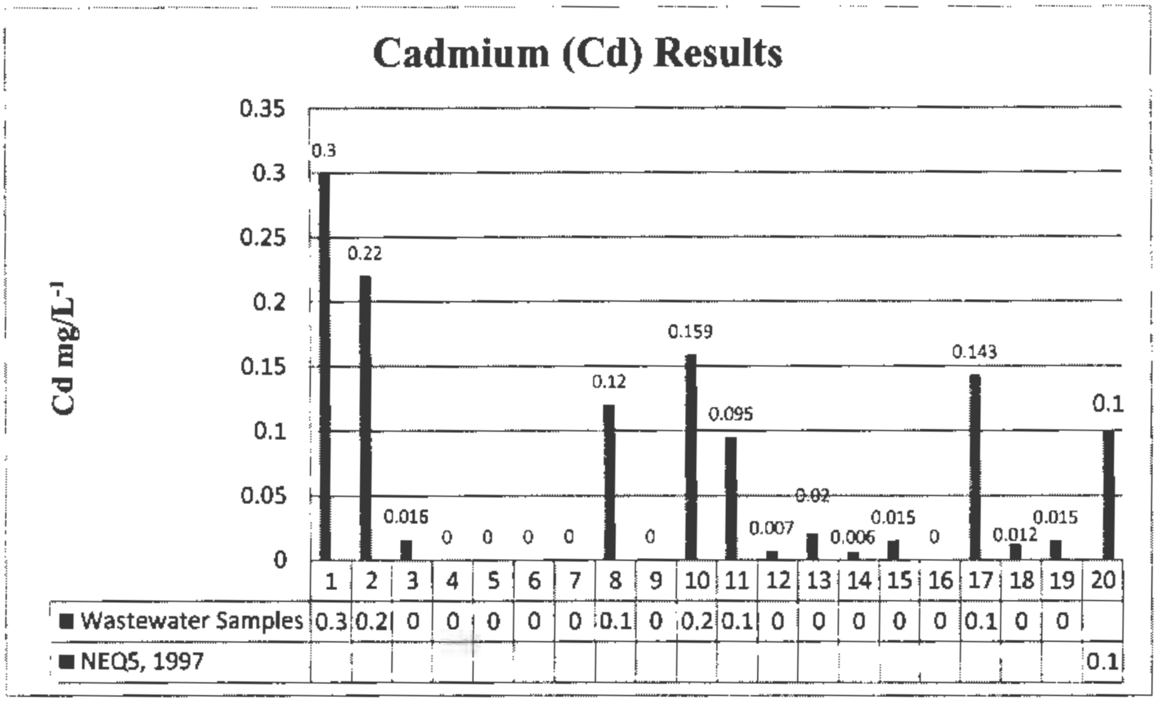
Water with high mineral contents is called hard water (Ramya et al., 2015). Water Hardness primarily depends on concentration of calcium and magnesium ions in water (Rao, 2011; Ramya et al., 2015). Iron, zinc, strontium, magnesium and aluminum can also contribute in water hardness, but these metals are found in very minute concentration (NRC, 1974). Excess magnesium intake creates inefficiency in kidney and decease its capability to excrete. More than 3/4 of kidney stones are composed from calcite salts. Drinking water containing high concentration of Calcium and Sulfate having laxative effects on health (Pallav, 2013). Hardness are of two types carbonate hardness (temporary hardness) and non-carbonate hardness (Permanent hardness). Carbonate hardness can remove by boiling whereas non- carbonate hardness cannot remove through boiling (Ramya et al., 2015).

The standard value for Hardness in drinking water is 500 mg/L^{-1} (NSDWQ, 2010). The average value of Hardness in (49) groundwater samples was 709.39 mg/L^{-1}. Maximum value of Hardness in groundwater samples was 1564 mg/L^{-1} which was analysed in sample#26 of bore water. Minimum value of Hardness in groundwater samples was 124 mg/L^{-1} which was observed in sample#17.

4.11 Cadmium (Cd):



Graph 4.11: Cd Variations in Groundwater Samples.



Graph 4.11.1: Cd Variations in Wastewater Samples.

Table 4.11: Cadmium (Cd) Permissible Limit Crossed Values of Groundwater Samples

S.No	Cadmium (Cd) Concentration	Sample Number	Source of Water	Permissible Limit 0.01 mg/L^{-1} NSDWQ, 2010, 0.003 mg/L^{-1} WHO
1	0.036	43	Bore water	
2	0.028	2	Hand pump Bore water	
3	0.023	42	Tube well (Filtration Plant)	
4	0.021	16	Bore water	
5	0.021	41	Bore water	
6	0.021	47	Tube well	
7	0.019	33	Tube well	
8	0.018	23	Tube well	
9	0.016	40	Bore water	
10	0.012	28	Bore water	

Table 4.11.1: Cadmium (Cd) Permissible Limit Crossed Values of Wastewater Samples

S.No	Cadmium (Cd) Concentration	Sample Number	Source of Water	Permissible Limit 0.1 mg/L^{-1} (NEQS, 1997)
1	0.3	1	Nalla passing through I-9 Industrial Area Islamabad (Adjacent to Kataria Pull)	
2	0.22	2	Nalla passing through I-10 Industrial Area Islamabad (Adjacent to Kataria Pull)	
3	0.159	10	Nalla Lai	
4	0.143	17	Nalla Lai	
5	0.12	8	Nalla Lai	

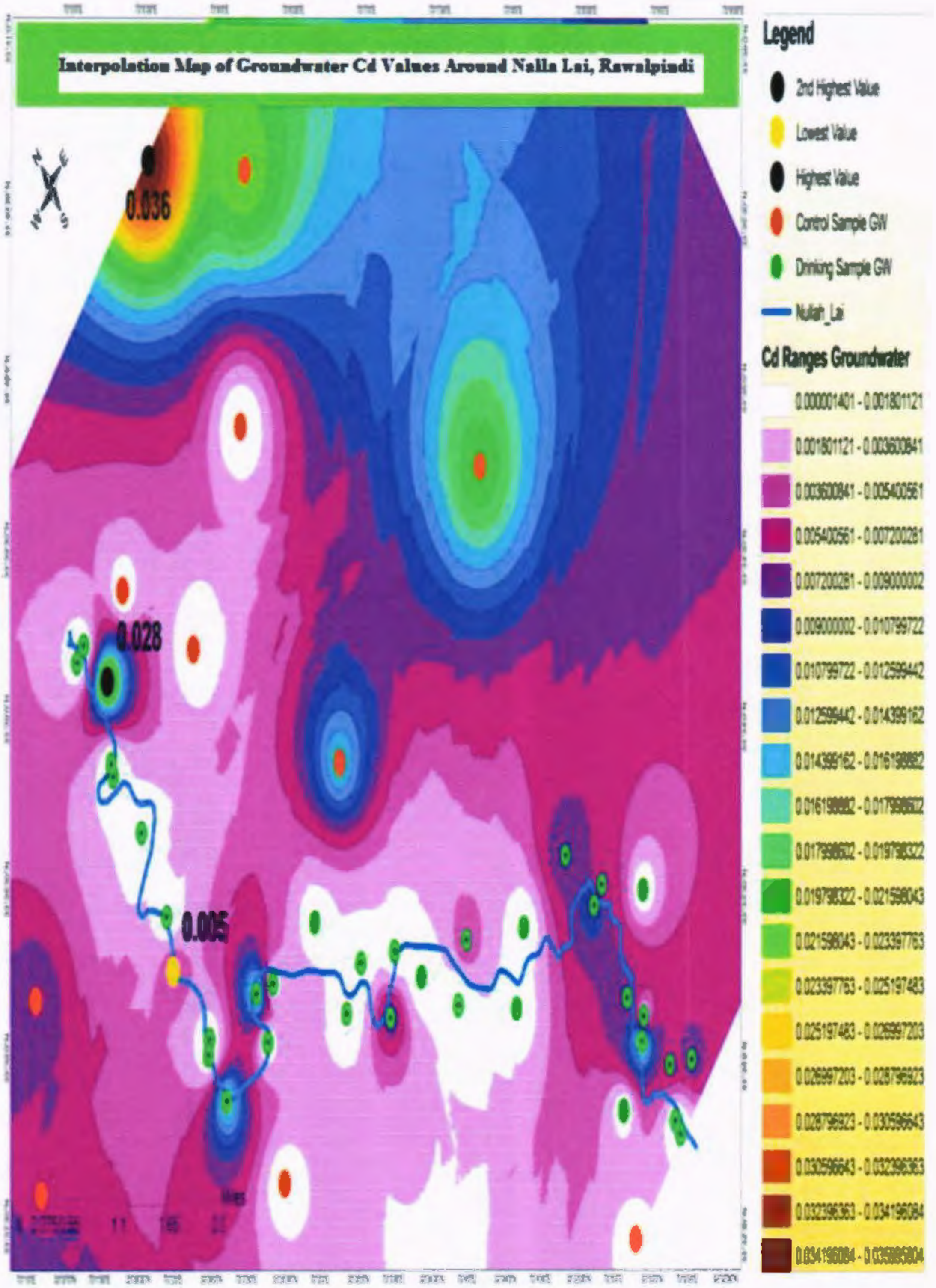


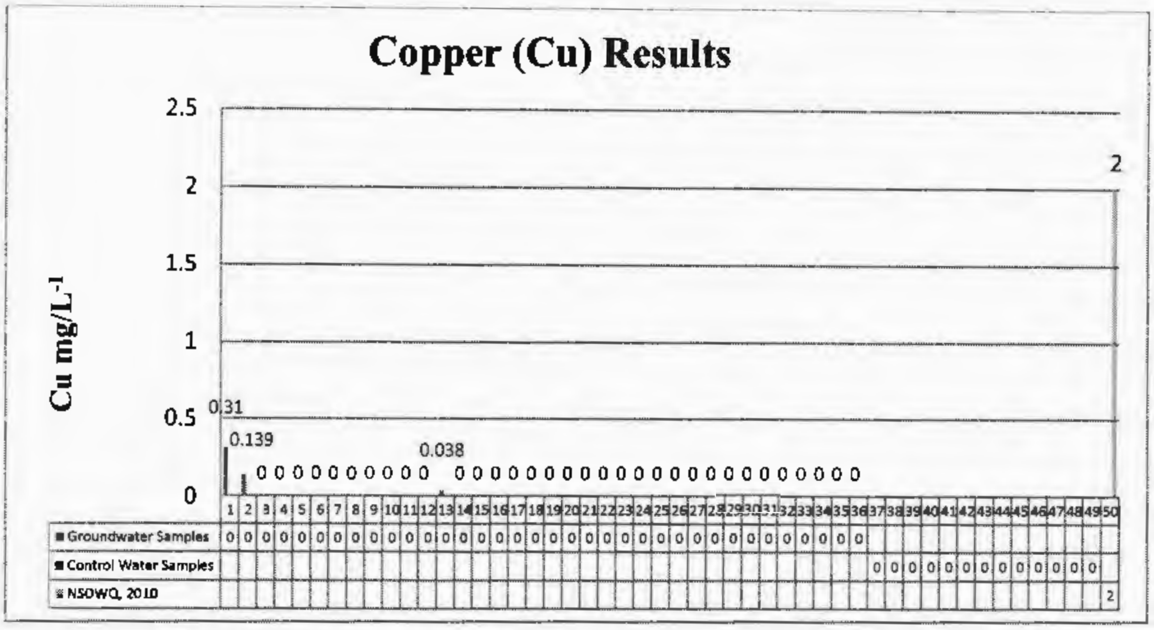
Figure 4.11: Interpolation Map Showing Highest and Lowest Cd Location Points of Groundwater.

Cadmium seeks attention due to its toxic nature (Azizullah, 2011). Cadmium can be toxic if its level exceeds 0.01 mg/l in both drinking and irrigation water (Hem, 1989). Industrial and mining activities are the potential sources of Cadmium in water (Taha, 2004). Its concentration in quaternary aquifer ranges from 0.010-0.062 ppm (Tslalom and Kiflim, 2005). Cadmium ingestion can cause gastrointestinal disease like vomiting and diarrhea (Nordberg, 2004). Its chronic exposure can cause Kidney failure (Barbier et al, 2005), Reproductive diseases (Frery et al., 1993., Piasek and Laskey, 1999., Johnson et al., 2003), Damage of bones (Kazantzis, 1979) and Cancer disease (Waalkes et al., 1988).

The standard value for Cadmium in drinking water is 0.01 mg/L^{-1} (NSDWQ, 2010), 0.001 mg/L^{-1} (WHO). The average value of Cadmium in (49) groundwater samples was 0.01 mg/L^{-1}. Maximum value of Cadmium in groundwater samples was 0.036 mg/L^{-1} which was analysed in sample#43 of bore water. Minimum value of Cadmium in groundwater samples was 0.005 mg/L^{-1} which was observed in sample#10, sample#13 and sample#22. Overall (10) samples out of (49) groundwater samples showed excess concentration of Cadmium than the standard value set by NSDWQ 2010.

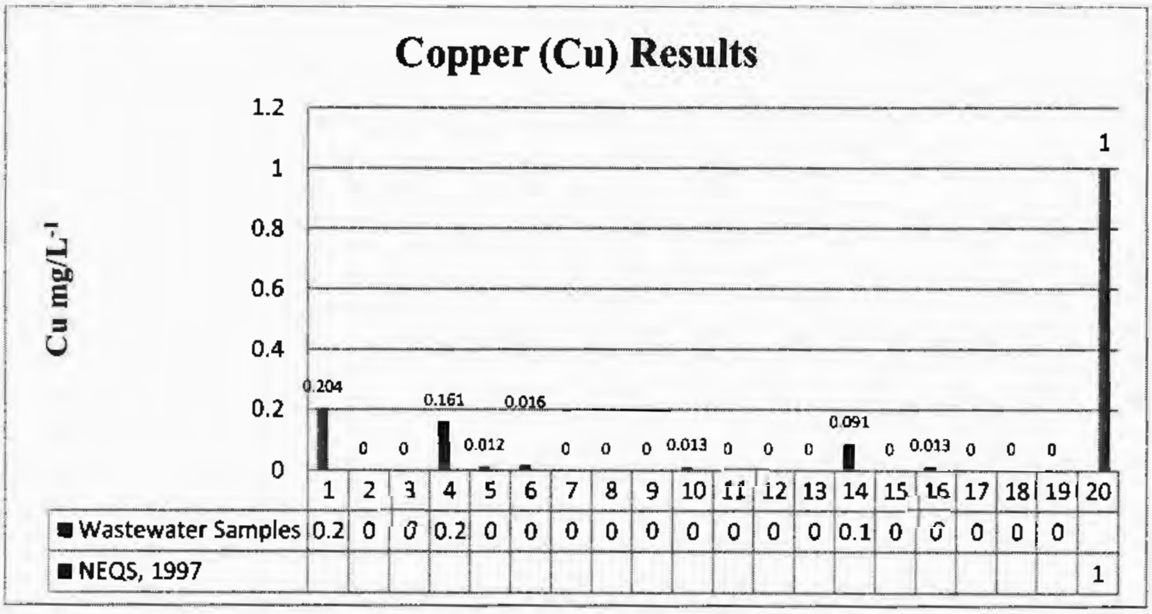
The standard value for Cadmium in wastewater is 0.1 mg/L^{-1} (NEQS, 1997). The average value of Cadmium in (19) wastewater samples was 0.09 mg/L^{-1}. Maximum value of Cadmium in wastewater samples was 0.3 mg/L^{-1} which was analysed in sample#1. Minimum value of Cadmium in wastewater samples was 0.006 mg/L^{-1} which was detected in sample#14.

4.12 Copper (Cu):



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
■ Groundwater Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
■ Control Water Samples																																					0	0	0	0	0	0	0	0	0	0	0	0	0	
▨ NSDWQ, 2010																																																		2

Graph 4.12: Cu Variations in Groundwater Samples.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
■ Wastewater Samples	0.2	0	0	0.2	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	
■ NEQS, 1997																				1

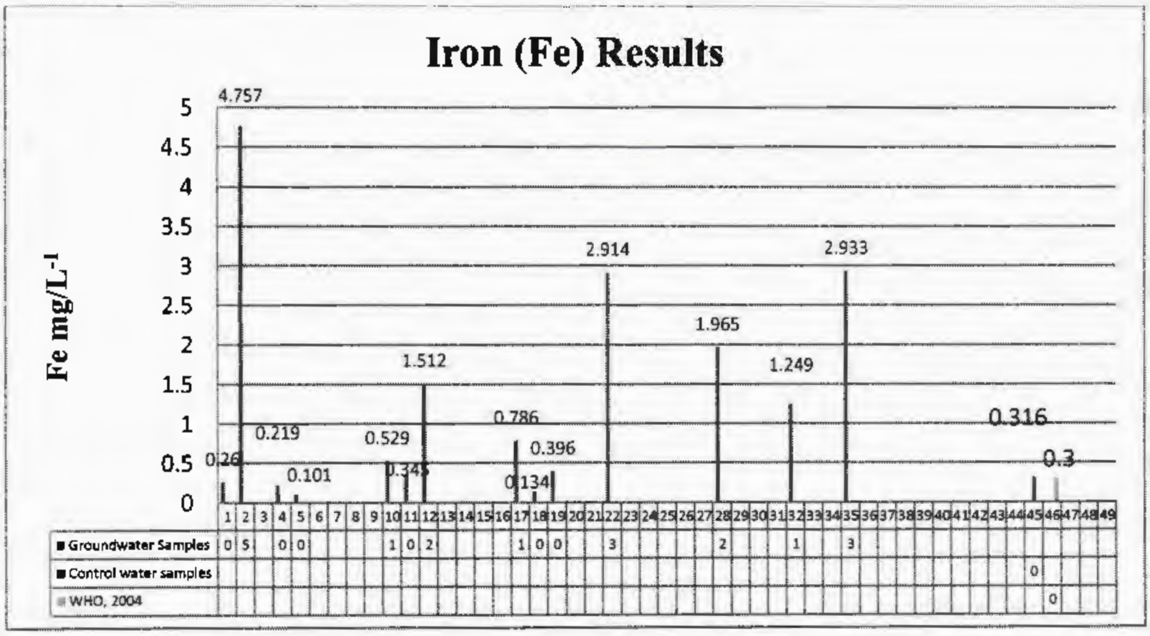
Graph 4.12.1: Cu Variations in Wastewater Samples.

Copper is a necessary element present in enzymes and its minute concentration is critical for the synthesis of hemoglobin (Tiwari, 2013). Its excess concentration can cause neurological problems, hypertension, kidney and liver failure (Krishna and Govil, 2004; Khan et al., 2010). In infants its ingestion can cause death, vomiting of short lived, diarrhea etc (Barzilay, 1999).

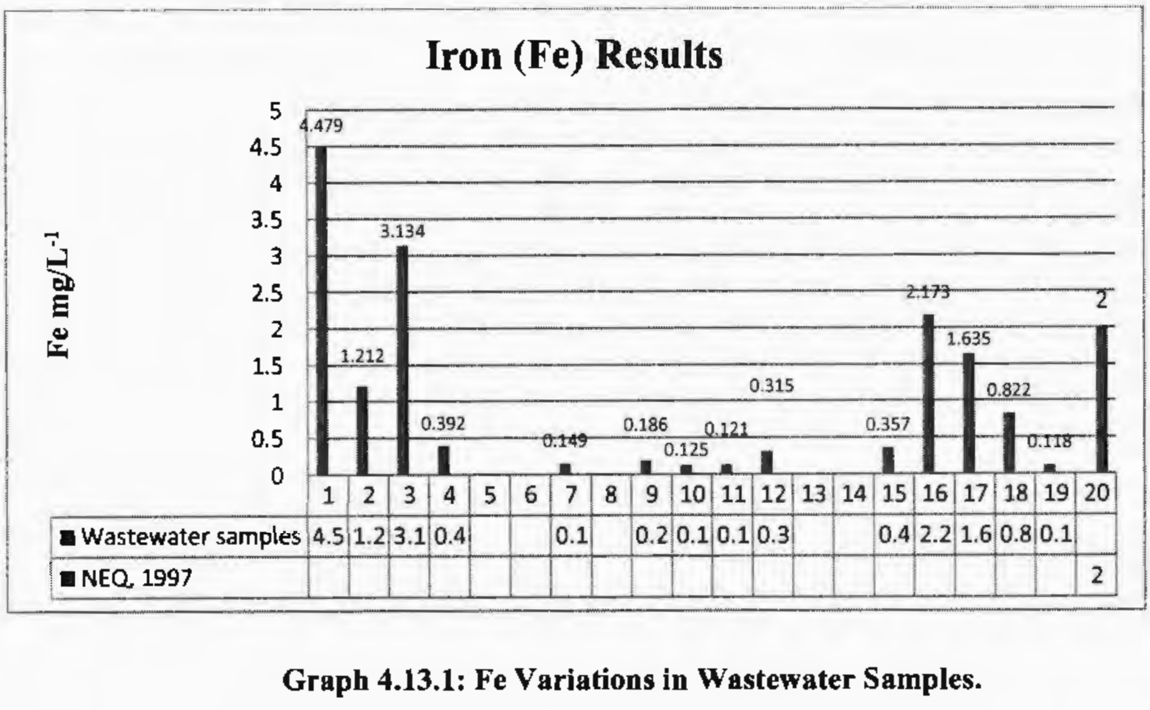
The standard value for Copper (Cu) in drinking water is 2 mg/L^{-1} (NSDWQ, 2010). The average value of copper in (49) groundwater samples was 0.10 mg/L^{-1}. Highest value of copper in groundwater samples was 0.139 mg/L^{-1} which was analysed in sample#2 of hand pump bore water. Lowest value of copper in groundwater samples was 0.038 mg/L^{-1} which was observed in sample#13.

The standard value for Copper in wastewater is 1 mg/L^{-1} (NEQS, 1997). The average value of copper in (19) wastewater samples was 0.07 mg/L^{-1}. Maximum value of copper in wastewater samples was 0.204 mg/L^{-1} which was analysed in sample#1. Minimum value of copper in wastewater samples was 0.012 mg/L^{-1} which was detected in sample#5.

4.13 Iron (Fe):



Graph 4.13: Fe Variations in Groundwater Samples.



Graph 4.13.1: Fe Variations in Wastewater Samples.

Table 4.13: Groundwater, Sample Information of Permissible Limit Crossed Iron (Fe) Values

S.No	Iron (Fe) Concentration	Sample Number	Source of Water	Permissible Limit 0.3 mg/L^{-1} WHO, 2004
1	4.757	2	Hand pump Bore water	
2	2.933	35	Bore water	
3	2.914	22	Bore water	
4	1.965	28	Dug well	
5	1.512	12	Bore water	
6	1.249	32	Spring water	
7	0.786	17	Bore water	
8	0.529	10	Tube well	
9	0.396	19	Tube well	
10	0.345	11	Bore water	
11	0.316	45	Bore water	

Table 4.13.1: Wastewater, Sample Information of Permissible Limit Crossed Iron (Fe) Values

S.No	Iron (Fe) Concentration	Sample Number	Source of Water	Permissible Limit 2 mg/ L^{-1} NEQS, 1997
1	4.479	1	Nalla passing through I-9 Industrial Area Islamabad (Adjacent to Kataria Pull)	
2	3.134	3	Nalla Lai	
3	2.173	16	Nalla Lai	

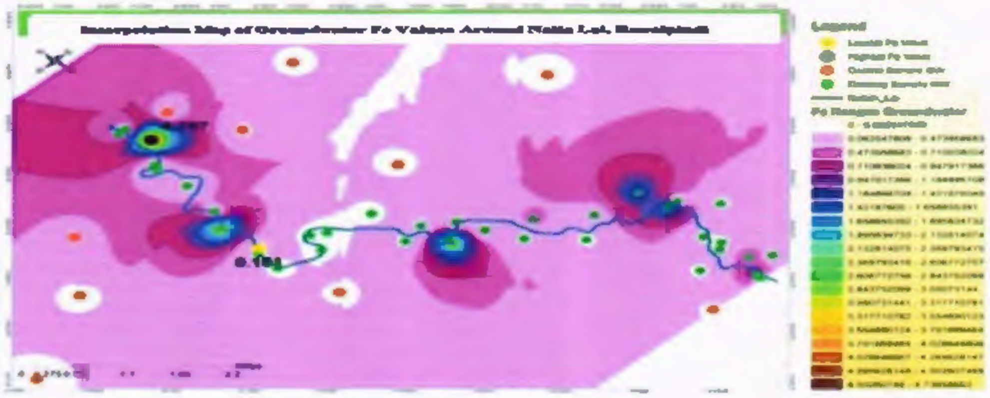


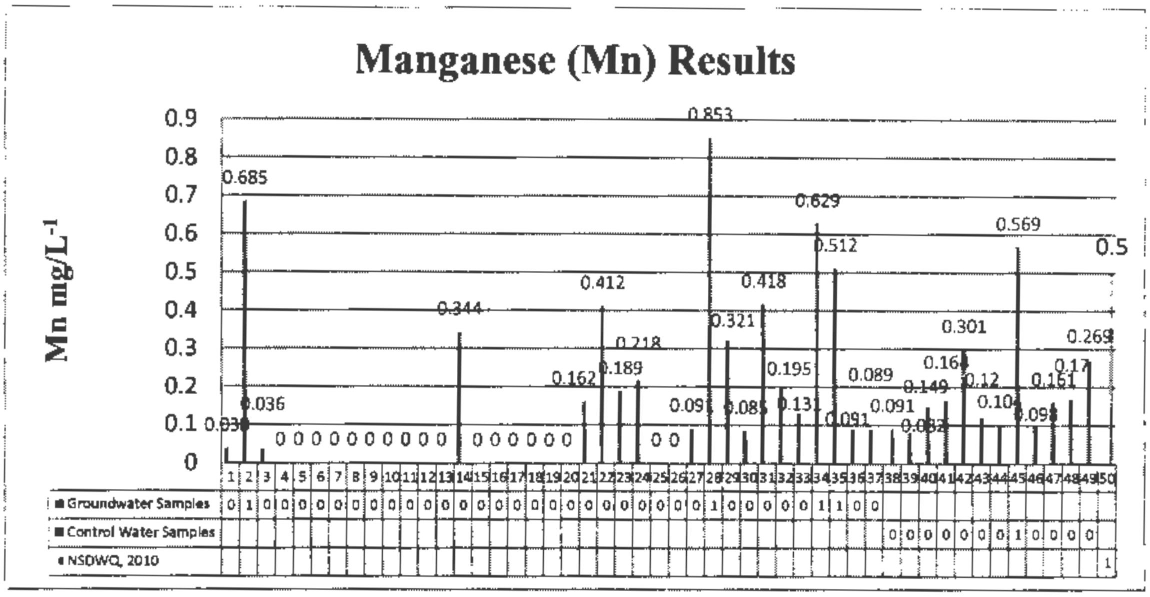
Figure 4.13: Interpolation Map Showing Highest and Lowest Fe Location Points of Groundwater.

Iron is one of the most plentiful element found on earth. Iron is necessary for normal physiological function of an organism and its deficiency and excess concentration can harm both plants and animals (Anonymous, 2008). Iron is an essential micronutrient but its high consumption through drinking water can leads to liver disease (Gyamfi et al., 2012). As compare to its deficiency its overload and overexposure can cause numerous health problems such as cancer (Beckman et al., 1999; Parkkila et al., 2001), Diabetes problem (Ellervik et al., 2001; Parkkila et al., 2001; Perezde Nanclares et al., 2000), Heart and Liver diseases (Milman et al., 2001; Yang et al., 1998; Rasmussen et al., 2001) and neurological problems as well (Sayre et al., 2000; Berg et al., 2001).

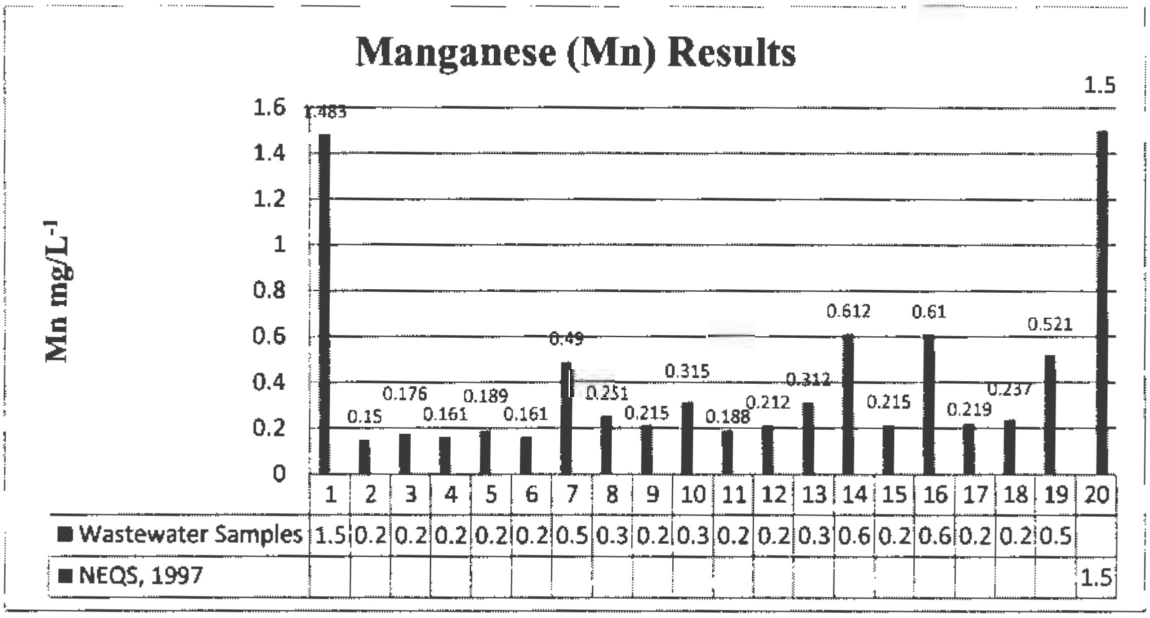
The standard value for Iron (Fe) in drinking water is 0.3 mg/L^{-1} (WHO, 2004). The average value of Iron in (49) groundwater samples was 1.23 mg/L^{-1}. Maximum value of Iron in groundwater samples was 4.757 mg/L^{-1} which was analysed in sample#2 of hand pump bore water. Minimum value of Iron in groundwater samples was 0.101 mg/L^{-1} which was observed in sample#5. Overall (11) samples out of (45) groundwater samples showed Iron concentration beyond the permissible limit.

The standard value for Iron (Fe) in wastewater is 2 mg/L^{-1} (NEQS, 1997). The average value of Iron in (19) wastewater samples was 1.09 mg/L^{-1}. Maximum value of Iron in wastewater samples was 4.479 mg/L^{-1} which was analysed in sample#1. Minimum value of Iron in wastewater samples was 0.118 mg/L^{-1} which was detected in sample#19.

4.14 Manganese (Mn):



Graph 4.14: Mn Variations in Groundwater Samples.



Graph 4.14.1: Mn Variations in Wastewater Samples.

Table 4.14: Groundwater, Sample Information of Permissible Limit Crossed Manganese Values

S.No	Manganese (Mn) Concentration	Sample Number	Source of Water	Permissible Limit 0.5 mg/L^{-1} NSDWQ, 2010
1	0.853	28	Dug well	
2	0.685	2	Hand pump Bore water	
3	0.629	34	Bore water	
4	0.569	45	Bore water	
5	0.512	35	Bore water	

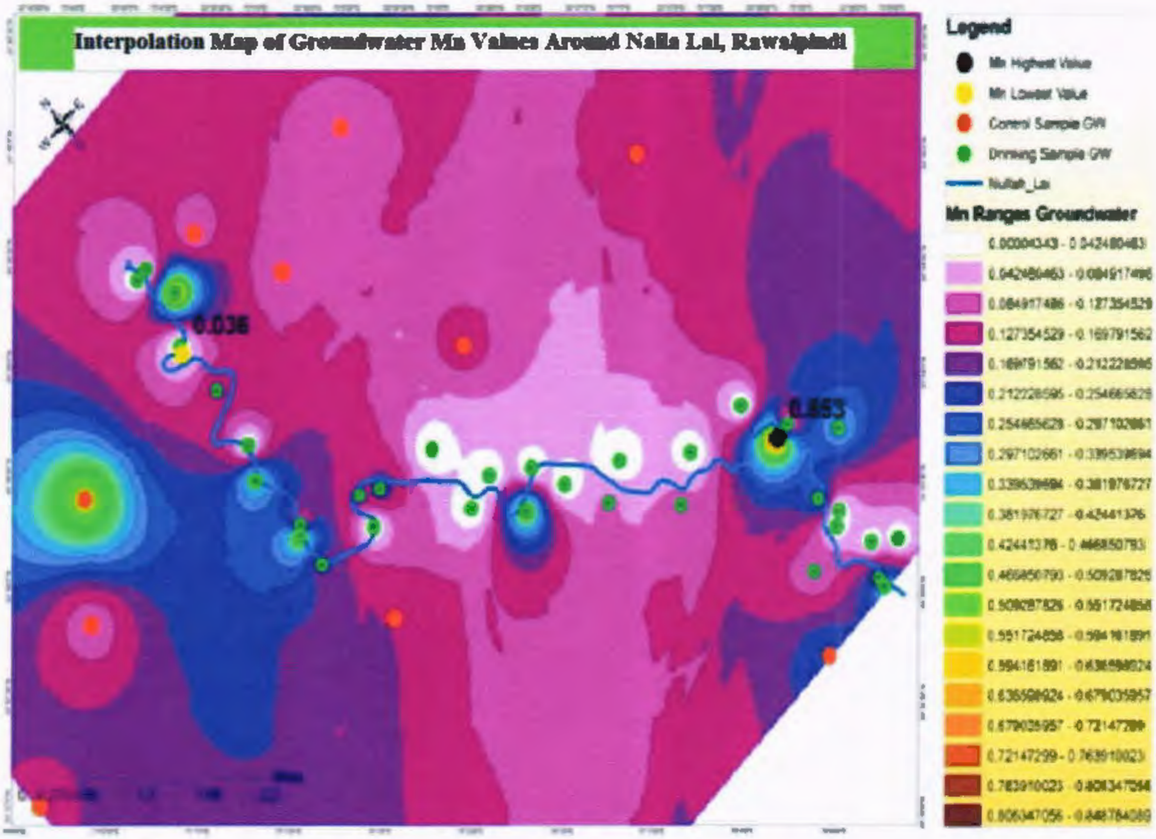


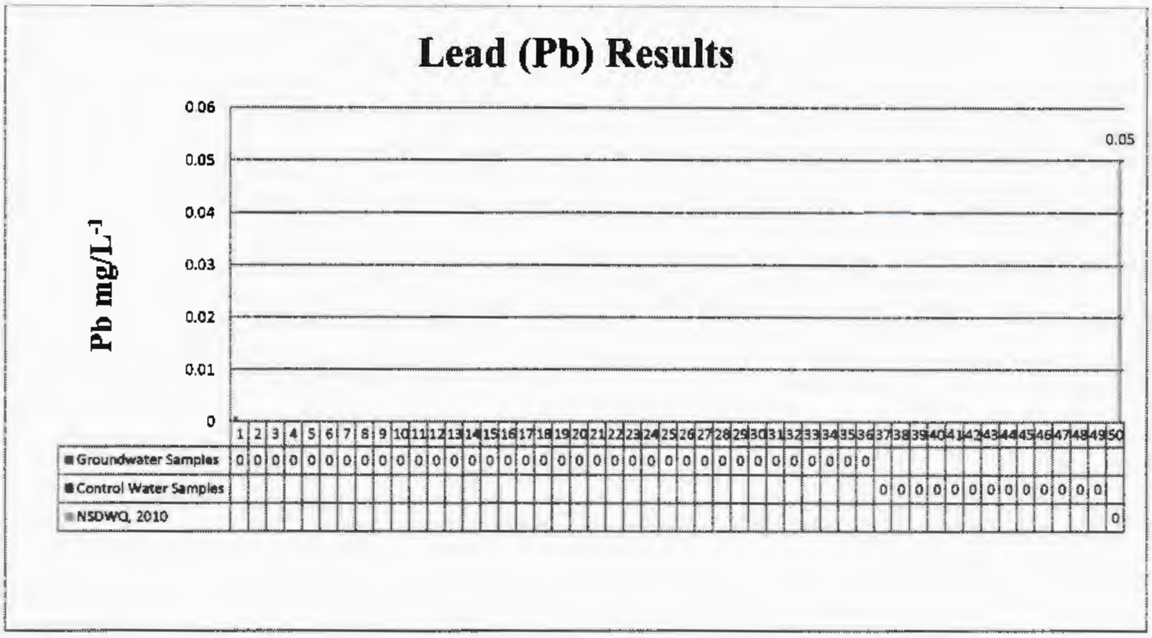
Figure 4.14: Interpolation Map Showing Highest and Lowest Mn Location Points of Groundwater.

Manganese occurs naturally in both surface and groundwater. Anthropogenic activities are also responsible for its introduction in water (US EPA, 2004). It is an important trace nutrient for all living organisms (Emsley, 2003). It binds or regulates numerous enzymes of body but excess dose of Manganese targets nervous system of brain (Crossgrove and Zheng, 2004). It may also cause permanent neurological disorders having symptoms which are related to Parkinson's disease (Barbeau, 1984; Inoue and Makita, 1996).

The standard value for Manganese (Mn) in drinking water is 0.5 mg/L^{-1} (NSDWQ, 2010). The average value of Manganese in (49) groundwater samples was 0.25 mg/L^{-1}. Maximum value of Manganese in groundwater samples was 0.853 mg/L^{-1} which was analysed in sample#28 of dug well water. Minimum value of Manganese in groundwater samples was 0.036 mg/L^{-1} which was observed in sample#3. Overall (5) groundwater samples out of (49) samples showed Manganese concentration above the standard value.

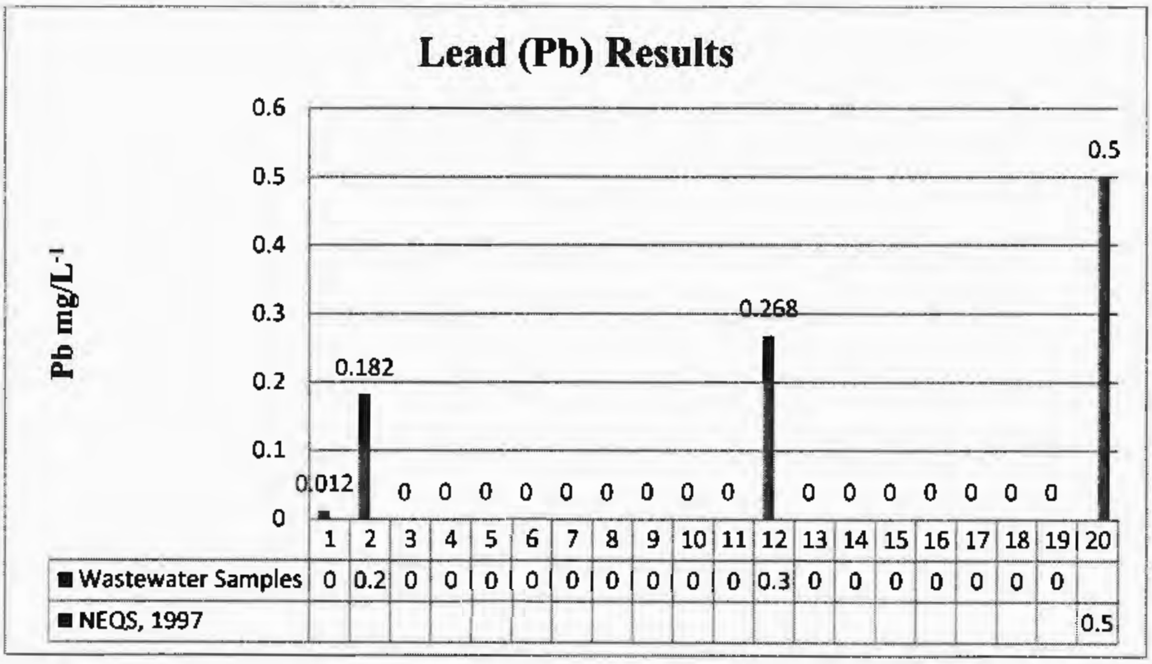
The standard value for Manganese in wastewater is 1.5 mg/L^{-1} (NEQS, 1997). The average value of Manganese in (19) wastewater samples was 0.35 mg/L^{-1}. Maximum value of Manganese in wastewater samples was 1.483 mg/L^{-1} which was analysed in sample#1. Minimum value of Manganese in wastewater samples was 0.150 mg/L^{-1} which was detected in sample#2.

4.15 Lead (Pb):



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
■ Groundwater Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
■ Control Water Samples																																					0	0	0	0	0	0	0	0	0	0	0	0	0	
■ NSDWQ, 2010																																																		0

Graph 4.15: Pb Variations in Groundwater Samples.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
■ Wastewater Samples	0	0.2	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	
■ NEQS, 1997																				0.5

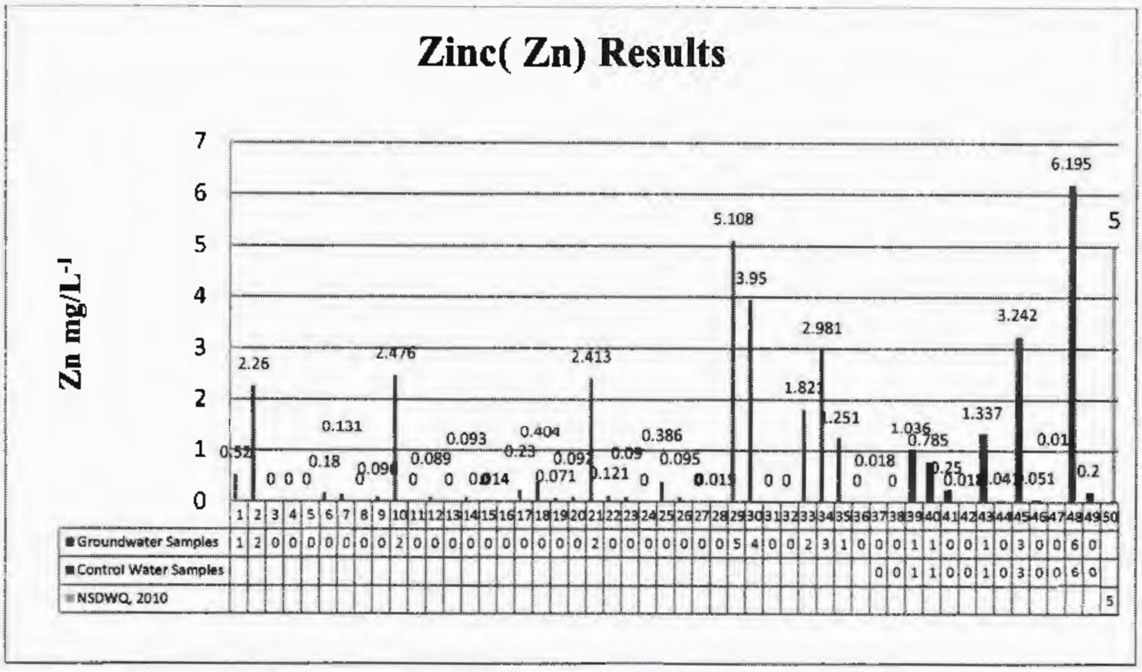
Graph 4.15.1: Pb Variations in Wastewater Samples.

Lead is common element exist in earth's crust and its minute concentration is naturally occurring in soil and water (Raviraja et al., 2008). Lead contamination occurs in drinking water through different sources like domestic paints, vehicular emissions and wastes from industrial activities (Nadeem et al., 2009). Long term exposure to lead can leads to several diseases and harmfully affect vital organs such as nervous system, digestive system, cardiovascular system, Haematopoietic system, reproductive system, immunological system, kidneys and skeleton as well (Gidlow, 2004; Venkatesh, 2004).

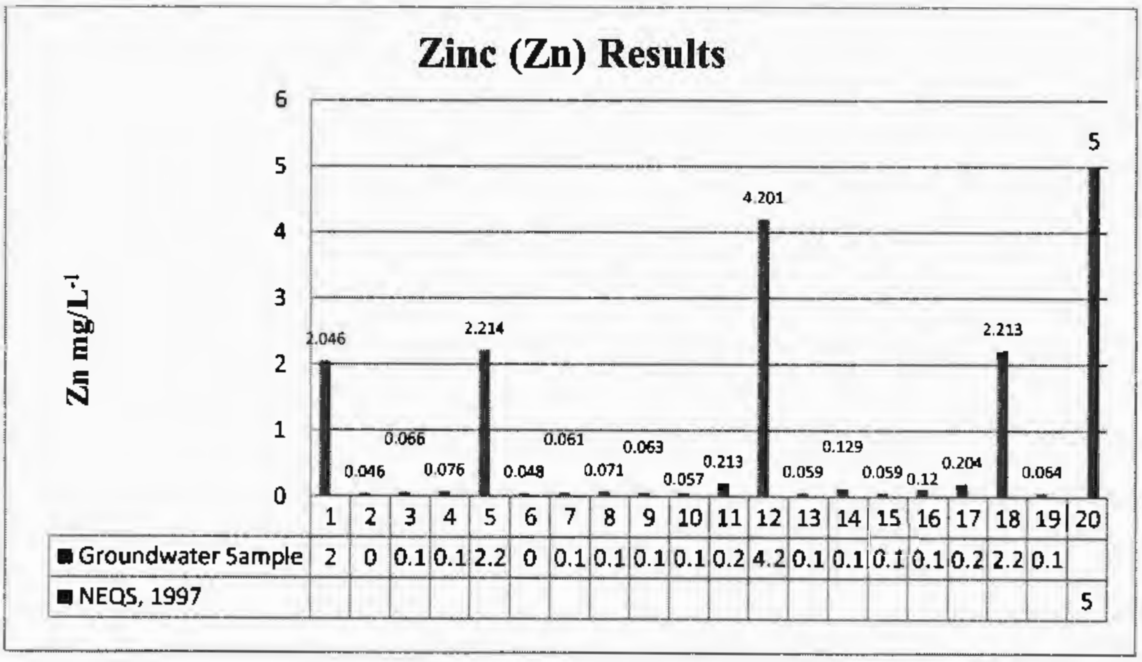
The standard value for Lead (Pb) in drinking water is 0.05 mg/L^{-1} (NSDWQ, 2010). Among (49) groundwater samples Lead was only detected in sample#1 in a very minute concentration i.e. 0.001 mg/L^{-1}.

The standard value for Lead (Pb) in wastewater is 0.5 mg/L^{-1} (NEQS, 1997). Lead was detected in only three wastewater sample among (19) samples. The average value of Lead in (3) wastewater samples was 0.15 mg/L^{-1}. Maximum value of Lead in wastewater samples was 0.268 mg/L^{-1} which was analysed in sample#12. Minimum value of Lead in wastewater samples was 0.012 mg/L^{-1} which was detected in sample#1.

4.16 Zinc (Zn):



Graph 4.16: Zn Variations in Groundwater Samples.



Graph 4.16.1: Zn Variations in Wastewater Samples.

Table 4.16: Zinc (Zn) Permissible Limit Crossed Values of Groundwater Samples

S.No	Zinc (Zn) Concentration	Sample Number	Source of Water	Permissible Limit 5 mg/L^{-1} NSDWQ, 2010
1	6.195	48	Bore water	
2	5.108	29	Bore water	

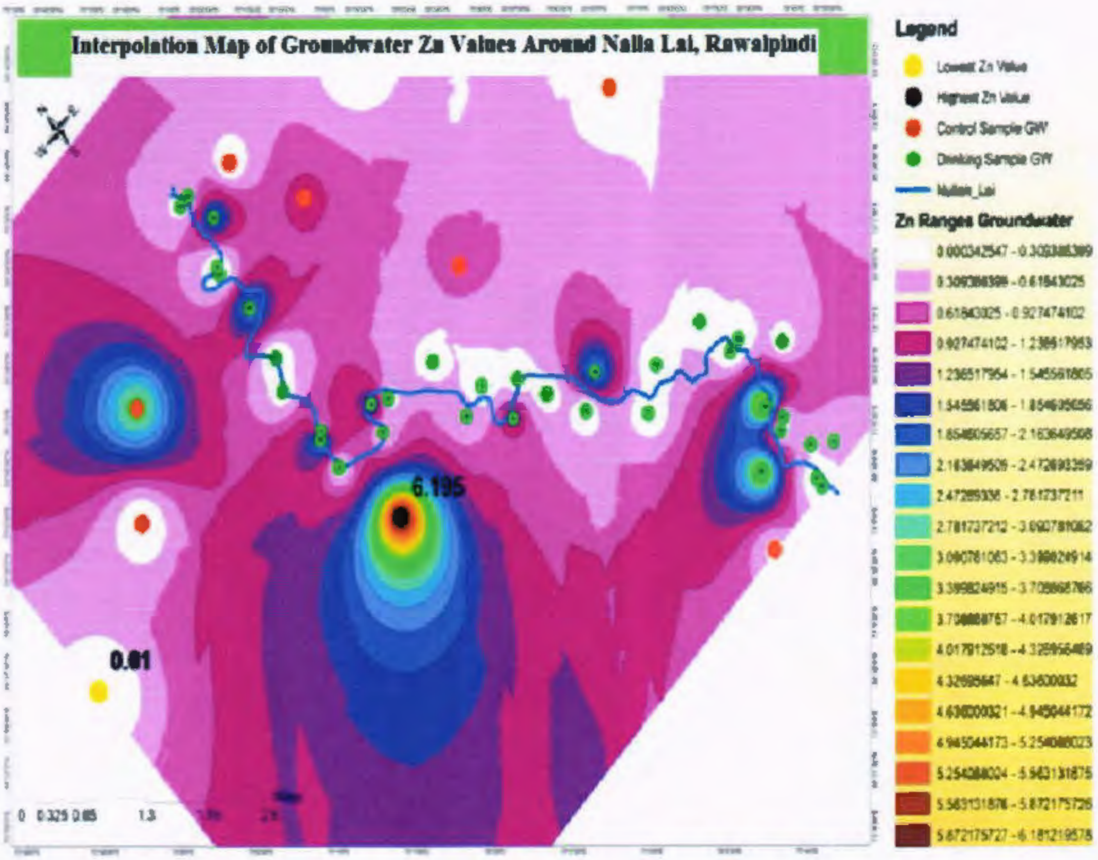


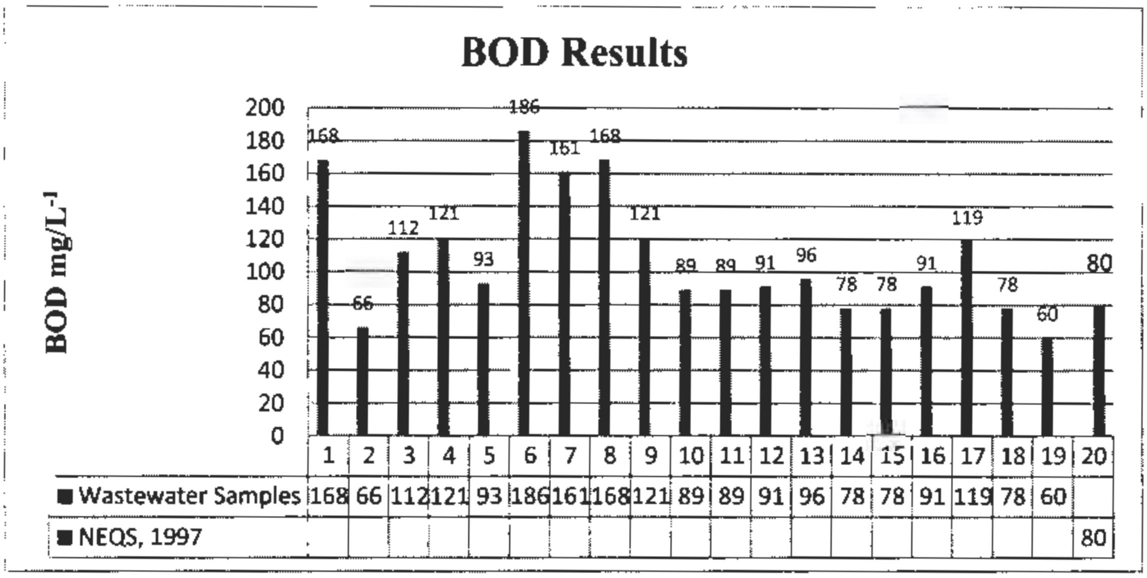
Figure 4.16: Interpolation Map Showing Highest and Lowest Zn Location Points of Groundwater.

Zinc is a necessary element for human health (Solomons and Ruz, 1998). Maintaining zinc concentration in body cells is vital for survival. Zinc releases from food as a free ions during digestion in body (Nazanin et al., 2013). Its high concentration can cause health problem (Fosmire, 1990; Singh et al., 2006).

The standard value for Zinc (Zn) in drinking water is 5 mg/L^{-1} (NSDWQ, 2010). The average value of Zinc in (49) groundwater samples was 1.06 mg/L^{-1}. Maximum value of Zinc in groundwater samples was 6.195 mg/L^{-1} which was analysed in sample#48 of bore water. Minimum value of Zinc in groundwater samples was 0.010 mg/L^{-1} observed in sample#47. Overall 2# samples out of (49) groundwater samples showed Zinc concentration above the standard value.

The standard value for Zinc in wastewater is 5 mg/L^{-1} (NEQS, 1997). The average value of Zinc in (19) wastewater samples was 0.68 mg/L^{-1}. Maximum value of Zinc in wastewater samples was 4.201 mg/L^{-1} which was analysed in sample#12. Minimum value of Zinc in wastewater samples was 0.048 mg/L^{-1} which was detected in sample#6.

4.17 Biological Oxygen Demand (BOD):

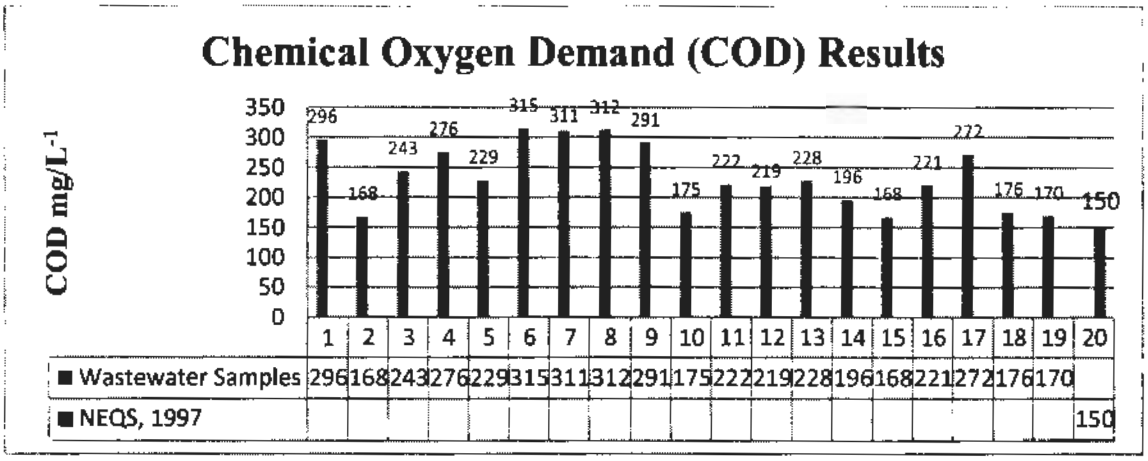


Graph 4.17: BOD Variations in Wastewater Samples.

BOD determines the amount of oxygen utilized by aerobic bacteria or microorganism to decompose organic matter. It measures the load of organic matter in a stream and quantifies the level of dissolved oxygen (Auju, 2015). The normal range of BOD in domestic wastewater is 100-300 mg/L^{-1} (Khaled and Gina, 2014).

The standard value for BOD in wastewater is 80 mg/L^{-1} (NEQS, 1997). The average value of BOD in (19) wastewater samples was 108.68 mg/L^{-1}. Maximum value of BOD in wastewater samples was 186 mg/L^{-1} which was analysed in sample#6. Minimum value of BOD in wastewater samples was 60 mg/L^{-1} which was detected in sample#19 (the end point of Nalla Lai).

4.18 Chemical Oxygen Demand:



Graph 4.18: COD Variations in Wastewater Samples.

Chemical Oxygen Demand is the measure of oxygen level required to decompose both organic and inorganic matter in water (Anju, 2015). COD is basically chemically breakdown of pollutants where oxygen is required to execute absolute oxidation to CO_2 and H_2O (Naveed et al., 2013). There is a strong correlation between COD and BOD. COD value is normally four times higher than that of BOD value because it measures both biodegradable and non-biodegradable waste but it also varies on the nature of contaminants and raw materials. COD is very fast and more perfect method than BOD. Industries usually conduct COD of waste effluents whereas municipalities focus on BOD test.

The standard value for COD in wastewater is 150 mg/L^{-1} (NEQS, 1997). The average value of COD in (19) wastewater samples was 236.21 mg/L^{-1}. Maximum value of COD in wastewater samples was 315 mg/L^{-1} which was analysed in sample#6. Minimum value of COD in wastewater samples was 168 mg/L^{-1} which was detected in sample#2. Both highest and lowest values of BOD in analysed samples of the Nalla Lai wastewater were exceeding the standard value of NEQS, 1997.

4.19 E.coli:

Escherichia coli are basically a fecal coliform and a sub group of total coliform which is absolute indicator of fecal contamination. The presence of E.coli in drinking water indicates fecal contamination because it is commonly found in mammalian feces. Drinking contaminated water can cause diseases like cholera, diarrhea, typhoid, hepatitis (Azizullah et al., 2014).

Total (33) groundwater samples were tested for microbial analysis. The results revealed that (26) samples out of (33) samples showed fecal contamination whereas (7) samples showed positive result.

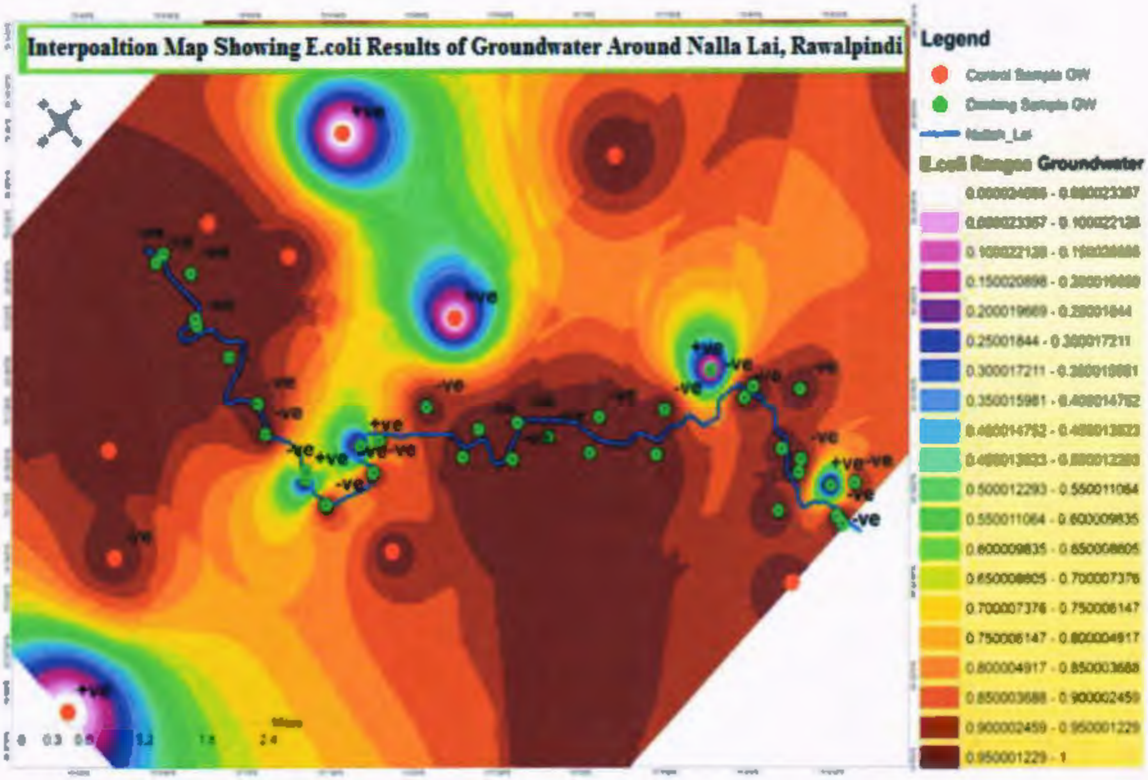


Figure 4.19: Location Points of Positive and Negative Results of E.coli in Groundwater.

Table 4.19: Microbial Results of Groundwater Samples

S. No	Sample No	Source of Sample	Location Area	Sampling Site of Nalla Lai	Sampling Point	Results	
						Positive	Negative
1	1	Tube well	Kataria Mohallah	Left Site	Pipe		-ve
2	2	Bore water	City Coloney- E-Block	Left Site	Hand Pump		-ve
3	3	Tube well	New Phakware	Left Site	Cooler		-ve
4	4	Tube well	Kashmir Coloney Mujahid Abad	Left Site	Cooler		-ve
5	5	Tube well	Ratta Mohin Pura	Left Site	Cooler		-ve
6	6	Bore water	Itehad Coloney	Left Site	Tap stand		-ve
7	7	Bore water	Aria Mohallah	Left Site	Inlet water		-ve
8	8	Tube well	Dhoke Cherage Deen	Left Site	Tap stand		-ve
9	9	Tube well	Qazi Abad	Left Site	Tap stand		-ve
10	10	Tube well	Chaklal Scheem Askai 3	Left Site	Tap stand		-ve
11	11	Bore water	Askari 1	Left Site	Inlet water		-ve
12	12	Bore water	Chaklal Scheem 3	Left Site	Inlet Pipe	+ve	
13	13	Bore water	Dhoke Choderia	Left Site	Tap stand		-ve
14	14	Bore water	Dhoke Choderia	Left Site	Cane		-ve
15	15	Bore water	Bostan Valley	Left Site	Bottle		-ve
16	17	Bore water	High Court Road Timber Market	Left Site	Tap stand	+ve	
17	18	Bore water	High Court Road	Left Site	Tap stand		-ve
18	19	Tube well	Amin Abad Khayaban Sir Syed	Right Site	Tap stand		-ve
19	22	Bore water	Hazara Coloney	Right Site	Tap stand		-ve
20	23	Tube well	Ratta Imran Kachey Abaday	Right Site	Bucket		-ve
21	24	Bore water	Darya Abad Gawal Mandey	Right Site	Tap stand		-ve
22	26	Bore water	Ghanda Street-6	Right Site	Tap stand		-ve
23	28	Dug well	Ghulistan Coloney line Numb-3	Right Site	Tap stand		-ve
24	31	Spring	Sua Adda	Right Site	Spring source		-ve
25	32	Spring	Sua Adda Darbar	Right Site	Pipe		-ve
26	33	Tube well	Serat Gunj	Right Site	Tap stand	+ve	
27	34	Bore water	Mohellah Melad Nagar	Right Site	Inlet water	+ve	
28	35	Bore water	Ghanda Chichi Street Number-7	Right Site	Inlet water		-ve
29	37	Tube well	Dhoke Paracha	Left Site	Tap stand	+ve	
30	40	Bore water	Chaudhery Dhoke Farman Ali	Left Site	Hand Pump	+ve	
31	44	Bore water	Pakistan Town	Left Site	Inlet water		-ve
32	46	Bore water	Chak Madad khan	Right Site	Tap stand		-ve
33	47	Tube well	Ali Abad	Right Site	Tap stand	+ve	

4.20 Statistical Relationship:

Correlation is the statistical relationship between two or more than two variables. It is a useful way to predict a relationship, measurement of strength and significance of relationship between two or more parameters (Nikunj et al., 2015). It is used to measure the degree of relationship, how much which two variables are related. All types of correlation having two properties i.e. strength and direction. The strength of the correlation is determined by the numerical values and the direction of correlation is determined whether the correlation is positive or negative. X describe the explanatory variable whereas, Y describes the response variable.

Correlations are of three types, Positive correlation, Negative correlation and No correlation.

a. Positive Correlation:

A correlation is said to be positive correlation when two variables are changing in same direction e.g. Height and Weight.

b. Negative Correlation:

A correlation is said to be negative correlation when two variables are changing in opposite direction e.g. Price and quality.

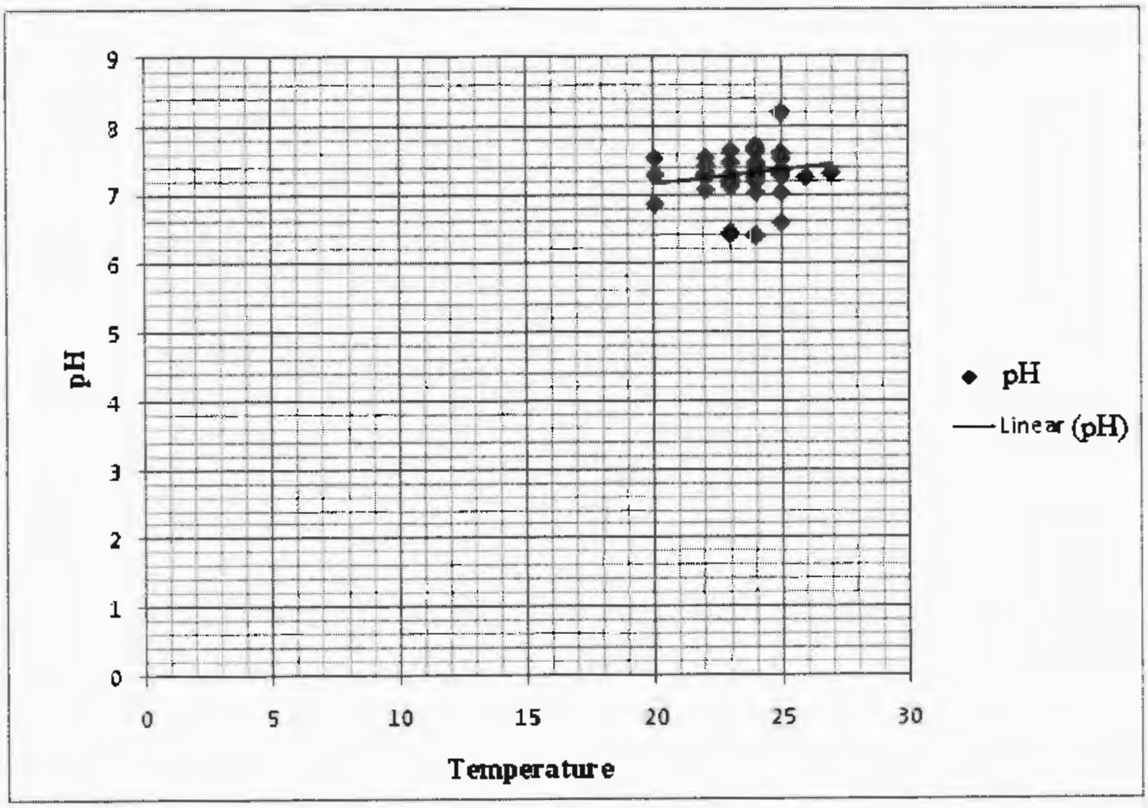
c. No Correlation:

A correlation is said to be no correlation when there is no apparent relationship between two variables e.g. shoes price and salary.

4.21 Correlations between Groundwater Parameters:

The correlation between different parameters of groundwater samples is established on the basis of analysed results. The objective of correlations was to observe whether two different parameters have strong correlation, weak correlation or no correlation between different parameters.

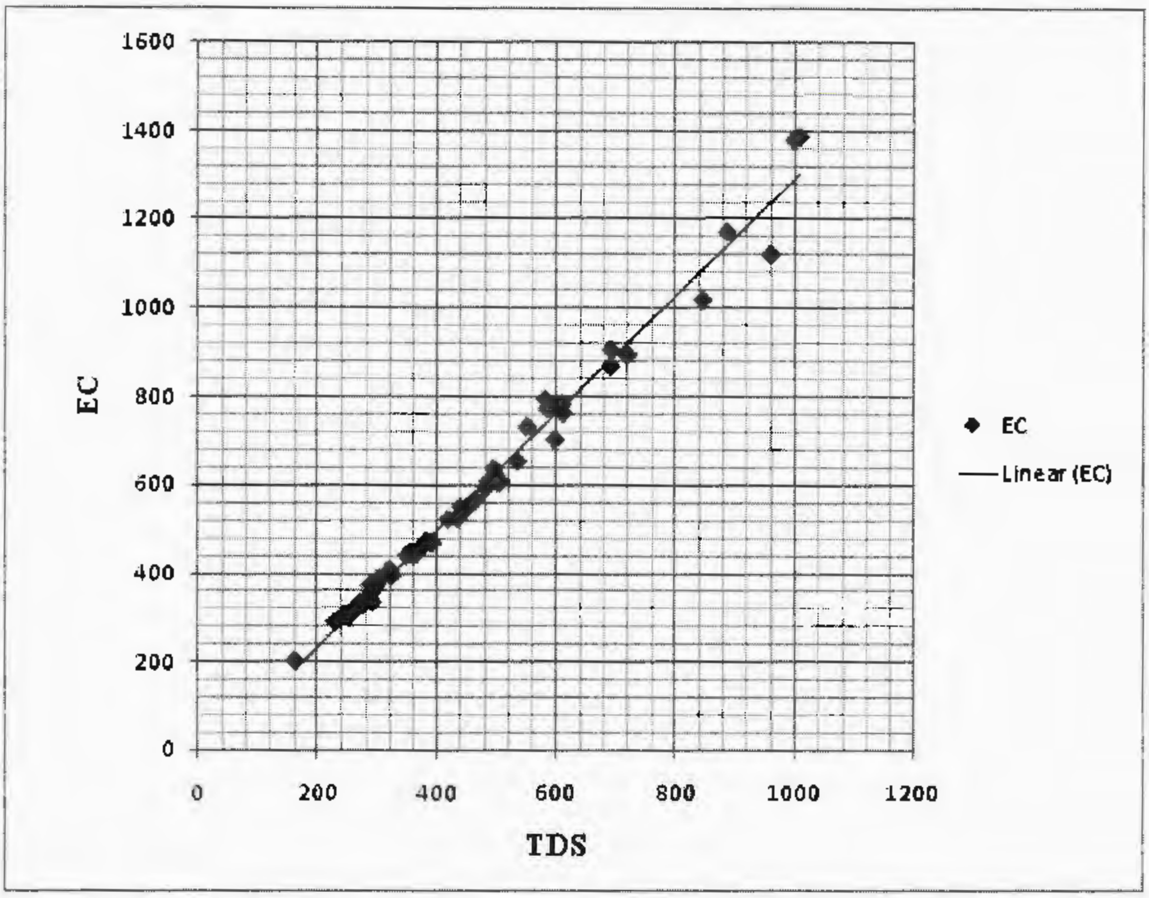
4.21.1 Correlation of Temperature and pH:



Graph 4.21.1: Correlation Between Temperature and pH.

The best fit line in the graph indicates that no correlation existed between temperature and pH. The increase or decrease in temperature scale has no relationship with pH values in the graph.

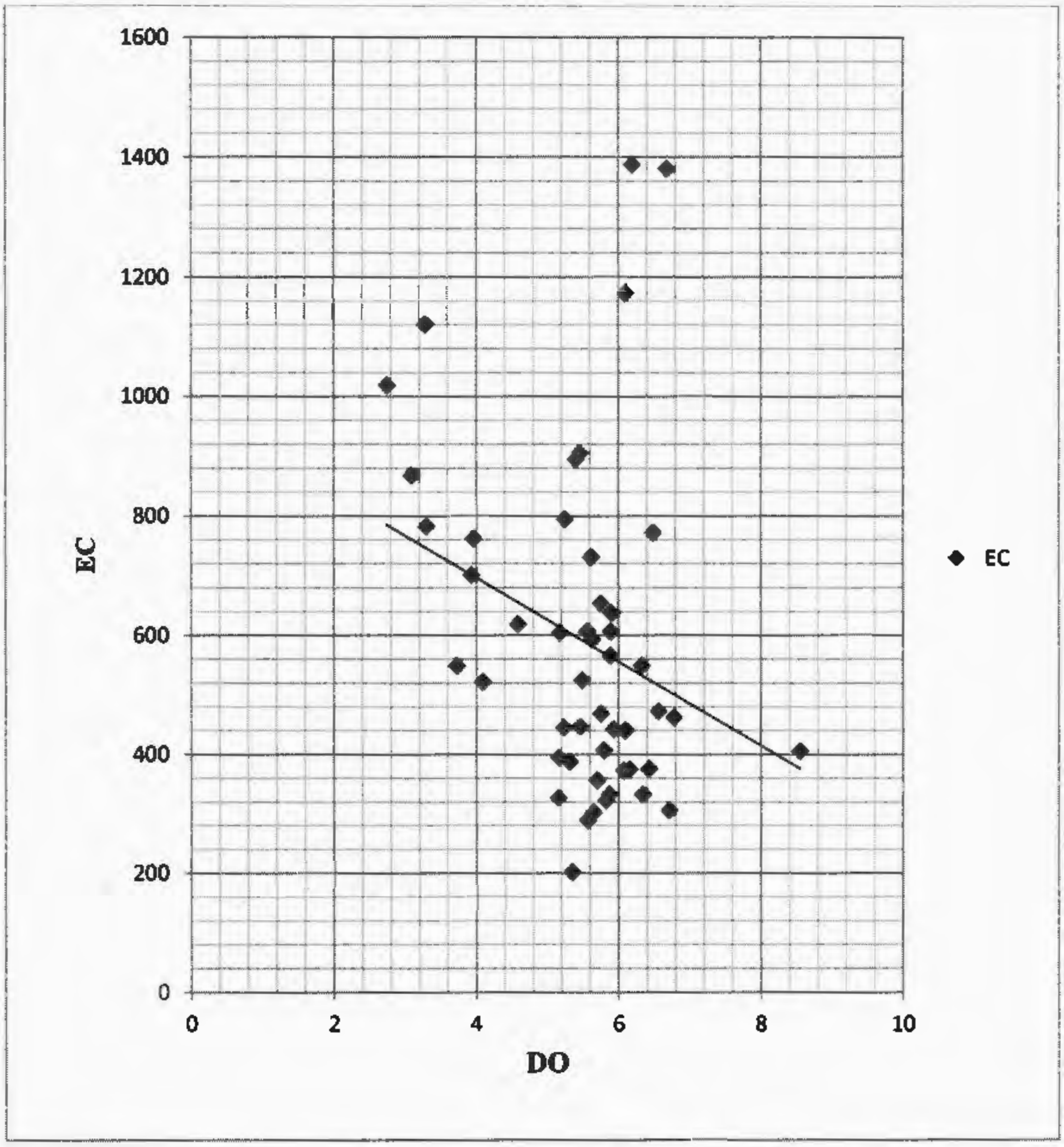
4.21.2 Correlation of TDS and EC:



Graph 4.21.2: Correlation Between TDS and EC.

The graph shows a positive linear correlation between TDS and EC values. The data points are concentrated around regression line which indicates a positive linear correlation between TDS and EC. As TDS values increases or decreases EC values also increases and decreases in the graph.

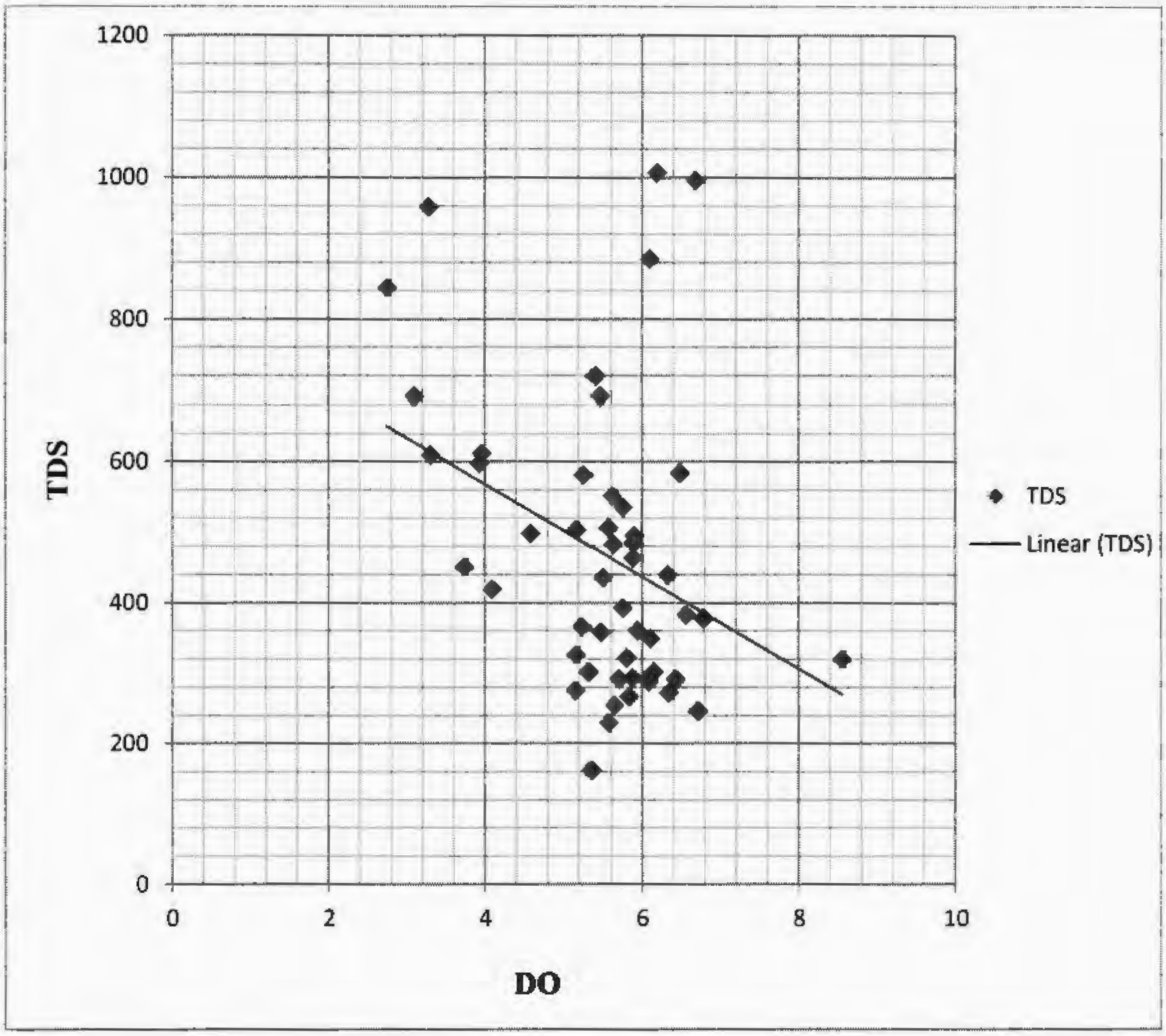
4.21.3 Correlation of DO and EC:



Graph 4.21.3: Correlation Between DO and EC.

The graph shows a weak negative linear correlation between DO and EC values. Many data points are located in regression line but maximum data points are in scattered form in the graph.

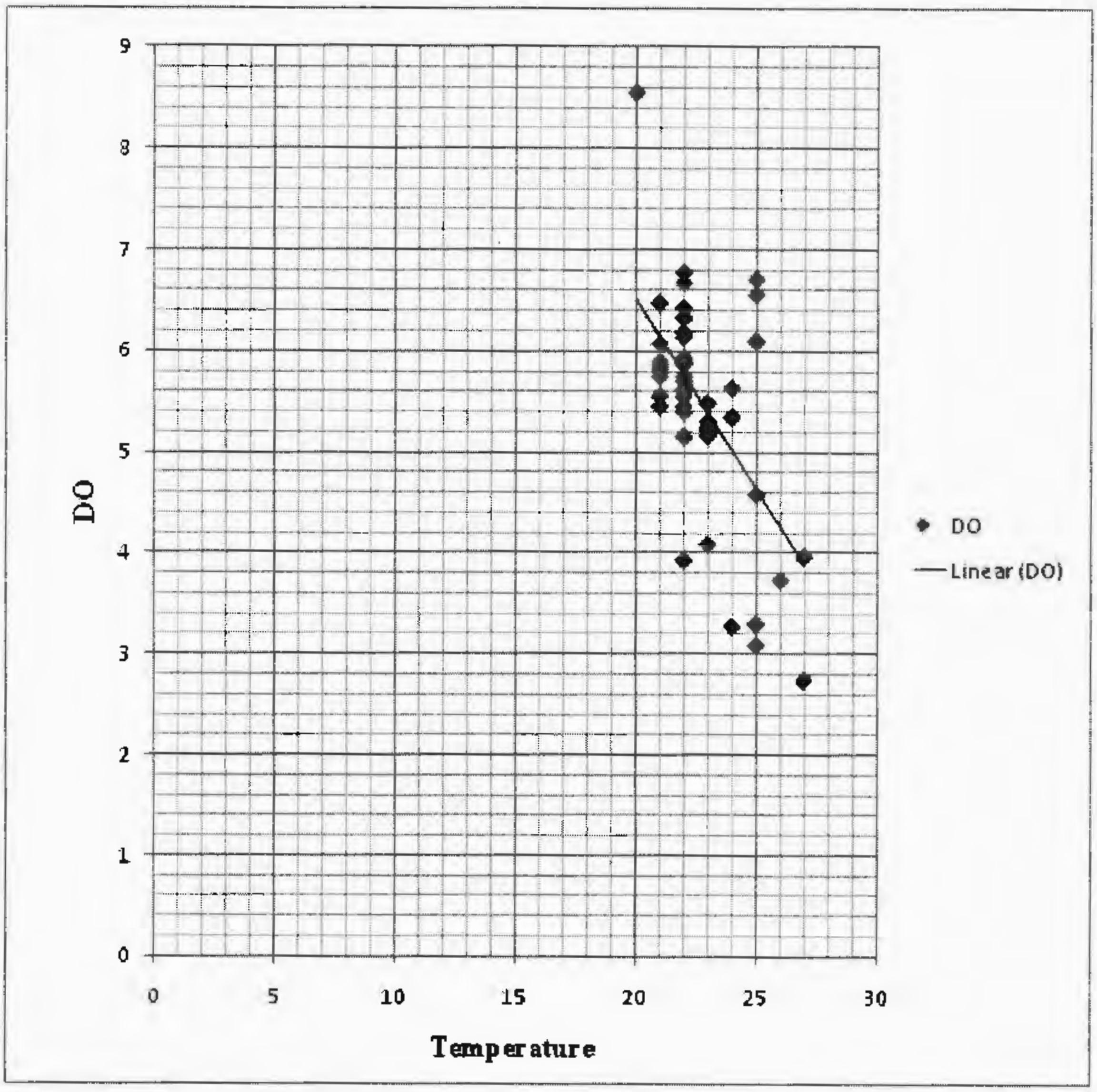
4.21.4 Correlation of DO and TDS:



Graph 4.21.4: Correlation Between DO and TDS.

The graph shows a weak negative linear correlation between DO and TDS values. Many data points are located in regression line indicate that when DO values increase or decreases TDS values also increases and decreases.

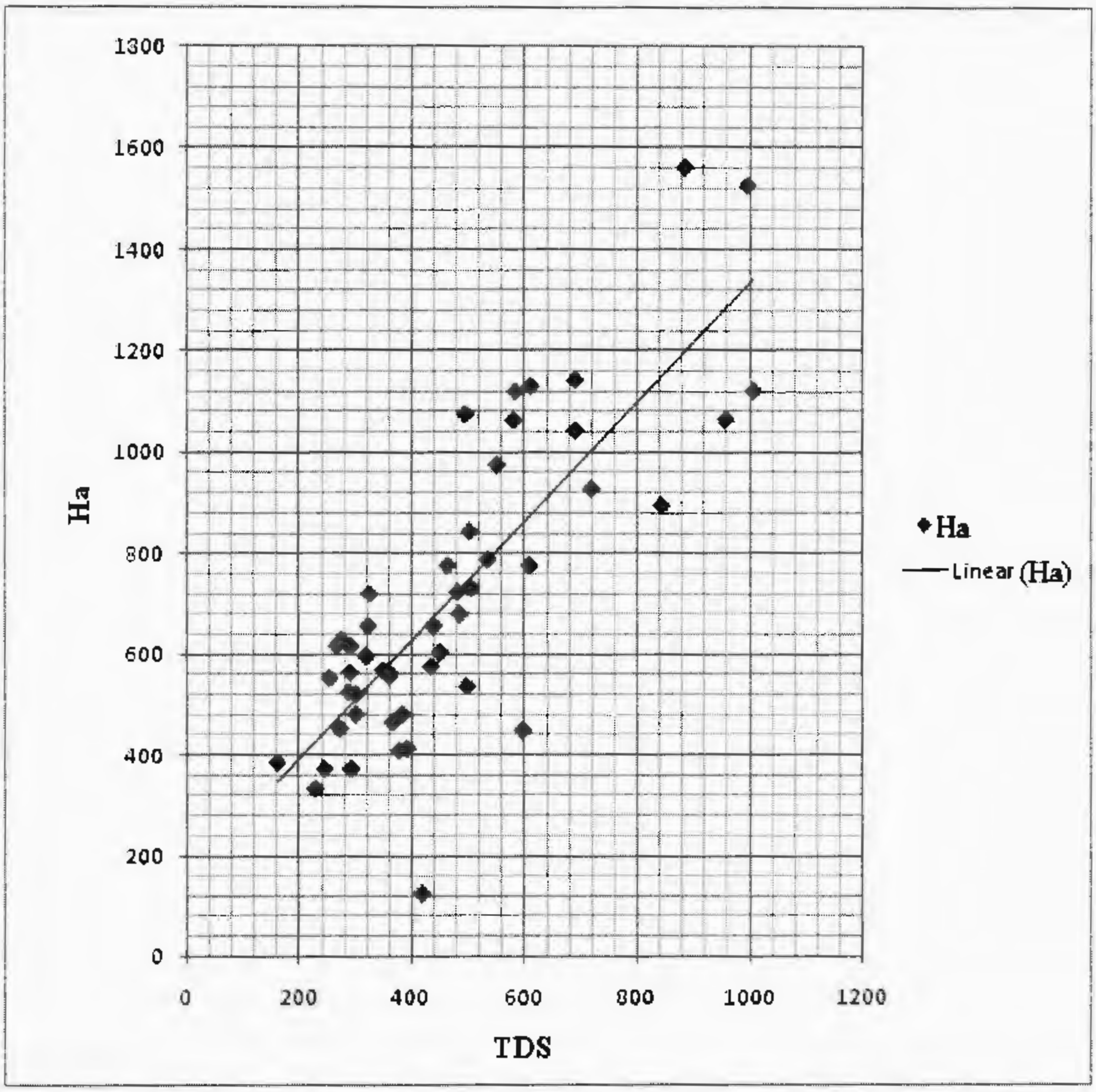
4.21.5 Correlation of Temperature and DO:



Graph 4.21.5: Correlation Between Temperature and DO.

Weak negative linear correlations existed between temperature and DO values. As many data points are concentrated around regression line between the region 20-25 along x-axis.

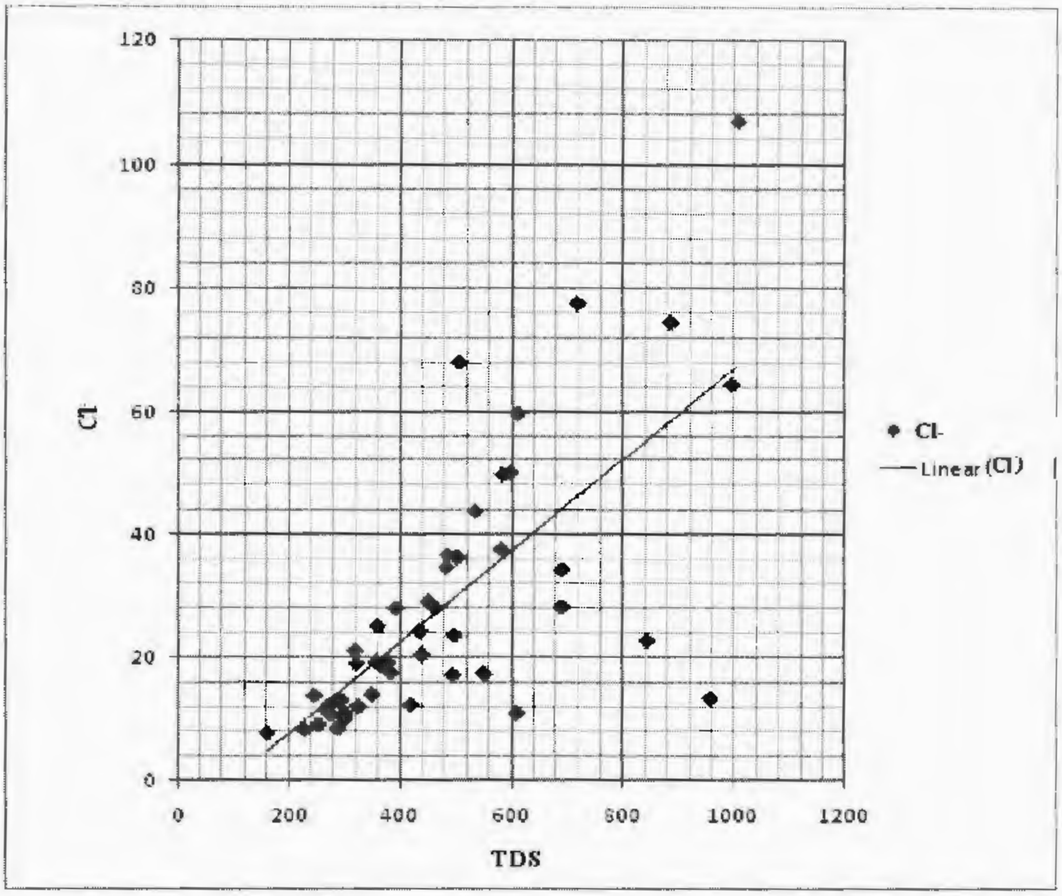
4.21.6 Correlation of TDS and Hardness (Ha):



Graph 4.21.6: Correlation Between TDS and Hardness.

The graph shows a weak positive linear correlation between TDS and Hardness values. Maximum data points are located between the regions of 200-600 along x-axis and the values are spreading away with increasing regression line till end point.

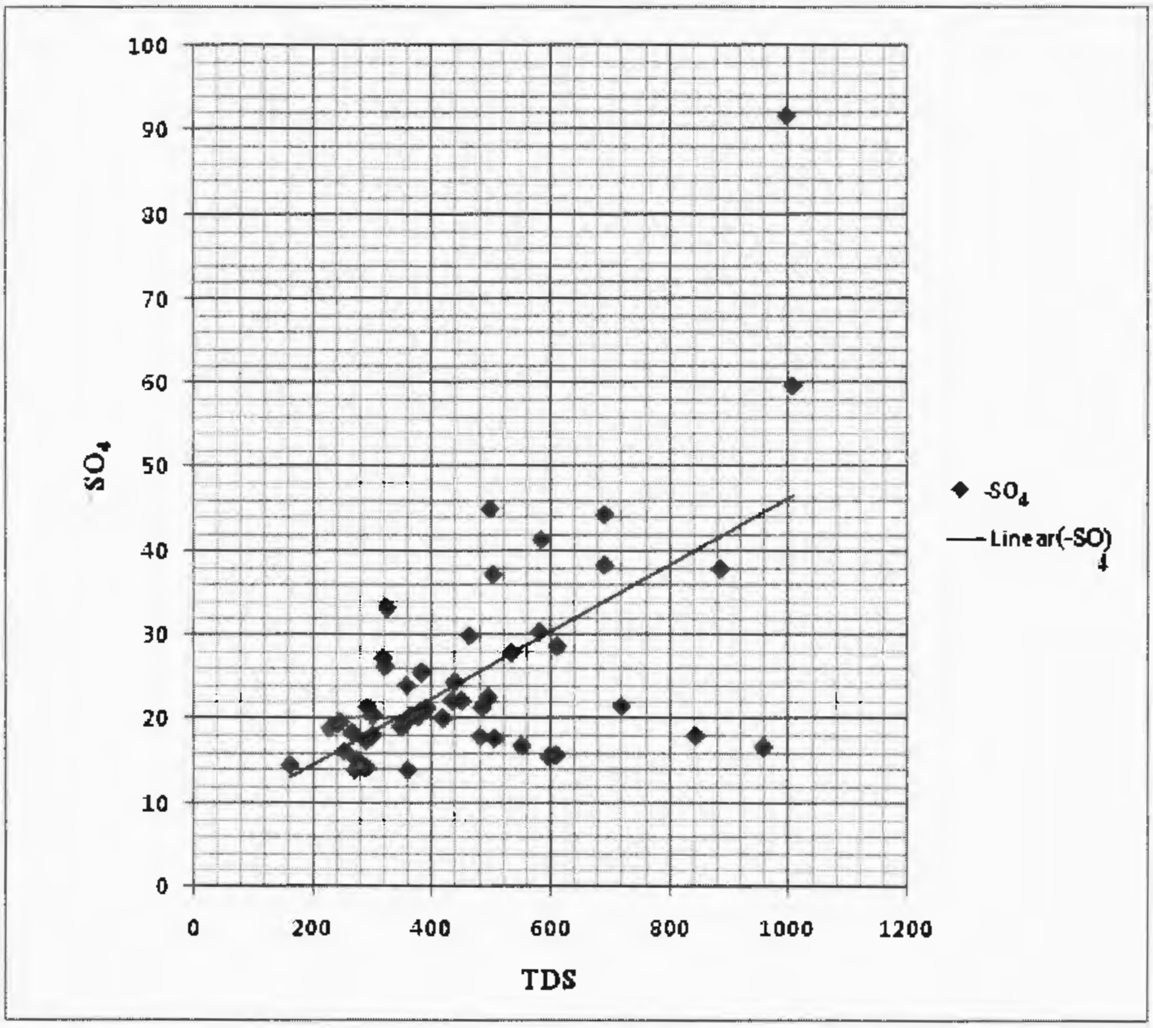
4.21.7 Correlation of TDS and Chloride (Cl⁻):



Graph 4.21.7: Correlation Between TDS and Chloride.

A weak positive linear correlation is observed between TDS and Chloride values. The graph shows maximum data points located near regression line between the regions 200-600 along x-axis.

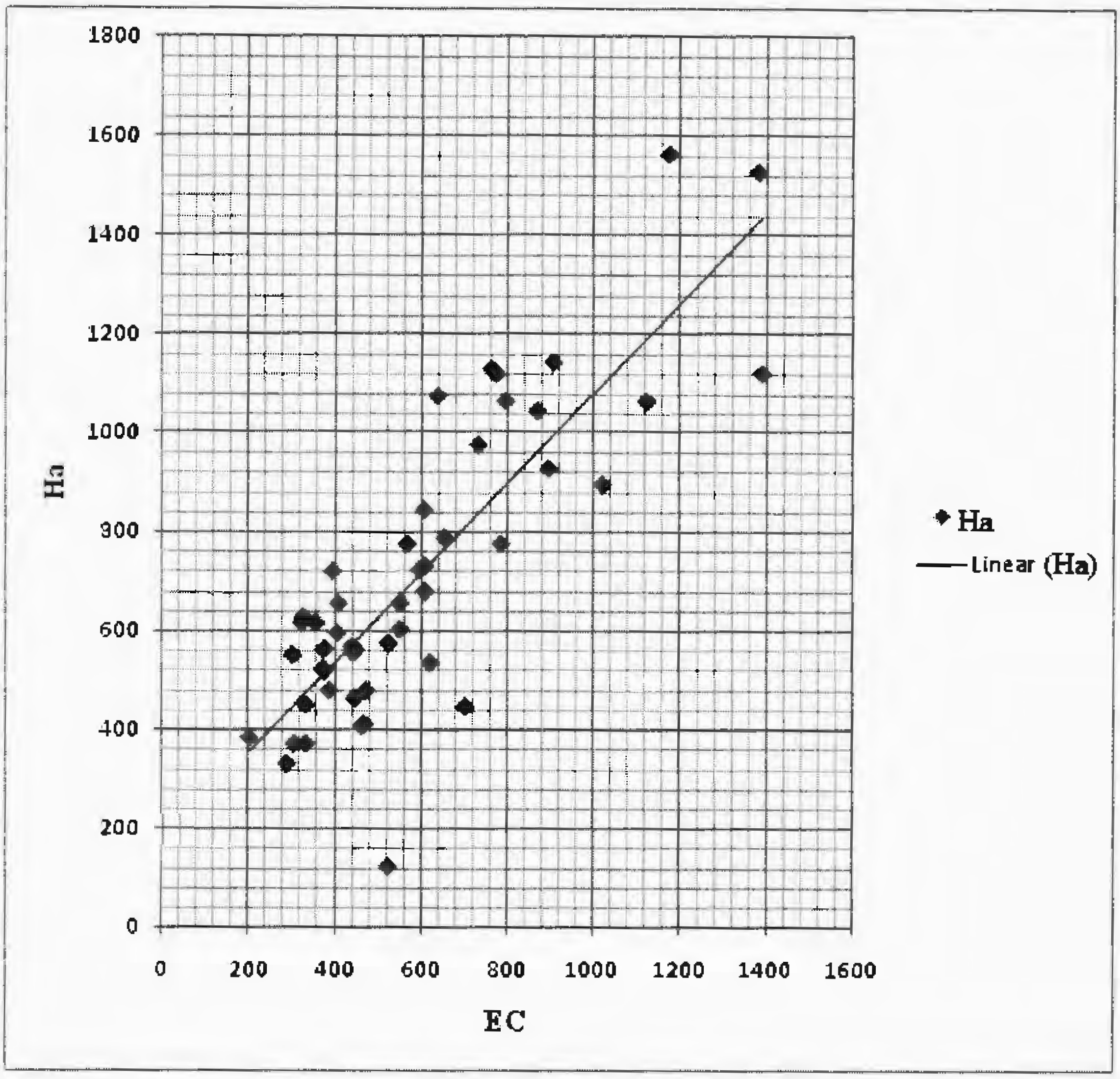
4.21.8 Correlation of TDS and Sulfate(-SO_4):



Graph 4.21.8: Correlation Between TDS and Sulfate

A weak positive linear correlation is found between TDS and Sulfate values. The graph shows that maximum data points are concentrated between the regions of 200- 600 along x-axis in the graph and the data is spreading away with increasing regression line till end point.

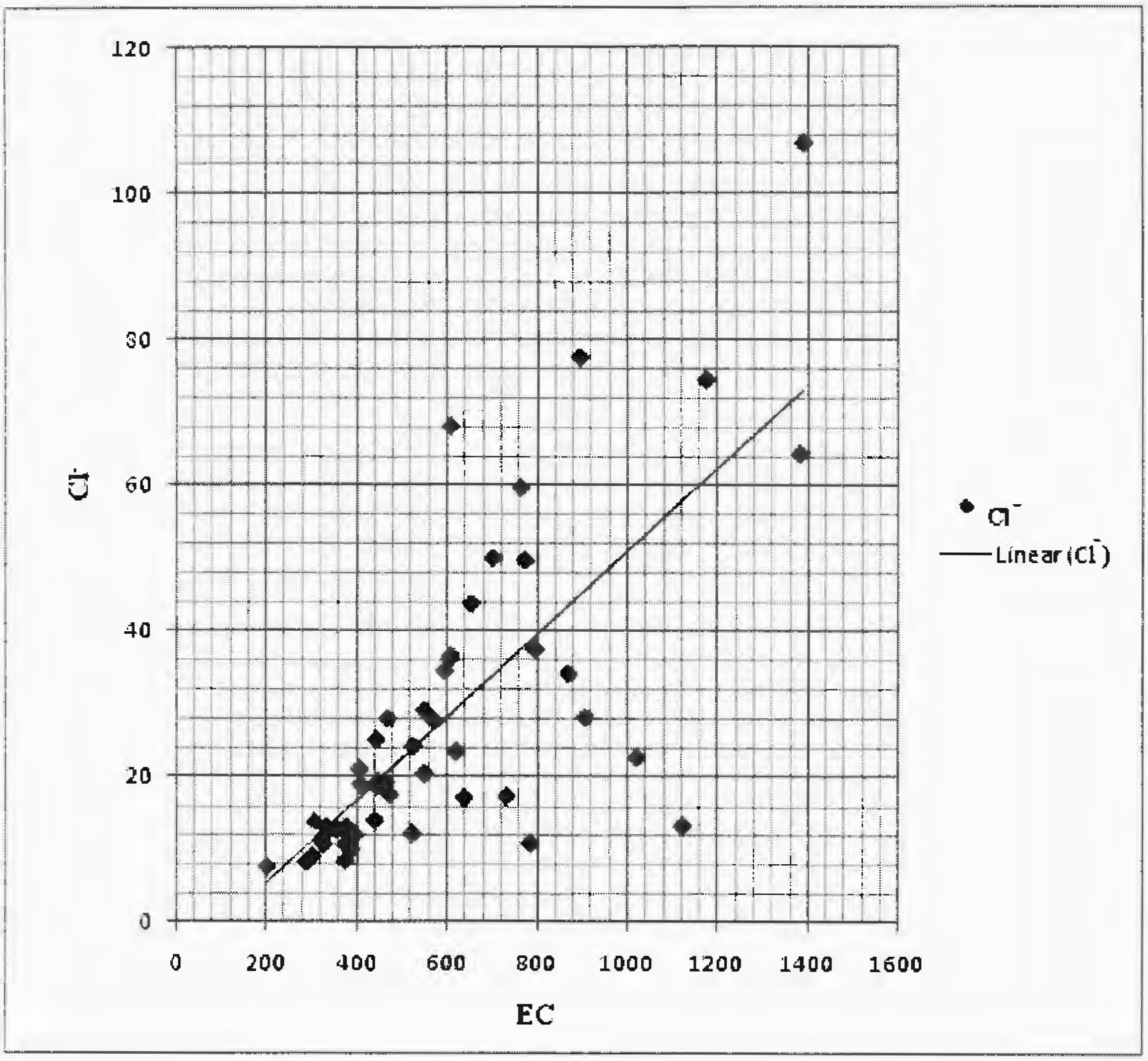
4.21.9 Correlation of EC and Hardness (Ha):



Graph 4.21.9: Correlation Between EC and Hardness

A weak positive linear correlation was found between EC and Hardness values in the graph. Maximum data points are concentrated in the regions 200-600 along x-axis. The data points are then spreading away with increasing regression line till end point.

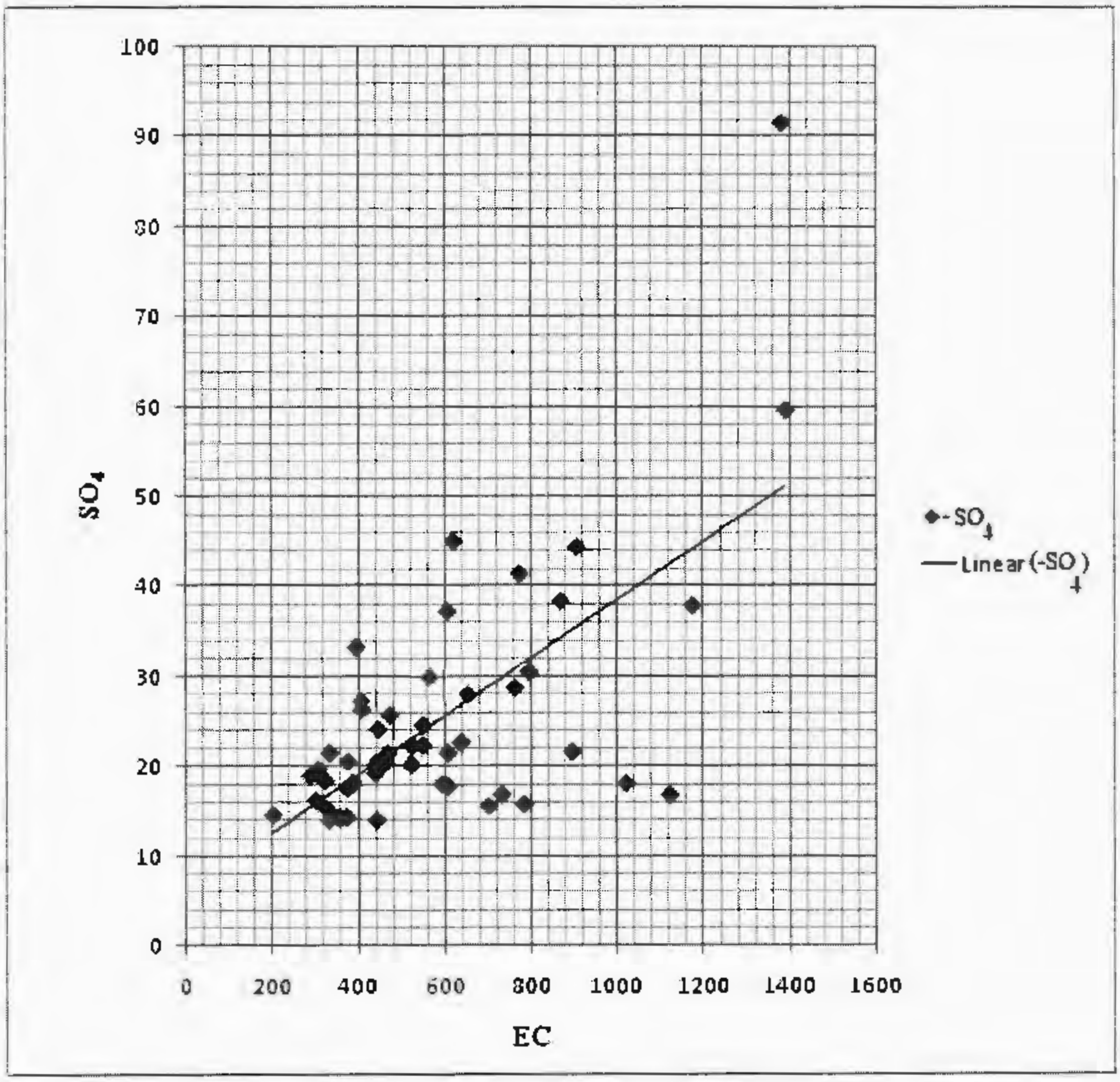
4.21.10 Correlation of EC and Chloride (Cl^-):



Graph 4.21.10: Correlation Between EC and Chloride.

The graph shows a weak positive linear correlation between EC and Chloride values. Maximum data points are located between the regions 200-600 along x-axis. The values are spreading away from regression line with increasing its length.

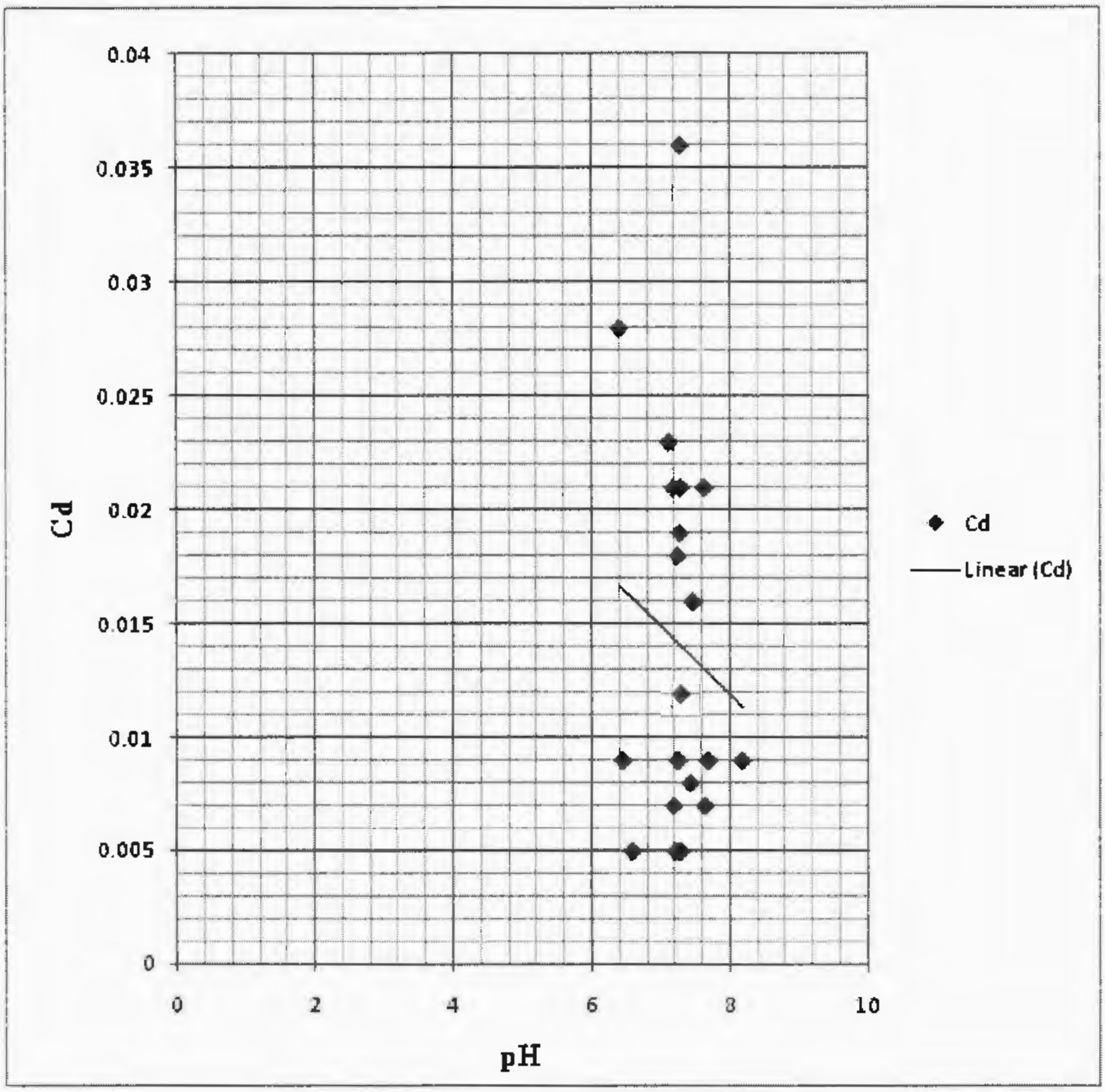
4.21.11 Correlation of EC and Sulfate (-SO_4):



Graph 4.21.11: Correlation Between EC and Sulfate

A weak positive linear correlation is observed between EC and Sulfate values. Maximum data points are located between the regions of 200-600 along x-axis. The values are spreading away from regression line with increasing the length of line.

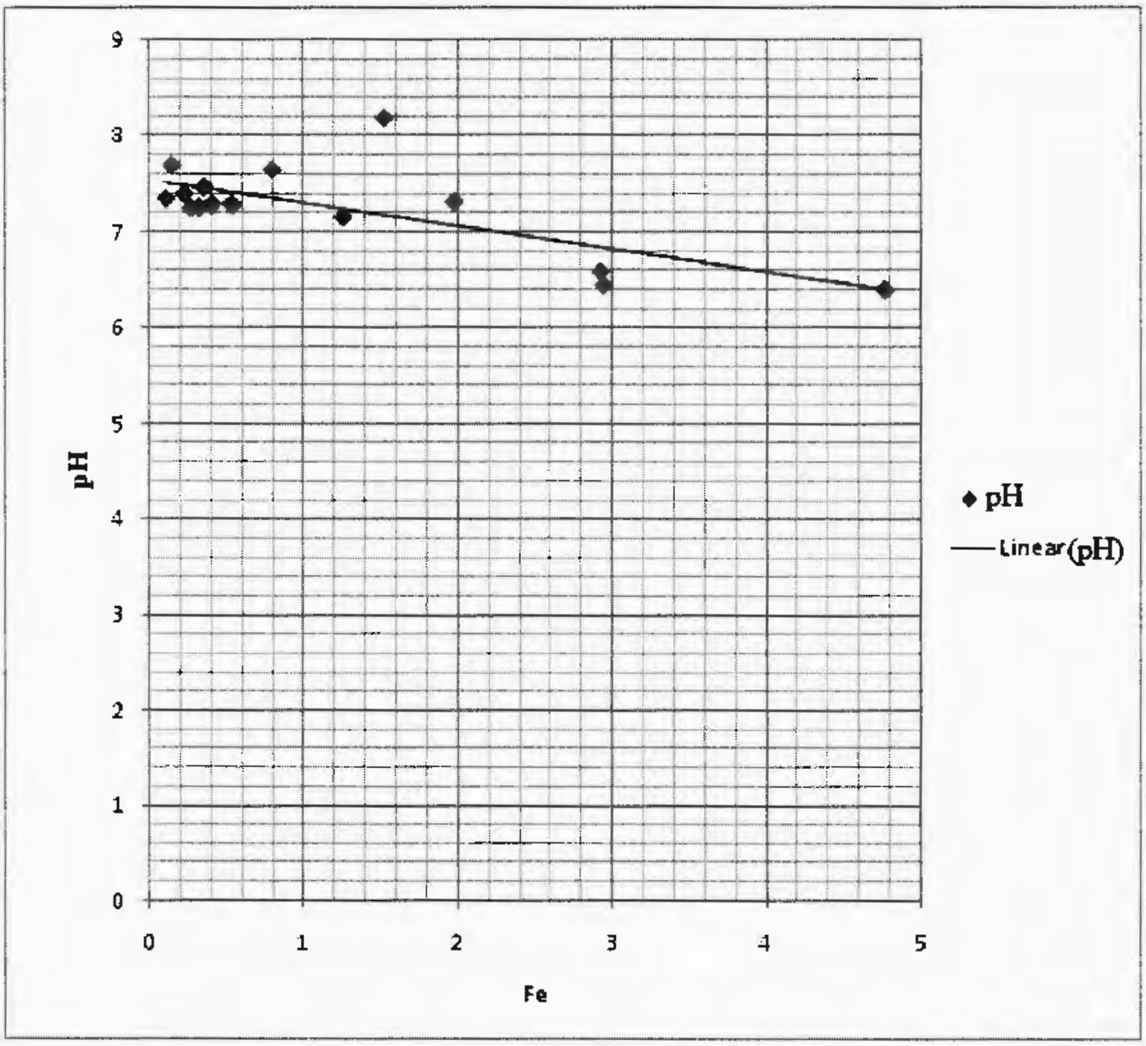
4.21.12 Correlation of pH and Cadmium (Cd):



Graph 4.21.12: Correlation Between pH and Cadmium.

A very weak negative linear correlation is observed between pH and Cadmium in the graph. All the data points are located away from regression line in the graph.

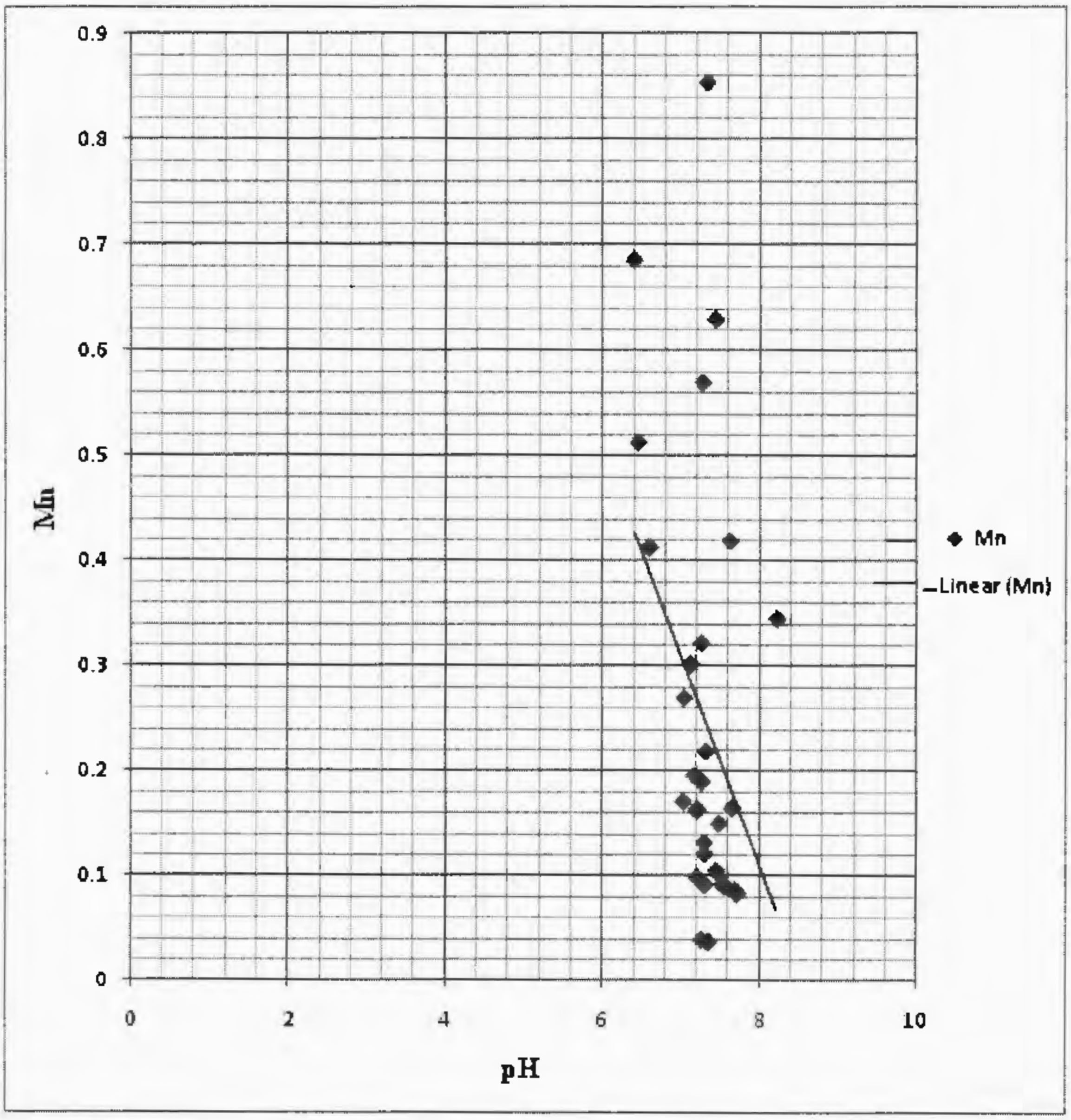
4.21.13 Correlation of Iron (Fe) and pH:



Graph 4.21.13: Correlation Between Iron and pH.

A weak negative linear correlation is observed between Iron and pH in the graph. Three data points are located adjacent to regression line while maximum data points are located between 0-1 along x-axis.

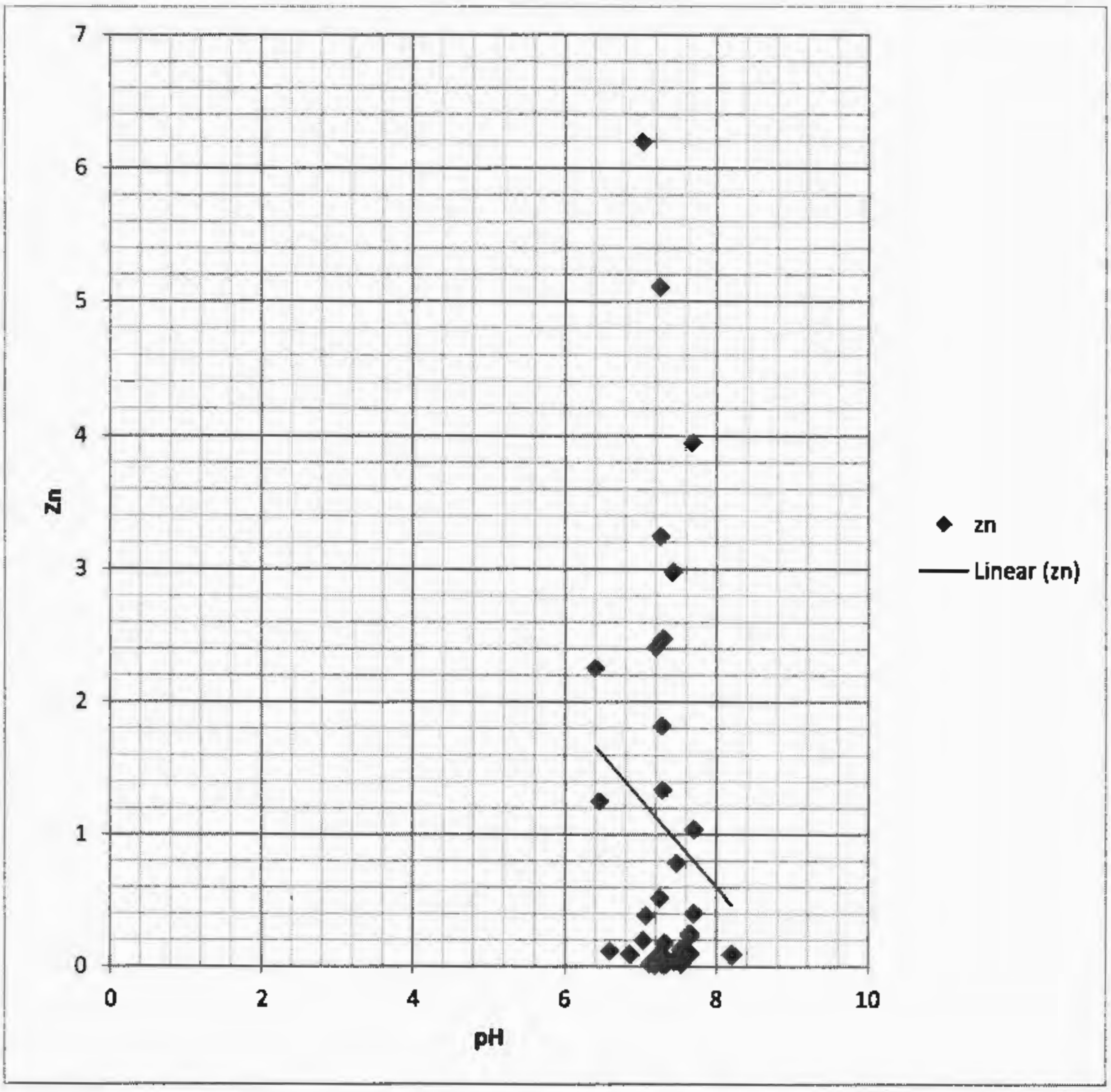
4.21.14 Correlation of pH and Manganese (Mn):



Graph 4.21.14: Correlation Between pH and Manganese.

A weak negative linear correlation is observed between pH and Manganese. Maximum data points are concentrated in regions 7-8 along x-axis.

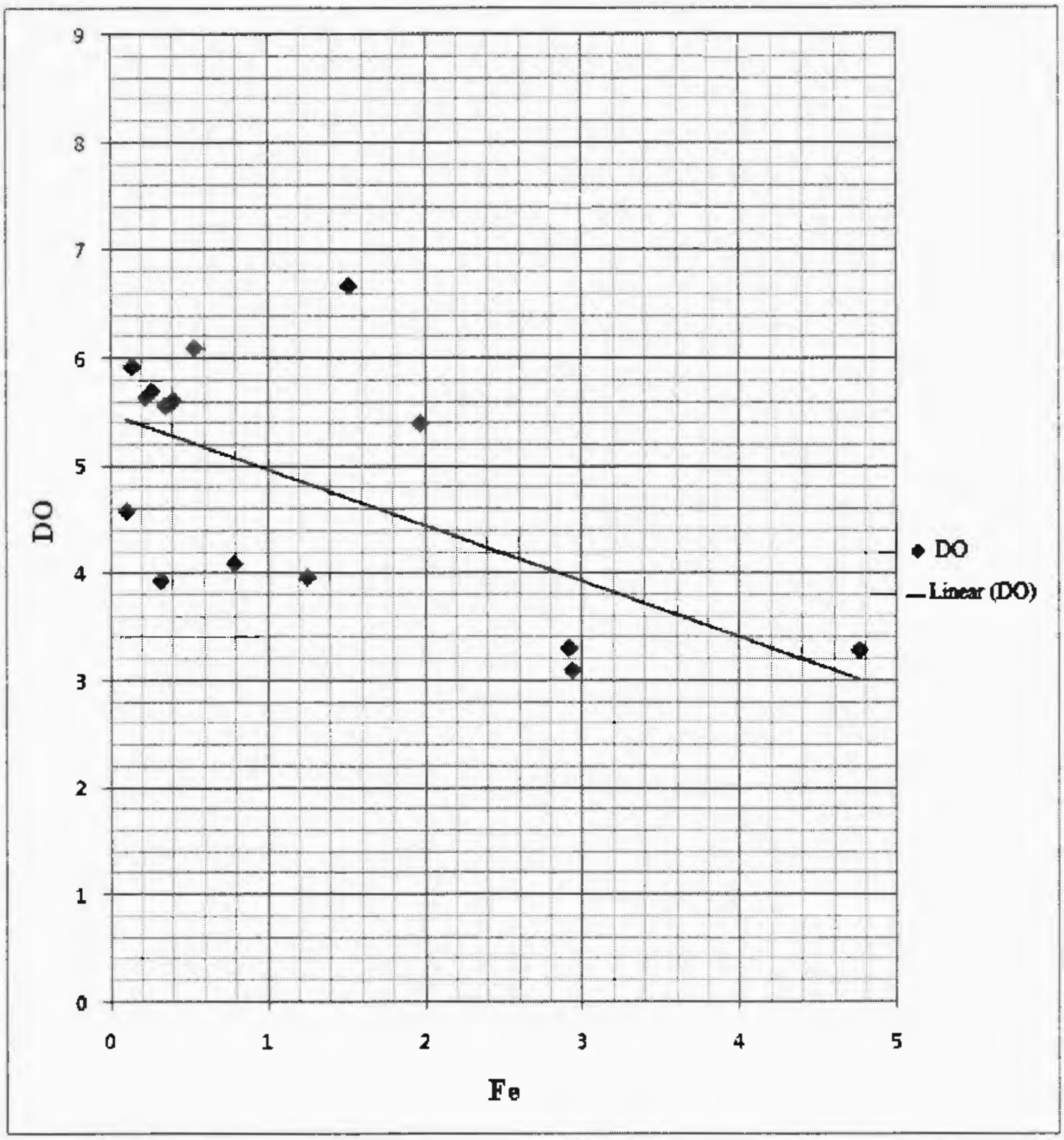
4.21.15 Correlation of pH and Zinc (Zn):



Graph 4.21.15: Correlation Between pH and Zinc.

A very weak negative linear correlation is observed between pH and Zinc in the graph. Maximum data points are located between the regions 7-8 along x-axis.

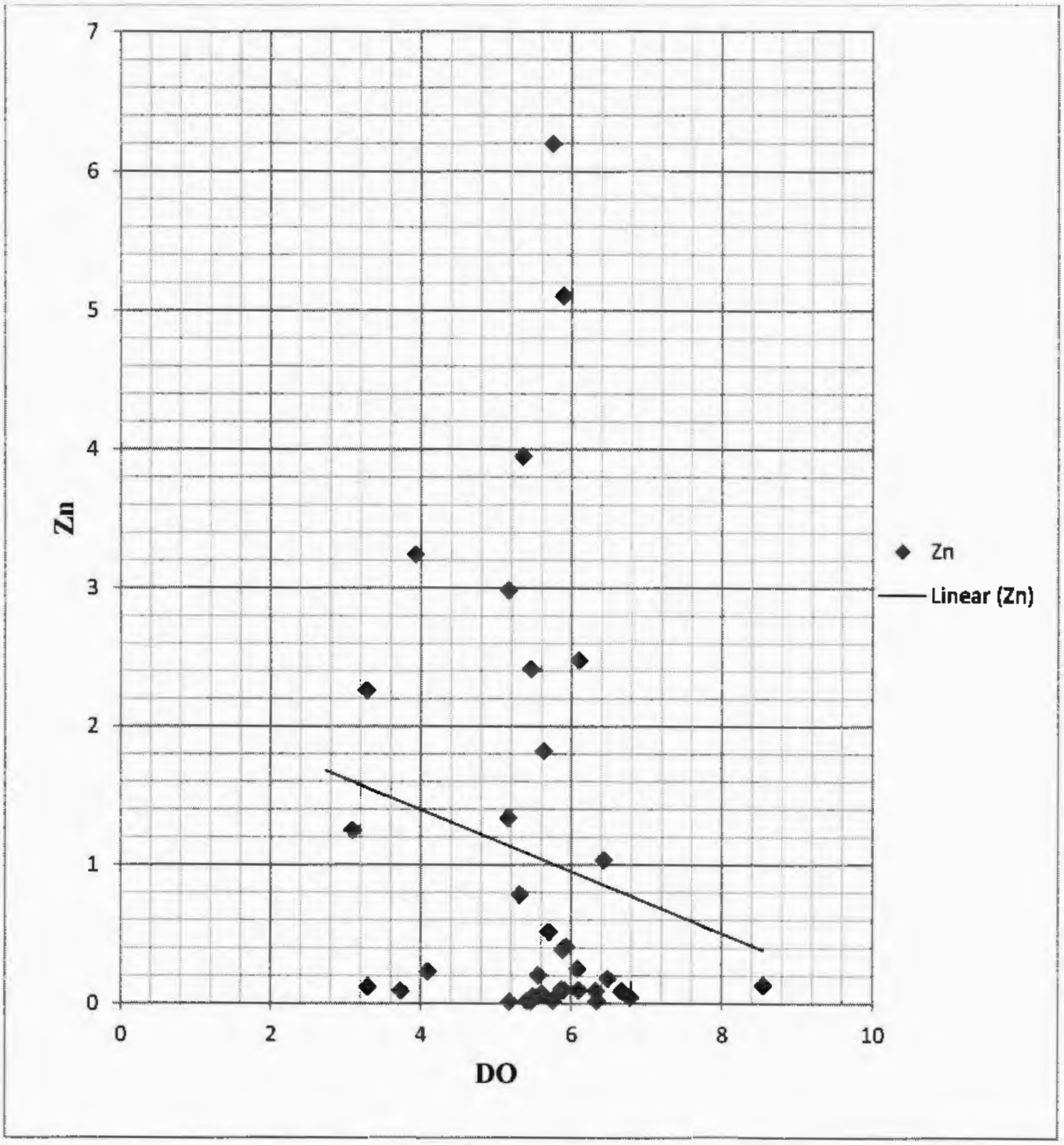
4.21.16 Correlation of Iron (Fe) and DO:



Graph 4.21.16: Correlation Between Iron and DO

A very weak negative linear correlation is observed between Iron and DO in the graph. Maximum data points are away from regression line.

4.21.17 Correlation of DO and Zinc (Zn):



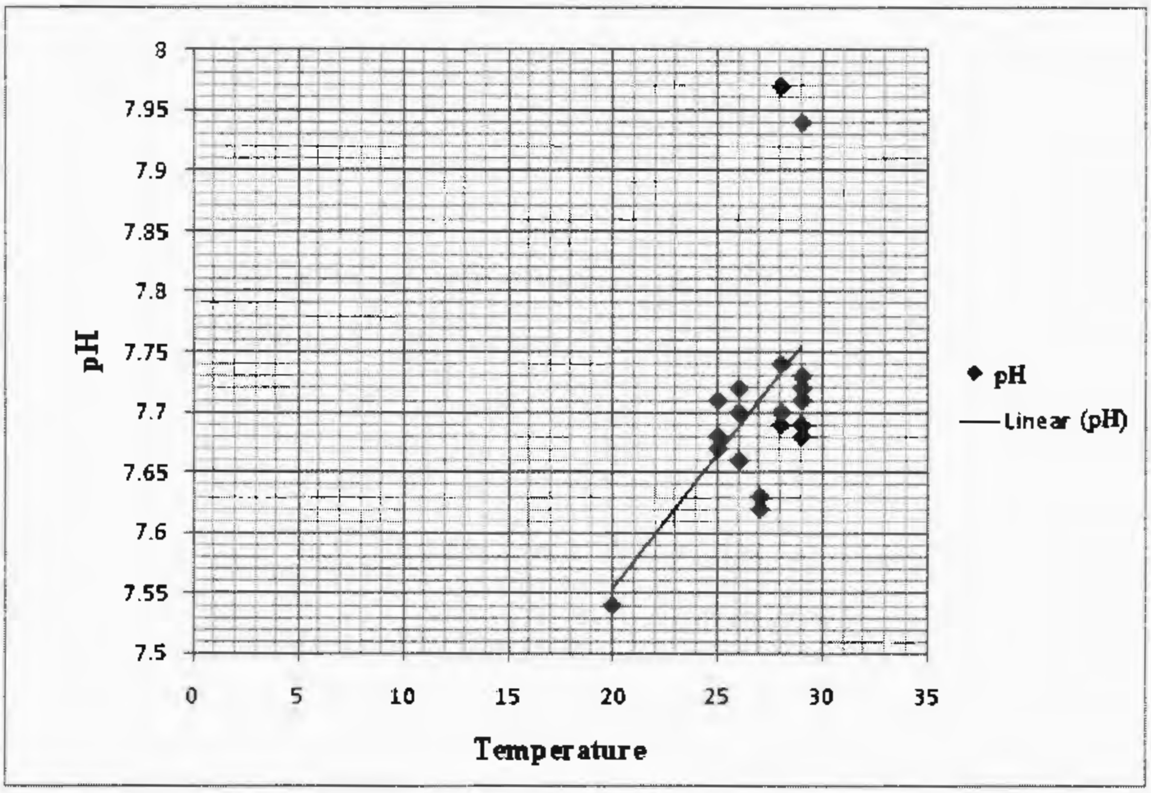
Graph 4.21.17: Correlation Between DO and Zinc.

The graph shows a very weak negative correlation between DO and Zinc. The data points are away from regression line and existing in scattered from in the graph.

4.22 Correlations between Wastewater Parameters:

The correlation between different parameters of wastewater samples is established on the basis of analysed results. The objective of correlations was to observe whether they have strong correlation, weak correlation or no correlation between different parameters.

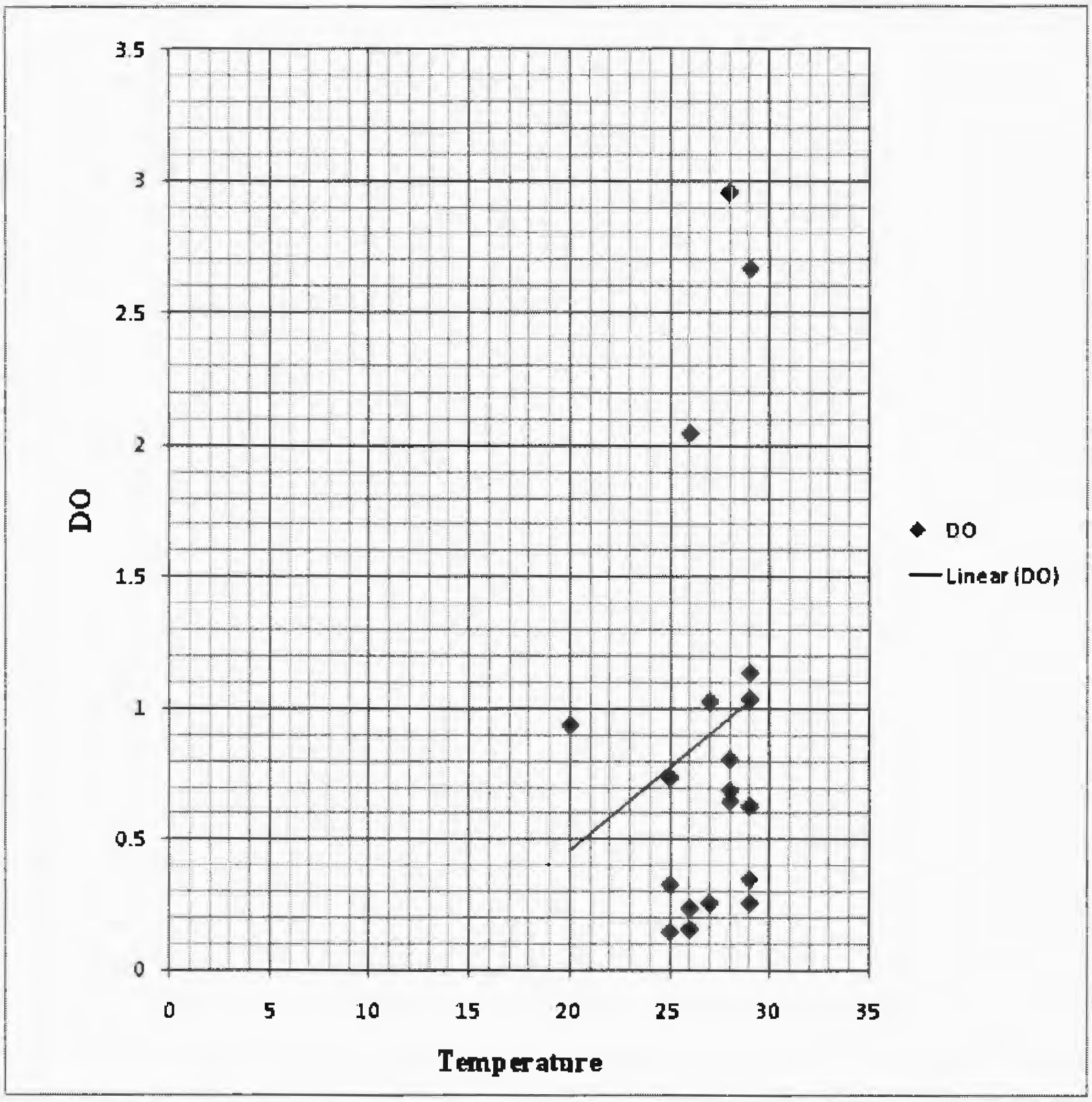
4.22.1 Correlation of Temperature and pH:



Graph 4.22.1: Correlation Between Temperature and pH.

A weak positive linear correlation is observed between temperature and pH in the graph. Approximately all data points are located between the regions 25-30 along x-axis.

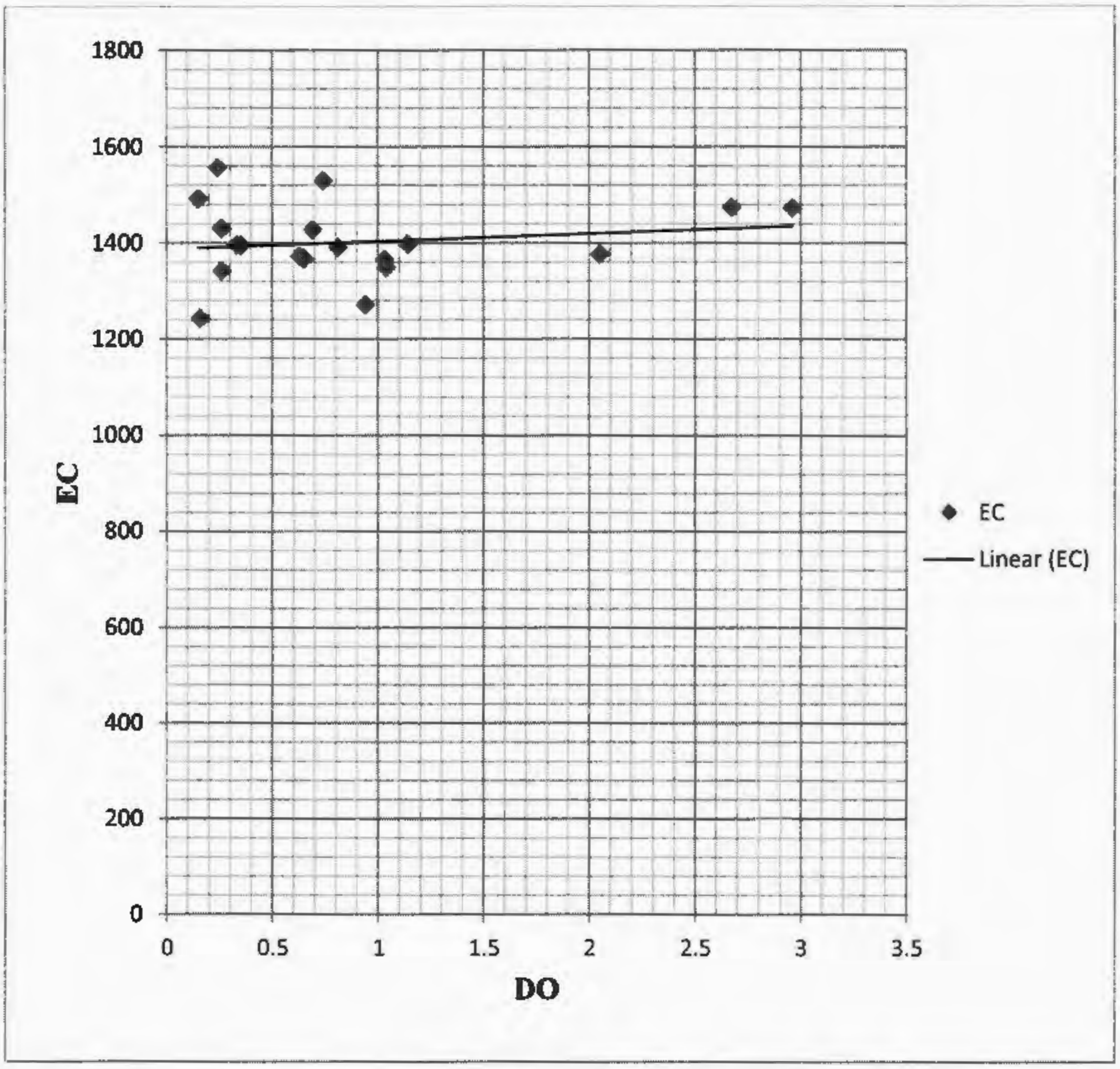
4.22.2 Correlation of Temperature and DO:



Graph 4.22.2: Correlation Between Temperature and DO.

A weak positive linear correlation is observed between temperature and DO in the graph. The data points are in scattered form in the regions 20-30 along x-axis.

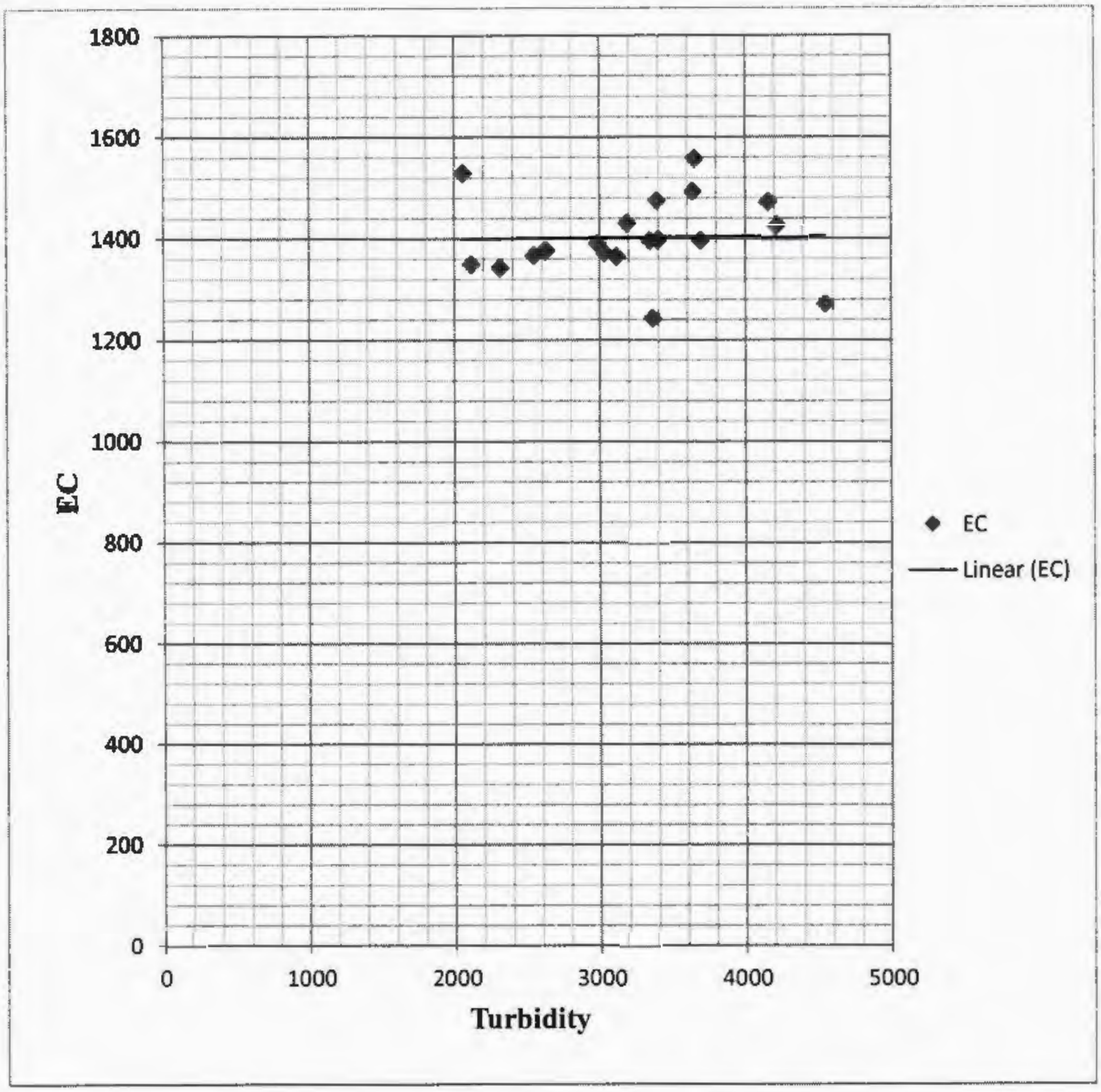
4.22.3 Correlation of DO and EC:



Graph 4.22.3: Correlation Between DO and EC.

Best fit line in the graph shows that no correlation existed between DO and EC values. The increase or decrease in DO values have no relationship with EC values.

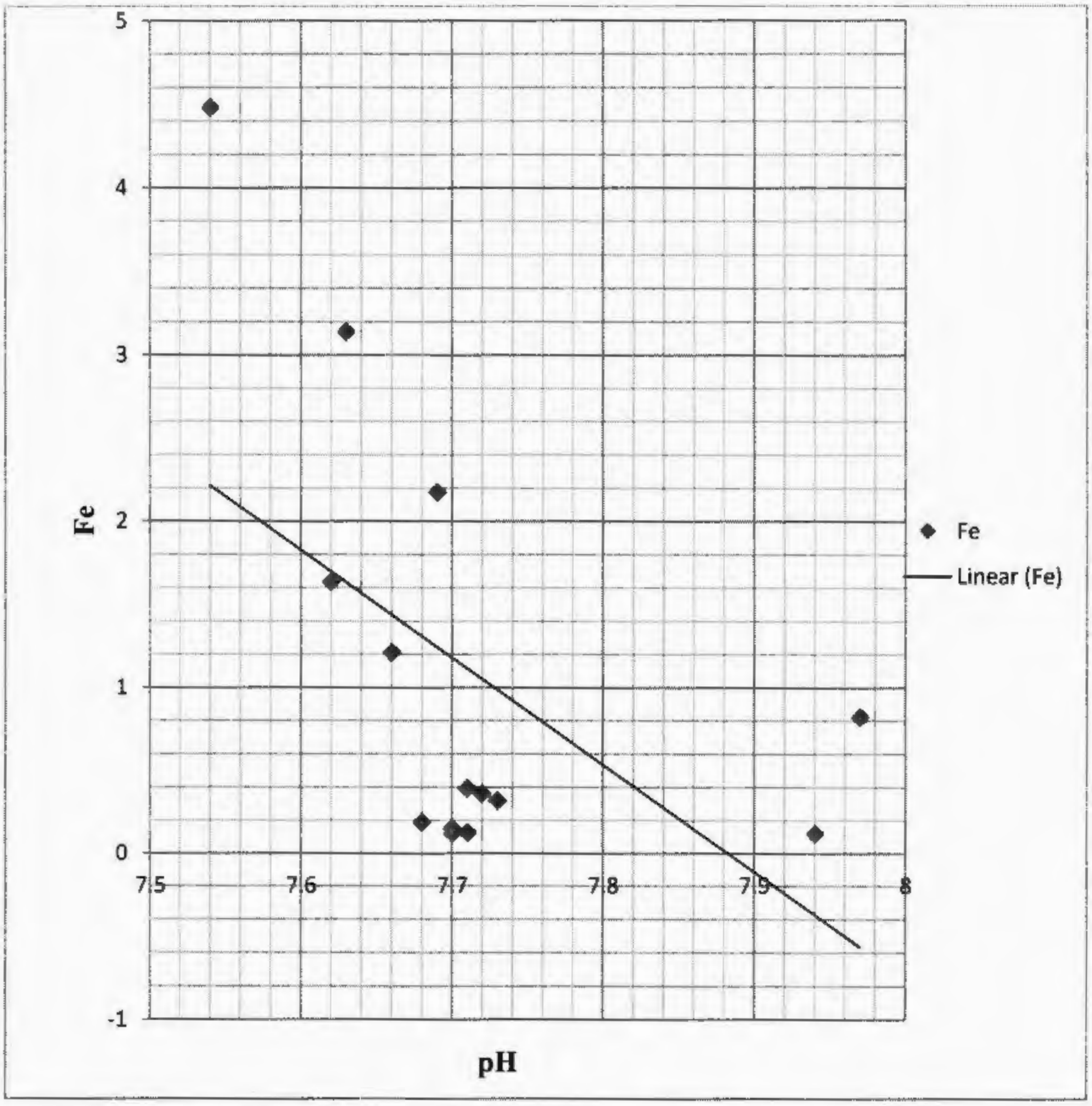
4.22.4 Correlation of Turbidity and EC:



Graph 4.22.4: Correlation Between Turbidity and EC.

The best fit line in the graph shows that no correlation existed between turbidity and EC values. The relationship between turbidity and EC values has not established.

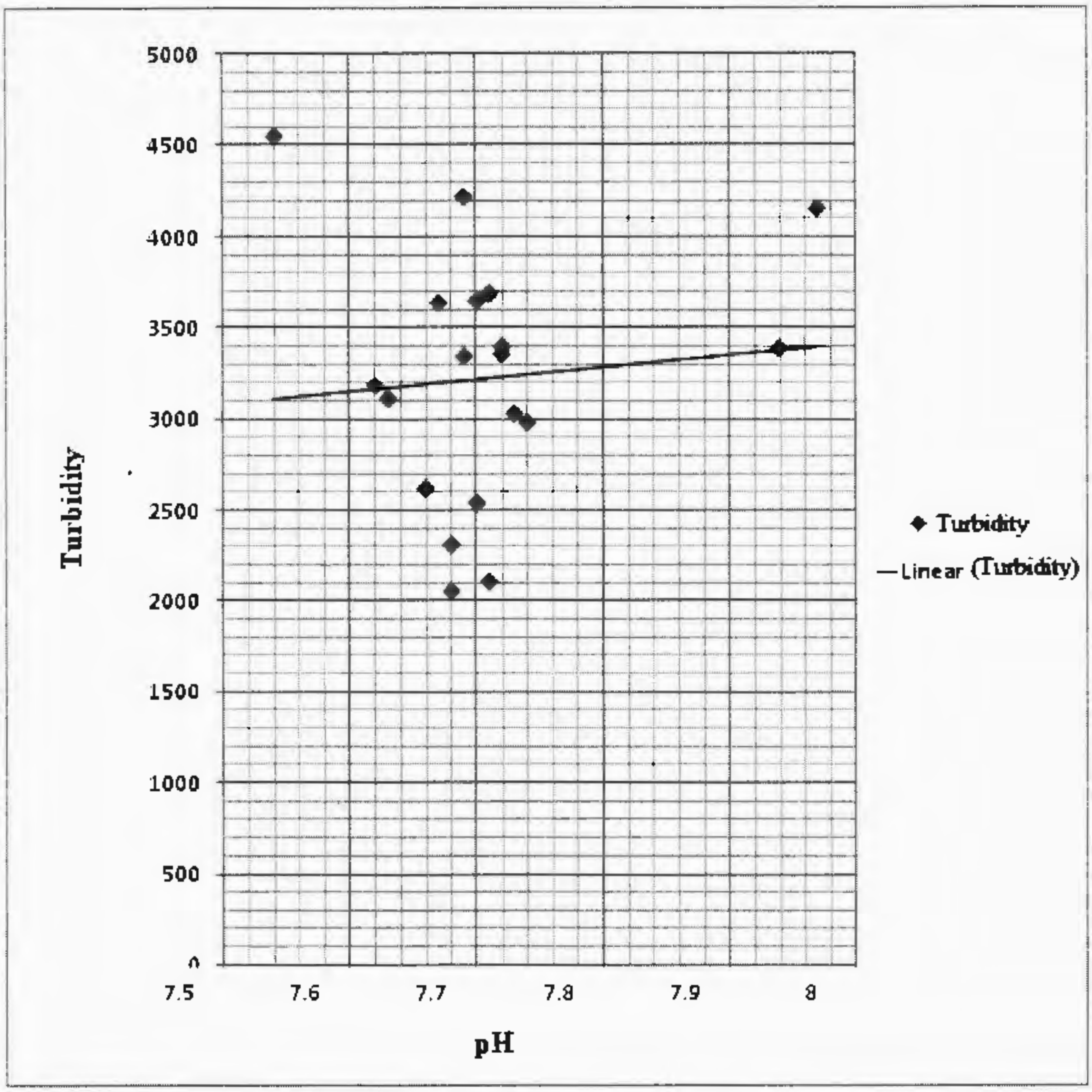
4.22.5 Correlation of pH and Iron (Fe):



Graph 4.22.5: Correlation Between pH and Iron.

A very weak linear correlation is observed between pH and Iron values. Approximately all data points are located away from regression line.

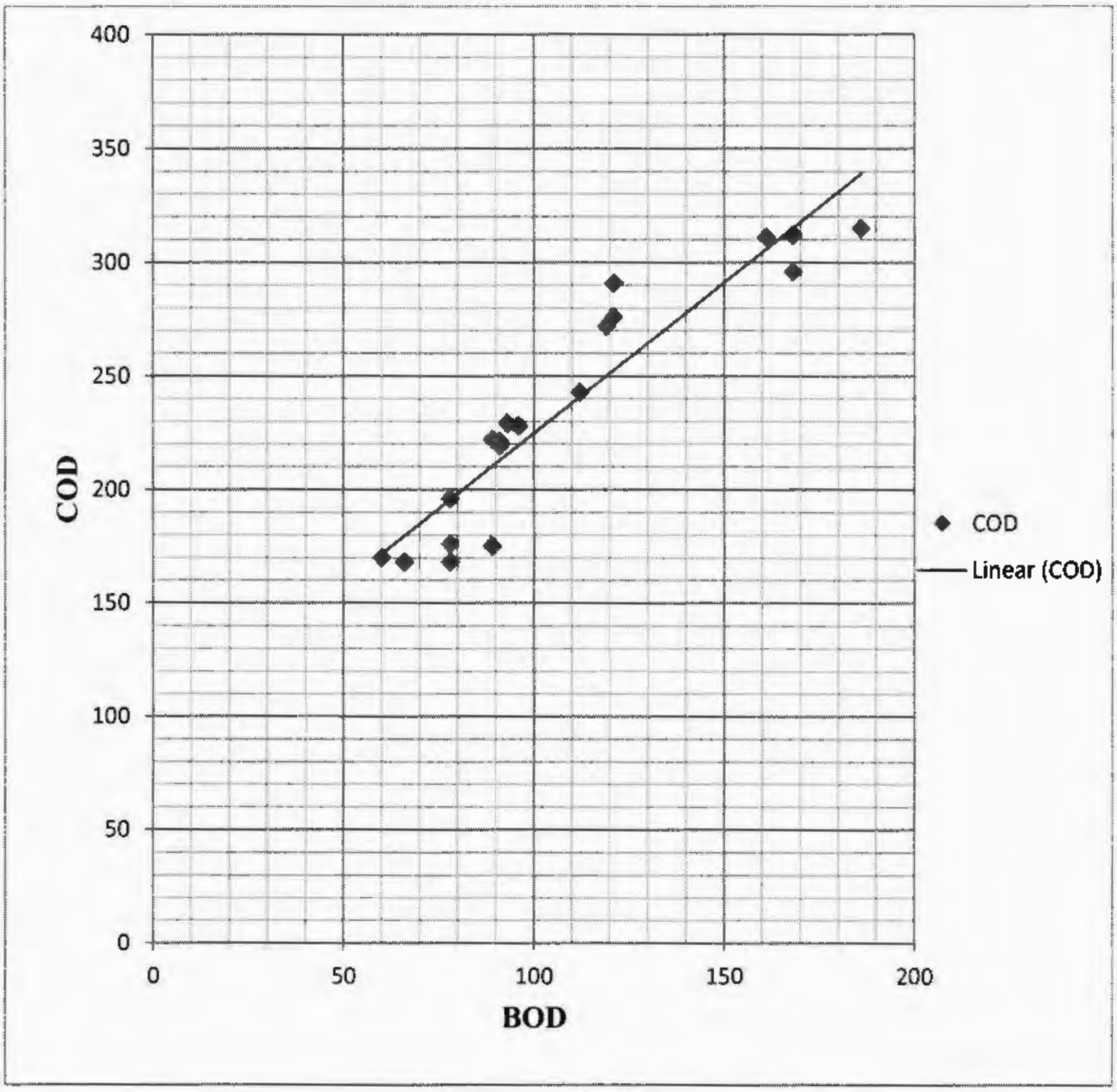
4.22.6 Correlation of pH and Turbidity:



Graph 4.22.6: Correlation Between pH and Turbidity

The graph shows that no correlation existed between pH and turbidity. The pH values increase or decrease in graph have no relationship with turbidity values.

4.22.7 Correlation of BOD and COD:



Graph 4.22.7: Correlation Between BOD and COD.

The correlation graph sbows a medium linear positive correlation between BOD and COD values. This relationship shows that when BOD increase or decreases COD values also increase and decreases in the graph. Maximum data points are closed to the regression line.

CHAPTER 5

DISCUSSION

5.1 Discussion:

The physico-chemical and microbiological parameters of groundwater in the vicinity of Nalla Lai and characterization of surface wastewater of Nalla Lai revealed that many parameters of groundwater and wastewater samples were exceeding the threshold values and certain elevated results of groundwater parameters were directly linked with surface wastewater percolation from Nalla Lai.

Total (14) tube wells, (19) boreholes, (2) springs and (1) dug well samples within 100 meter distance along both sites of Nalla Lai were tested for physico-chemical and microbiological analysis. Whereas (10) control samples of bore water and (3) tube well water samples were also tested.

- Iron and Cadmium were found in high concentration in both surface wastewater of Nalla Lai and groundwater samples of tube wells, boreholes, springs and a dug well in the vicinity of Nalla.

- Out of (19) wastewater samples, Iron were detected in (14) samples. Iron concentration in (3) wastewater samples was exceeding the wastewater standards of NEQS, 1997. Total (49) groundwater samples were tested and Iron was detected in (15) groundwater samples. Ten ground water samples in close proximity to Nalla or within 100 meter distances along both sites of Nalla Lai showed Iron concentration higher than set standard of NSDWQ, 2010. The results clearly revealed that Iron is percolating from surface wastewater of Nalla Lai to ground water in its vicinity.

  Iron value was also found in high concentration in only one bore water control sample i.e. sample#45.

- Out of (19) wastewater samples, Cadmium was detected in (13) wastewater samples of Nalla Lai and (5) wastewater samples showed Cadmium concentration elevated that NEQS, 1997.

  In groundwater samples Cadmium were found in (21) samples and (5) samples within 100 meter distance along both sites of Nalla Lia showed Cadmium concentration higher than standard value of NSDWQ, 2010. Both surface and groundwater values of Cadmium revealed that Cadmium is also percolating from surface wastewater of Nalla Lai to groundwater in its proximity.

  Cadmium values in (5) control samples were also exceeding the standard values and it needs further investigation to identify the potential source of its contamination.

- Similar kind of study was also conducted in tube well water and associated health risk to local population in Mailsi area of Punjab, Pakistan. Total (44) groundwater samples were collected for laboratory analysis. The concentration of heavy metals like Iron, Arsenic, Lead, Cadmium and ions of Sodium, Bicarbonates and Sulfate were exceeding the WHO permissible limit. By applying statistical tools, the results revealed that both natural and anthropogenic activities are responsible for excessive Arsenic, Cadmium and other heavy metals contamination in groundwater (Atta et al., 2016).

- Manganese and Zince were found in all wastewater samples in a considerable concentration. Similarly, out of (49) groundwater samples, Manganese was detected in (31) groundwater samples and Zince was found in (36) groundwater samples.

- Manganese was detected in elevated concentration in (4) groundwater samples which were collected within 100 meter distance along both sites of Nalla Lai. Manganese high concentration depicts that it may percolated from surface wastewater of Nalla Lai.

  Manganese was also detected in elevated level in one bore water control sample i.e sample#45.

- Zinc was detected in (1) groundwater samples in high concentration which was taken from 100 meter vicinity on the right site of Nalla Lai. The elevated concentration depicts that zinc may also percolated from surface wastewater of Nalla Lai.

  Zince concentration was also exceeding the standard value in one borewater control sample i.e sample#48.

- A study on metals in the proximity of tannery effluents was conducted by collecting soil and groundwater samples from Multan, Pakistan. The samples were tested on Flame Atomic Absorption Spectrophotometer. The analysed results revealed that Chromium (Cr), Sodium (Na), Calcium (Ca), Potassium (K), Cadmium (Cd), Iron (Fe) and Magnesium (Mg) were found in high concentration according to WHO standard in both soil and groundwater samples which can prone to environmental hazard. The heavy metals emerge in different steps of leather production such as liming, tanning and finishing stages. (Saadia et al., 2010).

- Copper and Lead were not detected in high concentration in both surface wastewater of Nalla Lai and groundwater samples.

- Copper was detected in (7) wastewater samples and Lead was detected in (3) wastewater samples in a very minute concentration.

  Copper was detected below the permissible limit in only three samples of groundwater i.e. sample#1, sample#2 and sample#13.

- Lead was detected only in sample#1 of groundwater within a permissible limit.

- A research study was conducted in 2000-2001 on surface and groundwater quality of two provinces i.e. Sindh and KPK. The aim of the study was to investigate different heavy metals like Copper (Cu), Lead (Pb), Zinc (Zn), Iron (Fe), Manganese (Mn), Chromium (Cr), Cadmium (Cd) and Nickel (Ni) originating from different industrial wastes and their repercussions on surface and groundwater quality. Total (16) samples of surface water and (8) samples of groundwater were taken from KPK province whereas (8) samples of surface water and (4) samples of groundwater were collected from Sindh province. The results revealed that various surface and groundwater parameters of trace elements were within range and many parameters were beyond the WHO and US-EPA standard limits. Anthropogenic activities like industries are core responsible of both surface and groundwater contamination by discharging their effluents and wastes into water bodies (Midrar et al., 2005).

- Total dissolved solids were detected in elevated level in only one groundwater sample.
- Total Dissolved Solids was found in high concentration in sample#13 (bore water) which was located within 100 meter distance of Nalla Lai. The value exceeded the standard threshold value NSDWQ, 2010 which showed that pollutants percolating from surface wastewater of Nalla Lai.
- The research revealed that TDS values were increasing when contaminants recharged and dissolved in water. The TDS values were increasing in ascending order i.e. forested areas < agriculture land < residential area < traffic site < industrialized zone respectively. The overall results confirmed that major sources of groundwater pollution were a variety of contaminants originating from anthropogenic activities in urban settlements (Byoung et al., 2005).
- pH values of all wastewater and groundwater samples were within the range except sample#2, sample#15 and sample#35 of groundwater.
- Sample#2, Sample#15 and Sample#35 were collected within 100 meter distance from Nalla Lai. These were bore water samples which showed very low pH value. Due to low pH value, Iron, Cadmium and Manganese were found in high concentration in this sample.

  When pH decreases in water then metals solubility increases (JICA, 2005).
- Color values of all groundwater samples were below 15 TCU except sample#28.
- Color value of sample#28 showed high color value from the standard value set by NSDWQ, 2010. Sample#28 was dug well water which was using for drinking purpose. It was located less than 100

meter distance on the right site of Nalla Lai. Color elevated value shows different dissolved chemical in water. The high color value represents direct percolation of wastewater of Nalla Lai into Dug well water.

- ➢ Physico-chemical and microbial parameters of groundwater quality were assessed from twelve dug wells. The research proved that the contaminants were increasing in the period of rainy season and reducing with escalating distance from the waste dump. The analysed results showed that total coliform colonies, Lead (Pb), Nitrate (-NO_3) and Cadmium (Cd) concentration were beyond the World Health Organization (WHO) standards for drinking water quality. The dug well water was not potable for drinking purpose without appropriate treatment (Adekunle et al., 2007).
- ♦ Turbidity of all (49) groundwater samples were zero which indicated the groundwater was free from suspended particles.
- ♦ Total (49) groundwater samples were tested to detect Hardness concentration. The results revealed that (37) groundwater samples were exceeding the permissible limit set by NSDWQ, 2010.
- ➢ Total (17) borewater samples, (11) tube wells, (1) spring and (1) dug well water sample showed elevated concentration of Hardness. These samples were collected within 100 meter distance along both sites of Nalla Lai. The results give the clue of percolation of contaminants from surface waste water of Nalla Lai.

  Hardness concentration in (7) control samples were also exceeding the standard value.
- ➢ Groundwater is harder than surface water due to its high solubilizing potential with calcite, gypsum and dolomite rocks. Sewage, run-off through limestone formations and building materials, magnesium containing textile and paper materials (Olumuyiwa et al., 2012).
- ♦ Other parameter of ground and surface wastewater samples were with the permissible limit.
- ➢ Sulfate and Chloride values in groundwater samples were within the permissible limit of drinking water quality standards, NSDWQ, 2010.

- Temperture, Sulfate and Chloride values were below the permissible limit in wastewater samples when compared with NEQS, 1997 standard values.
- There are no set standard values in NSDWQ, 2010 for DO and EC and similarly no standard value for Turbidity in NEQS, 1997 for wastewater.
- High DO levels indicate good water quality. The average DO value in (49) groundwater samples was 5.49 mg/L^{-1}.
- EC represents mobility of free ion in water. In (49) groundwater samples the average EC value was 591.51 µ S/cm.
- Turbidity analysis showed that turbidity of wastewater was exceeding 4000 NTU in (3) samples which revealed the high turbidity level of Nalla Lai wastewater due to suspended and colloidal particles.
- The microbial analysis of (33) groundwater samples revealed that (26) groundwater samples showed microbial contamination due to wastewater percolation from Nalla Lai. Whereas (7) samples showed positive result.
- Fifteen bore water samples within 100 meter distance along both sites of Nalla Lai were tested for microbial analysis. The results revealed that (12) samples showed microbial contamination whereas sample#12, sample#17 and sample#34 were free from microbial contamination.
- Eleven tube well water samples within 100 meter distance along both sites of Nalla Lai were tested for microbial analysis. The results revealed that in (9) samples microbial contamination was detected whereas sample#33 and sample#37 showed positive result.
- Two springs and (1) dug well within 100 meter distance from Nalla Lai were also tested for microbial analysis. The results showed that in both springs and dug well water microbial contamination was detected.

- Total (4) control samples were tested to detect microbiological contamination. The results revealed that microbial contamination was detected in (2) control water samples i.e. sample#44 and sample#46 whereas samples#40 and sample#47 showed positive results.
- Similar kind of study was conducted on groundwater quality of Rawalpindi city, Pakistan. Water samples were collected from (220) tubewells from different locations in the year 2007.The analysed results revealed that 50% groundwater samples of tubewells showed bacterial contamination. The prime source of microbial contamination is percolation of Lai Nalla wastewater. Nalla lai acts as an open sewer which carries 65% sewage of the city (Islam et al., 2007).

5.2 Conclusion:

- The study identified that heavy metals were found in elevated concentration in both surface waste water of Nalla Lai and shallow (Bore water, Dug well and springs) and deep groundwater (Tube well) in the vicinity of Nalla. The research work revealed that certain heavy metals are percolating from surface wastewater of Nalla and contaminating the nearby tube wells, bore water, springs and dug well water.

  Similarly, microbial contamination was also detected in groundwater samples collected from the proximity of Nalla Lai. Due to puncturing of underground rocks from different locations bacteria can find route and easily access to the groundwater table (Islam et al., 2007)

- Cadmium was detected in high concentration from the standard value in (5) wastewater samples i.e. sample#1, sample#2, sample#8, sample#10 and sample#17. Cadmium was found in elevated concentration in (5) groundwater samples located within 100 meter distance along both sites of Nalla Lai i.e. sample#2 (Bore water), sample#16 (Bore water), sample#23 (Tube well), sample#28 (Dug well) and sample#33 (Tube well). Ground water in these locations can severely harm human health.

- Iron was detected in high concentration from the standard value in (3) wastewater samples i.e. sample#1, sample#3 and sample#16. Iron was found in elevated concentration in (10) groundwater samples located within 100 meter distance along both sites of Nalla Lai i.e. sample#2 (Bore water), sample#10 (Tube well), sample#11 (Bore water), sample#12 (Bore water), sample#17 (Bore water), sample#19 (Tube well), sample#22 (Bore water), sample#28 (Dug well), sample#32 (spring water) and sample#35 (Bore water). The groundwater in these locations can cause adverse health impacts.

- Manganese and Zinc were detected in all wastewater samples of Nalla Lai within permissible limit.

- Manganese was found in elevated concentration from the standard value in (4) groundwater samples located within 100 meter distance along both sites of Nalla Lai i.e. sample#2 (Bore water), sample#28 (Dug well), sample#34 (Bore water) and sample#35 (Bore water).
- Zinc was detected in elevated concentration from the standard value in (1) groundwater sample i.e. sample#29 (Bore water) which was located within 100 meter from Nalla Lai.
- Copper was detected in (7) wastewater samples i.e. sample#1, sample#4, sample#5, sample#6, sample#10, sample#14 and sample# 16 in a very minute concentration. Lead was also detected in (3) wastewater samples i.e. sample#1, sample#2 and sample#12 in a very minute concentration.
- Copper was detected in only three samples of groundwater i.e. sample#1 (Tube well), sample#2 (Bore water) and sample#13 (Bore water) in a very minute concentration.
- Lead was detected only in sample#1 (Tube well) of groundwater within a permissible limit.
- Total Dissolved Solids (TDS) was found in high concentration from the standard value in sample#13 (bore water) which was located within 100 meter distance from Nalla Lai.
- pH values of all wastewater and groundwater samples were within the range except sample#2 (Bore water), sample#15 (Bore water) and sample#35 (Bore water) of groundwater which were collected within 100 meter distance from Nalla Lai. These were bore water samples which showed very low pH. The low pH level indicates the presence of high metal contents in water. Groundwater in these localities of can adversely harm human health and it can cause cancer related diseases.
- Color values of all groundwater samples were below 15 TCU except sample#28 (Dug well) which showed high color value from the standard value of NSDWQ, 2010. High Color value indicates the presence of different dissolved chemical contaminants. The groundwater in the location of sample#28 can severely affect human health.

- Turbidity values in all (49) groundwater samples were zero. Average value of turbidity in (19) wastewater samples were 3228.54 NTU. Turbidity values in (3) wastewater samples were exceeding 4000 NTU.
- Hardness was elevated from the standard value in (17) bore water, (11) tube wells, (1) spring and (1) dug well water sample located within 100 meter distance along both sites of Nalla Lai. High concentration of hardness indicates that groundwater in these localities are not potable for drinking purpose.
- Temperture, Sulfate and Chlorides were within the permissible in both surface wastewater and groundwater samples.
- Total (11) tube wells, (15) boreholes, (2) springs and (1) dug well water sample were collected within 100 meter distance along both sites of Nalla Lai to detect microbiological contamination.
- The results revealed that (9) tube wells and (12) boreholes located within 100 meter distance along both sites of Nalla Lai showed microbial contamination whereas (2) tube well and (3) bore water samples were free from microbial contamination. The results of (2) springs and (1) dug well located within 100 meter distance from Nalla Lai also showed microbial contamination. Ground water of microbially contaminated localities can cause waterborne disease.
- BOD of all wastewater samples was exceeding the threshold value. Whereas COD of (14) wastewater samples were elevated from the standard value. Both BOD and COD elevated results revealed the presence of high concentration of both organic and inorganic pollutants in surface wastewater of Nalla Lai.
- Many parameters in control groundwater samples were also beyond the permissible limit i.e. Iron was found in high concentration in sample#45, Cadmium in sample#40, sample#41, sample#42, sample# 43 and sample#47, Manganese in sample#45, Zince in sample#48, and Hardness in sample #39, sample#41, sample#43, sample#46, sample # 47, sample#48 and sample#49. Microbial

contamination was also detected in sample#44 and sample#46. The elevated results of different parameters in control samples needs further investigation to identify the potential source of contamination.

- The research work also highlighted that sample (1) was potential source of elevated concentration of Iron and Cadmium in wastewater of Nalla Lai which finally percolates into groundwater. Sample (1) was collected from the Nalla which carries Industrial waste of I-9 sector Islamabad and finally mixes with Nalla Lai at the point of Kataria Bridge.

  Likewise, sample#2 (Bore water), sample#28 (Dug well), and sample#35 (Bore water) are highly vulnerable groundwater localities in terms of physico-chemical and microbial contamination. These samples were located within 100 meter distance along both sites of Nalla Lai

- Sample (2) was collected from City Coloney -E- Block, Rawalpindi where Cadmium, Iron, Manganese and Hardness values were beyond the standard limits. The pH level of water was also low and declined towards acidity. Microbial contamination was also detected in this sample. The groundwater in this locality is not safe for drinking purpose and it can cause waterborne diseases and the chronic effect of drinking this water can leads towards cancer.
- Sample (28) was dug well water sample which was collected from Ghulistan Coloney line Number-3, Rawalpindi where Cadmium, Iron, Manganese, Hardness and Color values were exceeding the standard values of NSDWQ, 2010. The water sample was also not safe bacteriologically. The water quality of sample (28) is not potable for drinking purpose and it can cause cancer related diseases.
- Sample (35) was third highly contaminated bore water sample collected from Ghanda Chichi Street Number-16, Rawalpindi where Iron, Manganese and Hardness values were beyond the standard limits set by NSDWQ, 2010. The pH of water was also low from the standard value and declined towards acidity. The water sample was also found bacteriologically contaminated. Groundwater in this location is not safe for drinking purpose and it can cause adverse health effects.

Table 5.2: Highly Vulnerable Groundwater Localities Within 100 Meter Distance From Nalla Lai

Highly Vulnerable Groundwater Localities			
Parameters	Sample: 2 (Bore water)	Sample: 28 (Dug well)	Sample: 35 (Bore water)
	Concentration	Concentration	Concentration
Cadmium Standard value NSDWQ, 2010/WHO 0.01, 0.003 mg/l	0.028 mg/l	0.012 mg/l	
Iron Standard value NSDWQ, 2010 0.3 mg/l	4.757mg/l	1.965 mg/l	2.933 mg/l
Manganese Standard value NSDWQ, 2010 0.5 mg/l	0.685 mg/l	0.853 mg/l	0.512 mg/l
PH Standard value NSDWQ, 2010 6.5-8.5	6.40		6.45
Color Standard value NSDWQ, 2010 15 TCU		17.89	
Hardness Standard value NSDWQ, 2010 .500 mg/l	1065 mg/l	928 mg/l	1044 mg/l
E.Coli: Standard value NSDWQ, 2010 0/100 ml	E.Coli Detected	E.Coli Detected	E.Coli Detected

5.3 Future Work Recommendations:

- Tube wells, boreholes and dug wells should be installed at least 300 meter away from Nalla Lai to prevent any type of percolation and leaching from wastewater of Nalla.
- There should be proper laboratory testing of physico-chemical and microbiological parameters of new installed tube well or bore water before water supply to public.
- Periodic monitoring of all tube wells and bore water should be conducted to cope with wastewater percolation issue.
- Groundwater extraction should be promoted from deeper aquifer and increase the depth of existing shallow water boreholes.
- Enforce effective and efficient management plan for domestic and commercial solid waste of Rawalpindi and Industrial waste effluents of I-9 and I-10 Islamabad. Solids waste should not dump on the banks of Nalla water which increases the chances of leachate formation and percolation of contaminatats into groundwater.
- Groundwater percolation can be prevented through proper management of wastewater of Nalla Lai which includes proper sanitation system of Rawalpindi city.
- Water filtration plants should be installed in each inhabitant colony to ensure public health.
- The percolation of wastewater of Nalla Lai can be fully prevented through proper cementation by using concrete in the base of Nalla Lai and by construction of concrete walls on the banks of Nalla Lai.
- Wastewater treatment plant should be installed near Soan river to treat wastewater of Nalla Lai before discharging into Soan river.
- The responsible authorities should take initiatives to protect both surface and groundwater resources of Rawalpindi and enforce environmental regulations.

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APPENDIX 1: Groundwater Sampling Pictures

APPENDIX 2: Wastewater Sampling Pictures

APPENDIX 3: Microbial Sampling (Groundwater)

APPENDIX 4: Pictures During Analysis in Water Testing Lab

Figure: EPA Laboratory Islamabad.

APPENDIX 5: Pictures of Various Instruments Used During Analysis in Water Testing Laboratory

Turbdity Analyzer

UV/VisibleSpectrophotometer

Atomic Absorption Spectrometer (AAS)

Temperature Controller (4 °C)

APPENDIX 6: Standards of Drinking water Parameters

S. No	Parameters	Standard Value for Pakistan	WHO standards	US EPA
1	E.coli	Must not be detected in 100 ml sample	Must not be detected in 100 ml sample	
2	Color	< 15 TCU	< 15 TCU	
3	pH	6.5-8.5	6.5-8.5	
4	Turbidity	< 5 NTU	< 5 NTU	
5	TDS	<1000 mg/l	<1000 mg/l	
6	Hardness	< 500 mg/l		
7	Sulfate			< 250 mg/l
8	Chloride	< 250 mg/l	< 250 mg/l	
9	Cadmium	0.01 mg/l	0.003 mg/l	
10	Copper	2 mg/l	2 mg/l	
11	Iron		0.3 mg/l	
12	Manganese	0.5 mg/l	0.5 mg/l	
13	Lead	0.05 mg/l	0.01 mg/l	
14	Zinc	5 mg/l	3 mg/l	

APPENDIX 7: Standards of Waste water Parameters

S. No	Parameters	National Environmental Quality Standards (NEQS, 1997)
1	Temperature	40 °C
2	pH	6-10
4	TDS	<1000 mg/l
6	Sulfate	600 mg/l
7	Chloride	1000 mg/l
8	Cadmium	1 mg/l
9	Copper	1 mg/l
10	Iron	2 mg/l
11	Manganese	1.5 mg/l
12	Lead	0.5 mg/l
13	Zinc	5 mg/l
14	BOD	80 mg/l
15	COD	150 mg/l