ASSESSMENT OF GROUNDWATER QUALITY OF AN INDUSTRIAL AREA USING MULTIVARIATE STATISTICAL ANALYSIS: A CASE STUDY OF GHAZIABAD, U.P.

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CERTIFICATE

This is to certify that the research work embodies in this dissertation entitled: **“ASSESSMENT OF GROUNDWATER QUALITY OF AN INDUSTRIAL AREA USING MULTIVARIATE STATISTICAL ANALYSIS: A CASE STUDY ON GHAZIABAD, U.P.”**has been carried out in the Department of Environmental Engineering, Delhi Technological University, New Delhi. This work is original and has not been submitted in part or full for any other degree or diploma to any university or institute. This work is approved for submission.

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ABSTRACT

In this study attempts are made to evaluate the water quality of an industrial city in India and confirm the adverse effects of this industrial cluster on groundwater. In India, the city Ghaziabad is a region of northern Indo-Genetic alluvium plain. Ghaziabad city is suffering from increasing industrial activities, which make the groundwater polluted and develop extreme pressure on groundwater resources of the city. To perceive the problem occurring from expansion of industrialization and increasing population and set some remedies may ensure the deep-rooted and lifelong sustainability of groundwater resources. Water quality determination is an important criterion to check the suitability of water for drinking and irrigation purpose. Physiochemical characteristics has been analysed of Sahibabad Site IV area and nearby areas in Ghaziabad. Groundwater samples from various locations have been collected and investigate to access the status of water quality in study area and its potability. Results are compared with drinking water standards; IS: 10500 along with discussion. Further it was found that some of the parameters are exceeding the standard limit of drinking water and some are not. Physiochemical parameters of groundwater studied which is used to determine correlation & regression analysis, water quality index, temporal variation and Collin's ratio for assessing the drinking water quality of groundwater. Statistical analysis has been also considered to check the groundwater suitability and availability for irrigation purpose. In the present study, AQUA software also applied to the groundwater data and constructs the useful graphs for analyzing the hydrochemistry of water. The analysis shows high concentration of various parameters in study area viz. Salinity, EC, TDS, Chloride and Hardness with their cations and anions were showing harmful concentrations for drinking purpose as they overshoot the standard desirable limit for drinking purposes. TDS, EC and salinity are highly correlated and continuously increasing in the past years of studies. The critical concentrations of these parameters may adversely affect the human lives and deteriorate the quality of life.

CHAPTER-1
INTRODUCTION

CHAPTER-1
INTRODUCTION

1.1 GENERAL

Water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations is called groundwater. Groundwater is recharged according to hydrological cycle. Hydrological cycle is the process in which due to effect of air, water from oceans and from other surface water bodies gets evaporate. Transpiration process also takes place with evaporation in which moisture from plants and trees also lifted up in atmosphere. This total moisture started to condensed and form clouds. These clouds start precipitation due to heat which is also called rainfall. This water again reaches the ground and flowing on the surface in the form of runoff. This water accommodates in surface water bodies and also starts percolate in deep groundwater. This complete cycle recharge the groundwater and called hydrological cycle. Flow diagram of a simple hydrological process is shown in fig 1.

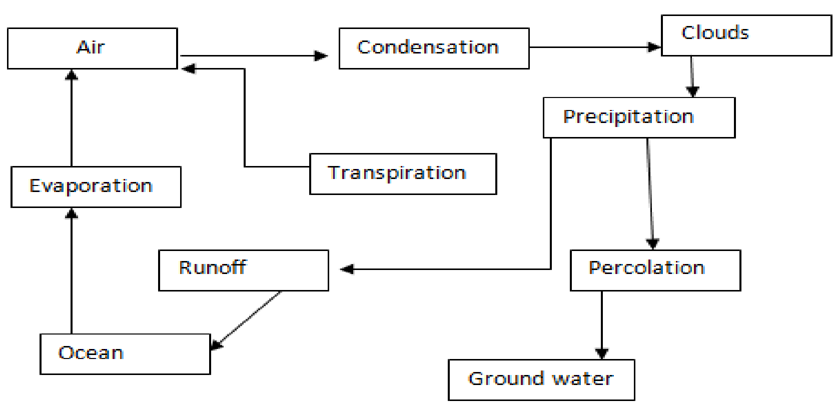

Fig 1.1: Hydrological Cycle

Groundwater occurring in two zones: Unconfined Aquifers and Confined Aquifers. Aquifer is the structure of soil, sand, gravel or rock which is suitable to retain water. An unconfined aquifer is the aquifer type which exists near to the water table and having pressure equal to water table. These kinds of aquifers are also names as upper boundary of aquifers.

1.2 GROUNDWATER: GLOBAL SCENARIO

Water is a unique resource of society for human beings and other living organisms. Life sustainability cannot be possible on earth without water. It is the necessary element of daily needs of human being like cooking washing and drinking etc. as well as for industrial purpose, irrigation purpose and other commercial activities. Water plays a significant role in economic development of a country, city or town and is helpful general well being of the society.

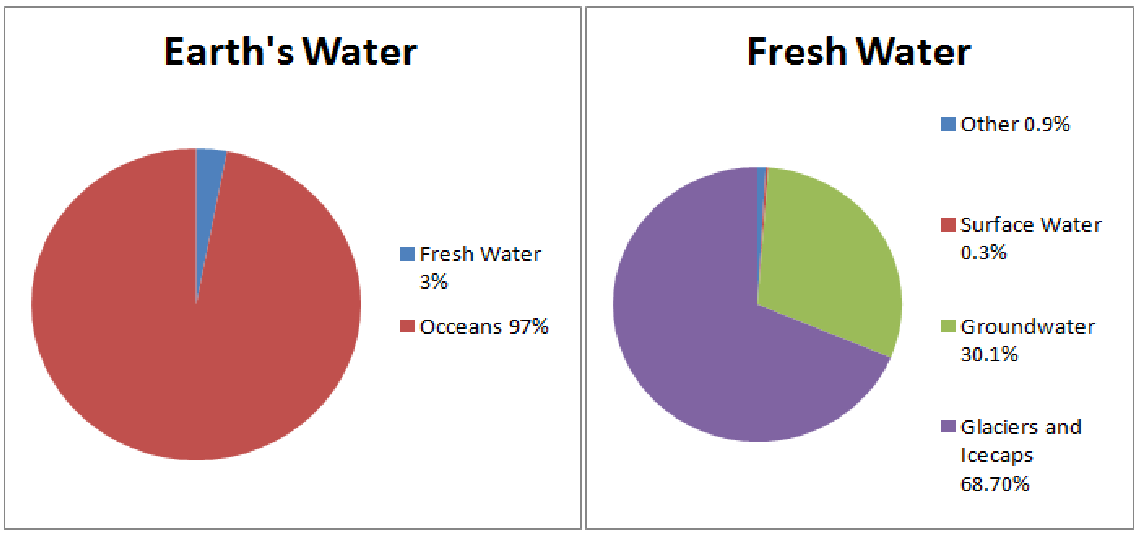

Fig 1.2: Distribution of Earth's Water(Source- USGS)

Freshwater available at earth is 3% only. Other 97% is in the form of saline water and is captured in oceans. Groundwater is only 30.1% available of this 3% of fresh water. Water present in subsurface and within the aquifer is called groundwater. This groundwater is getting contaminated continuously and it is under overuse scenario in India. India is the largest country for using groundwater. It is approximately about 230 cubic kilometers of groundwater per year which is used by Indian population (World Bank Report, 2012). In India more than 60% of irrigation and more than 85% of drinking water needs are groundwater dependent. It is very valuable resource for human being of water but now a days it is going to be a critically affected by overuse of groundwater. Aquifers are suffering from great load and attain exploitation levels which reduce the sustainability of groundwater. The World Bankreport: Deep Wells and Prudence reported if current trends of water uses will be followed by human being, 60% of aquifers will be in a risky situation or will be in coming 20 years. Groundwater is getting contaminated continuously and it is overexploited by the Indian population. This overuse of groundwater followed by scarcity of water and it will produce serious problem for agricultural sustainability, food safety, human life, and economical growth of country. There is a serious and extreme requirement to overcome this problem and certainly try to change the present scenario for smooth and safe future life.

1.3 GROUNDWATER CONTAMINATIONS DUE TO THE URBAN LINE SOURCES

In recent years, groundwater quality threatened by anthropogenic activities and it became an important issue for society. Groundwater is getting polluted by man's activity i.e. domestic and discharge, agricultural discharge mixed with pesticides etc, contaminated disposal of industries waste on surface. Due to such kind of reasons of groundwater contamination, groundwater quality varies by season to season, place to place, due to variation of water table, industries present in particular areas and varying concentration of particular parameters i.e. TDS, Salinity and others. The major groundwater trouble is due to contamination of surface water bodies as well as misuse of water available. Groundwater is the water source present on beneath of the earth, that's why exact problems of water bodies are hard to distinguish and also it is a big problem to solve them. Groundwater analysis is a complex procedure due to many factors i.e. sampling, geochemistry of water, soil-groundwater interaction etc.

Groundwater flow occurs in such a way that it comes in contact of different kinds of materials or rocks present in geologic strata. Due to this fact, dissolved solids present in high concentration in groundwater. The water used by society should be examined because of high concentration of physical, chemical and biological contamination occurs in groundwater. The water which is been used for drinking or other household purposes strictly followed by prescribed limits by any recommending agency and there is no compromise in this. It should be free from toxic elements, trace element, excess minerals, organic matter which can be hazardous.

Groundwater contaminations occur mainly due to industrial wastes coming from various industries, domestic discharge, agricultural runoff, leachate contamination, mining process, natural process due to rocks and many other problems.Groundwater pollution magnitude is less than surface water because it is exposed to environment. In case of groundwater large particles, colloidal particles and some soluble pollutants are trapped by soil on to the surface of the earth. There is soluble particles are responsible for contamination of groundwater which cannot be trapped by soil by the process of mechanical trapping. Contaminants get infiltrate into the groundwater mostly through sandy soil and pollution chances are high where the groundwater table is high. Waste dumping stations are also responsible for groundwater contamination through the liquid leakage from the waste called Leachate.

The groundwater quality mainly depends upon the industrial cluster of Ghaziabad. In Ghaziabad, increasing industrialization is the main cause of pollution of surface water as well as groundwater. Hindon River is a tributary of Yamuna River also flows from Ghaziabad. Many of industries are discharging their effluents in Hindon River and distributaries of Hindon River. Hindon River is an unlined surface water body and the contaminated water gets infiltrate to the subsurface followed by deep percolation into groundwater. Mainly TDS, Salinity, EC, Chloride found high in the groundwater of Ghaziabad. Salinity patterns are like that salinity in shallow groundwater is low and when it goes to deeper, salinity increases and severely deteriorate the deep groundwater quality or confined aquifers. Many types of trace metals are also present in groundwater due to the industrial area present in Ghaziabad city. Lead, iron, chromium found very high as compared to standards in some specific areas. In this manner, the groundwater water quality of Ghaziabad continuously deteriorates and water is being unhealthy and unfit for social use. There is an immediate need to estimate the pollution load, their main causes for making the groundwater usable and free from contamination.

1.4 OBJECTIVES OF PRESENT STUDY

To commence the study it is required to define the Objective which canexhibits the main aspects and conclude the summary ofdissertation. Following are the main objectives of study:

1. Toanalyse the vulnerability factors forgroundwater quality of an urbanized area which is contaminated by different industries located in Ghaziabad.
2. To study the changes or trend analysis of groundwater over the period of time.
3. Identify major problems and class of groundwater with the estimation of the water quality index.
4. Application of 'AQUA SOFTWARE' to determine the groundwater quality.

CHAPTER-2
LITERATURE REVIEW

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

The groundwater quality is the major source of usable water for society. It is used as drinking water, irrigation purposes, industrial uses as well as commercial uses etc. Groundwater consumption in households of urban areas is 50% and 80% consumed by rural areas apart from irrigation and industrial uses. In India around two fifth outcome of India come from area irrigated by groundwater source (Anita and Gita 2008). Natural water is seldom chemically pure. When rain starts, water flows in the form of run-off and organic and inorganic suspended particulate matter, gases, vapours, mists etc get dissolved in the water. In addition water carries surface pollutants and contaminants during the flow over the ground. That water when percolates into the ground, different kind of soluble pollutants get enter into groundwater. Water, which percolates into the ground having contact from rock bodies present in the travel path and dissolves various salts. Therefore groundwater gets high amount of total dissolved solids. This vast resource of water is getting contaminated by different types of hazardous sources. Due to large population in society, different industrial development activities, agricultural practices and other development activities are necessary in India. Such type of continuous development is responsible for enhancement of pollutants in the water resources.

These developments are the main causes of water overuses and will definitely affect the quantity and quality of water, if not protected (Singh and Singh, 2008). Groundwater quality have also been deteriorated because of Industries are rapidly growing and urbanization is also taking place (Shankar et. al. 2008; Sajjad et. al. 2008). In this present scenario, quality of water is essential analysis because it is having exact relationship with human health and enclosed environment, however it should be necessary to study the quality and quantity of water for safe water resource management (Varade et. al. 2014; Tiwari et. al. 2011). There is an ultimate need of attention to water quality and related environmental issues as well as planning for better management also needed (Ramesh and Elango 2011).

Contamination of drinking water supplies from industrial waste is a result of various types of industrial processes and disposal practices. Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources. Other disposal practices which cause water contamination include deep well injection and improper disposal of wastes in surface impoundments.

2.2 GROUNDWATER POLLUTION

Groundwater is a seriously important resource among all available water bodies because large amount of groundwater present beneath the earth surface. It is vitally important source for human life sustainability, industrial purposes, irrigation water demands, mining etc. 97% of water captured in oceans and due to high salinity of this water it cannot be consumed. Apart from that the water present is going to be decaying at global scale. The main reason behind that the continuous development and increased manmade activities (carpenter et.al. 1998; Chen et al. 2002). Groundwater is mostly used water body and it played very important role in many sectors in water consumption category. As discussed earlier it is a dominant source of water for development of any country. The fast growing urbanization which includes industries, agricultural as well as social activities become unfavorable for groundwater due to excessive use. It creates enormous pressure on groundwater resources and it followed by groundwater pollution. Such activities are also creates negative impact on environment. Groundwater resources are more dependable than others and from pollution point of view, these cannot be easily contaminated.

The water resource has its own natural protection from environment and requires less treatment issues (Kumar et al. 2010). Once it gets contaminated by surrounding activities, it became hard to treat and clean groundwater. Major groundwater contamination sources are increased industrialization which is the main and vital economic development criteria of any developing country like India. Rapidly growing industries are using water irregularly as well as their effluents disposed without any proper treatment to the surface water bodies leads to groundwater pollution (Jameel and Sirajudeen 2006). Due to aforesaid reasons there is an immediate need to save the groundwater resources and to supervise the contamination and diminishing rate of water quality. However, multiple numbers of studies have been performed and many are still in progress of determination of groundwater quality.

As discussed earlier, in India, the water quality issues are arising due to disposal of contaminated wastewater onto the land surfaces and in surface water bodies. It is not lawful and a contravention of rules and regulations of environment. There are many options provided under Indian pollution abatement rules and regulations to industries to discard the polluted effluent i.e. in surface water bodies, on land surfaces, in sewer lines etc. after adequate treatment. There are given standards for disposing the effluents on inland surface water bodies by CPCB, 2001. Industries may follow any one of the standard prescribed to them to discharge their effluent as per their convenience. These standards are designed in such a manner that the pollution load may adopt by receiving body and neutralize the coming pollution so that there will be no such environmental issues will occur. In this manner, when the adopting limit may cross in ecological media, there would be a chance of major groundwater and surface water pollution. These kinds of examples have been reported in western part of Uttar Pradesh such as: Ghaziabad, Meerut, Saharanpur, Mujaffarnagar, Agra etc (Singh et.al. 2013).

2.3 ACCOUNTABLE FACTORES OF GROUNDWATER CONTAMINATION IN INDIA

Industries may use water for variety of purposes, such as for manufacturing goods, heating, cooling, washing of materials, as raw material career etc. while in the small amount of water comes out as end product. Some of it diminished by evaporation process and after that the water converted into industrial waste water. These industrial effluents pollute soil or land area at which it is disposed off, concerning water bodies in which it is discharged. These effluents can also deteriorate the quality of air by producing obnoxious smell. Water consumed for industries is in very less amount as compare to other uses but it may contaminate the water body on which it disposed and make it unsuitable (Buechler and Mekala 2005; Ghosh 2005; Behera and Reddy 2002; Tiwari and Mahapatra 1999).

Industrial waste consists of both organic and inorganic substances. Organic wastes include pesticide residues, solvents and cleaning fluids, dissolved residue from fruit and vegetables, and lignin from pulp and paper etc. Effluents can also contain inorganic wastes such as brine salts and metals. There are standards for the permitted release of a limited amount of contaminants into waterways given by Clean Water Act. This is an incentive for industry to pre-treat their water by neutralizing the chemically active components, recycling, dilution or extraction and collection for proper disposal. More than 200,000 sources of waste water are regulated by the National Pollutant Discharge Elimination System (NPDES) permit program. Central pollution control board has also given different standards for each specified industry. Apart from the discharge of contaminated effluents on land or in water bodies there are other causes of industrial pollution. There are main origin of pollution and their possible causes as follows:

Table 2.1:Origin of industrial pollution and accountable elements (Morris et al, 2003)

Origin	Responsible elements
Storage tank: below ground level or at the surface of the ground, water conveying system: pipes or other transfer mechanisms.	Unlined structures leakage and insufficient arrangements for high level system failure
Sewer lines for industrial effluents and collecting chambers	Leaking occurs due to no preventive measures
Soaking tanks, wells for waste inserting	Discard the waste without suitable arrangements
Chemical storage tanks in large amount	Leakage and improper supervision
Lagoons for effluents coming from various sources	Infiltration of the waste/effluent due to inferior system
Solid waste disposal lands	Leachate contamination due to unlined landfills
Unfortunate leakage and discharge	Fire, blasts, resources loss

In these vast clusters of industries, there are many type of pollutants associated i.e. heavy metals, organic solvents and other toxic materials. This kind of pollution have already been reported and recorded in papers in many organizations. Every industry dispose different kind of waste in different amount as well as their concentration depends upon the processes using by industries. Leather industry discards solid or liquid waste materials in which chromium, organic carbon, nitrogen concentration, many kinds of solvents and sodium chloride etc. in different amount on the basis of processes occurring in industry (Armienta and Quéré, 1995; Chilton et al, 1998). There are many of small leather industries in many cities i.e. Agra, Kanpur as well as Tamil Nadu state, 500 small leather industries were reported. These industries having small area to develop and these are dispersed in many different units (Muthu, 1992; Armienta et al, 1997).

There are a lot of studies have been summarised to detect pollutants which contaminate the groundwater, coming from various industries by (Foster *et. al.* 1988; Morris et. al. 2003). Industrial chemicals are also reported in different industries and their useful references also studied by (Schmoll et al, 2006; Mercer and Cohen, 1990; Montgomery, 1996 and Pankow and Cherry, 1996). Such valuable and important information about industrial pollution are also available on USEPA website. Industrial pollutants, which are arising from different processes of industries, can be arranged into different categories for better understanding of pollutants and their characteristics (Morris et al, 2003) (refer table 2.1). Every industrial pollutant and chemicals used in industries are having different characteristics and these affect the groundwater in different ways according to their characteristics (Montgomery, 1996). In this manner, it can be found out that the pollutants occurring in deep groundwater and subsurface are both types: mixed with waste water or in immiscible type of pollutants. If the chemicals used in industries soluble in wastewater, the chances of their movement may increases as they can transport easily one place to another.

In industrial pollutants, phenolic compounds are more soluble in water as compare to hydrocarbons. Density of industrial pollutants is also responsible for their performance and shifting/ movement one place to another. In this manner we see fuel and oil are not soluble to water and they used to float at the top of the water. Some pollutants and chemicals are primarily less viscous and also temperature of subsurface makes them less mobile. On the other hand, chlorinated hydrocarbons and many other pollutants having low viscosity and these are denser as compare to water travel vertically and instantly mixed with groundwater. These descend in a rapid way to the aquifers (Pankow and Cherry, 1996). The chemical and pollutants goes downward to the aquifer and settle at the base of the aquifer, incompatible portion of these chemicals will remain in rock fractures and spaces. This incompatible portion of chemicals may dissolve to the sources of groundwater slowly and create a zone of pollution which can pollute the whole nearby water sources.

2.4 ISSUES ASSOCIATED WITH GROUNDWATER MANAGEMENT

In this rapidly growing scenario, water is being decline and sources are getting contaminated. In this situation fresh water quality is limited for irrigation. On the other hand there is a problem to decide optimum quantity of water for agricultural works. This is the primary challenge of present time to decide the water consumption in different fields and this is a challenging situation for best management of environmental. Water scarcity is the major issue of different areas and water demands are continuously increasing against less sources of water in irrigation. Though water demand of agricultural works is very high as compare to water used in industrial purposes, there is more contamination occurs due industrial disposal (Buechler and Mekala 2005; Ghosh 2005; Behera and Reddy 2002; Tiwari and Mahapatra 1999).

A study conducted by Madras institute of development studies in on lower basin of Bhavani River. The total water volume of river is 2341 mm^3 out of which 2 percent of water is consumed in industrial activities and abundant share is used in agricultural needs which is 67 percent of total water present in river. In this manner we see the industrial water consumption is very less as compare to agriculture activity. Though for industries water consumption is small but it plays very significant role in polluting surface water bodies, land as well as groundwater of nearby area. For industrial and domestic needs more than one-third of freshwater extracted by relative authorities and this water finally goes to the surface water bodies and in groundwater table naturally in the form of sewage and industrial effluent. This portion of sewage and industrial effluents apparently deteriorate the water bodies. In scars region, it has been recommended by experts that domestic sewage and industrial effluent should be treated and it may use as agricultural/ irrigation water needs. It has been proved that there are many water scars areas in India and marginal quality water is going to agricultural works so it is widely suggested by experts that treatment and reuse of sewage and industrial effluent may take place. It is reported that the treatment and reuse of industrial effluent in not common and effectively documented so that the vast consumption of water in agriculture may fulfill by this treated water. The environmental and social impact of reuse is not in trend where as in developing countries like India it should be arranged by active channels because the irrigation areas are very large and they consume a lot of fresh water for crop development.

In a case study of Tamil Nadu district, the severe pollution reported by industrial effluents in 1990s. High Court of Tamil Nadu declared that no industry will take place within the boundary of 1 kilometer of any river, stream or reservoir etc. After this decision of High Court, treatment of industrial effluent has been started for its reuse in irrigation purpose and it become widely renowned technique for the efficient use of industrial effluent. In this manner, surface water bodies saved from contamination from industrial effluent as well as groundwater table has also been unpolluted. The standards for disposal of industrial effluent on land or inland surface water standards are stricter, because it may dispose on land for irrigation water demand. These standards were followed especially for BOD, COD, TSS, TRC, and other toxic metals as per CPCB guidelines. Therefore, the discharge of industrial has been started on land surfaces. This continuous practice of discharging the industrial effluent, treated or untreated, on land may increase the possibility of groundwater and soil pollution and quality degradation because of the concurrence of pollutants. Now days, industries are disposing the effluent to the land and also without identifying the assimilation ability of that particular land area. Due to continuous discharge of an effluent on land surface, pollution load gets increased and therefore groundwater and soil are getting polluted. The above discussed scenario of industry effluent and their disposal on land is the important cause of groundwater pollution. Apart from this, at some industrial location there is the process of injecting the hazardous and untreated effluents to the groundwater also takes place through infiltration galleries and injection pits. It occurs due to the avoidance of cost of pollution arrangements (Sharma 2005; Ghosh 2005; Behera and Reddy 2002; Tiwari and Mahapatra 1999). Groundwater of this area is getting continuously polluted and shows unsuitability of water for drinking and agricultural purposes. As a result of application of contaminated groundwater without intervention, the soil becomes alkaline and saline in nature and it causes a big issue to farmlands.

Although the low cost option of irrigation water is domestic waste water coming from households. This is the helpful and cheep technique for farmers of water scarce areas. The high nutrient present in domestic wastewater gives the useful contribution to growing and fertilization of crops and also it doesn't require any significant amount or expenditure to provide extra fertilizers to crops. In the addition of this fact, farmers are forced to use wastewater for irrigation from the water scarcity problems arising due to the sectors which are demanding water for their growth. Wastewater consumed by farmers in irrigation is contaminated and it needs regular treatment and other preventive measures to avoid health hazards and environmental pollution (Bradford et al. 2003). Due to large investments in wastewater handling i.e. treatment, collection, and disposal etc., many local bodies and other organizations are using wastewater without proper treatment and any preventive measures.

In India, there is a big challenge to treat the mixed wastewater which combines hospital and industrial waste with domestic wastewater. On the other hand, the mixing of industrial wastewater is beneficial with domestic wastewater because the dilution of toxic elements may be done and the treatment will be easier. In India, most of the industries dispose their effluents in local public sewer to avoid the cost of the treatment of industrial wastewater. The primarily treated wastewater percentage is only 24 % in India before using in agricultural activities and dispose in inland surfaces even in metrocities (Minhas and Samra, 2004). There are many problems would arise i.e. groundwater pollution, land and soil deterioration, hazardous crops grown with the help of polluted water, if there will be no adequate treatment to the wastewater before disposing it (Scott et. al. 2004; McCornick et. al. 2003).

2.5PROBLEMS ASSOCIATED WITH GROUNDWATER OF GHAZIABAD

Ghaziabad city lies in the Upper Indo-Genetic Plain of north-east India. In past years it is the rapidly growing industrialized sector which is having many types of industries such as iron, plastic, dyeing, steel, chemical industries, pharmaceutical, battery manufactures etc. These industries dispose the effluent indiscriminately coming from different processes in treated or semi treated form and these are causing severe pollution to the surface water followed by groundwater(Kumari et al. 2013). The study of physiochemical properties and groundwater quality variations of any area shows influence and effect of natural and manmade activities (Subramani et al. 2005). Groundwater is having some chemical composition and to know about this, there is an essential need to determine the hydrochemistry of water. It leads to many studies on groundwater, its quality degradation, geochemical development of the groundwater in India as well as globally (Singh et al. 2013; Gupta et al. 2008).

In Ghaziabad as discussed above, many of industries present in a growing stage and the effluent disposed in surface water bodies without any treatment or partial treatment. This is not a legal practice of disposal of effluent and this is going to be a major source of groundwater pollution in Ghaziabad as well as nearby areas. It has been reported recently that LohiaNagar groundwater quality in Ghaziabad has been severely contaminatedby increased chromium concentration. This much of pollution load exhibits the urbanization and rapid industrialization in Ghaziabad city in last few decades. Chromium may increase in groundwater due to anthropogenic sources. The untreated effluents are disposed into inland surfaces, rivers and also it is used as irrigation water for growing the crops causing food contamination. It has also been reported that heavy metals found in soil and groundwater of nearby areas in Ghaziabad as well as several health hazards are occurring due to this contaminated water and soil (Chabukdhara and Nema 2013).

A study conducted onGhaziabad (Lohia Nagar, Sec-16, Jatwara and Sahibabad) area, where fluoride found was found to be 3.723, 1.66, 3.472, 4.68 ppm which is beyond standard limit of fluoride given by IS:10500 (Bisht et al. 2013). Groundwater weathering takes place of silicates and silicate associated minerals by which fluoride released and mixed with the groundwater (Apambire et al. 1997). Fluoride in form of minerals present in underground water as leachate due to fluorosilicates, apatite, fluorspar etc. (Thakare et al. 2005; Suratman 2011). When fluoride is present more than 1.5 ppm it leads to Fluorosis while it is less than 1 ppm it can cause tooth decay in human body (Tiwari et al. 2003). Some of the areas of Ghaziabad city Nitrate is also present in high concentration such as 99.79 ppm in Lohianagar Area and 187.583 ppm in Jatwara. In many areas nitrate is also present in low concentrations such as 5.658 and 5.365 ppm in Sec-16 and Sahibabad respectively (Bisht et al. 2013). In other study the nitrate concentration has also been observed as 0.4 to 60.7 ppm in transHindon area (Singh et al. 2013). The pH value in Ghaziabad city varies 6.82 to 8.40 in a past study which is both acidic and alkaline for different areas due to the percolation of dissolved elements into groundwater (Singh et al. 2013). Electrical Conductivity of study area has been reported 191.6 to 5260 µs/cm and the average value was1535.5 µs/cm. This is very high as compare to BIS specifications (>1400 µs/cm).

Dissolved Solids may consist many inorganic salts and if they are in high concentration causes hydrolysis of sodium and potassium and it is an important and predictable factor of groundwater chemistry (Chae et al. 2006). The TDS of some areas of Ghaziabad city has evaluated as 67 to 774 ppm (Sajjad et al. 2014). On the other hand some of areas which are extremely polluted having TDS range of 369 to 3470 ppm (Singh et al. 2013). Another study reveals that the TDS of Ghaziabad (Meerut and Bulandshahar Industrial Area) varies between 476-2694 mg/l (Kumari et al. 2013). Chloride concentration generally found in every type of water and in Ghaziabad it has been recorded 1198 ppm which is extensively high as compare to BIS standards of 250 mg/l (Srivastava et al. 2010). There is one another study on Ghaziabad in which chloride found to be 13-2005.7 ppm in different areas (Sajjad et al. 2014). Chloride concentration occurred in groundwater due to domestic sewage and many industries present in that area i.e. furnaces, glasses, refractory, printing, dye industry etc. Higher concentration of TDS, EC and chloride gives proof of higher value of salinity in that area (Shankar 2008). Nitrate concentration of Ghaziabad found in a range of 0 to 53 mg/l (CGWB 2010), 0.4 to 60.7 mg/l (Singh 2013), 0 to 200 mg/l (Sajjad, 2014). Kumari et al (2013) has been found calcium as 30-390.78 mg/l, magnesium as 6.08-492.18 mg/l. Same results of calcium and magnesium observed by Singh et al. (2013) as 3.2-304 mg/l and 4.8-361.1 mg/l respectively.

2.6 SCOPE OF THE STUDY

Ghaziabad groundwater quality has been deteriorated due to continuous development of city. It is situated near to NCT of Delhi and it is an industrial hub of western Uttar Pradesh. It also comes under NCR region of New Delhi. However these are the main causes of rapid industrialization of this city. This is the growing industrial cluster of Uttar Pradesh having various small, medium and large industries. Industrial effluents are disposing into the surface water bodies without any treatment or with some partial treatment. Many unlined channels are having industrial effluent of various industries e.g. paper, leather, pharmaceutical, steel, metal, battery making etc. and that water from unlined channels goes into infiltration galleries leads to mixing with groundwater. The continuous practice of withdrawal of groundwater to accomplish industrial water demand and discharging the effluents in unlined channels or land surfaces rendered high level of groundwater pollution in this area. However there are possible chances of water related diseases to people live nearby areas of industries. Groundwater of this area is also affecting the safe quality of life of residents. High concentration of dissolved salts is occurring and contaminates deep groundwater. As much as the salinity increases in Ghaziabad the water quality will be deteriorated. Therefore many attempts have to be made to save the water quality of Ghaziabad. There is crucial requirement to study the groundwater behavior in Ghaziabad and trigger up many solutions to save every drop of water.

CHAPTER-3
STUDY AREA

CHAPTER 3
STUDY AREA

3.1 GENERAL

Ghaziabad is a city of western Uttar Pradesh in India. It is situated proximity of New Delhi, capital of India. In previous time, it was sometimes mentioned as Gateway of Uttar Pradesh because it joins Uttar Pradesh to New Delhi (Ghaziabad Nagar Nigam). Ghaziabad is a part of National Capital Region (NCR). It is a city having large scale industrial development and it is well connected through roads and railways. It is a well developed commercial and educational center of Uttar Pradesh as well as it is a major junction of Northern Railways. It is situated in Upper Gangetic Plains and Hindon River divides into two major regions; west side it is Trans Hindon and east side it is CIS Hindon.

3.2 ENVIRONMENTAL PROFILE OF GHAZIABAD

Ghaziabad city is a zone of semi arid class of Uttar Pradesh and the environmental features of this city shows consecutive changesin typical patterns. To study about the groundwater it is necessary to explore the idea about the environmental profile of the city. The location of Ghaziabad city is shown in fig 3.1. Some important environmental features of Ghaziabad are described below:

3.2.1 LOCATION & TOPOGRAPHY

District Ghaziabad is situated in the middle of Ganga-Yamuna doab and spreads over 1966 sq Km. It is situated 2.5 km away from the Hindonriveralong grand trunk road. It is bounded by longitude 77^{0}12' and 78^{0}13' & latitude 28^{0}26' and 28^{0}54' and is underlain by Quaternary sediments. Ghaziabad district is drained by river Yamuna and Ganga and their tributaries namely Hindon and Kali, Minor distributaries of Kali Nadi being Hawa drain, ChhoiyaNala andChhoiyaNadi. The irrigation in major part of the district is done by minor irrigation structures such as tube wells, capacity wells and surface water bodies i.e. Canal. Upper Ganga canal and its tributaries irrigate western part of the district and AnupShalon branch of upper Ganga Canal irrigate eastern part of the district. Ghaziabad City is situated almost in the old flood plain of riverHindon. Morphologically, the area can be divided into 3 morpho units viz a viz (i) older Alluvial Plain (ii) Older Flood Plain and (iii) Active Flood Plain.

3.2.2 POPULATION

In Uttar Pradesh, Ghaziabad is a third most populated district out of 71 districts, according to Census 2011. Ghaziabad district is densely populated having population of 4.661,452 (Census

2011) and density is 2400/km^2. Urban population exists in Ghaziabad district is 54.8% (Census 2001).

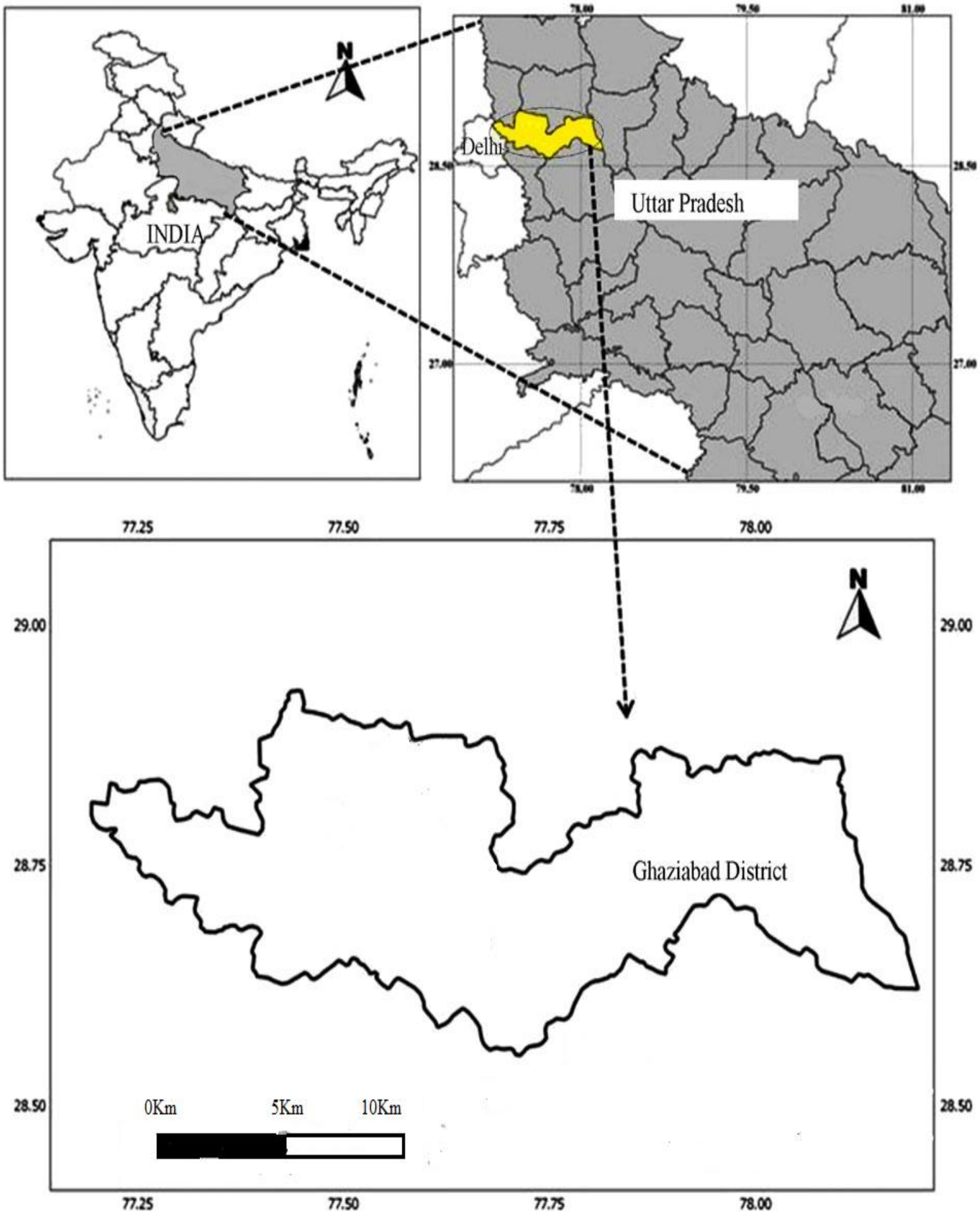

Fig 3.1: Location Map of Ghaziabad

3.2.3 GEOLOGICAL SETUP

In Ghaziabad district, Quartzite and Phyllite rocks types exist from lower Proterozoic age of rocks. Quartzite rock present in study area is very dense, in massive form, very hard, compacted, having high quality joints and in thick bedding as well as interpolated with slates and phyllite of thin beds. On the top of the surface these rock bodies are covered by sediments which are quaternary and in some areas like hills, pediments these are exposed in nature. As discussed earlier it is part of Indo-Gangetic Plain alluvium, which is having clay, reh, sand and kankar. The top strata consists sandy soil in this city. Fertility of soil in this area is good and loamy in nature.

3.2.4 HYDROGEOLOGICAL SETTING

The depth of sub-soil water table variesin Ghaziabad 10–15 m below ground level and at some places it is more than 20 m also. There is 5 m seasonal variation also occurs in this region. Ghaziabad city is having elevation of water table above mean sea level is around 194 m and water table slope is from north north- west to south south-east (CGWB report 2010). The decade wise analysis of water table in this area shows declining profile. If this trends will followed by water table then TubewellsSustainability will surely affected. Aquifer exploration drilling stage identifies the three layers of aquifer system. First system of aquifers varies 125 to 200 mbgl and depth of rocky structure is shallow in this area. Second tier aquifer system lies between 170 to 350 mbgl. This aquifer system is having fine grained to medium grained sand strata. It has also been found coarse grained at some locations. Third and last aquifer system exceeds upto 450 mbgl (Sinha 1980, Singh et al. 2013, CGWB 2009).

3.2.5 CLIMATE AND RAINFALL

The district is surrounded by a typical tropical climate with extreme summer heat and humidity as well as in winters it could be an extreme side. The temperature of this area increase upto 40°C or more than that every year in May and it drops down up to 5°C or less in January. Monsoon started from June end or first week of July month in every year and it rains till end of the September month.

3.3 INDUSTRIAL AND AGRICULTURAL ACTIVITIES

Ghaziabad is placed inwestern UP having large scale of agricultural activities. The soil types of Ghaziabad area are sandy loams, loams and clay loams having an area 26%, 43% and 12% respectively of the total area. The net irrigated area is 133.335 ha and total rainfall occurs in 10.595 ha. The main sources of irrigation in Ghaziabad are canals, Tubewells, open wells, lift irrigation schemes and other resources (Agriculture Contingency Plan of Ghaziabad).

Table 3.1: Various Industries in Ghaziabad (ghaziabad.nic.in)

Sr. No.	Type of Industry	No of industries in Ghaziabad
1	Food	12
2	Wooden Silk and Synthetic Textile	05
3	Chemical and Chemical products	17
4	Metal products	15
5	Machinery tools and parts	12
6	Electrical machinery equipments and parts	20
7	Soft drink and tobacco	06
8	Paper products and printing	08
9	Cotton textiles	03
10	Rubber plastics and petroleum	19
11	Non-metallic minerals	03
12	Transport equipment and parts	12
13	Basic Metal Products	08
14	Other miscellaneous products	05
	Total	145

The District Ghaziabad, a growing industrial city, has an important place in industrial development in Uttar Pradesh. Industries are divided into three categorized depending upon production, employment and turnover which are Small Scale Industries, Medium Scale Industries, Large Scale / Heavy Industries. There are many more industries in Ghaziabad i.e. Food Industry, Cotton and Textile Industry, Soft drink and Tobacco Industry, Chemical Industry, Paper and Paper Product Industry, Rubber Plastic and Petroleum Industry etc. Some of the industries situated in Ghaziabad and their units are listed below in Table 3.1.

CHAPTER-4
MATERIALSAND METHODOLOGY

CHAPTER-4
MATERIALS AND METHODOLOGY

4.1 INTRODUCTION

Groundwater of Ghaziabad is being deteriorated due to rapidly increased urbanization and industrialization. There is an essential requirement to analyse the problems occur in this area as well as explore the recommendations for those problems. Different locations of Ghaziabad city has been taken under this study and to attempt of finding the problematic areas and their possible causes in groundwater.

4.2 SAMPLING AND EXPERIMENTAL METHODS

Sampling strategy was figured out in which sampling is made to report such locations of TransHindon area which are the key sites and able to represent water quality of entire study area. Monthly sampling was done in November, January and March. Major sampling locations are from Sahibabad Site IV industrial area which is highly polluted due to industries effluent disposal on inland surface water bodies which follow the groundwater contamination.

4.2.1 SAMPLING METHODS

In this study, samples have been collected from different locations of trans Hindon area which include Sahibabad, Indirapuram, Vasundhara, Maharajpur Village, Karkar Model, Jhandapur Village and BrijVihar. 60 samples has been collected out of which 20 samples collected in November 2014 other 20 has been taken in January 2015 and rest 20 samples collected in March 2015 from different locations of Ghaziabad. The groundwater samples have been collected from Tubewellsafter flush the water for 8 to 10 minutes to avoid stagnant amount of water.Tubewells are selected for sampling was in active conditions and in continuous use for drinking and other domestic uses. Samples have been collected in such a way that a network formed of Tubewells by which the whole water quality can be predicted. The samples were collected in new and prewashed HDPE bottles after rinse carefully 2-3 times. These were previously washed with distilled water and dried before taking the samples. After taking samples hydrochloric acid was diluted as 2-3 drops in every bottle of samples for preserving the samples. Samples of groundwater immediately shifted to the laboratory from the sampling sites. All samples were stored at 4°C temperature in laboratory.

The groundwater quality has been than analysed by comparing the observed values with drinking water standards. Grab samples collected from study area in different months for the better assessment and understanding of groundwater quality of a portion of Ghaziabad city. There were three months in which samples were collected and these months are the best representatives of different climatic conditions. On the basis of distinct climatic conditions, the three months have been denoted as respective seasons. Respective seasons and their corresponding months are given in Table 4.1.

Table 4.1: Different sampling seasons and their corresponding months

S. No.	Month	Season
1.	November	Pre Winter Season
2.	January	Winter Season
3.	March	Post Winter Season

4.2.2 EXPERIMENTAL ANALYSIS

Many of physio-chemical parameters were analysed in this study such as pH, total dissolved solids (TDS), electrical conductivity (EC), salinity, total hardness, calcium, magnesium, total alkalinity (as $CaCO_3$), bi-carbonate (HCO_3 as $CaCO_3$), carbonate, chloride, nitrate, sulphate, fluoride, sodium and potassium. All parameter were examined in laboratory as per standards method APHA 2002.
To analyze the water quality of Ghaziabad city various physiochemical parameters have been determined. Analytical methods were used to determine these parameters are as follows:

pH

pH is expressed as the concentration of hydrogen ion in any serous solution. It is measured by pH meter at room temperature of 25°C.pH is measured by electrode attached with pH meter and this electrode should be calibrated before using with pH buffer solution of 4.0, 7.0 and 10.0 for different meters.pH when observed below 7, water is considered as acidic and on the hand it rendered alkaline when above 7.pH is an important and significant quality parameter of water and wastewater. It is expressed as:

$$\mathbf{pH = -Log_{10}\,[H^+]} \quad \ldots (4.1)$$

ELECTRICAL CONDUCTIVITY

Conductance represents the current passing capability through water. Electrical conductivity is the measurement of ion concentration in water and it is directly proportional to dissolved salts present in water. It is measured in µmhos/cm andmili-siemens/cm or µ-siemens/cm and µmhos/cm is approximately equal toµ-siemens/cm. It is measured by Thermo-Orion multi parameter kit in laboratory at room temperature.

SALINITY

Total no of dissolved particles and ions present in water are the key representatives of Salinity of water. It is measured in ppm and it is the significant parameter in deciding the water for irrigation purpose. It is measured by Multiparametermeter (thermo-orion). If the water contains high amount of salinity it may reduce the plant growing ability of soil when comes to soil contact. When water infiltrate to the ground, many of plants utilizes the water to nurture and in this phenomena water uptake by plants and the dissolved solids remain in soil. This continuous practice makes soil saline and hence it also goes to deeper and also increases the groundwater salinity and deteriorate deep water bodies. So this is the basic pattern of salinity in groundwater.

TOTAL DISSOLVED SOLIDS

TDS indicates the solids present in water samples which are in dissolved form. It is measured by heating the pre washed and dried evaporating dish at 180°C temperature till the whole liquid will evaporated. Before evaporation the samples should be well shaked and filtered through a filter paper. The evaporating dish primarily weighted.

$$\textbf{TDS} = \frac{\mathbf{A-B}}{\mathbf{VolofSample}} \times \mathbf{1000} \ldots (4.2)$$

Where, A = weight of evaporating dish with residue
B = weight of dish when it was empty

TOTAL ALKALINITY

It referred as acid neutralizing capacity of any aqueous solution. It contains carbonate and bi-carbonate ions.

$$\textbf{Alkalinity} = [HCO_3]+2[CO_3]+[OH]-[H] \ldots (4.3)$$

Where, [] presents the molecular weight of ions in moles/l. The alkalinity in samples of groundwater is determined by titration method (APHA 2002, Method 2320B). In this method, 0.1N H_2SO_4 acid isusedas titration agent. Before titration phenolphthalein indicator is used for reducing the pH till 8.3 and after that methyl orange indicator used till the pH decreased by 4.5. These are called phenolphthalein and total alkalinity of samples respectively.

TOTAL HARDNESS

Hard water rendered as the water which contains high amount of mineral as compared to soft water. The total hardness of water is the summation of calcium and magnesium ions present in water. These are mainly responsible cations of water hardness. When the water passes through or over the deposits of limestone, water carried out calcium in dissolved form from the limestone. Same as the magnesium found in water in dissolved form when the water passes from dolomite and other different magnesium containing structures. It is not harmful for human lives but when it is used in industries there are possible chances of scaling of boilers, clog plumbing through deposits of calcium or magnesium etc.

Total hardness of water is measured by EDTA Titration Method (APHA 2002, Method 2340 C). Total Hardness is determined by mixing 2 ml of NaOH buffer solution and a pinch of Erichrome Black T indicator. The color changes to pink and after that titrate with EDTA of 0.01 N till the color changes to purple.

$$\textbf{TH} = \frac{\textbf{Volumeconsumedoftitrant} \times \textbf{NofEDTA} \times \textbf{mol.wt} \times \textbf{1000}}{\textbf{VolofSample}} \quad \ldots (4.4)$$

In case of calcium, sodium hydroxide is used as buffer and meuroxide is used as indicator. Titrate with EDTA solution till color change.

Magnesium Hardness = Total Hardness – Calcium Hardness … (4.5)

CHLORIDE

Chloride present in various concentrations at different places. Chloride is generated from domestic wastes as well as from industrial effluent. It is determined by ArgentometricTitration Method (APHA 2002, Method 4500–Cl^- B). to determine chloride content in water take a sample in volumetric flask, add 1 ml of potassium dichromate ($K_2Cr_2O_7$) indicator and thus titrate by silver nitrate solution till the color changes to pinkish-yellow.

$$\textbf{Chloride} = \frac{\textbf{Volumeconsumedoftitrant} \times \textbf{NofSilverNitrate} \times \textbf{mol.wt} \times \textbf{1000}}{\textbf{VolofSample}} \quad \ldots (4.6)$$

FLUORIDE

The fluoride concentration in groundwater samples has been determined by SPANDS Method (APHA 2002, Method 4500-F^- D). To estimate fluoride concentration in water takes 50 ml of sample and add 5 ml of SPANDS solution and zyrconyl acid reagent added to the sample. The final solution was mixed and at 570 nm the optical density was measured. Take the reference of absorbance as zero.

NITRATE

Nitrate of the samples of groundwater was determined by U-V Spectrophotometer (APHA 2002, Method 4500-NO_3^- B). to determine Nitrate concentration in groundwater in 5 ml sample added 1 ml of BrucineSulphanilic acid and 10 ml of Sulphuric acid. This solution kept in dark for 10 min. After that distilled water added of 10 ml. It kept in dark again for 25 min after mix it well. After 25 min take the absorbance has been noted at 400 nm spectrophotometer. This absorbance has been multiplied by graph factor to determine the Nitrate concentration in groundwater.

SULPHATE

Sulphate concentration of groundwater has been determined by Turbidimetric Method (APHA 2002, Method 4500-SO_4^{--}E). 50 ml of sample was taken and mix 20 ml of standard buffer solution to it and also mix the Barium Chloride $BaCl_2$. Stir well the whole mixture and at 420 nm the turbidity of mixture was recorded with the help Spectrophotometer. Sulphate concentration was estimated by linear standard curve.

SODIUM

Sodium is the element which found on the earth surface in abundance amount and in all types of natural water bodies it is present in varying concentrations. Sewage and industrial effluents are mainly responsible for sodium concentration in water bodies and sea water intrusions may also causes sodium. To determine the sodium concentration flame photometer was used. Sodium ions present in water samples emitted light when came in a contact of gas flame at 589 nm of wavelength. The sodium amount present in sample has been determined by intensity of light in flame photometer because it is proportional to the element concentration. After that sodium concentration was figured out by calibration curve.

POTASSIUM

Potassium found in sea water in high amount. The clay minerals, feldspar etc carried potassium generally. It is observed in laboratory by flame photometer. The standard solutions of potassium of different N were aspirated and after that the sample aspiration was done. The light intensity was the measure of potassium in water sample and it was calculated from calibration curve.

4.3STANDARDS FOR DIFFERENT USES OF WATER

Every kind of water may be said as pure or may be as polluted if no water parameter limits are there. In this world, usage of water is different and many of them are very essential for human being. Water may use for drinking purpose, industrial activities, agricultural practices, commercial buildings (i.e. schools, parks, hospitals etc). For different uses of water, water quality may also be different and type of water may vary. The chemical, physical, and biological characteristics of water to check for the appropriate uses should be determined for assessing the water quality. For drinking purpose, water should be clear or having no color from aesthetic point of view. But in case of water which used as irrigation water and industrial purpose, there is no consideration for color, odour and aesthetics. Water which is having high BOD is not suitable for drinking because it is having high organic content, but it may be good for irrigation purpose because of nutrients presence in water. Many types of nutrients are useful in plant growth i.e. potassium, sodium and phosphate etc. Therefore, water has been classified for different uses and some standards were constituted for water. These standards are having limits for every parameter of water. In India, Bureau of Indian Standards was adopted standards for drinking water quality named as IS: 10500, Drinking Water Specification. This standard was initially publicized in 1983. This standard was constructed to fulfillment of the purpose of estimating the quality of water which comes from different resources and to examine the success rate of water treatment units installed in India.

Different water uses and their standards for recommending agencies- Groundwater can be used as drinking water. Even high amount of groundwater is using in drinking purpose only. Agricultural works are also being developed by groundwater. In many areas groundwater is the source full commodity for irrigation purposes. Other purposes are for industries also.

4.3.1 DRINKING WATER STANDARDS

The water intended for human uses i.e. drinking and cooking coming from any source, referred as drinking water.This is a water which include water supplied by any means that can be utilizes by human being. (Source- IS: 10500). Water is having many parameters (physical, chemical and biological) which provides the water classification as per their concentration in water. Water used as drinking purpose first analysed and determine the parameter concentration to decide the water is safe or not for human beings.Bureau of Indian Standard has given the standards for various parameters of water in IS: 10500 (Drinking Water Standard Code). In this code, safe limit has been defined as well as permissible limits when there is no other options are available. Desirable and permissible limits of different physiochemicalparameters given in IS: 10500 are as follow:

Table 4.2: Organoleptic and Physical Parameters (Source: IS: 10500)

S. No.	Characteristics	Unit	Required Acceptable Limit	Permissible Acceptable Limit
1	Color	Hazen	5	15
2	Odour	-	Agreeable	Agreeable
3	pH value		6.5-8.5	No relaxation
4	Taste	-	Agreeable	Agreeable
5	Turbidity	NTU	1	5
6	Total Dissolved Solids	Mg/l	500	2000

Table 4.3: General Parameters Concerning Substances Undesirable in Excessive Amounts(IS: 10500)

S No.	Characteristics	Unit	Required Acceptable Limit	Permissible Acceptable Limit
1	Aluminum (as Al), *Max*	mg/l	0.03	0.2
2	Ammonia (as total ammonia-N)	mg/l	0.5	No Relaxation
3	Anionic detergents (as MBAS)	mg/l	0.2	1.0
4	Barium (as Ba)	mg/l	0.7	No Relaxation
5	Boron (as B)	mg/l	0.5	1.0
6	Calcium (as Ca)	mg/l	75	200

7	Chloramines (as Cl2)	mg/l	4.0	No Relaxation
8	Chloride (as Cl), mg/l	mg/l	250	1000
9	Copper (as Cu)	mg/l	0.05	1.5
10	Fluoride (as F)	mg/l	1.0	1.5
11	Free residual chlorine	mg/l	0.2	1.0
12	Iron (as Fe)	mg/l	0.3	No Relaxation
13	Magnesium (as Mg)	mg/l	30	100
14	Manganese (as Mn)	mg/l	0.1	0.3
15	Mineral oil	mg/l	0.5	No Relaxation
16	Nitrate (as NO3)	mg/l	45	No Relaxation
17	Phenolic compounds (as C6H5OH)	mg/l	0.001	0.002
18	Selenium (as Se)	mg/l	0.01	No Relaxation
19	Silver (as Ag)	mg/l	0.1	No Relaxation
20	Sulphate (as SO4)	mg/l	200	400
21	Sulphide (as H2S)	mg/l	0.05	No Relaxation
22	Total alkalinity as ($CaCO_3$)	mg/l	200	600
23	Total hardness (as CaCO3)	mg/l	200	600
24	Zinc (as Zn)	mg/l	5	15

Table 4.4: Parameters Concerning Toxic Substances (Source: IS: 10500)

S No.	Characteristics	Unit	Required Acceptable Limit	Permissible Acceptable Limit
1	Cadmium (as Cd)	mg/l	0.003	No Relaxation
2	Cyanide (as CN)	mg/l	0.05	No Relaxation
3	Lead (as Pb)	mg/l	0.01	No Relaxation
4	Mercury (as Hg)	mg/l	0.001	No Relaxation
5	Molybdenum (as Mo)	mg/l	0.07	No Relaxation
6	Nickel (as Ni)	mg/l	0.02	No Relaxation
7	Pesticides	µg/l	In Table 5	No Relaxation
8	Polychlorinated biphenyls	mg/l	0.0005	No Relaxation
9	Polynuclear aromatic hydrocarbons (as PAH)	mg/l	0.0001	No Relaxation
10	Total arsenic (as As),	mg/l	0.01	0.05
11	Total chromium (as Cr)	mg/l	0.05	No Relaxation
12	Trihalomethanes:			
12(a)	Bromoform	mg/l	0.1	No Relaxation
12(b)	Dibromochloromethane,	mg/l	0.1	No Relaxation
12(c)	Bromodichloromethane	mg/l	0.06	No Relaxation
12(d)	Chloroform	mg/l	0.02	No Relaxation

4.3.2 IRRIGATION WATER STANDARDS

Water used for an artificial application of water to the agricultural land. This process is called irrigation. For irrigation water specified code IS: 11624 have also been established.Water used for irrigation may decide as per various parameter concentration analysis.

Water quality for irrigation can be classified on the basis of following parameters:

1. Total Salt Content
2. Sodium Adsorption Ratio
3. Residual Sodium Carbonate or Bi-Carbonate Ion Concentration
4. Boron Content

Table 4.8: Irrigation Water Quality Rating based on Chemical Properties (Source: IS: 11624)

Sr. No.	Chemical Properties	Class (Hazards Levels)			
		Low	Medium	High	Very High
1	Total Salt Content (in terms of EC in micromhos/s)	Below 1500	1500-3000	3000-6000	Above 6000
2	Sodium Adsorption Ratio	Below 10	10-18	18-26	Above 26
3	Residual Sodium Carbonate or Bi-Carbonate Ion Concentration	Below 1.5	1.5-3.0	3.0-6.0	Above 6
4	Boron Content	Below 1.0	1.0-2.0	2.0-4.0	Above 4.0

The irrigation water standards also depend upon many ions present in water. Sodium presence primarily contribute nutrient to soil but as it increases caused sodicity to water. Other elements like pH, sulphate, calcium, magnesium, carbonate, bicarbonate and chloride also responsible for the deterioration of groundwater for irrigation purpose. The western part of Uttar Pradesh specially Ghaziabad and nearby area are very promising sectors for agricultural practices. The Groundwater studies performed in this area shows positive nature of important parameters towards irrigation (Kumari et al. 2013).

CHAPTER-5
RESULTS AND DISCUSSION

CHAPTER 5
RESULTS AND DISCUSSION

5.1 INTRODCTION

The complete physiochemical analysis of groundwater of Sahibabad Industrial Area has been completed in this study and the comprehensive data of every month is summarized in Table 5.1, 5.2 and 5.3. In this study 20 samples of varying stations have been taken and observe the concentration in laboratory. The revealed data in this study shows various concentrations of different parameters and it has been compared by BIS standards for drinking purposes. On the basis of observed data water quality for irrigation purpose also has been analysed in this study.

5.2 STATISTICAL ANALYSIS FOR VULNERABILITY ASSESSMENTOF GROUNDWATER CONTAMINATION

The complete multivariate statistical analysis of groundwater of Ghaziabad was analysed. In this study, different three data set of three months have been considered and multiple analysis completed with these sets of data. Many parameters are having a great range and variations in standard deviation and it indicates the fluctuations of concentration of parameters due to different chemical composition. The groundwater may affected by many of anthropogenic activities and natural phenomena such as rock-water interaction.

The complete analysis of groundwater quality based upon physiochemical parameters for drinking purposes and effects of concentration of parameters on human lives, their lives are also discussed as follows:

5.2.1 pH

pH is a measure of alkalinity and acidity of water. pH is determined by estimating the hydrogen ion concentration in water. The pH limit given by BIS standards is 6.5 to 8.5 for drinking purposes. Although the pH value has no such significance for human health hazards but it is correlated to some other parameters of water (Pitt et al. 1999). It has been considered that water will be acidic if pH is below 7 and alkaline if it is above 7. Alkalinity and acidity of water is important to determine to check the corrosiveness of water. pH shows the pollution types and their intensity in water bodies. The pH of groundwater samples was 6.6-8.1 in Nov, 6.67-8.0 in Jan and 6.56-8.09 in Mar. The pH of groundwater is within the limit of given BIS standards and the comparison with standards is shown in fig 5.1. The observed value of pH shows that groundwater is slightly acidic to alkaline. Acidic nature of groundwater is represents the anthropogenic activities occurring in study area.

Table 5.1: Statistical Analysis of Groundwater (November, 2014)

Sr No	Parameter	Min-Max	Mean ± StdDev	BIS Standards	WHO Standards (2011)	Samples Beyond Desirable Limit
1	pH	6.6-8.1	7.455 ± 0.42	6.5-8.5	6.5-8.5	-
2	Salinity	230-3211	1495.15 ± 1004.25	1500	-	45%
3	EC	310-5950	2281.6 ± 1931.90	-	1400	70%
4	TDS	269-2870	1332.15 ± 905.73	500	1000	75%
5	Alkalinity	24.4-566.08	231.70 ± 212.84	200	200	45%
6	Calcium	20.8-311.6	81.53 ± 72.25	75	200	40%
7	Magnesium	100.8-1448	540.06 ± 385.21	30	50	70%
8	Hardness	132-1560	621.6 ± 403.53	200	500	85%
9	Chloride	60-1852	789.8 ± 579.42	250	250	80%
10	Fluoride	0.5-3.67	1.5905 ±1.270	1-1.5	1.5	95%
11	Nitrate	1.89-65.69	16.38 ± 18.49	45	50	15%
13	Sulphate	17.40-78.60	49.19 ± 23.75	150	250	-
14	Sodium	82-297	163.1 ± 57.92	-	200	20%
14	Potassium	5.6-16.21	10.45 ± 3.91	-	12	40%

Table 5.2: Statistical Analysis of Groundwater (January 2015)

Sr No	Parameter	Min-Max	Mean ± StdDev	BIS Standards	WHO Standards (2011)	Samples Beyond Desirable Limit
1	pH	6.67-8.0	7.432± 0.33	6.5-8.5	6.5-8.5	-
2	Salinity	297-3287	1522.85± 996.96	1500	-	45%
3	EC	421-5721	2319.4 ± 1996.80	-	1400	70%
4	TDS	269-2870	1329.05 ± 927.06	500	1000	75%
5	Alkalinity	21.2-493.32	224.58 ± 207.42	200	200	40%
6	Calcium	25.9-313.9	80.26 ± 72.06	75	200	40%
7	Magnesium	123.3-1476	548.06 ± 386.18	30	50	100%
8	Hardness	149.9-1594	628.32 ± 405.90	200	500	85%
9	Chloride	71-1901	819.95 ± 592.67	250	250	80%
10	Fluoride	0.45-3.71	1.571 ± 1.25	1-1.5	1.5	95%
11	Nitrate	1.91-65.21	16.41 ± 18.48	45	50	15%
12	Sulphate	16.94-108.8	49.16 ± 23.84	150	250	-
13	Sodium	83-297	165.2 ± 57.32	-	200	20%
14	Potassium	5.9-16.67	10.63 ± 3.94	-	12	40%

Table 5.3: Statistical Analysis of Groundwater (March, 2015)

S.No.	Parameter	Min-Max	Mean ± StdDev	BIS Standards (mg/l)	WHO Standards (2011)	Samples Beyond Desirable Limit
1	pH	6.56-8.09	7.432± 0.33	6.5-8.5	6.5-8.5	-
2	Salinity	302-3290	1522.85± 996.96	1500	-	45%
3	EC	387-6014	2284.5 ± 1913.31	-	1400	70%
4	TDS	199-2831	1361.25 ± 894.81	500	1000	75%
5	Alkalinity	24.98-512.67	242.31 ± 223.13	200	200	45%
6	Calcium	19.13-345.34	94.61 ± 84.11	75	200	40%
7	Magnesium	143.2-1134.8	557.98 ± 376.56	30	50	100%
8	Hardness	149.01-1601	662.59 ± 413.76	200	500	85%
9	Chloride	69-1889	798.8 ± 584.49	250	250	80%
10	Fluoride	0.42-3.96	1.66 ± 1.35	1-1.5	1.5	95%
11	Nitrate	1.95-67.11	16.75 ± 18.73	45	50	15%
12	Sulphate	17.23-109	49.77 ± 23.79	150	250	-
13	Sodium	82-298	164.6 ± 57.44	-	200	20%
14	Potassium	5.98-16.3	10.59 ± 3.95	-	12	40%

(all units are in mg/l except EC in µmhos/cm)

5.2.2 SALINITY

Salinity is the parameter of water which occurs due to different ions present in water. These ions are present in water in the form of dissolved salts and increase the soil salinity i.e. chloride, sodium, calcium, magnesium, sulphate, nitrate and bicarbonates etc. the most important salinity measures are: TDS and EC. TDS is the amount of dissolved salts in groundwater and EC is the conductance of groundwater and the ability to pass the current through salts. Due to growing industrialization and urbanization there is an increase withdrawal of groundwater in study area. When withdrawal of groundwater takes place, salts remains beneath the ground level and causes increasing salinity. The salinity varies in study area within the range 230-3211 in Nov, 297 to 3287 in Jan and 302-3290 mg/l in Mar month. The higher value of standard deviation of salinity indicates enormous variation due to the difference in depth of water table. It has been also observed that 45% of the samples are beyond the limit of BIS. The graphical representation of salinity and comparison with standard is shown in fig 5.2.The standard limit for salinity according to BIS standard is 1500 mg/l. Observed concentration of salinity in groundwater shown in fig 5.2. After rainfall groundwater table increases and salts may remain in diluted form and concentration will decreases in groundwater.

5.2.3 ELECTRICAL CONDUCTIVITY

Electrical conductivity is due to total salt content presence in the groundwater and however it renders as the level of inorganic salts. It is the current passing ability of the salts (Awofolu et al.

2007). The electrical conductivity ranges in present study was 310-5950, 421-5721 and 387-6014 µs/cm in Nov, Jan and Mar respectively. The standard value of EC given by WHO (2011) is 1400 µs/cm for drinking water. It is observed that 70% of samples of groundwater are unsuitable for drinking (fig 5.3). The higher values of EC are responsible for the disturbance of aquatic biota as it may spread negative effects on ecological system.

5.2.4 TOTAL DISSOLVED SOLIDS

Total dissolved solids referred as the combination of salts in groundwater both organic and inorganic, which are in dissolved form. It is also asignificant indicator of groundwater salinity (ANZECC, 2000). It has been considered as an important parameter of drinking water standards and other water quality standards (Varade et al. 2014). It is the main factor which consider as the deciding parameter of groundwater uses for any purpose (Nordstorm 1087). The standards for drinking water quality TDS limit defined as 500 mg/l in BIS and 1000 mg/l in WHO (2011). In the present study total dissolved solids observed as 269-2870, 269-2870 and 199-2831 mg/l in Nov, Jan and Mar respectively. Standard deviation of all values determined was 1361.25; it shows the significant variation in TDS of different locations. At some locations TDS lies within the range of 500 mg/l of BIS standard but at some location it is higher than that. In this manner, 75% of samples are contaminated as these are beyond standard limit (fig 5.4). TDS present in higher concentration in study area and it depicts excessive pollution activities and land use practice occurring in this area, sewage disposed in unlined channels. Sodium and potassium silicates started the process of hydrolysis when TDS is generally high in groundwater (Chae et al. 2006). Several health hazards may also take place in case of excessive TDS in drinking water i.e. gastrointestinal infections and other antagonistic physical reactions in human body (Dar et al. 2011).

5.2.5 TOTAL ALKALINITY

Total Alkalinity may describe as the acid neutralizing capacity of any water body. It occurs in water due to the existence of ions i.e. bi-carbonate, carbonate and hydroxide ions and sometimes due to sodium and potassium. The alkalinity value determined is in the range of 24.4-556.08, 21.2- 493.32 and 24.98-512.68 mg/l in the months of Nov, Jan and Mar respectively. The standard limit of alkalinity as per BIS and WHO (2011) is 200 mg/l. Out of 60 samples 27 samples are beyond limit of 200 mg/l; therefore 45% samples groundwater are contaminated (fig 5.5). Pharmaceutical and drug industry is present in study area and the higher values of alkalinity may attributed from this industry.

5.2.6 TOTAL HARDNESS

Total Hardness in water bodies is present due to polyvalent ions which are calcium and magnesium and these ions remains dissolved in waterbodies (Varade et al. 2014; Taiwo et al. 2011). BIS has limit the hardness concentration in water as 200 mg/l; beyond this hardness causes encrustation in structures of water supply and causes harmful effects on many domestic activities i.e. cooking, washing etc. The concentration of hardness in study area ranges 132-1560, 149.94-

1594 and 149-1601 mg/l in Nov, Jan and Mar. Hardness in study area was within the limit at some locations and on the other hand it is much higher than the standard limit (>200 mg/l). 85% of samples found to be exceeding the limit in the groundwater of study area and depict the groundwater is unsuitable for human uses (fig 5.6). The Sawyer Mc Carty's (1967) classification also confirms the water hardness in this area.

Table 5.4: Hardness based Water Classification by Sawyer and Mc Carty's (1967)

Range Variation in mg/l	Water Types (As per hardness)	Samples of Nov month (%)
0 – 75	Soft	-
76 – 150	Moderately hard	0.5%
151 – 300	Hard	30%
>300	Very hard	65%

5.2.7 CALCIUM

Calcium are formed due to the leaching process of the rocks mainly Calcite. The calcium concentration in drinking water is allowed upto 75 mg/l as per BIS specifications. The observed calcium content in groundwater was ranged between 20.8-311.6, 25.98-313 and 19.13-345.34 mg/l in the month of Nov, Jan and Mar respectively. The percentage analysis reveals that 40% sample are exceeding the standard limit of 75 mg/l (5.7). The increased concentration of calcium occurs due to residence time of groundwater because the flow of the groundwater is sluggish.

5.2.8 MAGNESIUM

Magnesium content is present in groundwater due to the various types of rocks. It mainly occurs due to dolomite, ferro-magnesium and silicate minerals such as; garnet, olivine, amphiboles and pyroxenes. Magnesium presence in excess amount in groundwater may affect the human digestion system and impart a bitter taste to drinking water. The standard concentration of magnesium in drinking water limits upto 30 mg/l given by BIS specifications of drinking water. The magnesium concentration in groundwater observed in Nov, Jan and Mar months as 100.82-1448, 123.30-1476 and 143.20-1134.85 mg/l respectively. In the study area all samples were overshooting the standard limit (>30 mg/l) (fig 5.8).

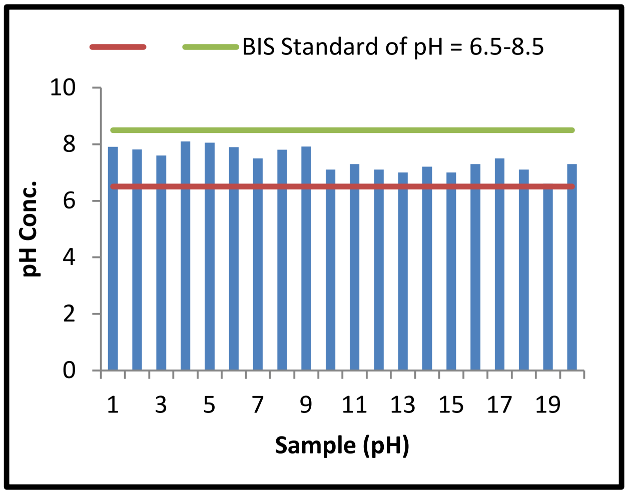

Fig5.1 Concentration of pH in study area

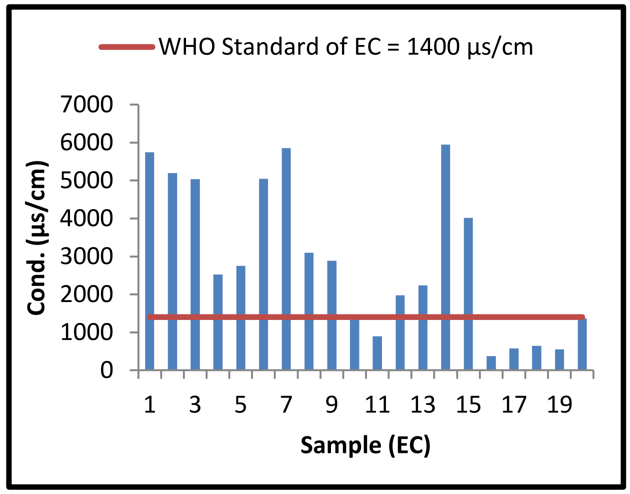

Fig5.2 Concentration of EC in study area

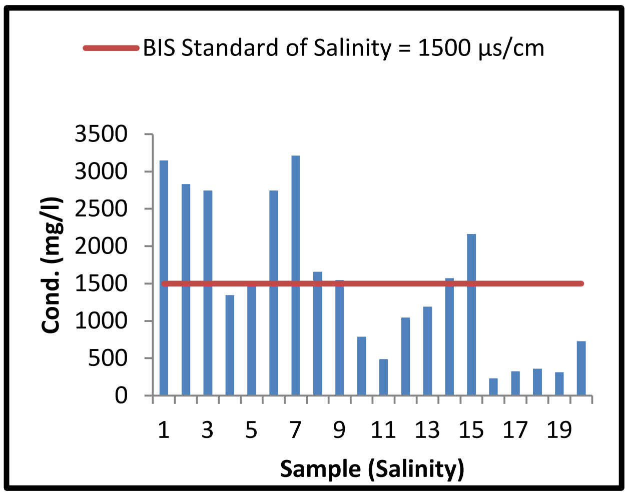

Fig 5.3: Concentration of Salinity in study area

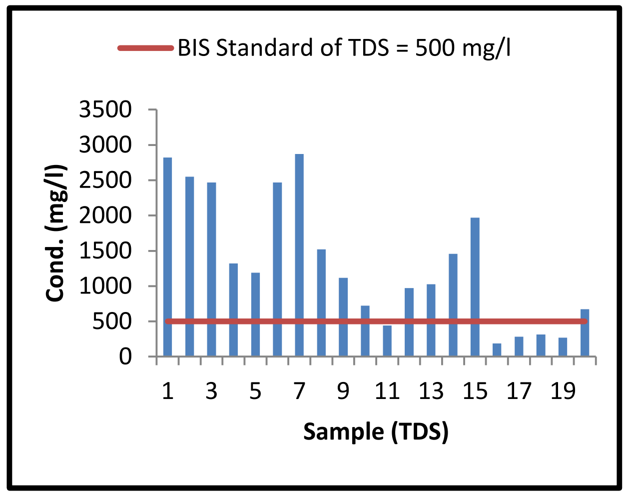

Fig 5.4: Concentration of TDS study area

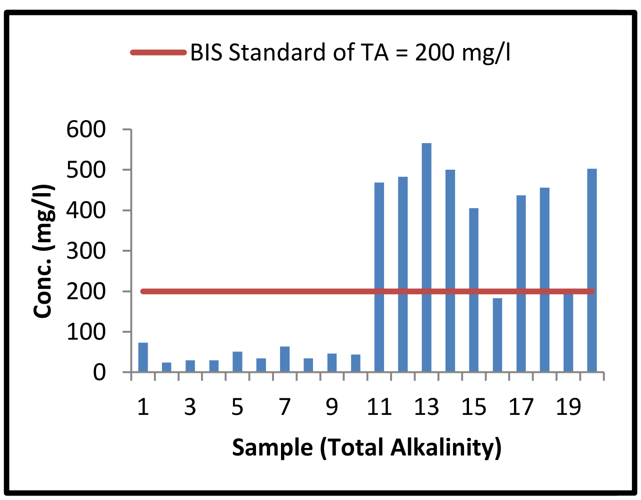

Fig 5.5: Concentration of TA in study area

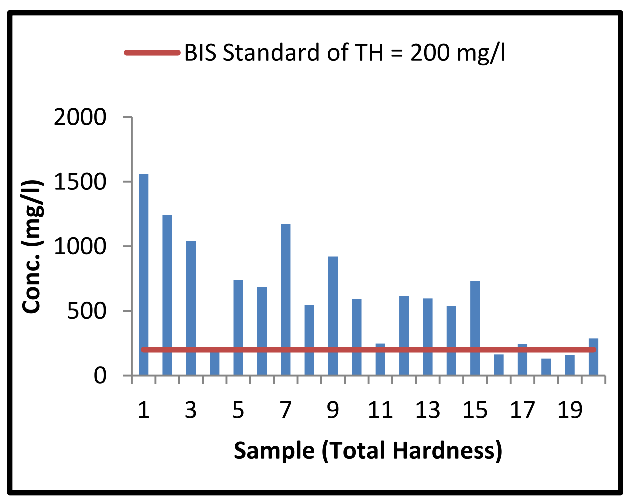

Fig 5.6: Concentration of TH in study area

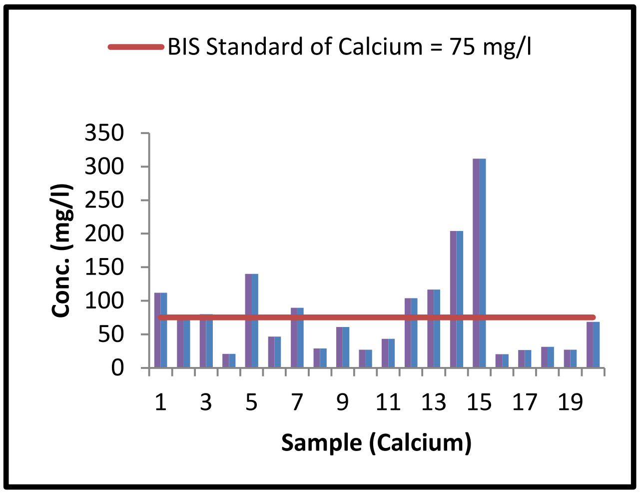

Fig 5.7: Concentration of Calcium in study area

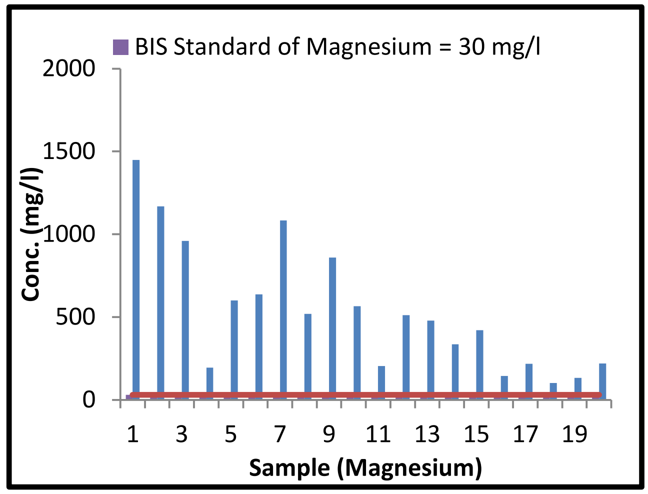

Fig 5.8: Concentration of Magnesium in study area

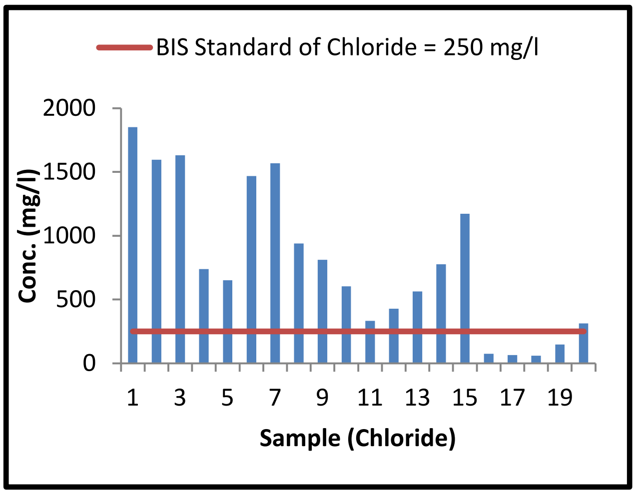

Fig 5.9: Concentration of Chloride in study area

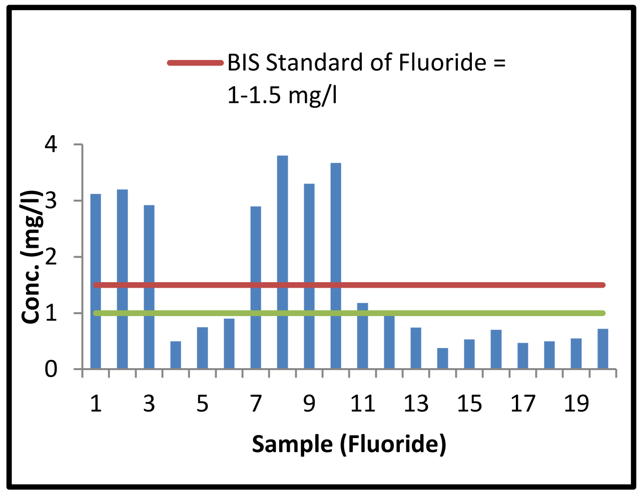

Fig 5.10: Concentration of Fluoride in study area

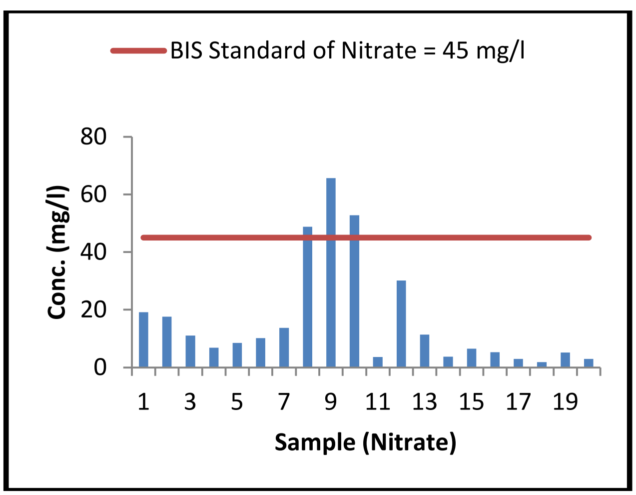

Fig 5.11: Concentration of Nitrate in study area

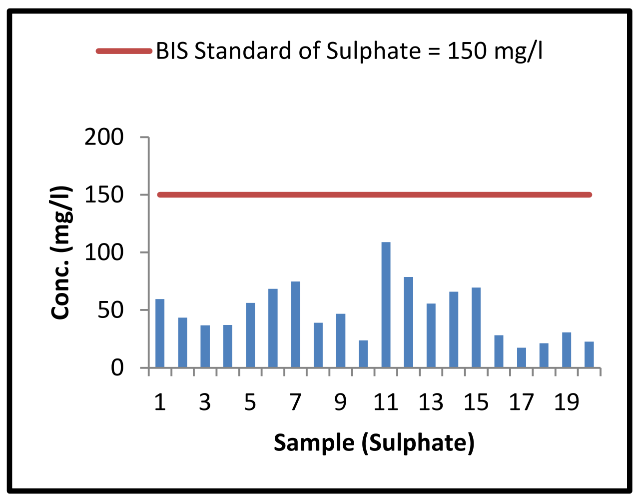

Fig 5.12: Concentration of Sulphate in study area

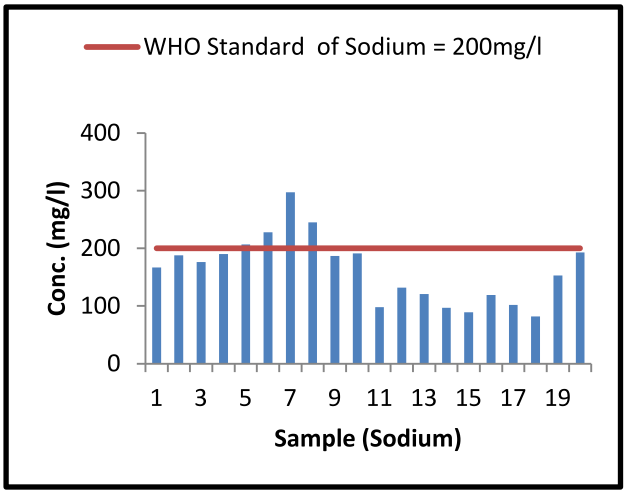

Fig 5.13: Concentration of Sodium in studyarea

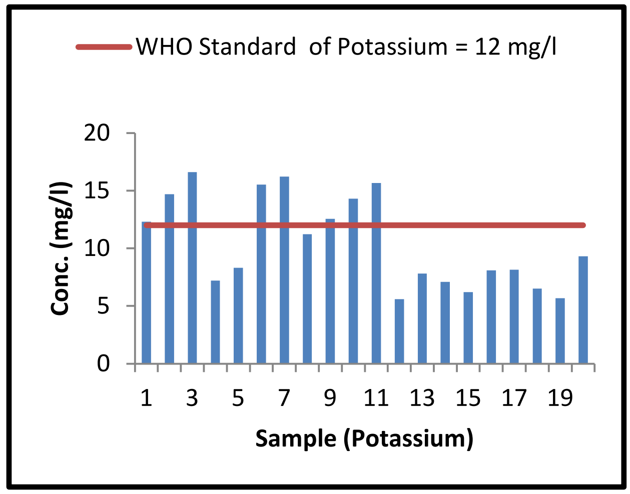

Fig 5.14: Concentration of Potassium in study area

5.2.9 CHLORIDE

Chloride produced in groundwater by both natural and anthropogenic activities e.g. surface runoff, domestic sewage, industrial effluent, animal feeds, landfill leachate and agricultural drainage etc. It can also be occurs by seawater intrusion in coastal regions (Department of National Health and Welfare 1978). It is a common toxin present in water which imparts salty taste to water and harmful for water supply pipe networks. Chloride does not assimilate by soil; it confirmed the independent motion of chloride in groundwater. It can cause burning and drying of leaves and their tissues when plants uses the excessive chloride water (Vasanthavigar et al. 2010).The safe limit given for chloride is 250 mg/l by BIS standards for drinking water. If the water is having more than 250 mg/l of chloride it can cause corrosion, impart bitter taste and affect the palatability of water (Hauser 2001). The chloride content in the month of Nov varied 60-1852, 71-1901 mg/l in Jan and in Mar 69-1889 mg/l. Chloride was present in study area in varying concentration and 48 sample out of 60 were contaminated; 80% of the samples having chloride beyond limit (>250 mg/l) (fig 5.9). No such harmful effects on human health have been reported of excessive chloride in water (Singh et al. 2013).

5.2.10 FLUORIDE

Fluoride in groundwater occurs due to fluoride bearing minerals, their availability, and solubility in water while they are leaching. Other factors also responsible for fluoride concentration in water are pH, geological elements; their type and residence time, temperature, porosity, depth of structures, carbonate and bicarbonate content in groundwater (Apambire et al. 1997). In this manner, there are some anthropogenic activities are also responsible for fluoride e.g. irrigation fertilizers and coal combustion process (Brindha and Elango 2011). Now days, excessive fluoride more than that of standards is the major problem in India with respect to toxicity and geo-environment. High amount of fluoride can cause skeletal Fluorosis to the human being and it is an critically important parameter in developing countries due to increase industrialization and agricultural practices. The fluoride range define by BIS is 1 to 1.5 mg/l. The observed concentration of fluoride from study area is 0.5-3.67, 0.45-3.71 and 0.42-3.96 in Nov, Jan and Mar respectively. The study reveals that many of the locations having high amount of fluoride and on the other hand at some locations fluoride deficiency occurs. As per the range of fluoride 7 samples are having fluoride greater than 1.5 mg/l and 11 samples are deficient in fluoride (fig 5.10). Only 2 samples lied in the range given by BIS.

5.2.11 NITRATE

Nitrogen content is a measure of organic pollution in groundwater. The possible sources of nitrate in water are application of agricultural fertilizers, septic tank practices, human and animal feces, degradation of dead animal bodies, domestic discharge and industrial pollution. The concentration of nitrate in groundwater occurred due to the leaching of nitrate with surface water percolation in groundwater. Nitrate in groundwater should not exceed 4-9 mg/l and nitrite content does not possess the value above 0.3 mg/l (USEPA 1987). The nitrate concentration in drinking water should not exceed 45 mg/l according to BIS specification. In the present study nitrate was found 1.89-65.69, 1.91-65.21 and 1.95-67.11 mg/l in Nov, Jan and Mar respectively. Only 9 samples are exceeding the limit (45 mg/l) out of 60 samples (fig 5.11). Therefore 15% of samples are contaminated in study area. Nitrate is present in higher concentration in groundwater causes infantile methemoglobinemia leads to death (USEPA 1977). Many of ailments may associated with high nitrate concentration e.g. diarrhea, respiratory diseases (Ward et al. 2005).

5.2.12 SULPHATE

Sulphate is a type of anion which occurs in all natural water bodies. It may present in water bodies due to industrial activities as well as natural source e.g. mineral dissociation (gypsum, epsomite and barite etc). it may present in groundwater in small quantity (Janardhana et al. 2013). High sulphate concentration may leads diseases like dehydration, gastrointestinal irritation and catharsis (Bertram and Balance 1996). Hardness due to calcium and magnesium causes due to leaching of sulphate minerals. BIS standard suggests the limit for sulphate is 150 mg/l for drinking purpose of water. The observed value of sulphate in study area is 17.40-78.60, 16.94-108.8 and 17.23-109 mg/l in Nov, Jan and Mar months. In study area, there was no sampling location having sulphate more than standard limit (fig 5.12).

5.2.13 SODIUM

Sodium salts are present in groundwater in soluble form and present in soluble form in water till it may extract by process of evaporation. It may present in the groundwater in the form of salts and high sodium concentration will be harmful for irrigation purposes. It is the important and significant parameter to determine the water class for irrigation practices. The allowable limit of sodium in groundwater is 200 mg/l given by WHO (2011). The value of sodium in groundwater has been observed as 82-297, 83-297 and 82-298 mg/l in Nov, Jan and Mar. The study reveals that only 12 samples are exceeding the limit of 200 mg/l out of 60 samples and values do not show much higher concentration of sodium in this area (fig 5.13). However the sodium consumption will not infect the human body in study area. The sodium content is not critically toxic in drinking water because kidneys discharged it with time. Sodium presence in high concentration causes vomiting, salts elimination from body, muscular twitching and rigidity, convolution and pulmonary disease.

5.2.14 POTASSIUM

Potassium is present in groundwater due to different silicate minerals of rocks (Karanth 2010). Potassium concentration in study area found in Nov, Jan and Mar are 5.9-16.67, 5.9-16.67 and 5.98-16.3 mg/l. The prescribed limit of potassium in drinking water is 12 mg/l by WHO (2011). In study area 40% of samples were beyond to the standard limit (fig 5.14).

5.3 CORRELATION AND REGRESSION ANALYSIS

Correlation matrix is a statistical method to measure the rate of relationship between two variables. The estimation of interrelationship between any two parameters is an important and significant tool for development of research methodologies (Patil and Patil 2009). Correlation between two parameters may interpret by correlation coefficient (r). It also develops regression equations between one dependent and one independent parameter with the help of correlation coefficient (r). Such kind of statistics may help to determine the dependent variable when the known value of independent variable. In water quality analysis, this is a helpful technique to determine the future concentration of one parameter if another one is known with the help of regression equations developed between two parameters as per their relationship. The correlation coefficient (r) may be calculated as:

$$r = \frac{N\sum(X_i Y_i) - (\sum X_i).(\sum Y_i)}{\sqrt{[N\sum X_i^2 - (\sum X_i)^2][N\sum Y_i^2 - (\sum Y_i)^2]}} \quad ...5.1$$

where, X_i and Y_i represents the values of two water quality parameters, N is the no of observations taken.

The correlation matrix of 14×14 and the degree of interrelationship between every two parameters in terms of coefficient of correlation of for every are tabulated in table 5.5. The higher positive values of correlation coefficient determine in between salinity and EC (0.938), TDS and salinity (0.996), TDS and EC (0.939), Hardness and salinity (0.888), Chloride and salinity (0.985), hardness and EC (0.811), Chloride and EC (0.916), magnesium and TDS (0.838), Hardness and TDS (0.864), chloride and TDS (0.984), hardness and magnesium (0.984), chloride and magnesium (0.874), fluoride and magnesium (0.733), chloride and hardness (0.891) and nitrate and fluoride (0.746). On the other hand negative values of correlation coefficient exposed between pH and alkalinity (-0.651) and sodium and alkalinity (-0.730). All associated parameters either proportional or inversely proportional to each other, are subjected to regression analysis. Regression equations are generated for different two parameters which are having significant negative or positive relationship. Computations of best fitted regression lines for every parameter are elaborated in table 5.6.

Correlation and regression analysis of study area reveals that, TDS and salinity are strongly interrelated with coefficient of correlation of 0.938. It proves that increased concentration of TDS in groundwater may lead higher values of salinity (fig 5.9). Electrical conductivity is a significant measure of salinity and water salinity may decide on the basis of EC in irrigation practices (Nosetto et al. 2013). EC and salinity are having r value 0.998 which shows high level of correlation between these two parameters and their dependency in study area (fig 5.10).

Salinity mainly occurs due to the presence of salts e.g. chloride, magnesium, sulphate and nitrate etc. The study shows a positive and higher correlation of salinity with chloride (r = 0.98) and magnesium and the patterns of variation in different areas are almost same (see fig 5.12, 5.13, 5.14). Electrical conductivity is the measure of current passing through the water and it shows proportional nature towards dissolved salts present in water. It may said as a direct function of total dissolved salts present in water and it is an important parameter to represent the TDS concentration in water (Harilal et al. 2004; Purandara et al. 2003). EC and TDS in present study show admirable relationship in groundwater with r value of 0.939. The trends of these two parameters at different locations are very close (fig 5.11).

Chloride, magnesium ions are present in various concentrations in study area and these are also adding their contribution in concentration of EC and TDS. The relationship between EC- Cl, EC- Mg, TDS- Cl and TDS- Mg is very significant as they are dependent to each other. Chloride present in study area is consequential parameter for existence of TDS with correlation coefficient of 0.984. Chloride and magnesium are also strongly interrelated parameters and it shows the permanent hardness of the groundwater in nature (Ramakrishnaiah et al. 2009).

Total Hardness of groundwater mainly occurs due to the concentration of magnesium and both having remarkable relationship (r= 0.98) as compare to hardness-Ca relationship. It manifested that magnesium is present in high concentration in water as compare to calcium. Fluoride also depends on magnesium ions in moderate fraction and having relationship with mg with r= 0.73. There are some negative relationships also prevailing in groundwater of Ghaziabad of pH-Alkalinity and Sodium- Alkalinity. This study of correlation and regression is basically release the affinity of parameters and contact to each other in groundwater. It is the productive analysis for future variations of parameters and promotes the genuine assessment of concentration of different parameters of groundwater.

Table 5.5: Correlation matrix for groundwater quality parameters

	pH	Salinity	EC	TDS	Alkalinity	Calcium	Magnesium	Hardness
pH	1							
Salinity	0.511123	1						
EC	0.430072	**0.938573**	1					
TDS	0.491394	**0.996562**	**0.939926**	1				
Bi-Carbonate	**-0.65183**	-0.52322	-0.38416	-0.50614	1			
Calcium	-0.17175	0.36011	0.478963	0.359989	0.303833	1		
Magnesium	0.494041	0.863012	0.760163	**0.838537**	-0.56053	0.165811	1	
Hardness	0.440861	**0.888308**	**0.811409**	**0.864923**	-0.48068	0.33733	**0.984288**	1
Chloride	0.508253	**0.985372**	**0.916552**	**0.984589**	-0.57009	0.316687	**0.874169**	**0.891184**
Fluoride	0.36918	0.510214	0.400195	0.489246	-0.6459	-0.20519	**0.733824**	0.66377
Nitrate	0.226926	0.11652	0.061048	0.079571	-0.42921	-0.18011	0.366878	0.317973
Sulphate	0.035241	0.346449	0.383493	0.34514	0.163702	0.435222	0.227532	0.295127
Sodium	0.539062	0.545142	0.417484	0.533978	**-0.73025**	-0.26736	0.515333	0.444066
Potassium	0.422132	0.56261	0.451207	0.549081	-0.53925	-0.25952	0.619661	0.545062

Hardness	*Chloride*	*Fluoride*	*Nitrate*	*Sulphate*	*Sodium*	*Potassium*
1						
0.891184	1					
0.66377	0.581424	1				
0.317973	0.167643	0.746088	1			
0.295127	0.316801	-0.04142	-0.07069	1		
0.444066	0.52367	0.581226	0.38526	-0.01466	1	
0.545062	0.617938	0.697614	0.287543	0.247911	0.55038	1

Table 5.6: Determination of regression line for associated samples

Parameters	X-axis	Y-axis	$\overline{X}$ (mean)	$\overline{Y}$ (mean)	$\delta\overline{X}$ (Stddev)	$\delta\overline{Y}$ (Stddev)	r	m = $r\times\frac{\delta\overline{X}}{\delta\overline{Y}}$	Y = mX + c
TDS & Salinity	TDS	Salinity	1332.15	1495.15	905.73	1004.25	0.938	1.040	Y = 1.04X + 109.71
Salinity & EC	Salinity	EC	1495.15	2912.5	1004.25	1975.95	0.998	1.963	Y = 1.963X – 22.185
TDS & EC	TDS	EC	1332.15	2912.5	905.73	1975.95	0.939	2.048	Y = 2.048X + 183.75
Hardness &Salinity	Hardness	Salinity	621.6	1495.15	403.53	1004.25	0.888	2.209	Y = 2.209X + 123.21
Chloride &Salinity	Chloride	Salinity	789.8	1495.15	579.42	1004.25	0.985	1.707	Y = 1.707X + 146.81
Hardness &EC	Hardness	EC	621.6	2912.5	403.53	1975.95	0.811	3.971	Y = 3.971X + 446
Chloride &EC	Chloride	EC	789.8	2912.5	579.42	1975.95	0.916	3.123	Y = 3.123X + 447.95
Magnesium &TDS	Magnesium	TDS	540.06	1332.15	385.21	905.73	0.838	1.96	Y = 1.96X + 273.6
Hardness &TDS	Hardness	TDS	621.6	1332.15	403.53	905.73	0.864	1.940	Y = 1.94X + 127.26
Chloride &TDS	Chloride	TDS	789.8	1332.15	579.42	905.73	0.984	1.53	Y = 1.53X + 124.83
Hardness & Magnesium	Hardness	Magnesium	621.6	540.06	403.53	385.21	0.984	2.51	Y = 2.51X – 1018.71
Chloride & Magnesium	Chloride	Magnesium	789.8	540.06	579.42	385.21	0.874	0.581	Y = 0.581X + 81.59
Fluoride & Magnesium	Fluoride	Magnesium	1.60	540.06	1.270	385.21	0.733	222.32	Y = 222.32X + 184.288
Chloride &Hardness	Chloride	Hardness	789.8	621.6	579.42	403.53	0.891	0.620	Y = 0.62X + 131.82
Nitrate &Fluoride	Nitrate	Fluoride	16.38	1.60	18.49	1.270	0.746	0.051	Y = 0.051X + 0.764
pH &Alkalinity	pH	Alkalinity	7.455	231.70	0.42	212.84	-0.651	-328.6	Y = 2681.4 - 328.6X
Sodium &Alkalinity	Sodium	Alkalinity	163.1	231.70	57.92	212.84	-0.730	-2.671	Y = 667.34 – 2.671X

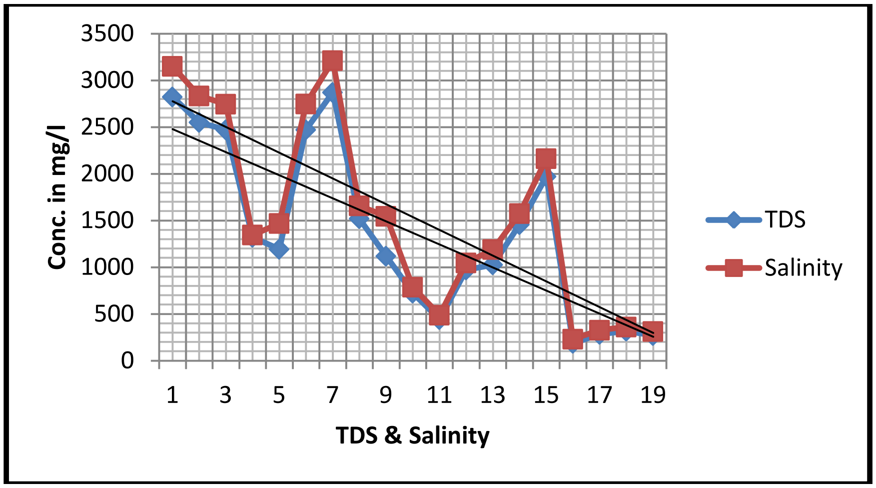

Fig 5.15Showing similar variations between TDS and Salinity

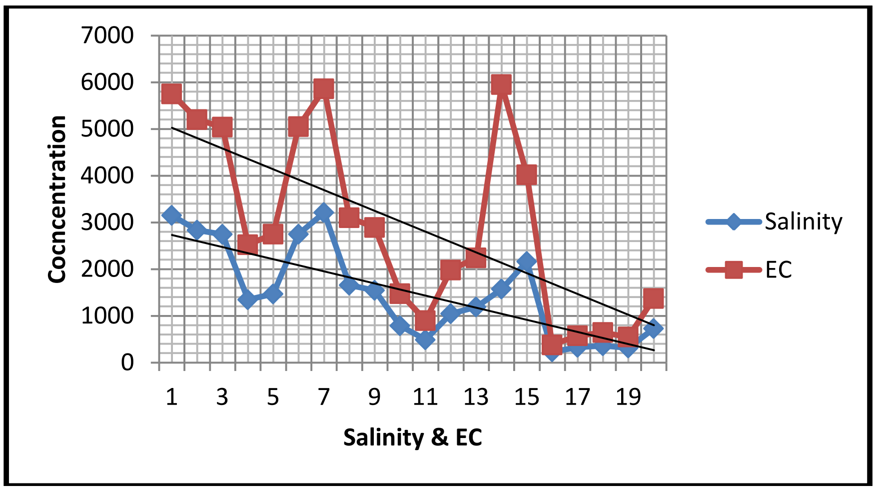

Fig 5.16 Showing similar variations between EC and Salinity

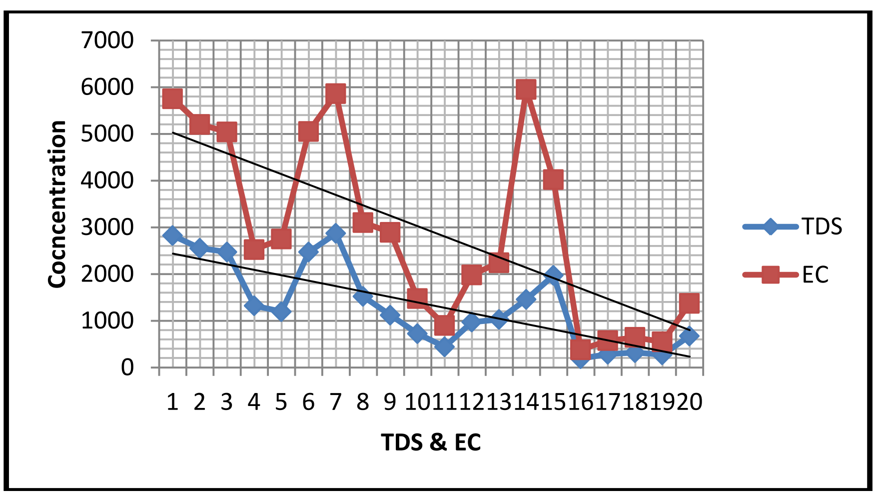

Fig 5.17 Showing similar variations between TDS and EC

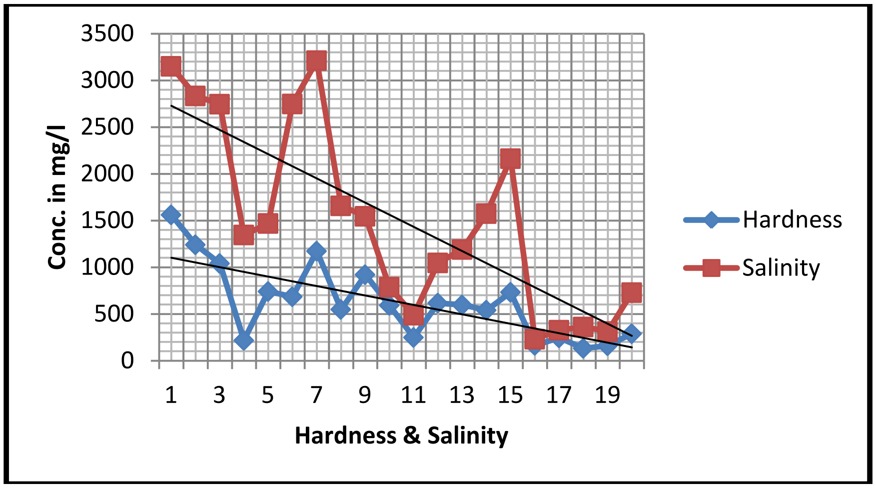

Fig 5.18 Showing similar variations between Hardness and Salinity

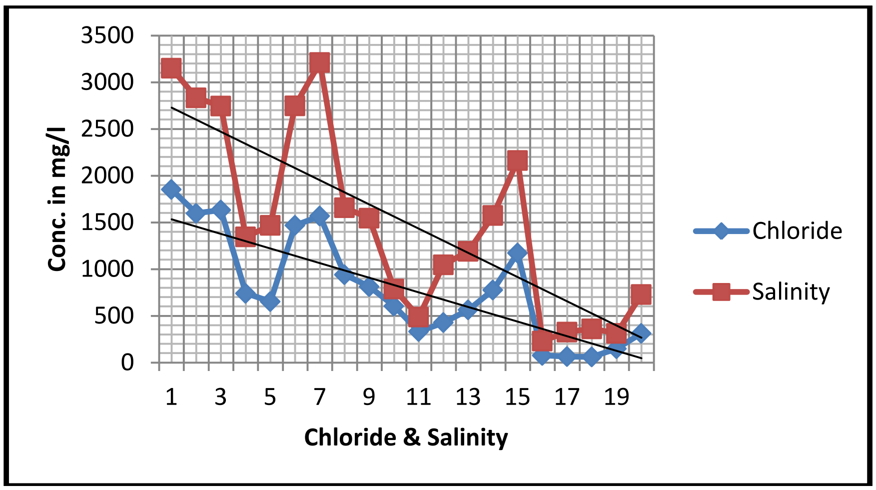

Fig 5.19 Showing similar variations between Chloride and Salinity

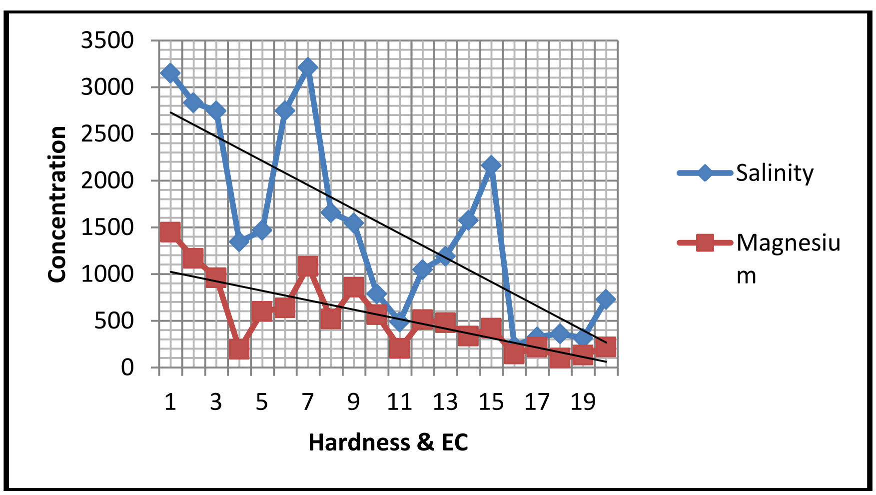

Fig 5.20 Showing similar variations between Hardness and EC

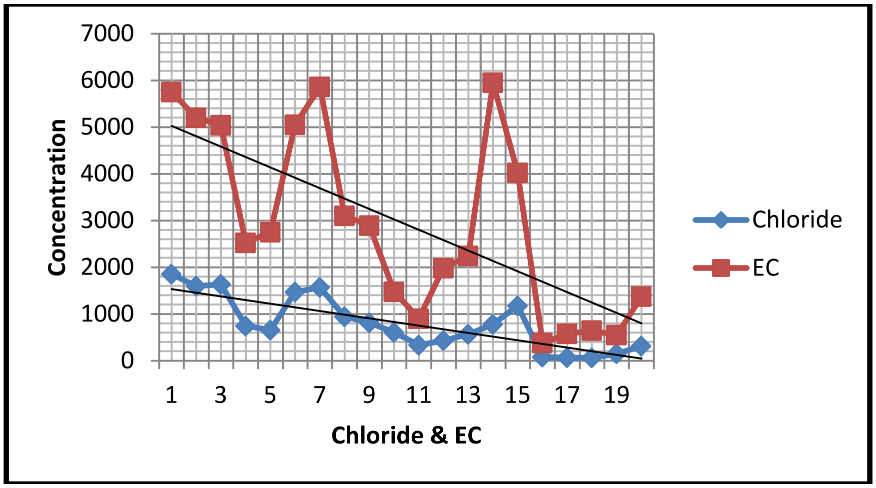

Fig 5.21 Showing similar variations between Chloride and EC

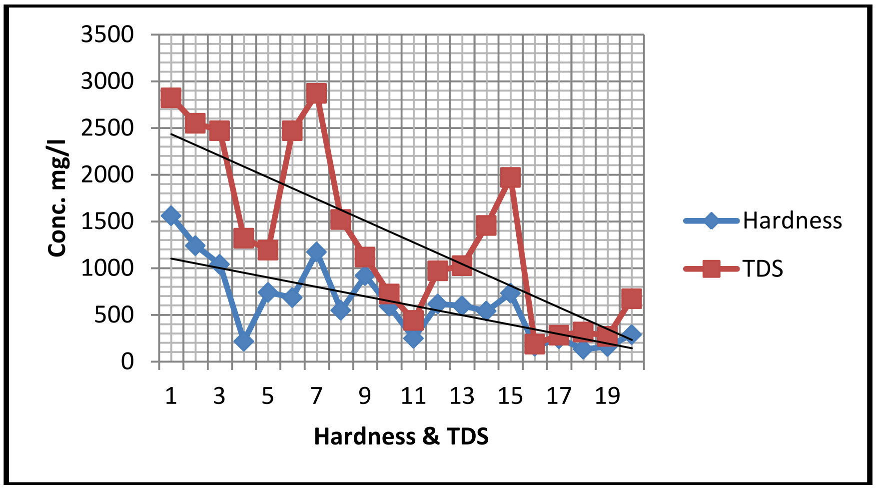

Fig 5.22 Showing similar variations between TDS and Hardness

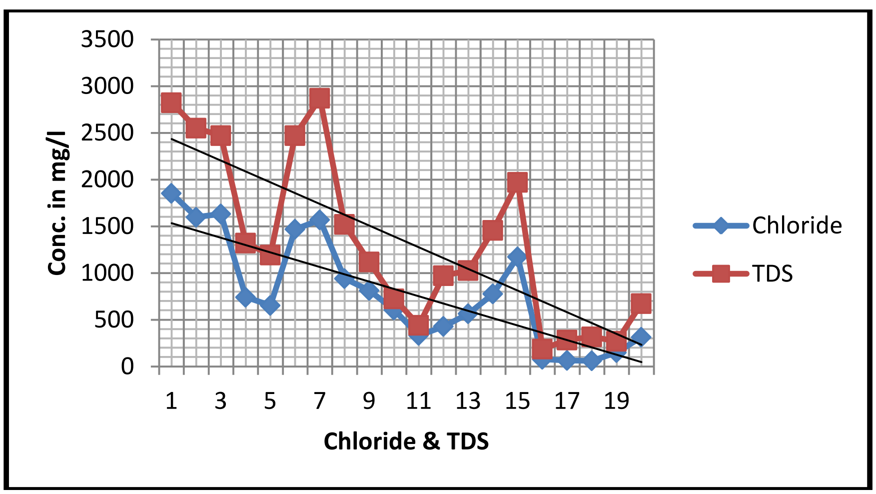

Fig 5.23 Showing similar variations between TDS and Chloride

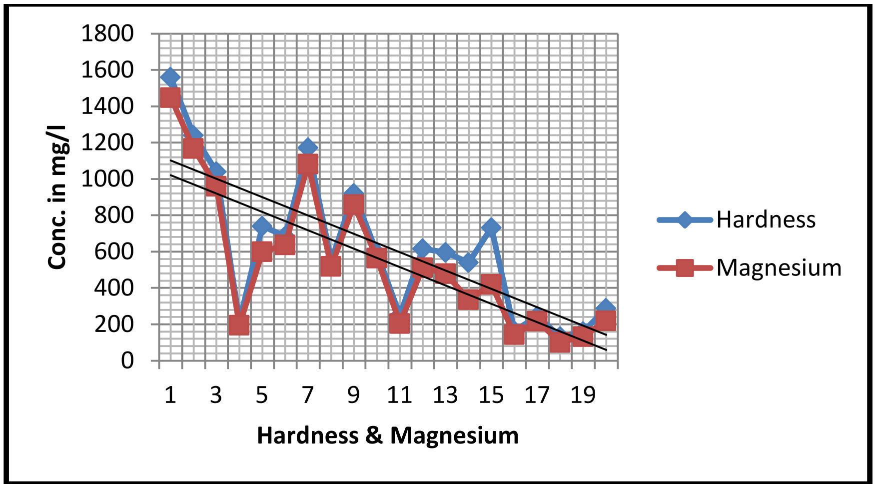

Fig 5.24 Showing similar variations between Hardness and Magnesium

5.4 TEMPORAL ANALYSIS OF GROUNDWATER

Many studies reveal that in last two decades the groundwater quality of Ghaziabad is being deteriorate and groundwater posses the unsuitability for drinking and irrigation purposes (Chabukdhara et al 2013; Kumari et al. 2013; Singh et al. 2013; Sajjad et al. 2014; CGWB 2013; Khan et al. 2010). The groundwater salinity is also overshooting the standard limit which may harm the agricultural land and crops as the western Uttar Pradesh is a reliable zone for irrigation. As the evaporation of water takes place and lower down the water table salts may start to go deeper with water table and deep groundwater may also contaminated. After rainfall, when water infiltrates to shallow groundwater bodies, the fresh salt concentration may take place which is coming from industrial effluents with runoff. In this manner salts increases in the groundwater in both the shallow and deep waters and salinity would increase year by year. Some important parameters and their concentration in increasing manner at every five years of interval are discussed in table 5.7.

Industrial practice in Ghaziabad is mainly responsible for heavy withdrawal of groundwater and depleting the water table and it is the highly weighted reason for groundwater contamination. The groundwater was available before 15 years at depth of 35 mbgl which is now extended from 150 to 200 mg/l (CGWB 2009). There are no such artificial recharge arrangements encouraged in this area to mitigate the groundwater pollution in past years. Hence the parameters which are most accountable in case of groundwater pollution are showing continuous addition to their concentration. In the present study of temporal variation the concentration of important parameters has been compared from 2000 to 2015. TDS, EC and Chloride shows increasing trends in these 15 years and surpass the standard values for drinking water given by BIS (refer fig 5.19 & fig 5.20). Parameters concentrations were continuously increasing in past years and trends are significantly confirming the findings of present study. If this scenario will continue and relevant hazards will also occur in future then such growing hazardous situations promote the major calamity to the groundwater and these will be the devastating situations in the history of groundwater resource.

Table 5.7: Temporal variation of different parameter (Source: CGWB Report, 2010)

Parameter Year	Concentration of various parameters (in mg/l except EC & pH)			
	March, 2000	June, 2005	March, 2010	Jan, 2015
pH	7.9	8.2	8.1	8.1
EC	1120	2650	4243	2319
TDS	750	1776	2843	2870
Bi-Carbonates	110	73	415	493
Chloride	318	873	1198	1901
Total Hardness	365	800	1070	1594
Calcium	26	64	140	313
Magnesium	73	156	173	1476
Nitrate	nd	25	16	65.21
Sulphate	19	35	51	108.8
Sodium	88	248	461	297
Potassium	5.6	8	9.9	16.67
Fluoride	nd	0.23	0.38	3.71
Depth of Water Tubewells (mbgl)	25-35	30-50	120-150	150-200

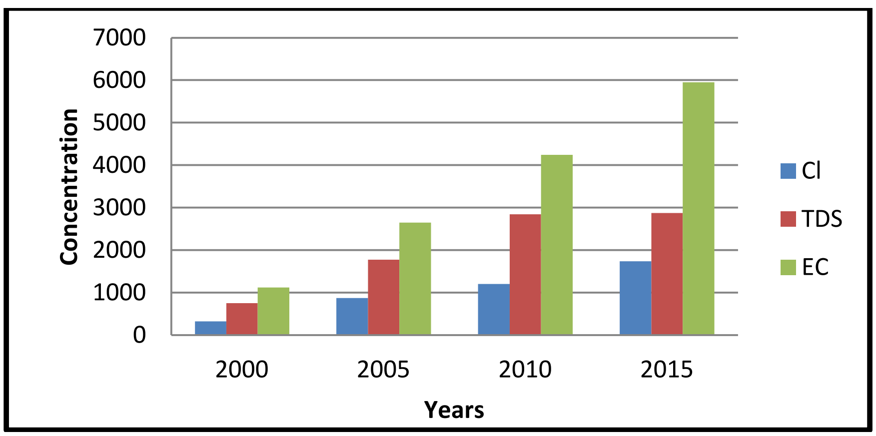

Fig 5.25: Increasing trend in last 15 years of EC, TDS &Cl

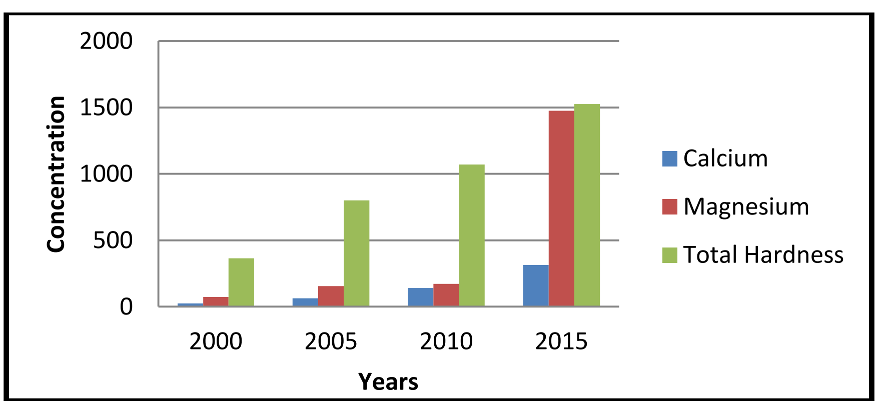

Fig 5.26: Increasing trend in last 15 years of TH, Mg &Ca

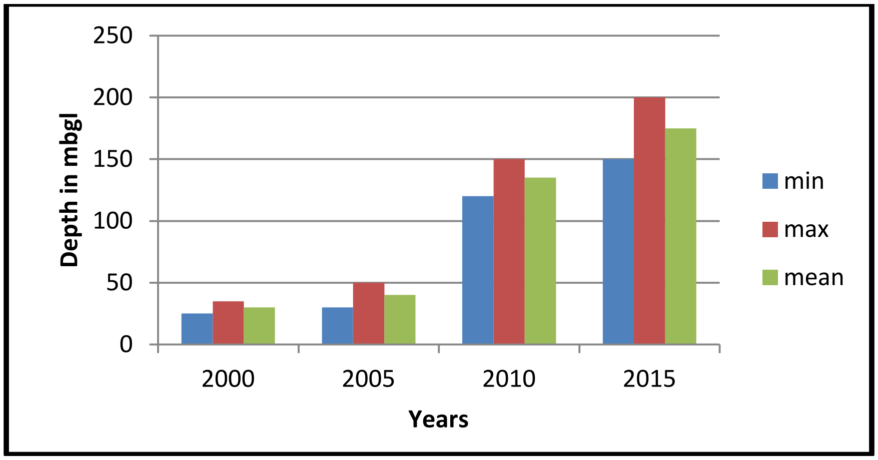

Fig 5.27: Increasing trend of depth of State Tubewells

5.5 WATER QUALITY INDEX OF GROUNDWATER

Water Quality Index is an important and significant tool for communicating the overall water quality in a form of single number (Pius et al. 2011, Asadi et al. 2007). The quality index of water is determined to check that the water is either suitable for human beings or not. To determine WQI of the study area all analysedphysio-chemical parameters has been taken. In this study 14 parameters considered and WQI calculated on the basis of their relative importance in groundwater. The WQI has been calculated by Weighted Arithmetic Index method(Brown et al. 1972) by following equation:

$$\text{WQI} = \sum \mathbf{S_i} \quad \text{... 5.2}$$

$$\mathbf{S_i} = \sum \mathbf{W_i Q_i} \quad \text{... 5.3}$$

*Q_i is the quality rating which may calculate as:

$$\mathbf{Q_i} = \frac{[\mathbf{V_i} - \mathbf{V_{io}}]}{[\mathbf{S_n} - \mathbf{V_{io}}]} \times 100 \text{...5.4}$$

S_i= Sun-index, Q_i= Parameter quality rating of nth parameter of water, V_n= Observed value of nth parameter at sampling station, S_n= Standard value of parameter within permissible limit, V_{io}= ideally predicted value of nth parameter (i.e., for DO and pH it is 14.6 mg/l and 7 respectively. For all other parameters it should be zero.)

*$W_i$is the unit weight of each parameter, which may calculate as:

$$\mathrm{W_i} = \frac{\mathbf{w_i}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{w_i}} \text{...5.5}$$

Where, W_i is the unit weight of parameter, n is the total number of parameters has been taken. $w_i$is the weight of parameter, which assigned on the basis of their relative importance in drinking water quality. Weight of 4 is given to pH because pH has a great importance in drinking water. Relative weight of each parameter has been calculated and given in Table 5.8.

Water Quality Index quantifies a single number for water quality of whole area which deviates from good, normal and ideal concentrations due to many parameters and summarizes water quality condition throughout the range as compare to single parameter (UNEP 2007). The water quality index of study area has been calculated for whole area which elaborated in table 5.9 and the value of water quality index of Ghaziabad is 209.553 which indicate the very poor groundwater quality of study area (lies between 20-300, refer table 5.10).

Table 5.8: Relative Weight of each Parameter

Sr. No.	Parameters	Standards	Weight	Relative Weight
1	pH	6.5-8.5	4	0.0952
2	Salinity	1400 µs/cm	3	0.0714
3	EC	1500 mg/l	3	0.0714
4	TDS	500 mg/l	4	0.0952
5	Total Alkalinity	200 mg/l	2	0.0476
6	Calcium	75 mg/l	2	0.0476
7	Magnesium	30 mg/l	5	0.1190
8	Hardness	200 mg/l	4	0.0952
9	Chloride	250 mg/l	4	0.0952
10	Fluoride	1-1.5 mg/l	5	0.1190
11	Nitrate	45 mg/l	2	0.0476
12	Sulphate	150 mg/l	1	0.0238
13	Sodium	200 mg/l	1	0.0238
14	Potassium	12 mg/l	2	0.0476

According to WQI values groundwater considered as impact fully contaminated due to various industries present in study area as well as urbanization scenario. Water quality classification is shown in table 5.10 as per the estimated WQI values. The WQI of groundwater is calculated for mean values of 60 samples as well as WQI also determined every set of values for every individual location. The percentage classification of contamination based upon WQI is figured out in table 5.10.

The WQI of groundwater is calculated for mean values of 60 samples as well as WQI also determined every set of values for each individual location. Any sample does not have <50 as excellent water type. In the study, sample location 19 of Vasundhara sector 4 is having the value of WQI between 50- 100 and is a good water quality area.Sample locations 16, 11 and 18 possess WQI between 100- 200 which comes under the poor water quality class. Highly contaminated samples which are beyond 300 of WQI are 2 and 3 sample locations which are present in Sahibabad industrial area and the water is unsuitable in the category. Water samples of location 1, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 17 and 18 lie between the WQI of 100-200 (refer fig 5.22) and the water type in this area is very poor and may unhealthy for residents of this area.

The percentage classification of contamination based upon WQI is figured out in table 5.10. In this study the fact reveals that 70% of groundwater is suffering from high level of contamination and poses very poor quality of groundwater. Among these locations, 10% of the locations are having water unfit for drinking and the purity of water has been totally vanished from these area. 5% of locations show good water quality index and the water is suitable for drinking and may use for other purposes. Rest of the sample location are found to consist poor groundwater quality and such water may also used if there is no alternative present of water after simple boiling or after some initial treatment.

Table 5.9: Calculation of water quality rating

Sr. No.	Parameters	Standards	Weight	Relative Weight	Observed Values	Q_i	S_i =Qi×Wi
1	pH	6.5-8.5	4	0.0952	7.455	30.3	2.856
2	Salinity	1400 µs/cm	3	0.0714	1495.15	99.7	7.11
3	EC	1500 mg/l	3	0.0714	2818.6	201	14.35
4	TDS	500 mg/l	4	0.0952	1332.15	266	25.32
5	Total Alkalinity	200 mg/l	2	0.0476	231.7	116	5.52
6	Calcium	75 mg/l	2	0.0476	81.53	109	5.188
7	Magnesium	30 mg/l	2	0.472	540.06	1802	85.05
8	Hardness	200 mg/l	2	0.0476	621.6	311	14.80
9	Chloride	250 mg/l	3	0.0714	789.8	316	25.56
10	Fluoride	1-1.5 mg/l	5	0.119	1.59	106	12.61
11	Nitrate	45 mg/l	5	0.1190	16.38	36.4	4.33
12	Sulphate	150 mg/l	1	0.0238	49.19	32.8	0.78
13	Sodium	200 mg/l	1	0.0238	163.1	81.6	1.94
14	Potassium	12 mg/l	2	0.0476	10.45	87.1	4.145
Overall WQI = ΣS_i					= 209.553		

Table 5.10: Water quality of Ghaziabad based on WQI Values

Water quality index range	Quality of water	Percentage of samples
<50	Excellent	00
50-100	Good	5%
100-200	Poor	15%
200-300	Very Poor	70%
>300	Water, unfit for drinking	10%

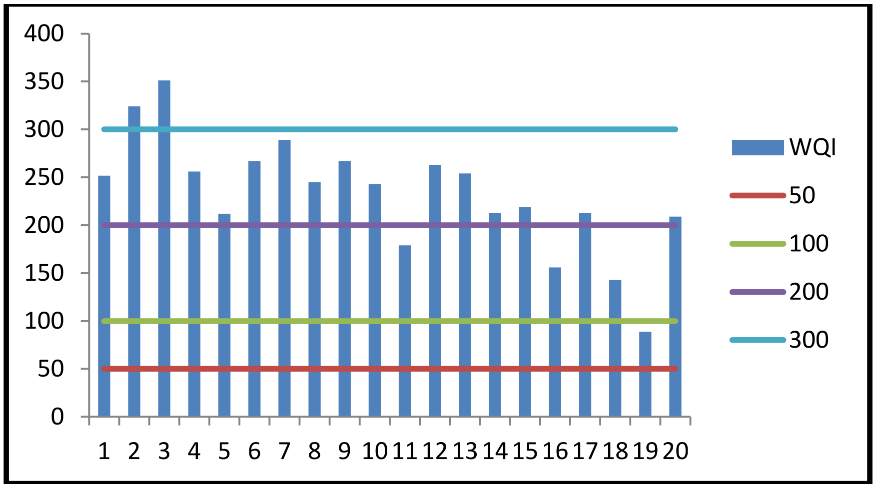

Fig 5.28: Water Quality Index for each sample station

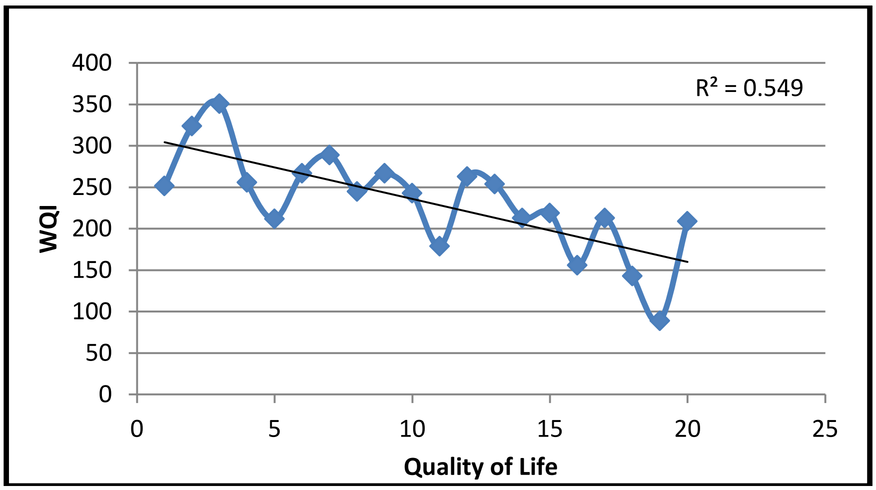

Fig 5.28: Quality of Life variation with WQI

In this study an attempt madeto derive the relation between WQI to Quality of Life. The karlPreson's two tailed correlation has been used to determine the variation in quality of life with respect to WQI. The correlation between life quality score (by an inventory of simple questionnaire) and water quality index is calculated as -0.89 and it is a significant negative correlation as well as it shows that WQI is inversely proportional to the Quality of Life. The above correlation derived not only for human life but for whole biotic aquatic life. This shows the moderate relationship with R^2 vale of 0.57; thus it has been found that 57% of QOL variation may explained by WQI of the groundwater. In fig 5.23, it has been shown as the WQI of groundwater increases, the quality of life found to be decreases. Quality of life may improve if the water quality index lowers down to 100 or below 100.

5.6 COLLIN'S RATIO FOR THE DRINKING WATER SUITABILITY

Collin's ratio is calculated to decide the contamination level of groundwater. It is an important tool to check the water for drinking purpose. It is the ratio of chloride ions to summation of carbonate and bi-carbonate ions in meq/l (refer equation 5.6)(Varade et al. 2014). In this manner, the value of collin's ratio comes out less than or equalto 1, the water is suitable for drinking; while the value is between 1 to 3, water may show contamination at some extent and water having value more than 3 being injurious and unhealthy for drinking purpose (Tiwari 1988).

$$\textbf{Collin's Ratio} = \frac{\mathbf{Cl^-}}{\mathbf{HCO_3^- + CO_3^-}}\textbf{in meq/l}\ldots 5.6$$

The observed Collin's Ratio values for every sampling station are shown in table 5.11.

Collin's ratio of study area may also coincide with water quality index values. 1-10 sample locations are having most deteriorated water and it is unsuitable for human being and very hazardous for drinking purpose (refer table 5.11). Sample locations comparably far from industrial area of Sahibabad shows the acceptable water quality as well as some locations are having groundwater quality which may use if there is no substitute of drinking water (range 1-3). Collin's ratio is a significant approach of to select the groundwater for drinking purpose without possesses any harm. The groundwater quality in terms of salinity, chloride and alkalinity can be assessed by this technique in a very simple way.

Table 5.11: Water class as per Collin's Ratio calculation

Sample	Collin's Ratio	Range	Water Class
1	25.30	>3	Injurious to health
2	65.40	>3	Injurious to health
3	55.73	>3	Injurious to health
4	24.91	>3	Injurious to health
5	12.73	>3	Injurious to health
6	42.97	>3	Injurious to health
7	24.71	>3	Injurious to health
8	27.51	>3	Injurious to health
9	17.51	>3	Injurious to health
10	13.75	>3	Injurious to health
11	0.70	<1	Suitable for drinking
12	0.88	<1	Suitable for drinking
13	0.99	<1	Suitable for drinking
14	1.99	1-3	Contaminated
15	2.85	1-3	Contaminated
16	0.41	<1	Suitable for drinking
17	0.14	<1	Suitable for drinking
18	0.13	<1	Suitable for drinking
19	0.73	<1	Suitable for drinking
20	0.62	<1	Suitable for drinking

5.7 ASSESSMENT OF GROUNDWATER FOR IRRIGATION

The assessment of irrigation water quality is to identify the measure of unhealthy effects on soil properties from the concentration of salts present in water and crop yield (IS: 11624). To analyse the water quality for irrigation certain standards for different parameters are generated. Depending upon several factors suitability criteria has been formed for irrigation water.

5.7.1 SUITABILITY CRITERIA

The suitability criteria for irrigation water is dependable on variety of factors such as; quality of water, type of soil, plant features, various methods for irrigation, drain system, rainfall and climatic conditions and other local scenario. The combined effects of these features on irrigation water can be described by following relationship:

$$SI = \int \boldsymbol{QSPCD} \quad \ldots 5.7$$

Where; Q = irrigation water quality, S = Type of soil and other characteristics of soil, P = Salt toleration limit of grown crop, C = climate condition, D = drainage system

5.7.2 CRITERIA OF WATER QUALITY FOR IRRIGATION

Study of irrigation water quality is an important tool of water and soil management practices. Assessments of quality of irrigation water and management practices both are critically important to effective crop production. The water which applied in irrigation is responsible for crop yield as well as physical condition of soil but all other parameters should be favorable. The parameters are divided into three categories e.g. physical, chemical and biological. In this study all chemical parameters are discussed.   The chemical characteristics of water which may used for irrigation are EC, TDS, SAR, RSC, Chloride and hardness etc.

5.7.2.1 SALINITY

The main problem occurs with groundwater when it s used to irrigation is the salinity of water. Salinity is the measure of total dissolved solids present in water but it is not able to indicate the type of salts present in water. Salinity may harm to the soil and reduces the availability of water to the crop in field. Crop yield is inversely proportional to the salinity of groundwater. It may express in terms of electrical conductivity of water. Hazardous effects of salinity to the crop are means of dissolved solids is expressed in four major classes. In the present study of Ghaziabad, average groundwater value lies in the range of 'MEDIUM' salinity hazards on the basis of EC (refer fig 5.12) (Velstra et al. 2011). The salinity hazards varied at different sample locations as six locations show low salinity hazard (EC< 1500), five water sample location are from the category of medium salinity hazards (EC = 1500-3000) and rest 9 sample locations are having high level of salinity hazards for soil (EC = 3000-6000).

Table 5.12: Rating of water quality for irrigation as per salinity hazards

Sr. No.	EC (µs/cm)	Salinity Hazards
1	Below 1500	Low
2	1500-3000	Medium
3	3000-6000	High
4	>6000	Very high
Observed values for Groundwater	2912.5	Medium

5.7.2.2 SODIUM ADSORPTION RATIO (SAR)

This is the parameter which determines the sodium hazards in groundwater. It is the measure of sodium concentration in water. SAR also called sodicity of groundwater which is estimated in term of comparative concentration of sodium relevant to the summation of calcium and magnesium. SAR analysed the ability for infiltration difficulties due to imbalance of soil in irrigation water. Mathematically it may calculate as follows (equation 5.8):

$$\mathbf{SAR} = \frac{\mathbf{Na\ (meq/l)}}{\sqrt{\frac{\mathbf{Ca+Mg\ (meq/l)}}{\mathbf{2}}}} \quad ...5.8$$

The SAR value in this study is calculated as 1.43 and it falls in a category of low sodium hazards due to groundwater to the soil (refer table 5.12).All groundwater samples contain the SAR below 10 and show the suitability of groundwater for irrigation purposes. Groundwater has low concentration of sodium and other major nutrients as like surface water bodies and there are many types of ions present in groundwater generally. This value depicts the normal to excellent water quality for irrigation purpose due to low sodium amount present in water.

Table 5.13: Rating of water quality for irrigation as per sodium adsorption ratio

Sr. No.	SAR value	Sodium hazard
1	<10	Low
2	10-18	Medium
3	18-26	High
4	>26	Very high
Observed values for Groundwater	1.43	Low

5.7.2.3. RESIDUAL SODIUM CARBONATE

The RSC value in irrigation water is a measure of alkali hazards which possess due to high concentration of carbonate and bi-carbonate. Carbonate and bi-carbonate ions get precipitate with combination in calcium and magnesium and forms calcium carbonate and magnesium carbonate (Gupta 1986). This phenomenon takes place when soil is in dry state. The RSC of irrigation water can be expresses as the formula:

$$\text{RSC index} = [CO_3 + HCO_3] - [Ca^{2+} + Mg^{2+}](\text{in meq/l}) \quad \text{...5.9}$$

Table 5.14: Rating of water quality for irrigation as per RSC

Sr No	RSC Index	Alkali hazards
1	<1.5	Low
2	1.5-3	Medium
3	3-6	High
4	>6	Very high
Observed values for Groundwater	-11.24	-

In the present study RSC index has been evaluated and it comes in the form of negative number (refer table 5.12). A negative value RSC depicts the sodium formation in soil does not occur till sufficient calcium and magnesium which are in excessive concentration started to get precipitate in the form of carbonates.

5.7.2.4 CHLORIDE

Chloride content in groundwater occurs due to the concentration of TDS and EC and other soluble salts. Chloride does not has significant negative impact on soil but it may important for other regional factors which are responsible to add higher concentrations of chloride to groundwater e.g. anthropogenic activities as well as impact of settlement of soil towards (Islam &Shamsad 2009; Islam et al 1999). The chloride hazards may identify as per the concentration (refer table 5.13).As per this analysis fourteen samples related to high level of contamination, three samples lie in the range of moderate pollution and other 3 samples represents their location as good quality of water as low chloride hazards. The chloride concentration defines the water class of high contamination. This is not harmful for physical properties of soil as well as has not been absorbed by soil. Due the free movement of chloride it does not possess any adverse impact on soil.

Table 5.15: Rating of water quality for irrigation as per chloride concentration

Sr No	Chloride concentration	Water Class
1	<140	Low
2	140-350	Moderate
3	>350	High
Observed values for Groundwater	789.9	High

According to USSL classification of groundwater (refer fig 5.23), the water type lies in the category of C_4-S_1 which reveals the high electrical conductivity but low SAR or sodium hazards. This is an important criterion of irrigation standards, if the SAR value will be minimum of any type of water, water falls under the category of Excellent Water for irrigation purpose (Richards 1954). In the present study all samples are having the SAR value below 10 which depicts low sodium hazards to crop due to water.

Irrigation water quality assessment has been executed in this study with the help of different standards given in IS: 11624. All quality parameters have been analysed separately because all chemical characteristics are independent to each other anf having different water quality classification (IS: 11624). For example, in present study EC having higher values but SAR is not and even RSC index was calculated as negative value. These characteristics mat interact to each other and indicate adverse effects on soil which can cause reduction in crop yield and soil fertility. In the present study, groundwater quality of Ghaziabad is suitable for irrigation if there is no substitute available. Some parameters are showing negative effects on soil and some are showing positive. According to the water chemistry there is a chance and probability to use this groundwater in irrigation purposes. These effects may vary from soil to soil as well as for different type of crops also.

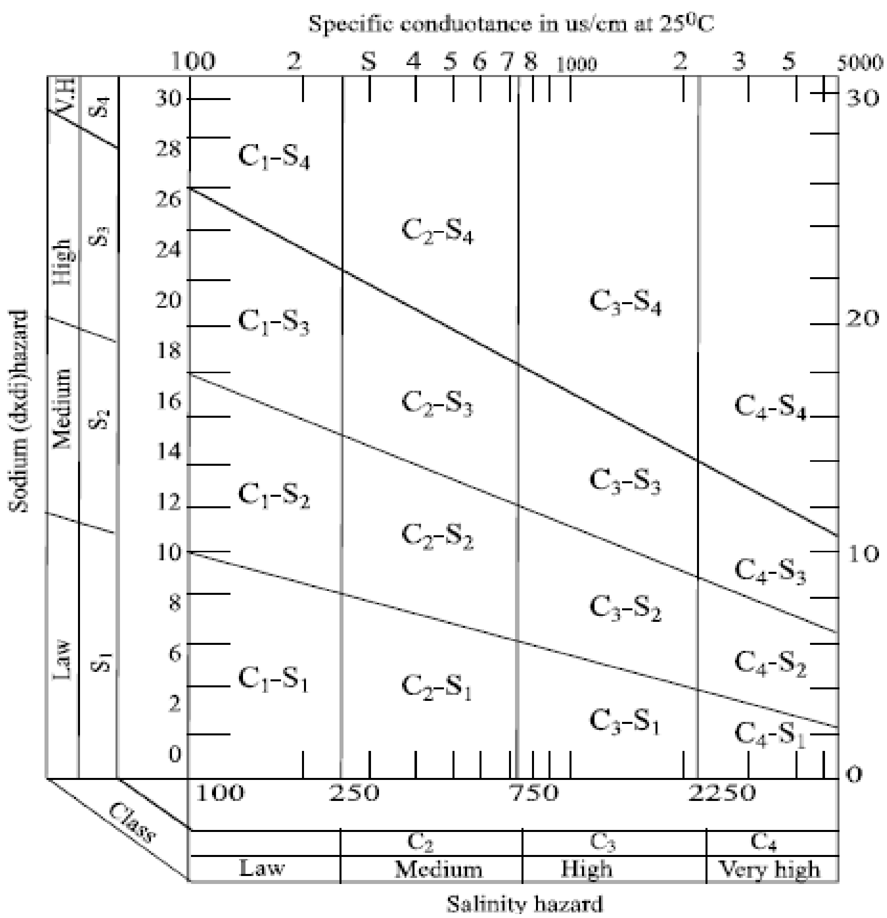

Fig 5.29: Groundwater classification according to USSL

CHAPTER-6
APPLICATION OF AQUA SOFTWARE

CHAPTER 6
APPLICATION OF AQUA SOFTWARE TO GROUNDWATER DATA

6.1 AQUA SOFTWARE

Aqua was initially designed software for assessing the water chemistry. This is an important tool to determine the cations and anions in any type of water. It develops different type of graphs, describe further in next segment, which may describe the water chemistry between different parameters. Aqua is the powerful and easy to learn tool for the chemical analysis of water as per observed chemical parameter concentrations. The graph formation in aqua is having following steps:

6.1.1. AQUA DATA SHEET

Aqua software starts with data sheet to the first. In this data sheet primarily change the unit of the concentration of studied parameter. There are two main responses to the data sheet of any user are analyte and samples. Analyte is the water quality parameter whether organic or inorganic, which has been taken to determinethe water chemistry and samples are the no of observations of parameters. There are two main functions for these two responses; add analyte& add samples.

6.1.2 INPUT OBSERVED DATA TO DATA SHEET

After all necessary settings in datasheet, enter the observed data in sheets in horizontal form or the data sheet may change to transpose view. Analysis will take place after feeding all the required data to recognize the water quality.

6.1.3 GRAPH CONSTRUCTION

After feeding all observed values of each analyte the software is ready to draw the graphs by data analysis automatically.

6.2 GRAPHICAL REPRESENTATION AND GROUNDWATER CHEMISTRY

In the present study following graphs has been constructed from the application of aqua software to observed data:
In this hydrochemical study, piper diagram for Ghaziabad groundwater area has been plotted to examine the groundwater chemical quality and to check the drinking water quality of Ghaziabad. It is an powerful tool to analyse the water chemistry (Kumar 2013).Water shows the tendency of permanent hardness because more of the samples are present at the top of the diamond. It depicts the dominance of Ca+Mg and Cl and SO_4 in groundwater (Sadashivaiah et al 2008; Varade et al 2014). The total hardness is dominantly present due to the presence of magnesium ions.

Most of the samples are showing less affinity to the CO_3+HCO_3 and other cations as compare to anions (refer fig 6.1).

Durov diagram (fig 6.2) represents the multivariate analysis in terms of pH, TDS and ion chemistry of groundwater. In the graph, results reveals that all the sample locations of groundwater are having pH is near to the neutral concentration of 7. Salts concentration is in varying conditions; more than 70% of samples are having TDS more than 500 which is the upper desirable limit for drinking purpose. In the pure water chemistry, it may observe that groundwater samples are having higher concentration of Magnesium among all cations and chloride in anions present in water. Few water samples also likely to represent the CO_3+HCO_3 ions in water. Ion-Balance plot of groundwater shows the cations are very high as compare to anions (fig 6.3). Many of studies exhibit that water should have very less electrical charge as the concentration of anions should be equal to or approximately balanced by cations. The cation to anion ratio should lie near to 1 to mitigate the electric charge between water ions. Same consequences findings are graphically represented in Pie chart, Radial Plot, Schoeller Diagram and Stiff diagram (fig 6.4, 6.5 & 6.6 & 6.8).

Series plot is a graph represents the concentration of major elements of groundwater as a whole. In the fig 6.7, it has been shown that the X-axis contains the sample no of 1-20 and Y-axis shows the concentration of parameter. TDS, chloride and magnesium possess high amount of concentration as shown in fig. Sodium, potassium, calcium and sulphate legends are comparatively low and graph indicates the inferior concentrations of these parameters.

Ternary Diagram has been drawn between Mg, Ca and Na. The water samples more than 80% are top of the diamond and delineate the tendency of hardness of water due to magnesium salts as compare to calcium and magnesium (fig 6.9). Cross plot between EC v/s TDS renders the good linear relationship between both the parameters and with the help of these plot, the value of one parameter may easily evaluated with reference to another parameter (fig 6.10). On the other hand the cross plot between the Mg and Ca represents the hardness predictions for water. From this graph, the fact release that at the lower value of Ca, Magnesium possesses high concentration in water.

The analysis of water chemistry and water classification as per the different important parameters of groundwater by has been completed by AQUA software. The study and graphical representation of parameter concentrations are very significant to decide the water quality. The groundwater of Ghaziabad shows the tendency of high EC, TDS, Mg, Chloride are proved in this graphical representation which may already determined in statistical analysis of groundwater. This was very useful tool to cross check this study and exhibits an influential analysis of groundwater for drinking purpose as well as for irrigation water quality analysis.

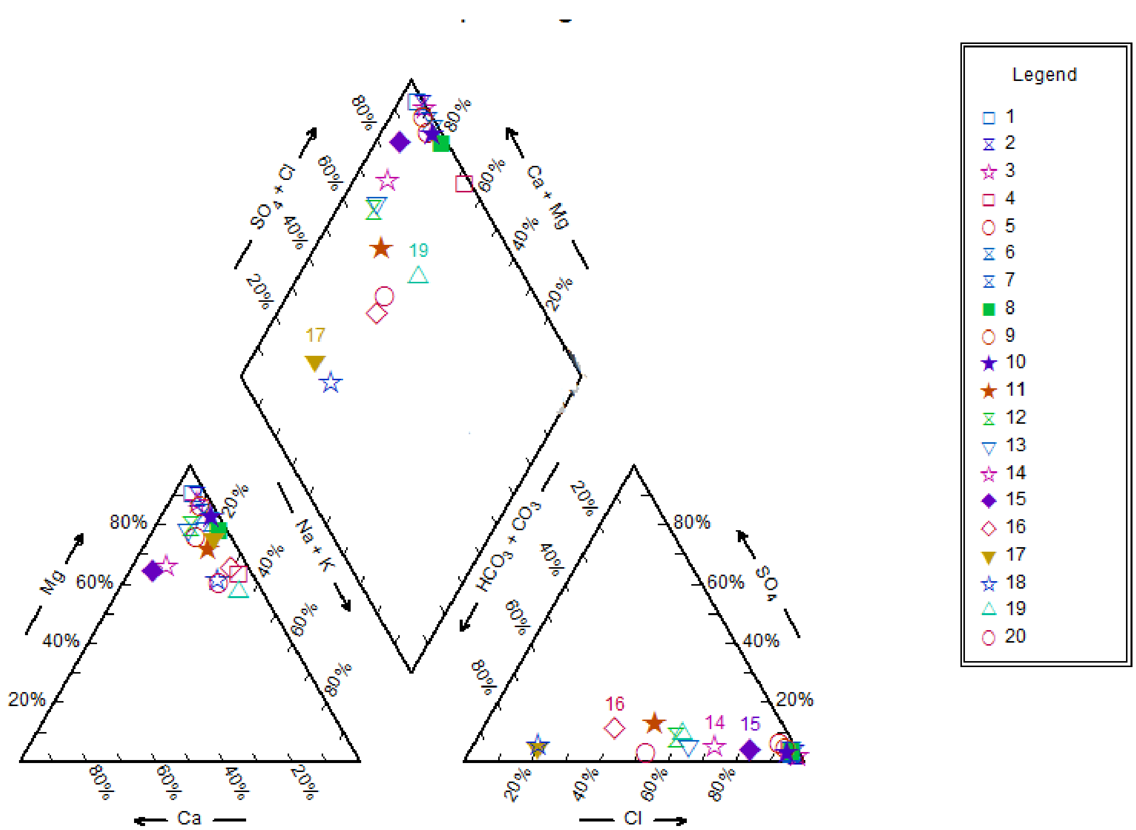

Fig 6.1: Piper Diagram

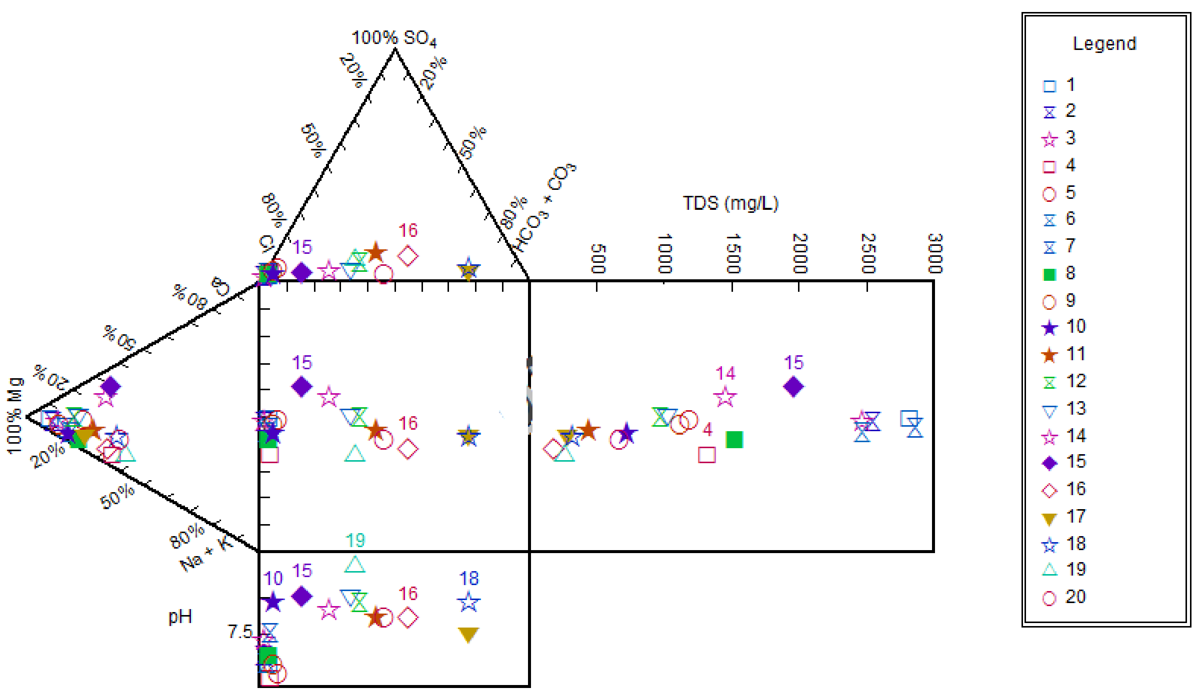

Fig 6.2: Durov Diagram

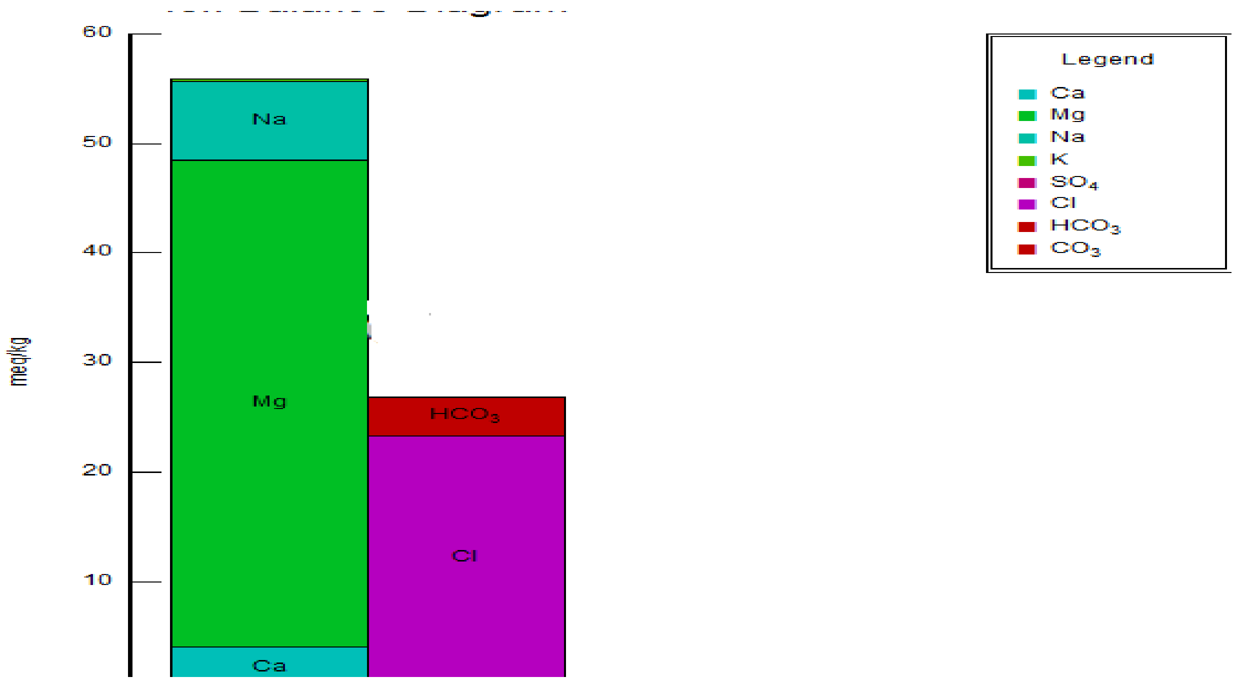

Fig 6.3: Ion Balance Diagram

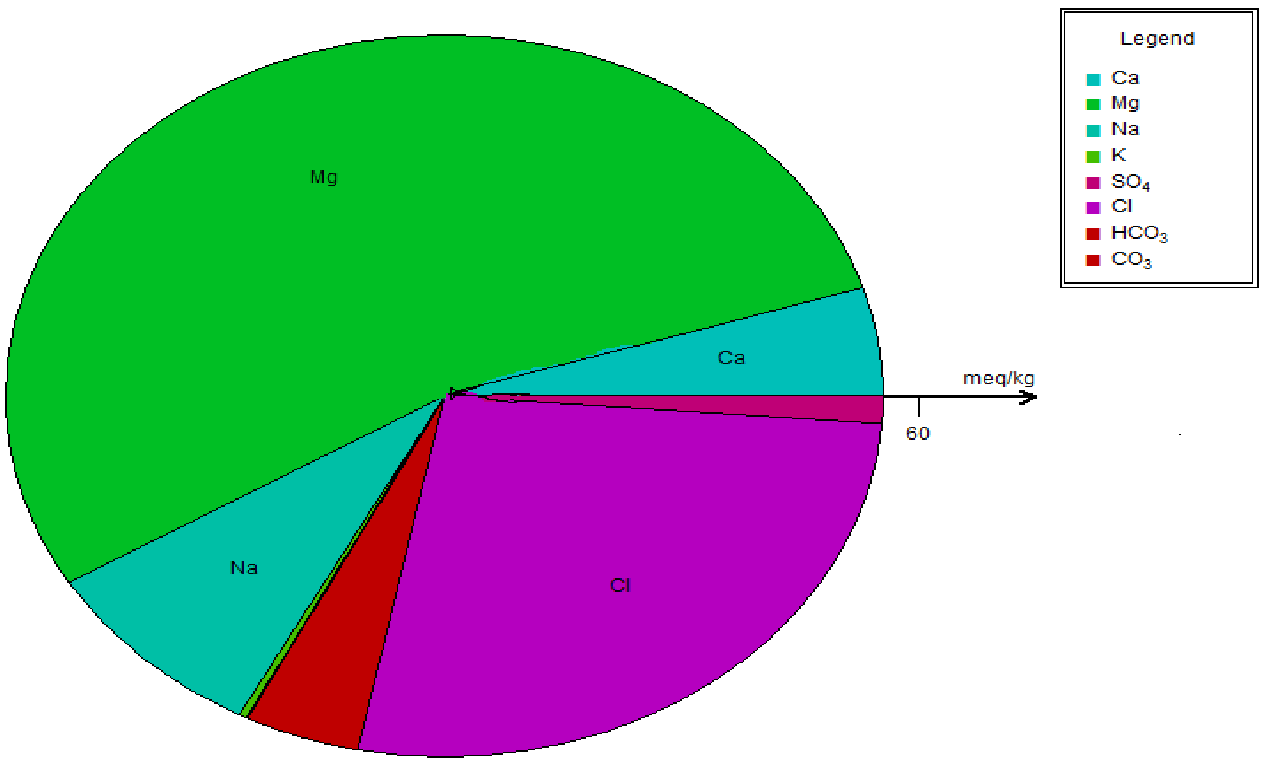

Fig 6.4: Pie Chart

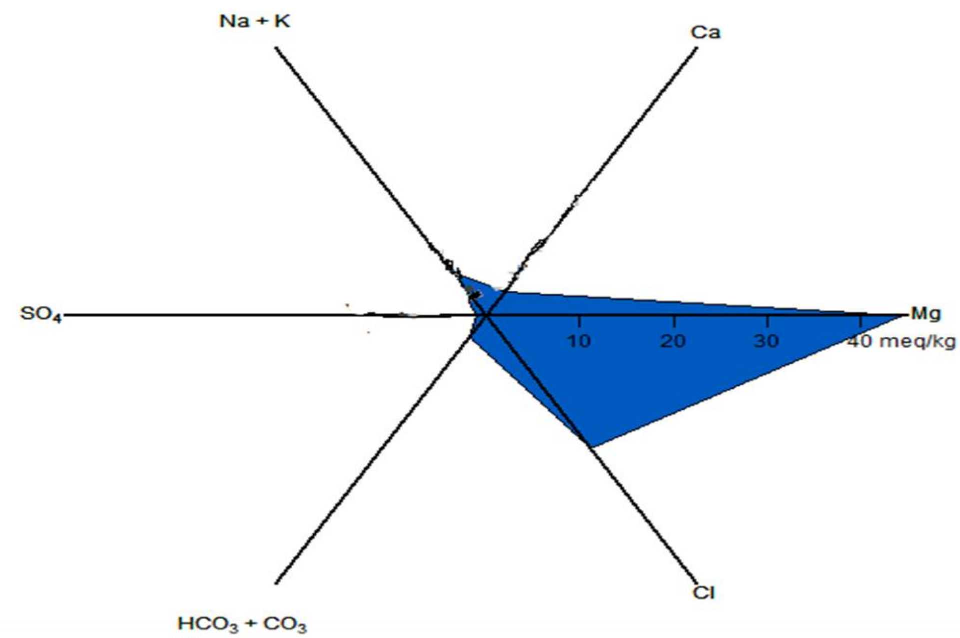

Fig 6.5: Radial Plot

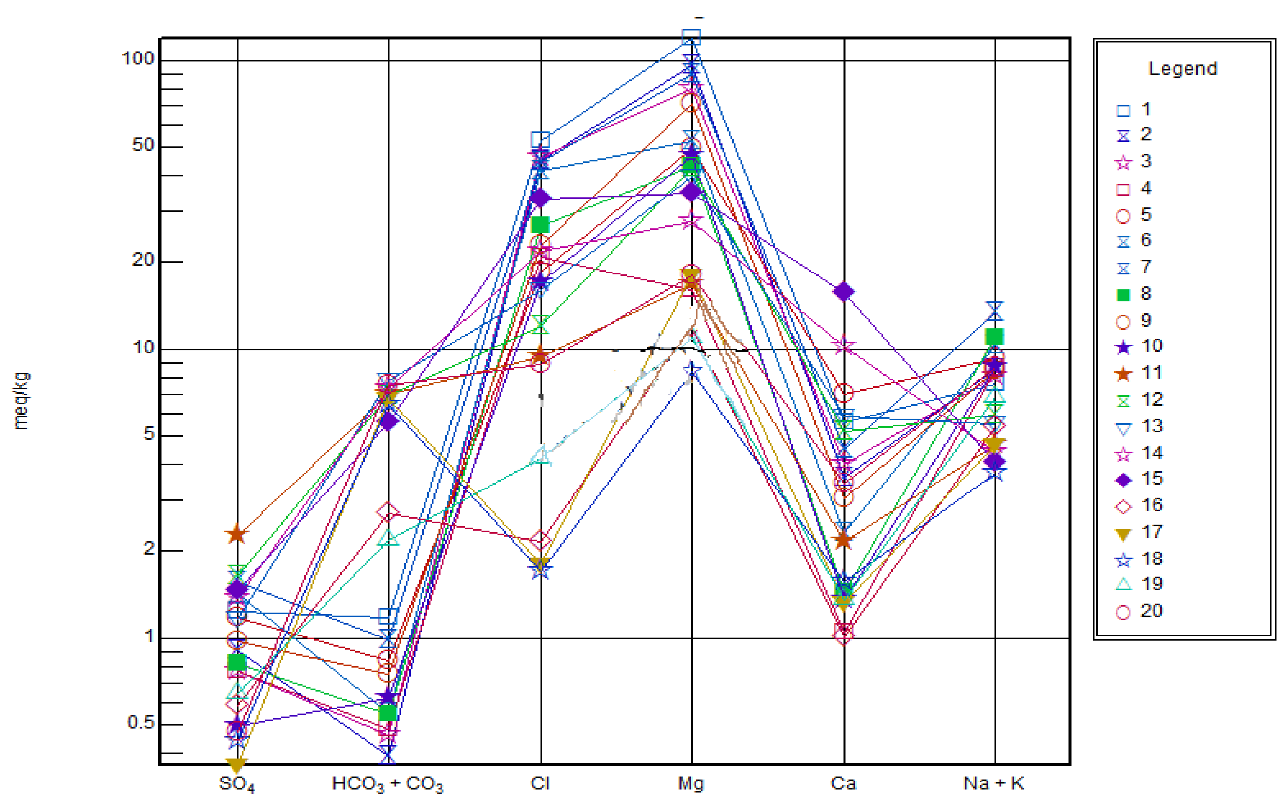

Fig 6.6: Schoeller Diagram

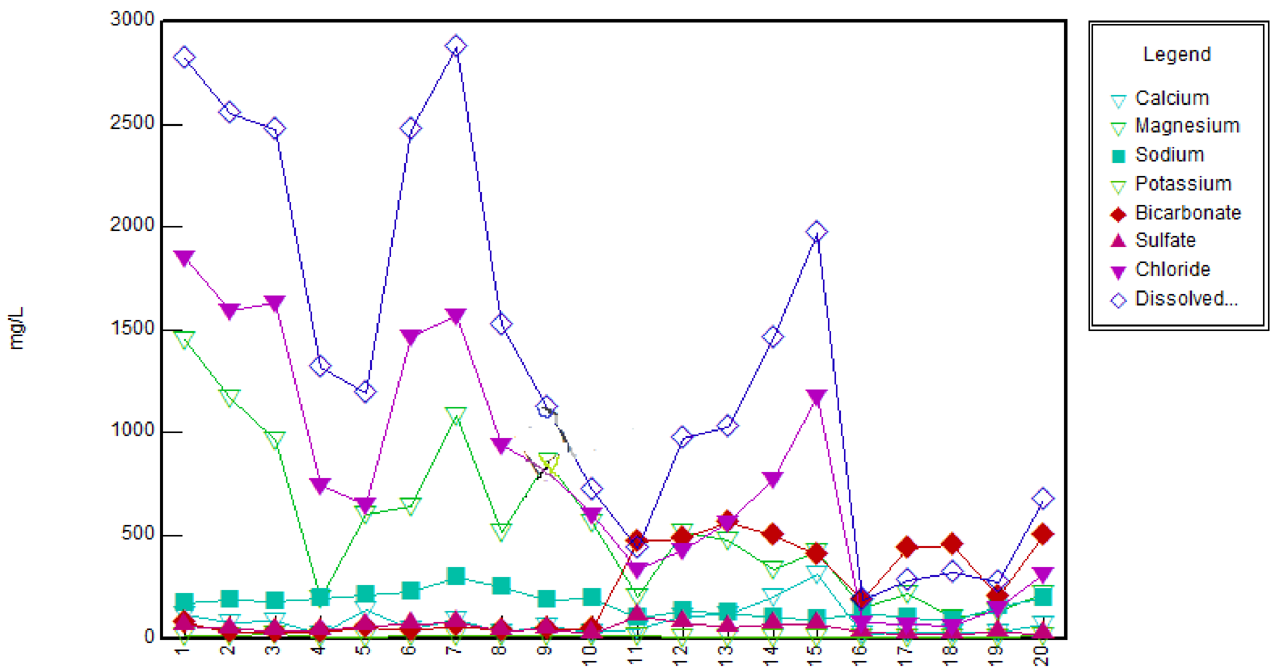

Fig 6.7: Series Plot

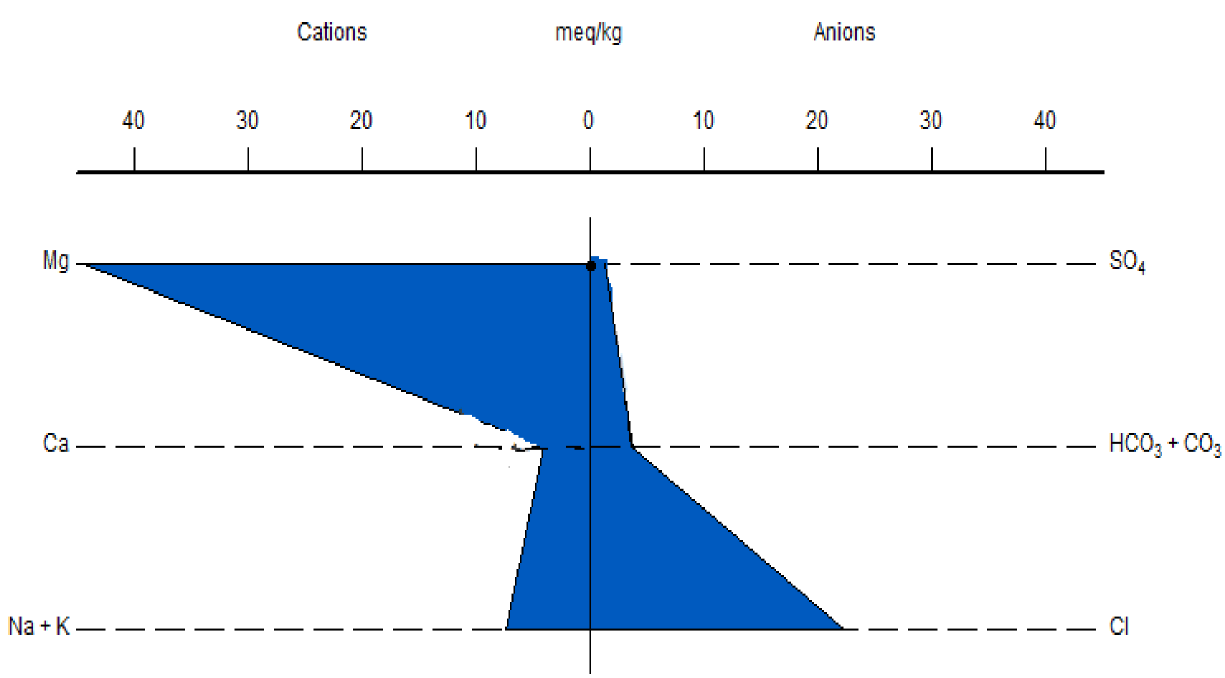

Fig 6.8: Stiff Diagram

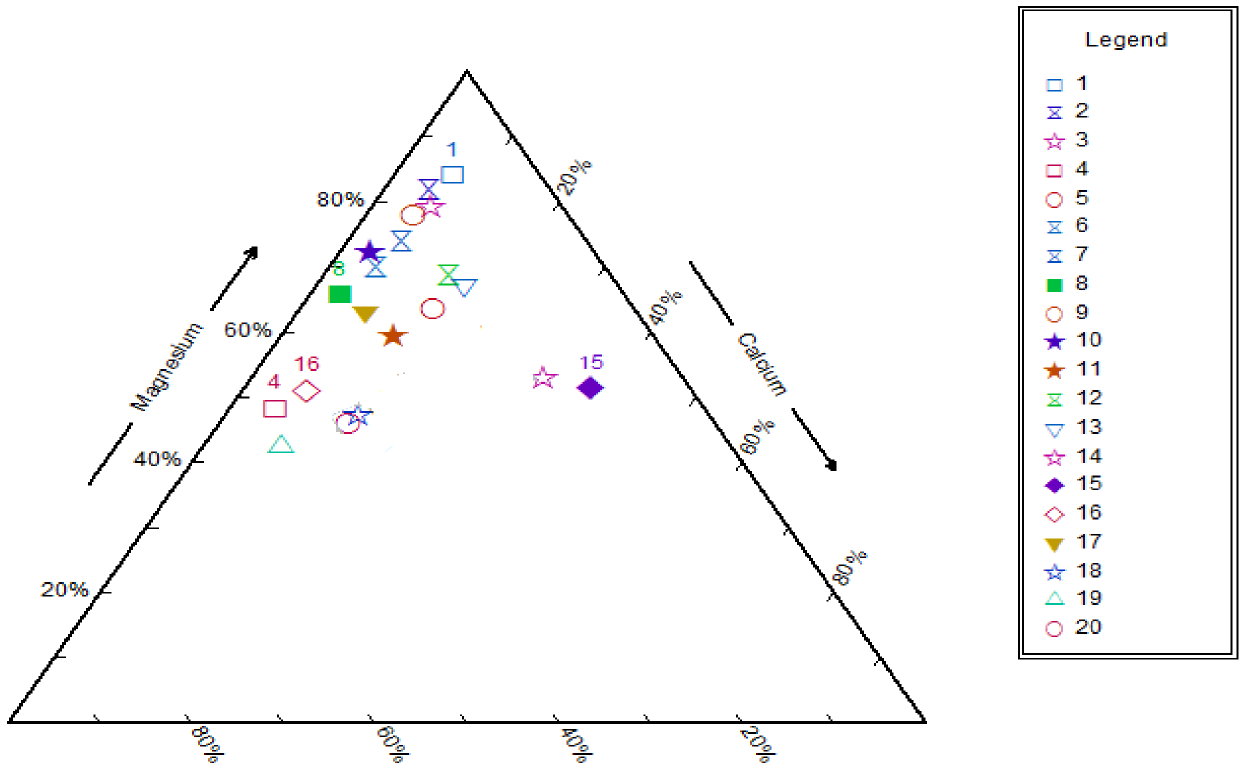

Fig 6.9: Ternary Diagram

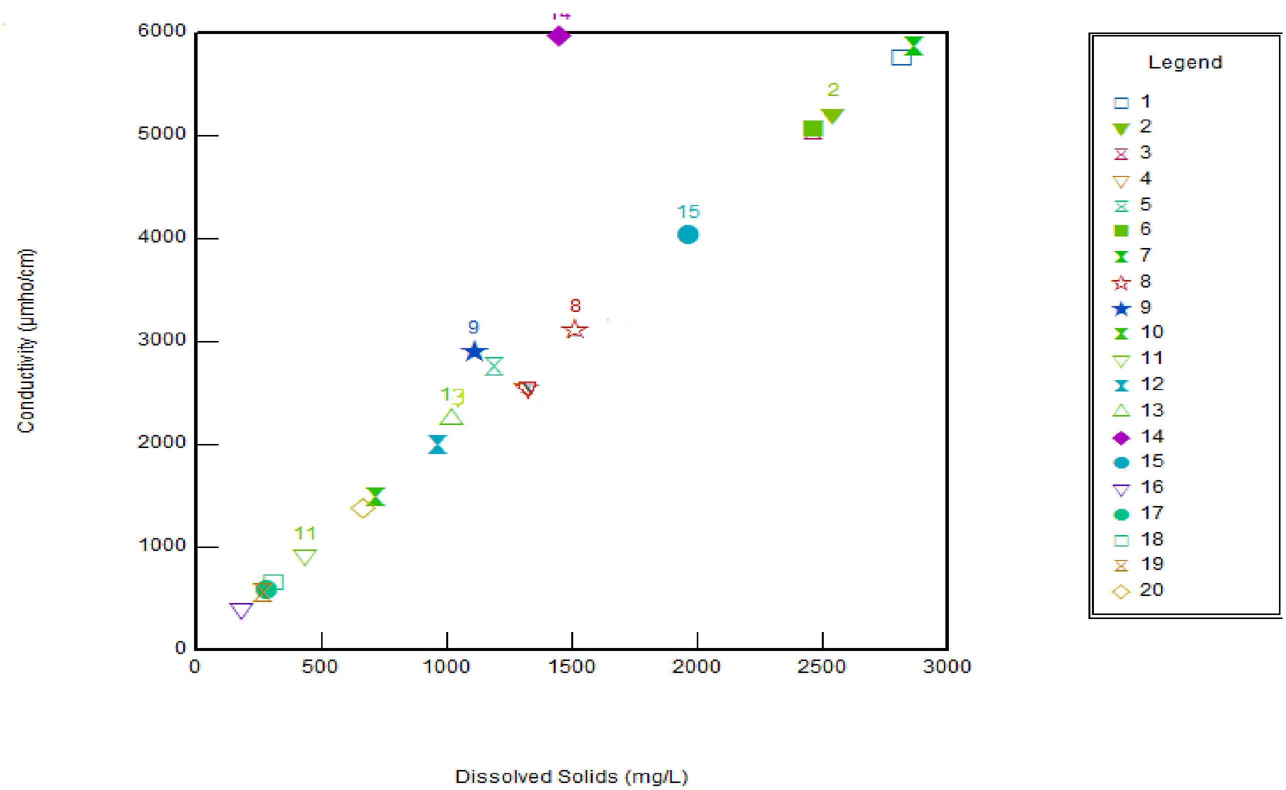

Fig 6.10: Cross Plot of Total Dissolved Solids v/s Conductance

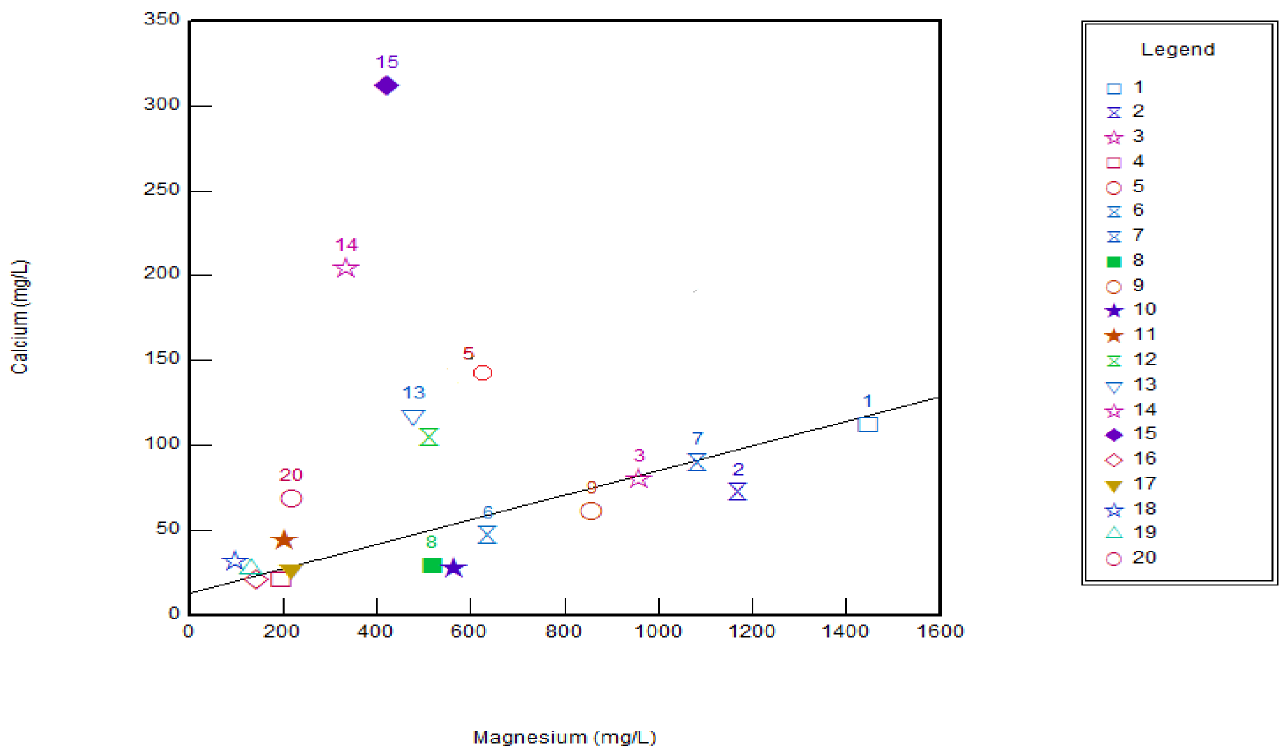

Fig 6.11: Cross Plot of Calcium v/s Magnesium

CHAPTER-7
CONCLUSIONS ANDRECOMMENDATIONS

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

The study conducted on the groundwater quality of Indo-Genetic Plain Ghaziabad reveals many type of significant abstractive information. It provides the summery regarding physiochemical parameters of groundwater which is used to determine correlation & regression analysis, water quality index, temporal variation and Collin's ratio for assessing the drinking water quality of groundwater. Statistical analysis has been also considered to check the groundwater suitability and availability for irrigation purpose. In the present study, AQUA software also applied to the groundwater data and constructs the useful graphs for analyzing the hydrochemistry of water. The meaningful evaluation of groundwater communicates following information:

1. The physio-chemical experimental analysis was performed in laboratory of samples collected in Nov 2014; Jan 2015 and Mar 2015 from the heavy industrial cluster of Ghaziabad. The analysis shows high concentration of various parameters in study area viz. Salinity, EC, TDS, Chloride and Hardness showing harmful concentrations for drinking purpose as they overshoot the standard desirable limit for drinking purposes. pH values at each of the study location are in limit of BIS Standard The critical concentrations of these parameters may adversely affect the human lives and deteriorate the quality of life.

2. In correlation-regression analysis a good relationship evolved between TDS-EC, EC- Salinity, Salinity-TDS, chloride-salinity, hardness-salinity, hardness-EC, hardness-magnesium and furthermore. The parameters which are interrelated, regression equations also developed for assess the future contaminations in same study area and period of study (Sazzad 2014). Total hardness correlated to chloride indicated permanent hardness in water and it is present due to magnesium salts.

3. The index for groundwater quality has also been evaluated of Ghaziabad. WQI values indicate the groundwater quality of Ghaziabad is very poor for drinking purpose and it continuously being deteriorated. Only 1 sample lies in the category of moderate water quality, 3 are having poor groundwater quality but it may use when no substitutes are there, 13 samples fall in the very poor category which may harmful and adversely affect the human beings. 3 samples are having more than 300 water quality which is unsuitable for drinking and should be refused at any cost. The overall WQI of groundwater came 209 and it also depicts that the water quality is very poor of Ghaziabad city. Such type of water promote the water related issues and diseases in living residents. According to Karl Person's two tailed correlation, when the WQI shows higher values of groundwater, the quality of life being degrade and consumption of such type of water may cause hazardous effects to lives.

4. The temporal variation has been analysed with the data of past 15 years. Significant parameters such as EC, TDS, Cl and salinity increases continuously from year 2000. Salt concentrations may get high and deteriorate the groundwater quality and that water will be refused to any uses by society. Hardness of water with cationsCa and Mg also shows the variations in increasing trend which may causes tasteless water and reduce the water availability to many of significant purposes of groundwater. In Ghaziabad city, rapidly increasing scenario of urbanization and industrialization are the main accountable factors of this deterioration of groundwater.

5. Collin's ratio is the important no to determine the drinking water quality of groundwater in simple calculation. The ratio calculated for groundwater of Ghaziabad reveals the mixed nature of water towards drinking. Collin's ratio determined more than 3 at 10 sampling locations; 3 locations having ratio 1-3 and 7 locations are safe for drinking.

6. Physiochemical parameter concentration was used to determine irrigation suitability of groundwater of a particular study area of Ghaziabad city. Different important criteria for irrigation water quality has been evaluates as SAR, RSC, Sodium Hazards, Salt concentration and Chloride index and compared with standards given by BIS (IS: 11624). Electrical conductivity of study area shows the high level of salinity hazards. SAR and chloride index of groundwater were within the safe limit for irrigation. It shows the positive tendency of groundwater for irrigation purpose.

7. Application of AQUA software also included in this study to assess the groundwater chemistry of Ghaziabad. In this study, different types of graphs has been formed and revealed the information about chemical properties of water. Form graphs, it has been summarized that cations in groundwater are dominantly present and anions are comparably less; only chloride present in critical concentration. The water hardness by piper diagram has been analysed as permanent hardness in groundwater. With the help of cross plot, it may determine that EC and TDS are having linear relationship and proportional to each other.

7.2 RECOMMENDATIONS

The groundwater quality which is deteriorating continuously necessarily requires the solution to lessendangeroussituation occurring in Ghaziabad. These are the appropriate recommendations that should be appliedtoobstruct the pollutants andenhances the groundwater quality.

1. The study area is well known for itsworsensituation of ground water and the detectable pollution is a current issue due to the development of industries and growth of populationwhich results the enormous pressure to groundwater resources.

2. Heavy withdrawal of groundwater is responsible for increment in salinity, which should be evadedto save thequality of ground water.

3. Rain Water harvesting should be persuaded to diminishdecaying of groundwater quality. Fresh water should be supplied to the salinity affected area.

4. The sampling sites identified in present study should be marked as red to aware the public regarding the contamination of water.

5. The effluent from industrial or domestic areas should not be disposedin the open drains as it is one of the major threats to groundwater quality as it later percolates to the groundwater.

6. Groundwater resources should be under professional monitoring with respect to seasonal variation, yearly variation and decade variations. The concentration of harmful parameters should be mitigating by means of treatment of effluents, sewage coming from various sources.

7. All surface water bodies having disposal of effluents from various sources should be lined and the effluent should go through prior treatment before dispose into surface water bodiesupto the extent of standards given for inland surface water.

7.3 FUTURE SCOPE OF THE STUDY

The results evaluated of the groundwater of Ghaziabad shows hazardous effects to human lives and surroundings. In the past years as concentration has been increased and depth of water table has been simultaneously decreased, it will definitely be major threat to whole groundwater and devastating situation will occurred in the important and well developed city of Uttar Pradesh.

As discussed earlier parameter concentrations are increasing per year in the groundwater, there should be continuous study performed for coming decade and also check the seasonal variation of parameters after and before rainfall. The salinity of groundwater with combination of EC and TDS increment and salinity patterns show the deterioration of deeper groundwater in sluggish flow and in fresh groundwater ate shallow depth also. It may harmful for soil and irrigation practices and may reduce the crop yield in future. The soil salinity should also be monitored of this area to mitigate the future contaminations and to save the crop production in surrounding areas.

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