

**Characterization and Assessment of Suitability of
Groundwater Quality for the Irrigation Purpose of Agra
District.**

**A
DISSERTATION
Submitted in partial fulfilment of the
Requirement for the award of the degree of
M.Tech.5 Year Integrated in
Applied Geology**



By

VINOD KUMAR

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**DEPARTMENT OF GEOLOGY
KURUKSHETRA UNIVERSITY
KURUKSHETRA**

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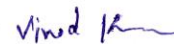
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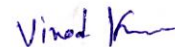
(VINOD KUMAR)

M.Tech (Applied Geology)

Roll No-1898312- Xth Sem.

CANDIDATE'S DECLARATION

I, hereby, certify that the Dissertation entitled "**Characterization and Assessment of Suitability of Groundwater Quality for the Irrigation Purpose of Agra District**" being submitted by me in partial fulfilment of the requirement for award of the degree of **M.TECH (APPLIED GEOLOGY)**, of the Kurukshetra University, Kurukshetra, India, during the period from **1st February 2016 To 22nd July 2016**, is a record of my own work under the supervision of **Dr. SURJEET SINGH, SCIENTIST 'D'**, Ground Water Hydrology Division, National Institute of Hydrology (NIH), Roorkee (Uttarakhand). The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.



(VINOD KUMAR)

M.Tech. (Applied Geology)

Roll No- 1898312, Xth Sem.

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.


22/07/2016

(SURJEET SINGH)

Scientist 'D', GWHD

National Institute of Hydrology (NIH)

Roorkee-247667 (Uttarakhand)

Abstract

The aim of the present study is the characterization and assessment of groundwater quality for irrigation purpose of Agra district. For this purpose, groundwater quality data of fifteen blocks of Agra district for nine years from 2006 to 2014 have been collected from the Ground Water Department, Govt. of Uttar Pradesh. The water quality data comprises of twelve water quality parameters viz. pH, EC, TDS, Cl^- , HCO_3^- , SO_4^{2-} , Si, Fe, Al, Ca^{++} , Mg^{++} and Na^+ . The water quality data of all fifteen blocks of the Agra district are characterized using Wilcox and Piper diagrams. These diagrams have been prepared using Aquachem 2011.1. The assessment on suitability of groundwater quality for the irrigation purpose is done using sodium percentage (Na%), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) for all the blocks. It is concluded that groundwater of various blocks of Agra district are of $\text{Na}^+ - \text{Cl}^-$, $\text{Ca}^{2+} - \text{Na}^+ - \text{HCO}_3^-$, $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^-$, $\text{Ca}^{2+} - \text{HCO}_3^-$, $\text{Ca}^{2+} - \text{Cl}^-$, $\text{Na}^+ - \text{Cl}^-$, $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^- - \text{SO}_4^{2-}$ and $\text{Ca}^{2+} - \text{Na}^+ - \text{HCO}_3^-$ Type. It is also concluded that the groundwater quality of water for the blocks Barouli Ahir, Fatehapur Sikari, Saiyan, Achhenera, Shamsabad, Khandouli, Pinahat, Jaitpur Kalan and Bah falls under Very Good to Medium category and can be used for the irrigation purpose. But, the groundwater quality for the blocks Bichpuri, Akola, Fatehabad, Khairagarh, Etmadpur and Jagner falls under Medium to Very bad category and hence cannot be used for the irrigation purpose.

CONTENTS

CHAPTER NO.	TITLE	PAGE
CHAPTER 1	INTRODUCTION	1
CHAPTER 2	LITERATURE REVIEW	4
CHAPTER 3	STUDY AREA	8
CHAPTER 4	METHODOLOGY	15
CHAPTER 5	RESULTS AND DISCUSSION	30
CHAPTER 6	SUMMARY AND CONCLUSIONS	66
	References	68

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1	Study area map of Agra district showing Yamuna river and variation of ground elevation.	9
2	Base area map of Agra district.	10
3.1	Representation of the Piper Trilinear diagram.	28
3.2	Facies of ground water quality.	29
3.3	Wilcox diagram for Achhanera block of Agra district	31
3.4	Piper diagram for Achhanera block of Agra district	32
3.5	Wilcox diagram for Akola block of Agra district	33
3.6	Piper diagram for Akola block of Agra district	34
3.7	Wilcox diagram for Bah block of Agra district	35
3.8	Piper diagram for Bah block of Agra district	36
3.9	Wilcox diagram for Barauli Ahir block of Agra district	37
3.10	Piper diagram for Barauli Ahir block of Agra district	38
3.11	Wilcox diagram for Bichpuri block of Agra district	39
3.12	Piper diagram for Bichpuri block of Agra district	40
3.13	Wilcox diagram for Etmadpur block of Agra district	41
3.14	Piper diagram for Etmadpur block of Agra district	42
3.15	Wilcox diagram for Fatehabad block of Agra district	43
3.16	Piper diagram for Fatehabad block of Agra district	44
3.17	Wilcox diagram for Fatehapur Sikari block of Agra district	45

3.18	Piper diagram for Fatehapur Sikari block of Agra district	46
3.19	Wilcox diagram for Jagner block of Agra district	47
3.20	Piper diagram for Jagner block of Agra district	48
3.21	Wilcox diagram for Jaitpur Kalan block of Agra district	49
3.22	Piper diagram for Jaitpur Kalan block of Agra district	50
3.23	Wilcox diagram for Khairagarh block of Agra district	51
3.24	Piper diagram for Khairagarh block of Agra district	52
3.25	Wilcox diagram for Khandouli block of Agra district	53
3.26	Piper diagram for Khandouli block of Agra district	54
3.27	Wilcox diagram for Pinahat block of Agra district	55
3.28	Piper diagram for Pinahat block of Agra district	56
3.29	Wilcox diagram for Saiyan block of Agra district	57
3.30	Piper diagram for Saiyan block of Agra district	58
3.31	Wilcox diagram for Shamsabad block of Agra district	59
3.32	Piper diagram for Shamsabad block of Agra district	60

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1	Block wise sources of Irrigation.	12
2	Agriculture production in Agra district.	13
2.1	Water sample location in the Agra district.	14
3	Details of analytical method and equipment.	15
4	Classification of water suitability for Irrigation for different value of SAR.	26
5	Guidelines for evaluation of irrigation water quality	61

CHAPTER 1: INTRODUCTION

India is blessed with a rich and vast diversity of natural resources, water being one of them. Water is mother Earth's most wonderful, abundant and useful compound. There are many essential elements for the survival of living beings; water is rated to be of the greatest importance. Without food, humans can survive for a number of days, but without water cannot survive for more than a day. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries. Groundwater is an important source of water supply throughout the world. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters. Knowledge of the occurrence, replenishment, and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources. (Mahananda et al., 2010) The demand for water has increased over the years, which has led to the water scarcity in many parts of the country. The situation is further aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management and environmental degradation of surface and ground water resources.

Monitoring of ground water regime is an effort to obtain information on ground water levels and chemical quality through representative sampling. In India, most of the population is dependent on groundwater as it the only source of drinking water supply particularly in rural areas. The groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dumping results in pollution of groundwater and health problems. Natural phenomena such as volcanoes, algae blooms, storms and earthquakes also cause major changes in the water quality ecology. As per the latest estimates of Central Pollution Control Board, about 29,000 million litre/day of wastewater generated from Class-I cities and Class-II towns, out of which about 45% is generated from 35 metro cities alone (Rupal et al., 2012).

Ground water quality is important to humans. Therefore it is important to ensure its quality is high at all time so that the consumer health is not compromised. Groundwater resources are affected mainly by three major activities: (i) excessive use of fertilizers and

pesticides in agricultural areas, (ii) untreated/partially treated wastewater to surface water bodies, and excessive pumping and improper management of groundwater resource. Solid waste disposal in open un-engineered landfill is the one of the factor that causes ground water pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, monitoring wells, etc (Mohamad et al., 2007). Groundwater pollution also occurs due to disposal of toxic wastes, especially from industries, or undetected leakage from pipes, waste storage containers, or underground tanks. According to WHO, about 80% of all the diseases in human beings are caused by water. Groundwater once contaminated, its restoration to actual state requires prolonged time and decontamination is not possible by just stopping the ingress of pollutants from the source. Contamination of groundwater by domestic, industrial effluents and agricultural pollutants is a serious problem being faced by developing countries. The industrial waste water, sewage sludge and solid waste materials are currently being discharged directly into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water. High rates of mortality and morbidity due to water borne diseases are well known in India. Therefore, access to safe drinking water supply remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or ground water (Palanisamy et al., 2005).

The quality of water is defined in terms of its physical, chemical and biological parameters. Its development and management plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development (Hiremath et al., 2011). In some areas of the world, people face serious drinking water shortage because of the ground water pollution. Thus, evaluation of groundwater quantity and quality is important for the development of further civilization and to establish database for planning future water resources development and management strategies. The quality of water may depend on geology of particular area and also vary with depth of water table as well as seasonal changes and is governed by the extent and composition of the dissolved salts depending upon the subsurface environment.

Water quality index, one of the most effective tools to communicate information on the quality of any water body, is a mathematical equation used to transform large number of water quality data into a single number. The water quality status thus generated through the WQI provides very useful information to the concerned citizens and policy makers in water quality

management. The advent of Satellite Technology and Geographical Information System (GIS) has also made easy to map the sampling area. GIS not only helps in decision making for managing spatial and attribute data of water quality monitoring stations but also in developing informative and user-friendly maps.

In this study, water quality characterization and assessment on suitability for the irrigation purpose has been carried-out for the Agra district, which is located in the Northern part of the Uttar Pradesh state of India. For this purpose, groundwater sampling and analysis from various hand pumps and bore wells has been carried-out.

Objectives:

1. Assessment of suitability of groundwater quality of Agra district for the irrigation purpose.
2. Characterization of groundwater quality of Agra district of Uttar Pradesh.

CHAPTER 2: LITERATURE REVIEW

The aim of the present study is the characterization and evaluation of ground water quality for irrigation by using Wilcox and Piper diagrams. A detailed review has been carried out for the assessment of ground water quality studies carried-out by various researchers. These reviews are presented in brief as follows:

Meenakshiet al. (2003) studied the fluoride concentration in underground water in four villages of Jind district of Haryana state (India) where groundwater is the only source of drinking water. Various other water quality parameters such as pH, electrical conductivity, total dissolved salts, total hardness, total alkalinity as well as sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride and sulphate concentrations were also monitored. A systematic calculation of correlation coefficients among different physico-chemical parameters was performed. The analytical results indicated considerable variations among the analyzed samples with respect to their chemical composition. Majority of the samples did not comply with Indian as well as WHO standards for most of the water quality parameters measured. The fluoride concentration in the underground water of these villages varied from 0.3 to 6.9 mg/l, causing dental fluorosis among people especially children of these villages. Overall water quality was found unsatisfactory for drinking purposes without any prior treatment except at eight locations out of 60.

Mahananda et al. (2010) investigated the ground water as well as surface water quality, nutrient status and physico-chemical characteristic of Bargarh district of Orissa, India. The was conducted by monitoring two types of ground water i.e. dug well water and bore well water of 10 wards of the town as well as 3 types of ponds, viz. temple pond, small community pond and large community pond. Attempts were made analyze the physico-chemical characteristics of the water using various parameters like Temperature, pH, Total suspended solids, and Total dissolved solids, Alkalinity, Dissolved oxygen, Chemical Oxygen Demand, Nitrate, Chloride, Sodium, Potassium, Phosphate, Fluoride, Total Coliforms (Pond water),etc in both dug well and bore well water as well as pond water of the town. The results concluded that the parameters values were found below the pollution level for ground water which satisfy the requirement for

the use of various purposes like domestic, agricultural and industrial. But in case of surface water, the water quality of small community pond are beyond the permissible limit.

Simpi et al. (2011) aimed at assessing the water quality index (WQI) for the groundwater of Hosahalli Water Tank in Shimoga District, Karnataka. Monthly Changes in physical and chemical dissolved solids, pH, dissolved oxygen, free carbon dioxide and total hardness, chlorides, alkalinity, phosphate and nitrates were analyzed for a periods of one year from 1st January 2007 to 31st December 2007. All Parameters were found within the permissible limits. The results indicated that the tank was non-polluted and can be used for domestic, irrigation and fisheries.

Rajappa et al. (2011) assessed the water quality index (WQI) of groundwater for different villages of Hariharataluk (India). The water samples from 25 sampling points of Hariharataluk were analyzed for their physico-chemical characteristics. Laboratory tests were performed for the analysis of samples for pH, hardness, chloride, alkalinity, TDS, etc. On comparing the results against drinking water quality standards laid by Indian Council of Medical Research (ICMR) and World Health Organization (WHO). It was found that some of the water samples are non-potable for human being due to high concentration of one or the other parameter. The usefulness of these parameters in predicting ground water quality characteristics were also discussed. Thus an attempt was made to assess the suitability of ground water quality for drinking purpose in and around Hariharataluk.

Kalra et al. (2012) determined the groundwater quality in five blocks (Udwantanagar, Tarari, Charpokhar, Piro and Sahar) which fall in the southern parts of Bhojpur district of Bihar. Ten groundwater samples were studied from each block for physico-chemical status of groundwater. In physico-chemical analysis, various quality parameters were measured including pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), sulphate (SO_4), Iron (Fe), DO, BOD, COD, total alkalinity (TA) and nitrate (NO_3). Also all these parameters were compared with ICMR standards of water quality. Classification of water samples was also done for all the five blocks on the basis of TDS and TH.

Sarala et al. (2012) collected water samples from the study area for two seasons i.e., post-monsoon and pre-monsoon in December 2007 and June 2008. The groundwater contour analysis was done using Arc GIS software. The study revealed that the concentration of major constituents are well within the permissible limits of IS (10500-1994), except in few cases where total hardness and fluoride concentrations are high. From the analysis it was observed that the groundwater is polluted in the entire study area. Due to this reason, during the monsoon season the rainwater drains into the solid waste polluting the land leachate existing in the surrounding areas and in the low lying areas. During last few years, the utilization of surface and groundwater for drinking, industrial and agricultural purposes has increased manifolds but consequently it was observed that the water is polluted and affecting the human health, soil nutrients, livestock, biomass and environment in certain areas. Hence this study was carried out for the quality of the available groundwater.

Dohare et al. (2014) proposed that groundwater is a natural resource for drinking water. Like other natural properties, it should be assessed regularly and people should be made aware of the quality of drinking water. Their study was aimed at assessing the water quality index (WQI) for the groundwater of Indore city and its industrial area. The ground water samples of all the selected stations from the wards were collected for a physio-chemical analysis. For calculating the water quality status by statistical evaluation and water quality index, various parameters were considered viz. pH, color, total dissolved solids, electrical conductivity, total alkalinity, total hardness, calcium, chromium, zinc, manganese, nickel. The obtained results were compared with Indian Standard Drinking Water Specification IS: 10500-2012. The study of physico-chemical and biological characteristics of the ground water sample suggested that the evaluation of water quality parameters as well as water quality management practices should be carried out periodically to protect the water resources.

Shrivastava et al. (2014) collected 14 water samples from different point sources of pollution and tested for physico-chemical parameters (pH, temperature, DO, BOD, COD, TSS, TDS, EC, PO_4^{3-} , $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$), metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) and microbiological parameter. Based on the results obtained, the water quality at most of the sampling stations was found to be unsuitable for drinking based on standards given by World

Health Organization (WHO) and the Bureau of Indian Standards (BIS). Hierarchical Cluster Analysis (HCA) classified the 14 sampling stations into three clusters. The HCA identified a uniform source of parameters (physico-chemical and nutrients) for all the sampling stations, excluding two sampling stations (7 and 12) that exhibited anomalous concentrations. Furthermore, as per the WQI, the water quality status of Patalganga River fell under good category, except at the sampling station 7 and 12 where the water quality index were bad (49) and medium (51) category, respectively, and were totally unfit for drinking purpose. Site-specific water quality management plan were also delineated and presented in the paper.

CHAPTER 3: STUDY AREA

Agra is famous for its historical monument Taj Mahal. The story of Agra begins much earlier than the Taj, However it finds mention in the epic Mahabharata when it was called Agrabana is Paradise. Tradition and legend ascribe the present city of Raja Badal Singh (around 1475 A.D.) who's Fort, Badalgarh, stood on or near the site of the present Fort. However, in the 12th century A.D. Persian poet Salman, too, Speaks of a desperate assault on the fortress of Agra, then held by one King Jaipal, by sultan Mahmud of Ghazni. It was Mughals who finally nurtured Agra with the finest monuments architects could design: The Taj Mahal of Shah Jhan, Agra Fort of Akbar, Itmad-Ud-Daulah and neighbouring Sikandra but few of the many that spangle the city, each of which stands in mute testimony to the city's grandeur over the ages.

The Agra district is situated in western U.P., between 27.11' degree Latitude North and 78.0' degree to 78.2' degree Longitude East (Figure 1). Its altitude is 169 meters above sea level. On the North it is bounded by Mathura District, on the South it is bounded by Dhaulpur District, on the East it is bounded by Firozabad District and on the West it is bounded by Bharatpur. Agra is situated on the bank of Yamuna River.

The Agra district is divided into Six Tehsils and 15 Blocks. Total number of Niyay Panchayats in the district is 114 while Gram Sabah stands at 636. The total populated villages are 904. Primarily the Economy of the Agra district is agriculture based while the economy base of Agra city is small scale industries, commerce and trade. Major crops are Wheat, Paddy, Bajra, Mustard, Potato, etc. Over 7200 Small Scale Industrial Units are spared all over the district. Agra city is famous for the Leather Goods, Handicrafts, ZariZardozi, Marvel and Stone carving & inlay work. Agra is also well known for eats sweets (Petha) and snacks (Dalmoth and Gajak).

In Agra Maximum Temperature in summer is 45D.C. and minimum temperature is about 21.9D.C. and in Winter maximum temperature in 13.7D.C. and minimum temp. in about 4.2D.C. The base map of Agra district with block boundary is shown in Figure 2.

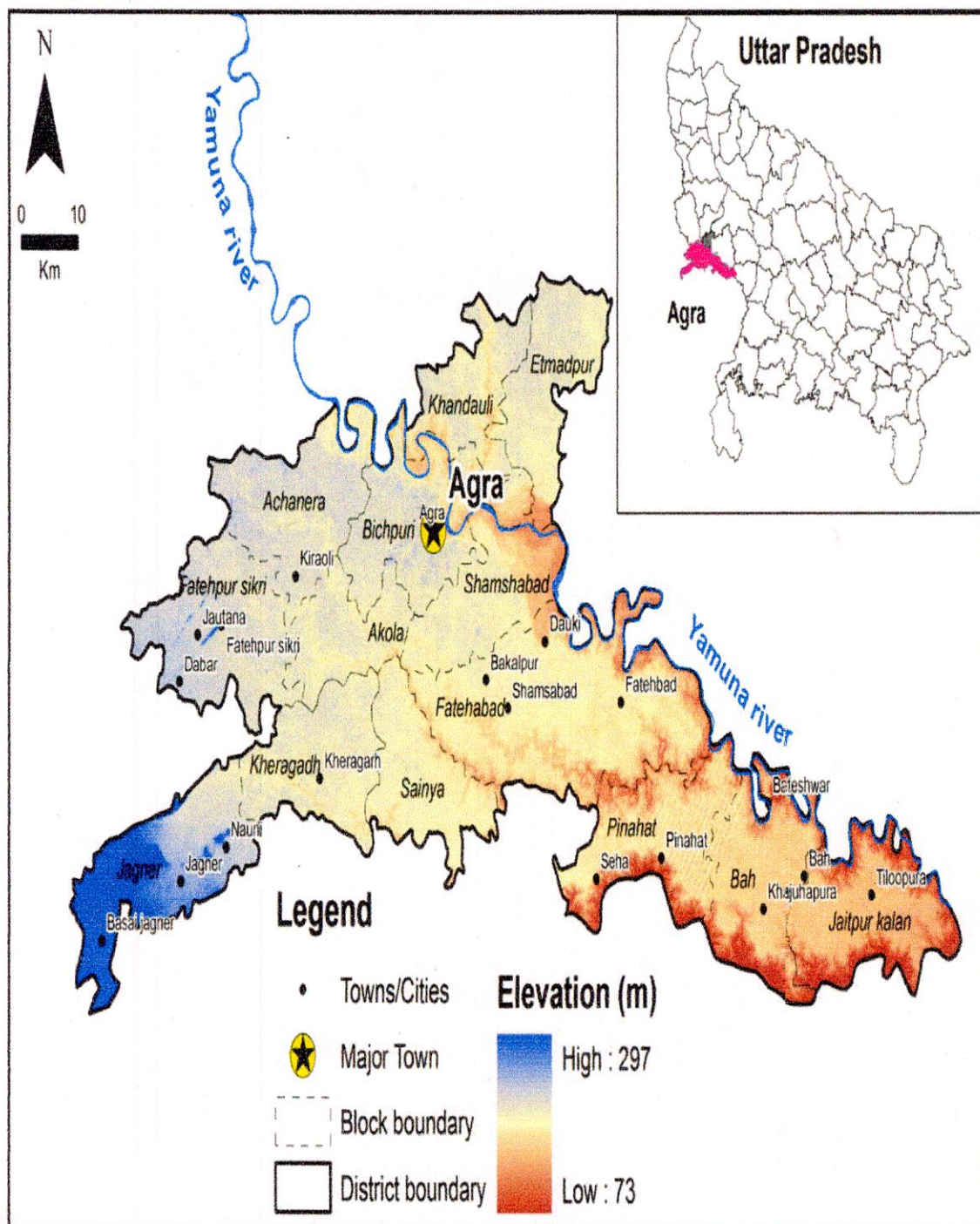


Figure 1. Study area map of Agra district showing Yamuna River and variation of ground elevation

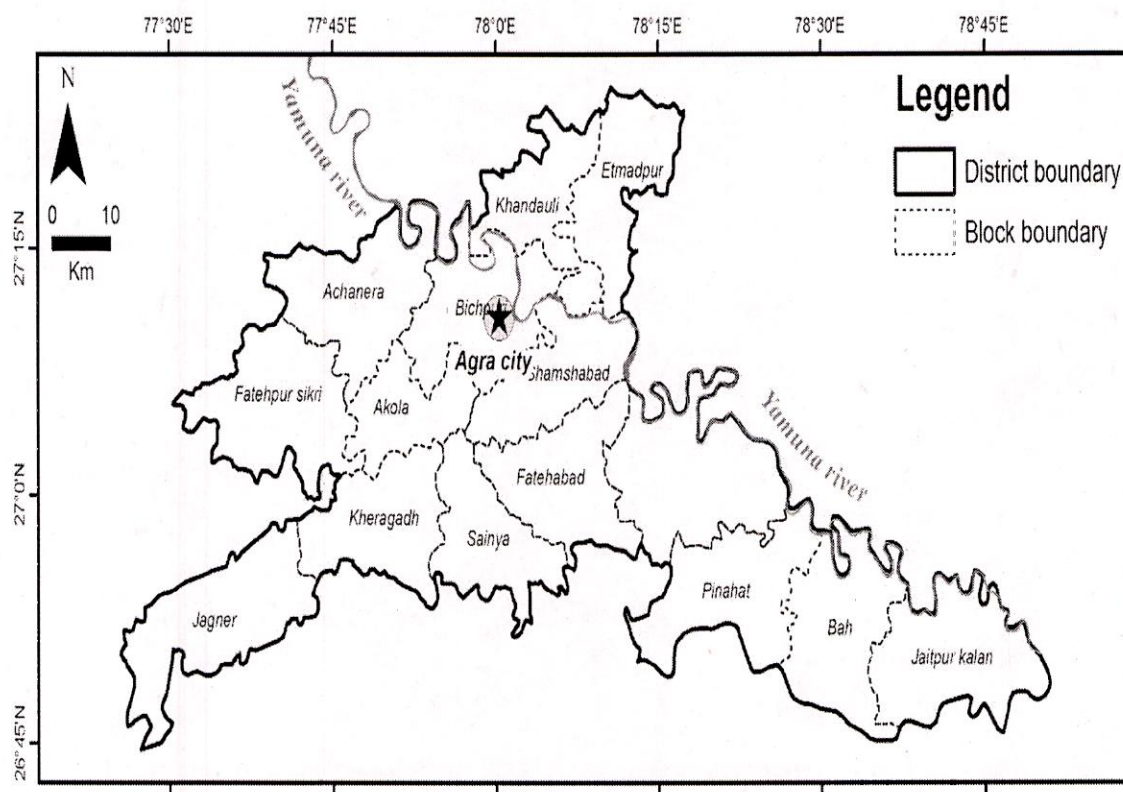


Figure 2. Base area map of Agra district showing Yamuna River and various blocks

According to Census 2011, the area of Agra district is 4027.00 sq.km, where rural area is 3838.60 sq.km and urban area is 188.40 sq.km. Based on the Census 2011, total population of Agra district is 44,18,797 out of which males are 23,64,953 and females are 20,53,844. Of the total population, 23,94,602 constitute the rural population and 20,24,195 are makes the urban population.

Climate

Agra, located in the Indo-Gangetic plains, has a continental sub-tropical climate, with long, hot summers from April to September when temperatures can reach as high as 45°C. During summers dry winds (loo) blow in this region. The monsoon months from July to September see about 67 cm of rainfall annually. In Agra Maximum Temperature in Summer is

45°C and minimum temperature is about 21.9°C and in Winter maximum temperature is 31.7°C and minimum temperature is about 4.2°C. Best season for tourist is from October to March.

Yamuna River

The Yamuna, sometimes called Jamuna, is the longest and the second largest tributary river of the Ganges (Ganga) in northern India. Originating from the Yamunotri Glacier at a height of 6,387 metre on the south western slopes of Banderpooch peaks in the uppermost region of the Lower Himalayas in Uttarkashi district of Uttarakhand, it travels a total length of 1,376 km and has a drainage system of 366,223 sq.km, 40.2% of the entire Ganges Basin, before merging with the Ganges at TriveniSangam, Allahabad at an altitude of 74 m. Yamuna is the longest river in India which does not directly flow to the sea.

Yamuna river crosses five states, namely Uttarakhand, Himachal Pradesh, Haryana, Delhi and Uttar Pradesh. The river passes through seven cities, namely Yamuna Nagar, Delhi, Mathura, Agra, Etawah, Kalpi and Allahabad. Six tributaries (Hindon, Sharda, Giri, Rishiganga, Hanuman Ganga and SasurKhaderi) join the river to the left side while five tributaries (Chambal, Betwa, Ken, Sindh and Tons) join to the right side. The river creates highly fertile alluvial, Yamuna-Ganges Doab-region between itself and the Ganges in the Indo-Gangetic plain. Nearly 57 million people depend on the Yamuna waters. With an annual flow of about 10,000 BCM and usage of 4,400 BCM (of which irrigation constitutes 96%), the river accounts for more than 70% of Delhi's water supplies. Just like the Ganges, the Yamuna too is highly venerated in Hinduism and worshipped as goddess Yamuna, throughout its course. In Hindu mythology, she is the daughter of Sun God, Surya, and sister of Yama, the God of Death, hence also known as Yami and according to popular legends, bathing in its sacred waters frees one from the torments of death.

The water of Yamuna is of "*reasonably good quality*" through its length from Yamunotri in the Himalayas to Wazirabad in Delhi, about 375 km, where the discharge of wastewater through 15 drains between Wazirabad barrage and Okhla barrage renders the river severely polluted after Wazirabad. There are three main sources of pollution in the river, namely households and municipal disposal sites, soil erosion resulting from deforestation occurring to make way for agriculture along with resulting chemical wash-off from fertilizers, herbicides, and pesticides and run-off from commercial activity and industrial sites.

Water Demand of Agra District

Agra, designated as a world heritage site, faces a number of challenges in terms of water, sewerage and financing municipal works. There is a bursting strain on the infrastructure and services, both from its own population and from the regular onslaught of visiting tourists, estimated at 1.80 million every year. In the city, Agra JalSansthan (AJS) is in charge of operation and maintenance, and revenue collection in supplying water, while all capital works related to water supply and sanitation are undertaken by Agra Jal Nigam (AJN). According to the AJS, the total water demand of the city is 320 million litre per day, which includes the demand for bulk supply, estimated at 75 mld. The block-wise sources of irrigation and agriculture production are given in Table 1 and 2, respectively (http://agra.nic.in/jalsansthan_agra.html).

Table 1. Block-wise Sources of Irrigation (<http://agra.nic.in/agriculture.html>)

Year / Block	Length of Canals (km)	Number of Government Tube wells	Number of Wells	Rahats	Pump Sets Ground Level	Pump Sets Boring	Deep Tube wells
FatehpurSikri	71	2	2	60	0	7977	30
Bichpuri	43	0	127	0	0	4151	0
Achenera	85	0	633	105	0	6643	0
Akola	45	0	0	42	0	7342	0
BaroliAhir	47	4	16	81	0	8503	7
Khandoli	27	8	0	0	0	4010	25
Etmadpur	81	4	77	0	0	3220	22
Jagner	0	0	801	0	30	2903	0
Kheragarh	78	0	0	0	0	4897	21

Saiyan	75	0	0	0	0	5135	32
Shamsabad	31	26	23	0	0	6409	22
Fatehabad	20	13	70	0	0	3466	97
Pinahat	54	95	0	10	0	1194	71
Bah	46	111	0	0	0	940	71
JaitpurKalan	34	84	0	0	0	910	59
Total Rural	614	347	1749	367	30	67700	463

Table 2. Agriculture Production in Agra District (<http://agra.nic.in/agriculture.html>)

S.N.	Name of Crop	Year	Area Covered (ha)	Production (Thousand Metric Tons)	Productivity (Quintal/ ha)
1	Wheat	2002-03	129700	428284	32.99
2	Barley	2002-03	9806	31122	30.89
3	Gram	2002-03	1886	7447	10.47
4	Peas	2002-03	308	638	16.66
5	Masoor	2002-03	42	586	9.75
6	Arhar	2002-03	959	3422	8.52
7	Rai/Mustard	2002-03	55055	90695	11.88
8	Rice	2002-03	858	1900	16.75
9	Corn	2002-03	111	518	11.77
10	Bajra	2002-03	254	154781	15.93

Table 2.1. Water sample locations in the Agra district

S. No.	Location	Latitude	Longitude
1	Agra	27°10'36.01"N	78°0'29.07"E
2	Achhanera	27°10'38.53"N	77°45'13.65"E
3	Akola	27°3'53.31"N	77°52'54.28"E
4	Bah	26°52'17.42"N	78°35'29.88"E
5	BarauliAhir	27°7'27.19"N	78°3'29.02"E
6	Bichpuri	27°10'26.49"N	78°3'29.02"E
7	Etmadpur	27°13'59.93"N	78°11'57.08"E
8	Fatehabad	27°1'19.82"N	78°18'26.65"E
9	FatehapurSikari	27°5'40.30"N	77°40'4.55"E
10	Jagner	26°51'51.84"N	77°36'12.56"E
11	JaitpurKalan	26°48'33.10"N	78°43'9.40"E
12	Khairagarh	26°57'14.21"N	77°49'21.02"E
13	Khandouli	27°18'40.95"N	78°1'45.27"E
14	Pinahat	26°53'2.02"N	78°22'17.12"E
15	Saiyan	26°57'13.30"N	77°56'43.11"E
16	Shamsabad	27°1'0.50"N	78°7'25.17"E

CHAPTER 4: METHODOLOGY

The physico-chemical analysis is performed as per the standard methods (APHA, 1992). To check the results of laboratory analysis, ionic balance has also been done. A total number of eleven water quality parameters were selected. The details of various water quality parameters, analytical methods and equipments are given in Table 3.

Table 3. Details of analytical methods and equipments

S. No.	Parameter	Method	Equipment
1	pH	Electrometric	pH Meter
2	Conductivity	Electrometric	Conductivity Meter
3	TDS		Conductivity/TDS Meter
4	Bicarbonate	Titration by H_2SO_4	Titration
5	Sulphate	Turbidimetric	Turbidity Meter
6	Chloride	Titration by AgNO_3	Titration
7	Iron	Spectrophotometer	Spectrophotometer
8	Calcium	Titration by EDTA	Titration
9	Magnesium	Titration by EDTA	Titration
10	Sodium	Flame Emission	Flame Photometer
11	Hardness	Titration by EDTA	Titration

Description of Various Water Quality Parameters and Methods for their Measurement

In the present study, various water quality parameters as given in Table 2.2 are described in detail as follows:

pH

pH value is a measure of hydrogen ion concentration and is the negative exponent of the logarithm of the hydrogen ion concentration. A low pH solution has a high hydrogen ion concentration and is therefore, acidic while high pH solution is low in hydrogen ion concentration and is alkaline (pH 7 being neutral). pH dimensionless.

The pH value of natural water is an important index of acidity or alkalinity and is the resulting value of the acidic/basic interaction of a number of its mineral and organic components. In pure or slightly polluted water, the value of pH are determined mainly by the correlation between the concentrations of free carbon dioxide, bicarbonate and carbonate ions. This correlation, in turn depends substantially on the intensity of the process of photosynthesis and the biochemical oxidation of organic substances as well as on chemical conversions of some mineral substances.

pH of most natural waters range from 4 to 9 and are often slightly basic due to the presence of carbonates and bicarbonates. A major deviation from the normal pH for given water indicates the industrial wastes. Practically every phase of water supply and wastewater treatment, e.g., acid- base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control, is pH dependent.

The pH value of water may be determined potentiometrically by a wide variety of pH meters which are portable and battery operated or run by standard-line power. They are equipped with glass and reference electrodes which require standardizing with standard buffer solutions before each measurement in the field. Care must also be taken that the pH meters are stored in a dry place to prevent them from getting wet.

PROCEDURE:-

- i) For detailed instructions, follow manufacturer's manual, Standardise the pH meter by immersing the electrode in buffer solution of known pH. Read the pH and correctly, adjust with the control until the meter indicates the correct value for pH of buffer solution.
- ii) Remove electrodes from first buffer, rinse thoroughly with distilled water, blot dry with a soft tissue, and immerse in second buffer, the reading should be within 0.1 unit for the pH of the buffer. If the response shows a difference greater than 0.1 pH unit from expected value, look for trouble with the electrode or pH meter.
- iii) Rinse the electrodes in distilled water and immerse them in the sample. Let the reading stabilize. Read the pH value.

ELECTRICAL CONDUCTIVITY

Conductivity is a measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substance in the water. Solutions of most inorganic acids, bases and salts are relatively good conductors. Conductivity measurements are commonly used to determine the purity of demineralised water and total dissolved solids in boiler and cooling tower water. Electrical conductivity is generally measured in terms of $\mu\text{S}/\text{cm}$.

REAGENTS:-

- i) **Conductivity water:** Pass distilled water through a mixed bed deionizer and discard first liter. Conductivity should be less than $1\mu\text{mho}/\text{cm}$.
- ii) **Standard potassium chloride solution, 0.01 N:** Dissolve 745.6 mg anhydrous KCl in conductivity water and dilute to 1000 ml at 25°C . This is the standard reference solution, which at 25°C has a conductivity of $1413\mu\text{mho}/\text{cm}$. It is satisfactory for most samples when the cell has a constant between 1 and 2.

PROCEDURE:-

- i) For detailed instructions, follow manufacturer's manual, Standardise the EC meter by immersing the electrode in distilled water of known EC. Read the EC is 0, Remove electrodes from distilled water and immerse in KCL EC meter read $1413\mu\text{mho}/\text{cm}$.
- ii) Remove electrodes from KCL, rinse thoroughly with distilled water, blotdry with a soft tissue. Immerse them in the sample. Let the reading stabilize. Read the EC value.

TOTAL DISSOLVED SOLIDS (TDS)

Solids refer to matter suspended or dissolved in water or waste water. Solids may affect water or effluent quality adversely in a number of ways. Waters with high dissolved solids generally are of inferior palatability and induce an unfavourable physiological reaction in the transient consumer. For these reasons, a limit of 500 mg/L is desirable for drinking water. A well-mixed sample is filtered through a standard glass fibre filter, and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight at 180°C . The increase in dish weight represents the total dissolved solids (TDS). Total dissolved solids are determined using the equation given below and are expressed in terms of mg/L.

$$\text{TDS} = \text{EC} \times 0.64$$

BICARBONATE

Bicarbonate is a major element in our body. Bicarbonates are naturally produced by the gastric membrane in the stomach. This production will be low in alkaline conditions and will rise in response to acidity. In healthy individuals this adaptive mechanism will control the pH perfectly. Bicarbonate is measured in terms of mg/L.

$$\text{Bicarbonate} = \text{Alkalinity} \times 1.22$$

ALKALINITY:

REAGENTS:-

- **Methyl orange indicator:** Dissolve 0.5 g of methyl orange in 1 L of distilled water.
- **Phenolphthalein indicator:** Dissolve 5.0 g phenolphthalein in 1 L of 5.0% ethyl alcohol. Neutralize the solution with 0.02 N NaOH solutions.
- **Sulfuric acid, 0.02 N:** Prepare stock H_2SO_4 solution (approximately 0.1N) by diluting 3 ml H_2SO_4 to 1 L of distilled water. Dilute 20 mL of the 0.1 N stock solution to 1 L with distilled water. Standardise the 0.02 N acid against 0.02 N sodium carbonate solutions.

PROCEDURE:-

- Take 100 ml sample in a conical flask and add 2-3 drops of phenolphthalein indicator and swirl to mix.
- Add 2-3 drops methyl orange indicator to the titrated solution and swirl to mix. Continue titration with sulfuric acid standard solution, 0.02 N, yellow to a pink colour or pH comes down to 4.5. Note the volume of sulfuric acid used.

$$\text{Alkalinity, as CaCO}_3(\text{mg/L}) = \frac{A \times 1000}{\text{Volume of sample, ml}}$$

Where, A = volume of sulfuric acid used.

SULPHATE

Sulphate appears in natural waters in a wide range of concentrations. Mine waters and industrial effluents frequently contain large amounts of sulphate from pyrite oxidation and the use of sulfuric acid. Sodium and magnesium sulphate exert cathartic action and hence its concentration above 250 mg/L in potable water is objectionable. Sulphate causes a problem of

scaling in industrial water supplies, and problem of odour and corrosion in wastewater treatment due to its reduction to hydrogen sulphide. Sulphate is measured in terms of mg/L.

REAGENTS:-

Buffer Solution: Dissolve 30 g magnesium chloride, $MgCl_2 \cdot 6H_2O$, 5 g sodium acetate, $CH_3COONa \cdot 3H_2O$, 1 gm. potassium nitrate, KNO_3 , and 20 ml acetic acid, CH_3COOH (99%), in 500 ml distilled water and make up to 1000mL.

Barium chloride crystals: 20 to 30 mesh.

PROCEDURE:-

- (i) Take 100 mL sample, or suitable portion made up to 100 ml, into a 250 ml flask. Add 20 ml buffer solution and mix in stirring apparatus. Add barium chloride crystals while stirring. Continue stirring for 1 minute after addition of barium chloride.
- (ii) Measure the turbidity developed after five minutes on colorimeter at 420 nm.
- (iii) Prepare standard curve by carrying standard sulphate solution through entire procedure. Space standards at 5 mg/L increment in the 0 to 40 mg/L range. Above 40 mg/L accuracy decreases and barium sulphate suspension loss stability.
- (iv) Read the concentration of sulphate present in the sample from the standard curve.

CHLORIDE

Chloride is one of the major inorganic anions in water and wastewater. Chlorides are present in all potable water supplies and in sewage, usually as a metallic salt. When sodium is present in drinking water, chloride concentrations in excess of 250 mg/L give a salty taste. If the chloride is present as calcium or magnesium salt, the taste detection level may be as high as 1000 mg/L. Chloride is measured in terms of mg/L.

Chloride is essential in the diet and passes through the digestive system unchanged to become one of the major components of raw sewage. The wide use of zeolite in water softeners also contributes a large amount of chloride to sewage and wastewaters.

High chloride concentrations in water are not known to have toxic effects on human, though large amounts may act corrosively on metal pipes and be harmful to plant life. The maximum allowable chloride concentration of 250 mg/L in drinking water has been established for reasons of taste rather than as a safeguard against physical hazard.

REAGENTS

- (i) **Potassium chromate indicator:** Dissolve 50 g of potassium chromate in a small quantity of distilled water. Add AgNO_3 solution to produce a light red precipitate. Allow to stand overnight and filter. Make up to 1 L.
- (ii) **N/35.5 Silver nitrate solution:** Dissolve 4.78 g of silver nitrate in 1 L of distilled water. Standardise with standard sodium chloride solution.

PROCEDURE:-

- (I) Take 100 mL sample in a conical flask. If the sample is highly coloured, add 3 mL aluminium hydroxide suspension, mix well, allow to settle and filter. If sulphide, sulphite or thiosulfate is present, add 1 mL hydrogen peroxide and stir for 1 minute.
- (II) Adjust the pH of sample between 7.0 and 10.0 if it is not in this range and add 1.0 mL potassium chromate indicator solution.
- (III) Titrate with standard silver nitrate solution, N/35.5, to a pinkish yellow end point. Note the volume of silver nitrate solution used. Place the same quantity of chloride free distilled water in another flask and establish reagent blank value by the titration method outlined above. A view of pinkish to yellow colour for chloride analysis.

$$\text{Chloride mg/l} = \frac{(A - B) \times 1000}{\text{Volume of Sample, mL}}$$

A = Volume of AgNO_3 , used for sample, mL, and

B = Volume of AgNO_3 used for blank, mL,

IRON

Iron in drinking water can be objectionable because it gives a rusty colour to laundered clothes and may affect taste. Frequently found in water due to large deposits in the earth's surface, iron can also be introduced into drinking water from iron pipes in the water distribution system. In the presence of hydrogen sulfide, iron causes a sediment to form that may give the water a blackish colour. The Illinois Environmental Protection Agency (IEPA) has established a maximum concentration for iron in drinking water of 1.0 mg/L. Iron, as it exists in natural groundwater, is in the soluble (ferrous) state but, when exposed to oxygen, is converted into the insoluble (ferric) state with its characteristic reddish brown or rusty colour. If allowed to stand

long enough, this rusty sediment will usually settle to the bottom of a container; however, it is difficult to use this type of settling to remove the iron. Iron is measured in terms of mg/L.

REAGENT:-

- 1) FerroZine® Iron Reagent Solution Pillow.

PROCEDURE:-

- (i) Operate the Spectrophotometer Press STORED PROGRAMS.
- (ii) Fill a clean 25-mL graduated mixing cylinder to the 25-mL mark with sample.
- (iii) **Prepared Sample:** Add the contents of one FerroZine® Iron Reagent Solution Pillow to the mixing cylinder. Press TIMER>OK. A five-minute reaction period will begin. A purple colour will develop if iron is present.
- (iv) **Blank Preparation:** Fill a square sample cell with 10 mL of sample. When the timer expires, pour 10 mL of the prepared sample into a second clean square sample cell. Insert the blank into the cell holder with the fill line facing right. Press ZERO. The display will show: 0.000 mg/L Fe.
- (v) Insert the prepared sample into the cell holder with the fill line facing right. Press READ. Results are in mg/L Fe.

CALCIUM

The ion Ca^{2+} is also the fifth-most-abundant dissolved ion in sea water by both molarity and mass, after sodium, chloride, magnesium, and sulphate. Water, described as "hard", is high in dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral build-up on fixtures and poor soap and/or detergent performance. Calcium is measured in terms of mg/L.

REAGENT:-

- (i) **Sodium hydroxide 2N:** Dissolve 80 g NaOH and dilute to 1 L.
- (ii) **Standard EDTA solution, 0.01 M:** Dissolve 3.723g EDTA sodium salt and dilute to 1000 mL. Standardize against standard calcium solution, 1 mL=1mg CaCO_3 .

PROCEDURE:-

- (i) Take 100 ml water sample in a conical flask and add to 1 ml sodium hydroxide solution to raise the pH to 12.0 and a pinch of murex indicator.
- (ii) Titrate with standard EDTA solution, 0.01M, till pink colour changes to purple. Note the volume of EDTA used.

$$\text{Calcium Hardness, mg/l} = \frac{B \times C}{\text{Volume of sample, ml}}$$

B = Volume of EDTA solution used with murex indicator, ml, and,

C = mg CaCO₃ equivalent to 1.0 ml EDTA titrant.

MAGNESIUM

Magnesium is a chemical element with symbol “Mg” and atomic number 12. Magnesium is the fourth most abundant cation in the human body and the second most abundant cation in intracellular fluid. It is a cofactor for some 350 cellular enzymes, many of which are involved in energy metabolism. It is also involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of Creatinine protein and decreased insulin sensitivity. Low magnesium status has been implicated in hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome. Magnesium is measured in terms of mg/L.

$$\text{Magnesium Hardness, mg/l} = [\text{Total Hardness} - \text{Calcium Hardness}] \times 0.243$$

SODIUM

Sodium ranks sixth among the elements in order of abundance and is present in most natural waters. Relatively high concentrations may be found in brines and hard water softened by the sodium exchange process. The ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio. Persons afflicted with certain diseases require water with low sodium concentration. A limiting concentration of 2 to 3 mg/L is recommended in feed water destined for high-pressure boilers. When necessary, sodium can be removed by the hydrogen-exchange process or by distillation. Sodium compounds are used in many applications, including caustic soda, salt fertilizers and water treatment chemicals, and represent the total dissolved solids. Sodium is measured in terms of mg/L.

PROCEDURE:-

Pre-treatment of polluted water and wastewater samples: Filter the sample passing through 0.45µm membrane filter.

Direct-intensity measurement: Prepare a blank and sodium calibration standards in stepped amounts in any of the following applicable ranges: 0 to 1.0, 0 to 10, or 0 to 100 mg/L. Starting with the highest calibration standard and working toward the most dilute, measure emission at 589 nm. Repeat the operation with both calibration standards and samples enough times to secure a reliable average reading for each solution. Construct a calibration curve from the sodium standards. Determine sodium concentration of sample from the calibration curve. Where a large number of samples must be run routinely, the calibration curve provides sufficient accuracy.

Internal-standard measurement: To a carefully measured volume of sample (or diluted portion), each sodium calibration standard and a blank, add with a volumetric pipette, an appropriate volume of standard lithium solution. Measure the intensity directly.

Bracketing approach: From the calibration curve, select and prepare sodium standards that immediately bracket the emission intensity of the sample. Determine emission intensities of the bracketing standards (one sodium standard slightly less and the other slightly greater than the sample) and the sample as nearly simultaneously as possible. Repeat the determination on bracketing standards and sample. Calculate the sodium concentration by the equation formed by standard calibration curve.

TOTAL HARDNESS

The Hardness of water was originally defined in terms of its ability to precipitate soap. Calcium and magnesium ions are the principle causes although iron, aluminium, manganese, strontium, zinc and hydrogen ions are capable of producing the same effect. High concentrations of the latter ions are not commonly found in natural waters. In conformity with current practice, total hardness is defined as characteristic of water which represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent. Hardness is measured in terms of mg/L.

Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium. Permanent hardness is mostly due to sulphate. When the total hardness has a value greater than total alkalinity, the amount of hardness equivalent to the alkalinity is called carbonate hardness and the excess amount is non-carbonate hardness. When total hardness is equal or less than the total alkalinity, there is no carbonate hardness.

REAGENT:-

- (iii) **Inhibitor:** Dissolve 4.5 g hydroxyl amine hydrochloride in 100 ml 95% ethyl alcohol.
Eriochrome black T indicator: Mix 0.5 g dye with 100 g NaCl to prepare dry powder or dissolve 0.19 of Eriochrome black T in 20 mL of ethyl alcohol.
- (iv) **Sodium hydroxide 2N:** Dissolve 80 g NaOH and dilute to 1 L.
- (v) **Standard EDTA solution, 0.01 M:** Dissolve 3.723g EDTA sodium salt and dilute to 1000 mL. Standardize against standard calcium solution, 1 mL=1mg CaCO₃.

PROCEDURE:-

- (i) Take 100 ml water sample in a conical flask and add to it 1-2 mL buffer solution followed by 1 mL inhibitor.
- (ii) Add 2 drops Eriochrome black T indicator and titrate with standard EDTA solution, 0.01 M, till wine red colour changes to blue. Note the volume of EDTA used.
- (iii) In another flask take 100 mL sample and add 1 ml sodium hydroxide solution to raise the pH to 12.0 and a pinch of murex indicator.
- (iv) Titrate with standard EDTA solution, 0.01M, till pink colour changes to purple. Note the volume of EDTA used.

$$\text{Total Hardness, mg/l} = \frac{A \times C}{\text{Volume of sample, ml}}$$

$$\text{Calcium Hardness, mg/l} = \frac{B \times C}{\text{Volume of sample, ml}}$$

A = Volume of EDTA solution used with Eriochrome black T indicator.

B = Volume of EDTA solution used with murex indicator, ml, and,

C = mg CaCO₃ equivalent to 1.0 ml EDTA titrant.

$$\text{Magnesium Hardness, mg/l} = [\text{Total Hardness} - \text{Calcium Hardness}] \times 0.243$$

SODIUM ABSORPTION RATIO (SAR)

SAR is the most commonly used for evaluating groundwater suitability for irrigation purposes. SAR values in irrigation waters have a close relationship with the extent to which Na is absorbed by soils. If water used for irrigation is high in Na and low in Ca, the ion exchange complex may become saturated with Na, which destroys soil structure because of dispersion of clay particles. As a result, the soil tends to become deflocculated and relatively impermeable. Such soils become very difficult to cultivate.

Sodium adsorption ratio can indicate the degree to which irrigation water tends to enter into cation-exchange reaction in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious. The SAR is a ratio of the concentration of sodium ions to the concentration of calcium plus magnesium ions. SAR can be written in the mathematical form as follows:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

Where, all the concentrations are expressed in meq/L. For the samples analyzed, the SAR value range from 0.05 to 0.3 and according to the SAR classification 100% of water sample falls in the excellent category, which can be used for irrigation on almost all soils.

SODIUM PERCENTAGE (Na%):

The sodium percentage is calculated as:

$$Na\% = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

where all the ionic concentrations are expressed in milliequivalent per liter.

Table 4. Classification of water suitability for irrigation for different values of SAR

S. No.	Type of Water and SAR	Quality	Suitability for Irrigation
1	Low sodium water SAR value: 0–10	Excellent	Suitable for all types of crops and all types of soils, except for those crops, which are sensitive to sodium.
2	Medium sodium water SAR value: 10–18	Good	Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soils.
3	High sodium water SAR value: 18–26	Fair	Harmful for almost all types of soil; Requires good drainage, high leaching gypsum addition.
4	Very high sodium water SAR value: above 26	Poor	Unsuitable for Irrigation.

If irrigation water contains relatively high amounts of bicarbonate ion, the bicarbonate can affect the calcium and magnesium concentration in a soil to which the water is applied. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilt. This will also lead to a decrease in infiltration and permeability of the soil leading to problems with crop production.

RESIDUAL SODIUM CARBONATE (RSC)

When the carbonate concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material which settles out of the water. This excess is denoted by residual sodium carbonate (RSC). The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate, as known from the black colour of the soil. Further, continued usage of high RSC waters affects crop yields also. RSC is calculated using the following equation:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Piper Trilinear Diagram:

The concept of hydrochemical facies can be used to denote the diagnostic chemical characteristics of water in hydrological system. The facies reflect the effect of chemical processes occurring between the mineral within the lithologic frame work and in the ground water. The diagram is useful in presenting graphically a group of analysis on the same plot.

The Piper trilinear diagram consists of two lower triangular fields at the left and right respectively and a central diamond-shaped field. All three fields have scales reading in 100 parts. The percentage reacting values of the three cations (Ca, Mg, Na+K) and three anions (HCO_3 , SO_4 , Cl) are plotted as a single point according to conventional trilinear coordinates at lower left and right triangles respectively. These are projected upwards parallel to the sides of the triangles to give a point in the central diamond-shaped field, which indicate the overall chemical character of the ground water. The position of this point indicates the relative composition of a ground water in terms of cation-anion pairs that correspond to the four vertices of the field. The three areas of plotting show the essential chemical character of ground water according to the relative concentrations of its constituents.

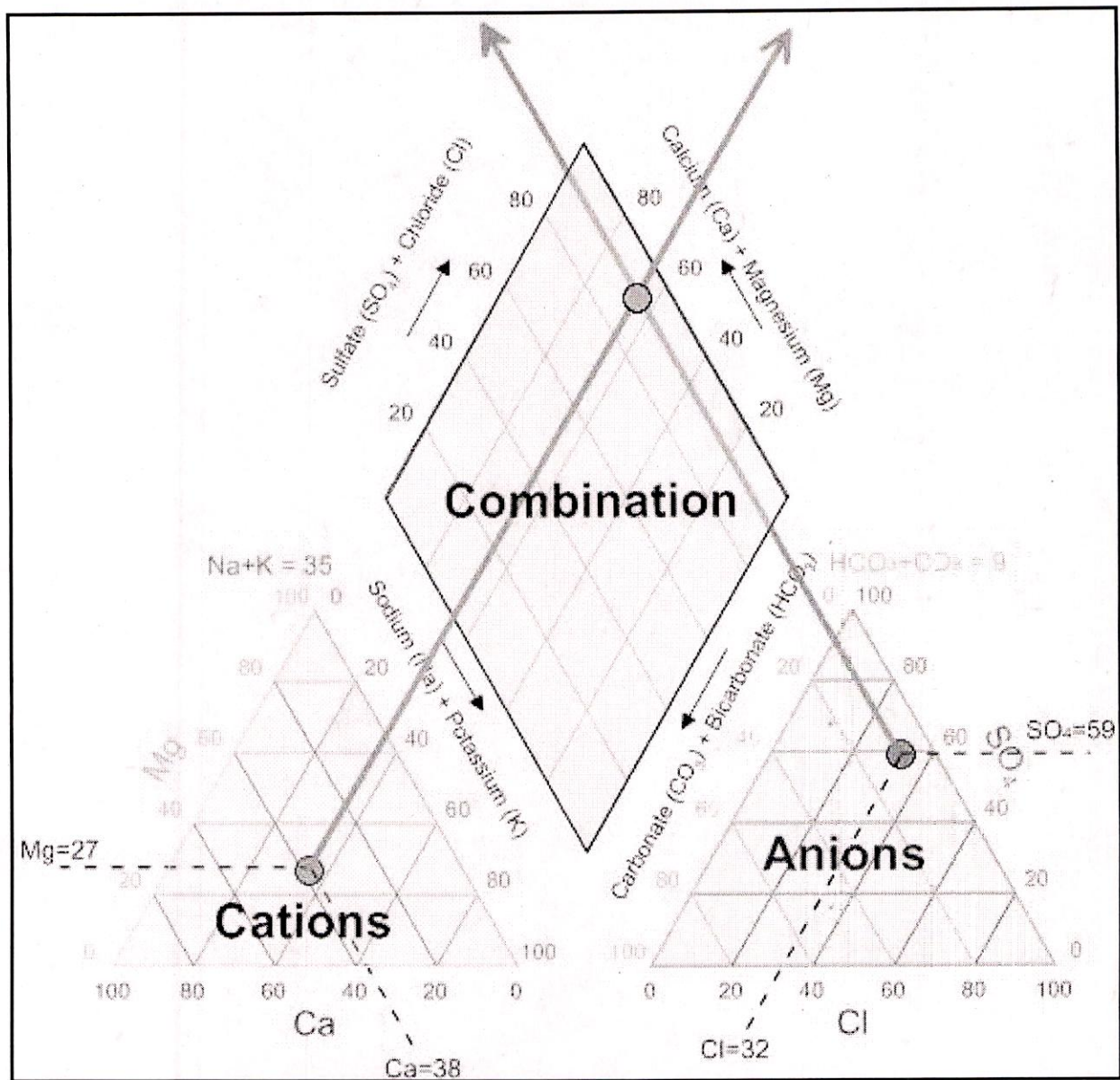


Figure 3.1. Representation of the Piper Trilinear Diagram

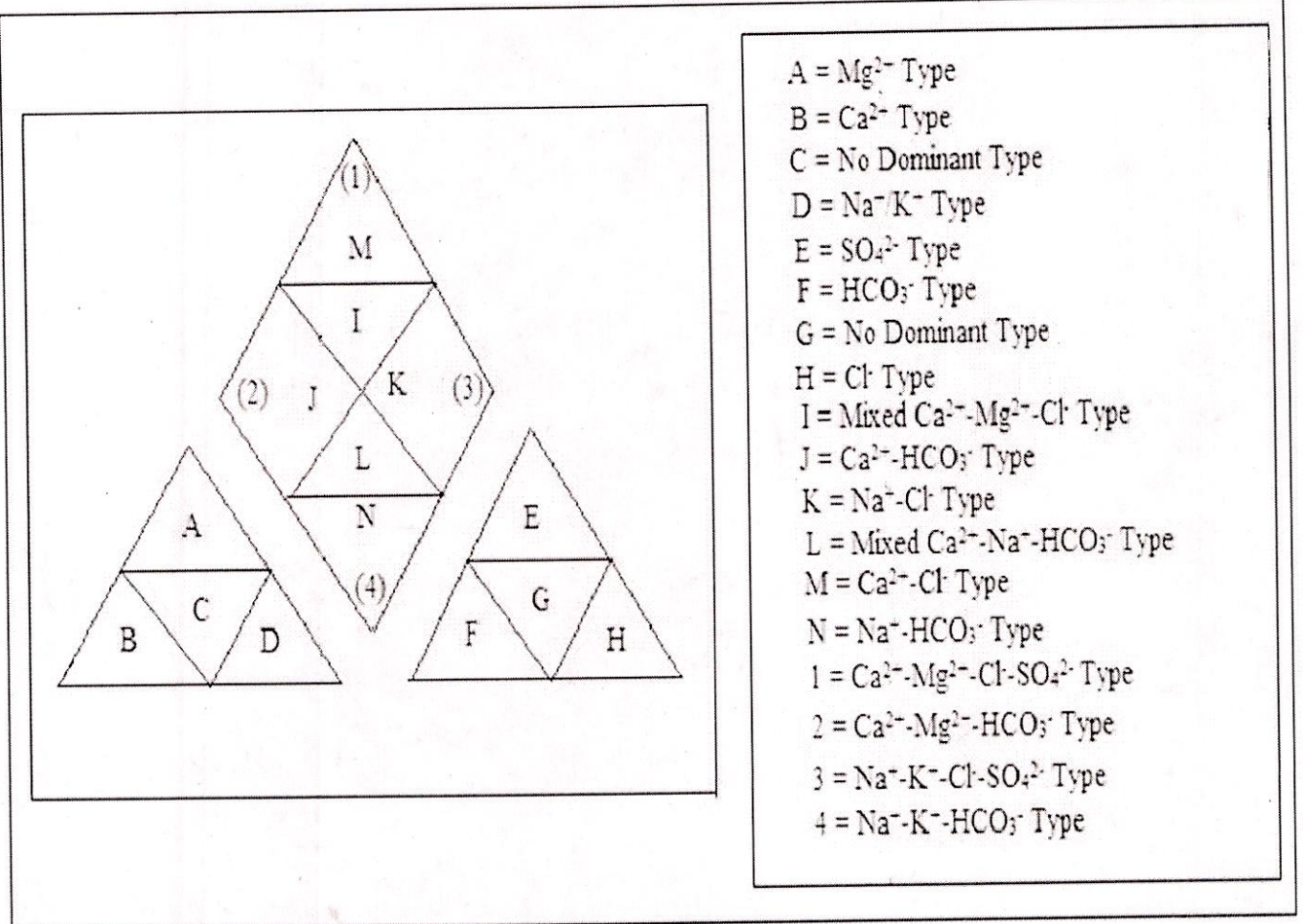


Figure 3.2. Facies of groundwater quality

CHAPTER 5: RESULTS AND DISCUSSION

In the present work, water quality characterization and assessment of suitability for the irrigation purpose has been done using the Wilcox and Piper diagrams, RSC, SAR and EC. For this purpose, groundwater quality data are collected from the Ground Water Department, Govt. of Uttar Pradesh. These data are collected for the period of nine years from 2006 to 2014 which include twelve water quality parameters viz. pH, EC, TDS, Cl^- , HCO_3^- , SO_4^- , Si, Fe, Al, Ca^{++} , Mg^{++} and Na^+ . The diagrams have been prepared using Aquachem 2011.1 software available at Centre of Excellence for Advanced Groundwater Research (CEAGR) at National Institute of Hydrology (NIH), Roorkee. Wilcox diagram plots conductivity on logarithmic scale on x-axis and SAR on the y-axis. The RSC and SAR values have been computed using the procedure described under methodology in Chapter 5.

Achhanera Block

The Wilcox and Piper diagrams for Achhanera block of Agra District are shown in Figure 3.3 and Figure 3.4 based on the water quality data for the period 2006 to 2014.

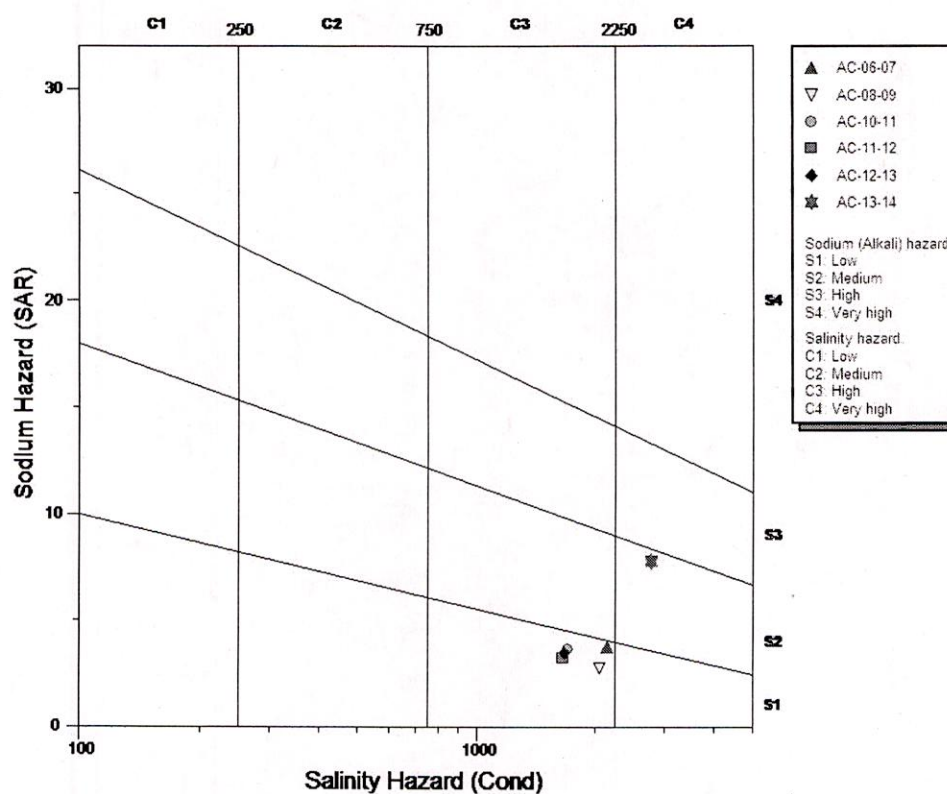


Figure3.3. Wilcox diagram for Achhanera block of Agra district

It is seen from Figure 3.3 that water quality data for the period 2006-2014 fall under S1 and S2 categories of Sodium Hazard and indicate Low to High Sodium. On the other hand, water sample data from 2006-13 falls in C3 class of Salinity Hazard indicating High Salinity except for the year 2013-14, which has C4 category such that the sample has Very High Salinity. In overall, the water of Achhanera block is characterized as C3S1 and C4S2.

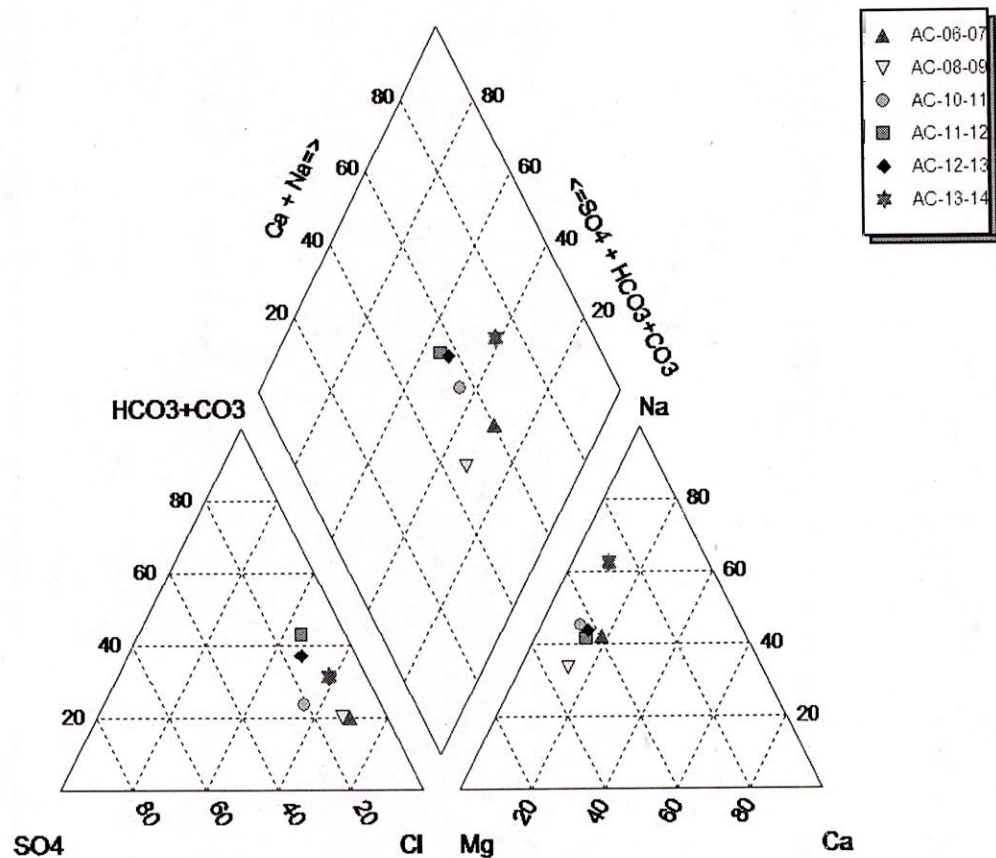


Figure3.4. Piper diagram for Achhanera block of Agra district

The Piper diagram for Achhanera block of Agra District is shown in Figure 3.4 based on the data from 2006 to 2014. It is seen from Figure 3.4 that for 2006-07 anions are 30% and cations are 60%, for 2008-09 anions are 37% and cations are 48%, for 2010-11 anions are 43% and cations are 58%, for 2011-12 anions are 58% and cations are 58%, for 2012-13 anions are 58% and cations are 59%, and for 2013-14 anions are 41% and cations are 71%.

In overall, data for the year 2006-07 and 2013-14 is $\text{Na}^+\text{-Cl}^-$ dominated; for 2008-09 is $\text{Ca}^{++}\text{-Na}^+\text{-HCO}_3^-$ dominated, and for 2010-13 is $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-Cl}^-$ dominated.

Akola Block

The Wilcox and Piper diagrams for Akola block of Agra District are shown in Figure 3.5 and Figure 3.6 for 2006-2014 data.

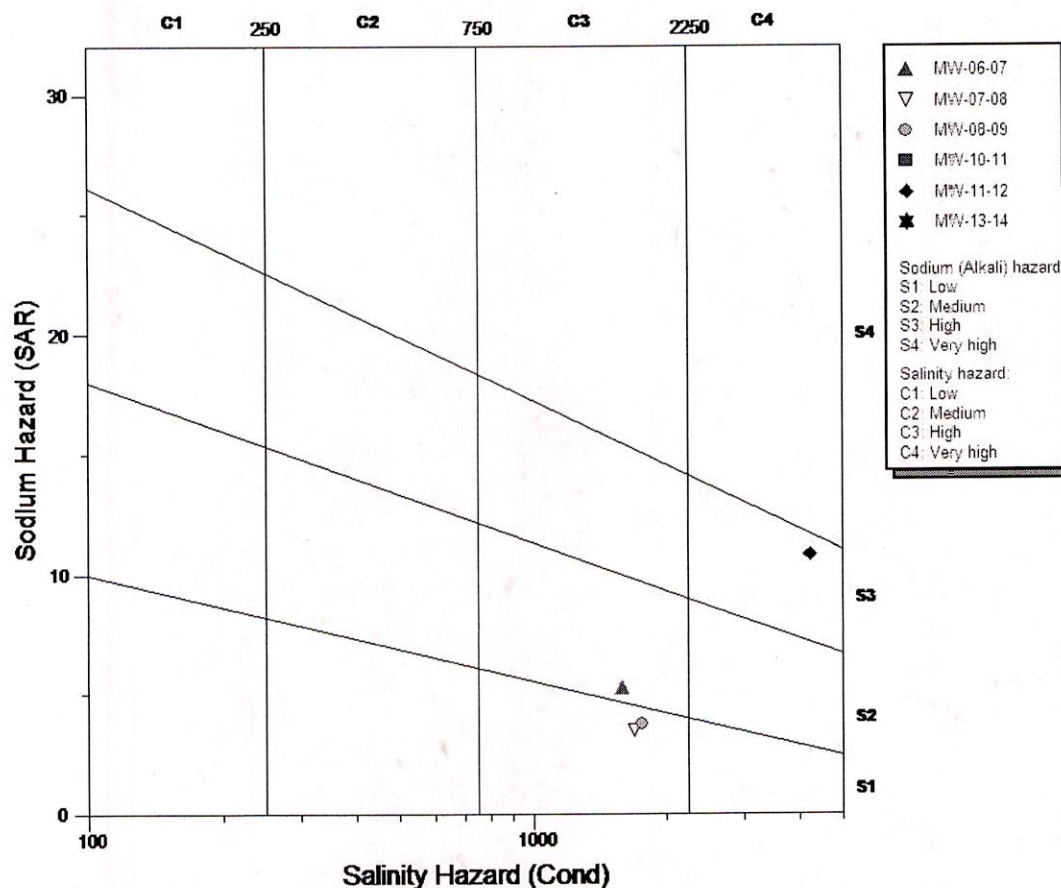


Figure 3.5. Wilcox diagram for Akola block of Agra district

It is seen from figure 3.5 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to High Sodium. On the other hand, water sample data from 2006-09 have C3 Salinity Hazard indicating High Salinity, except for the year 2010-11 has C4 category such that the sample has Very High Salinity. In overall, the water of Akola block is characterized as C3S1 and C4S2.

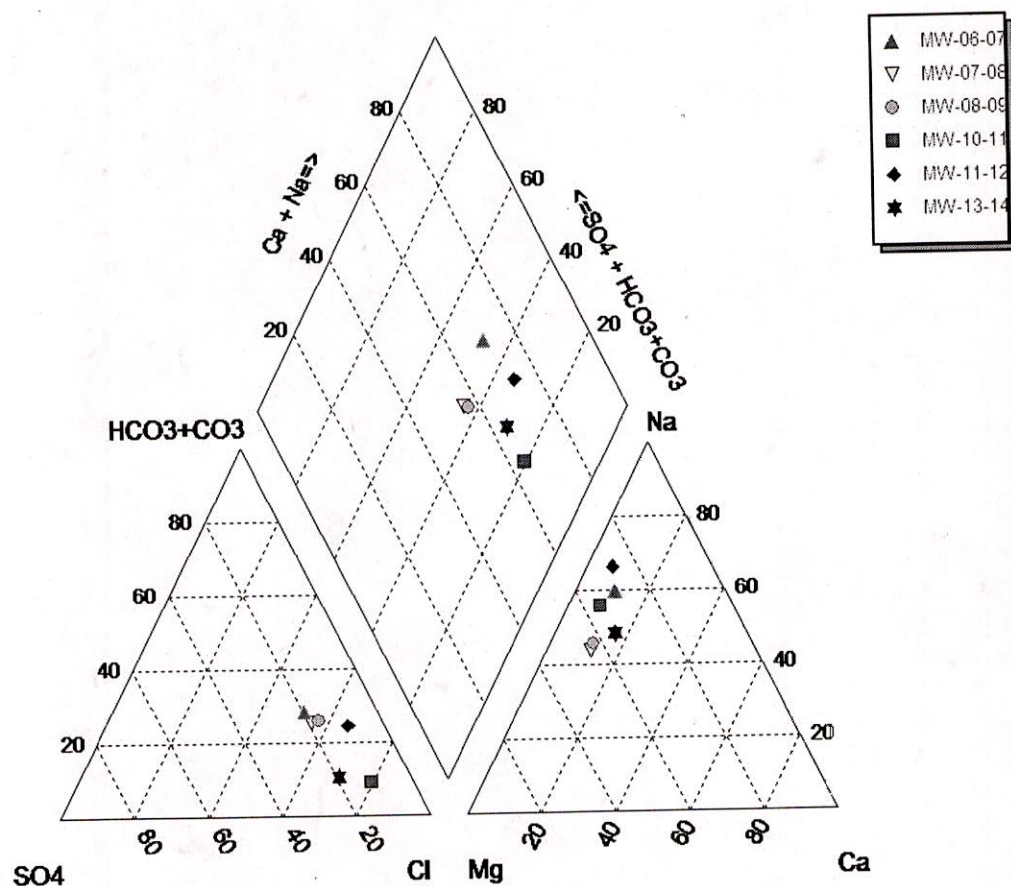


Figure3.6. Piper diagram for Akola block of Agra district

The Piper diagram for Akola block of Agra District is shown in Figure 3.6 for 2006-2014 data. It is seen from Figure 3.6 that for 2006-07 anions are 50% and cations are 70%, for 2007-08 anions are 42% and cations are 58%, for 2008-09 anions are 42% and cations are 58%, for 2010-11 anions are 20% and cations are 62%, for 2011-12 anions are 38% and cations are 76%, and 2013-14 anions are 30% and cations are 62%.

In overall, data for the year 2006-14 is Na^+ - Cl^- dominated.

Bah Block

The Wilcox and Piper diagrams for Bah block of Agra District are shown in Figure 3.7 and Figure 3.8 for 2006-2014 data.

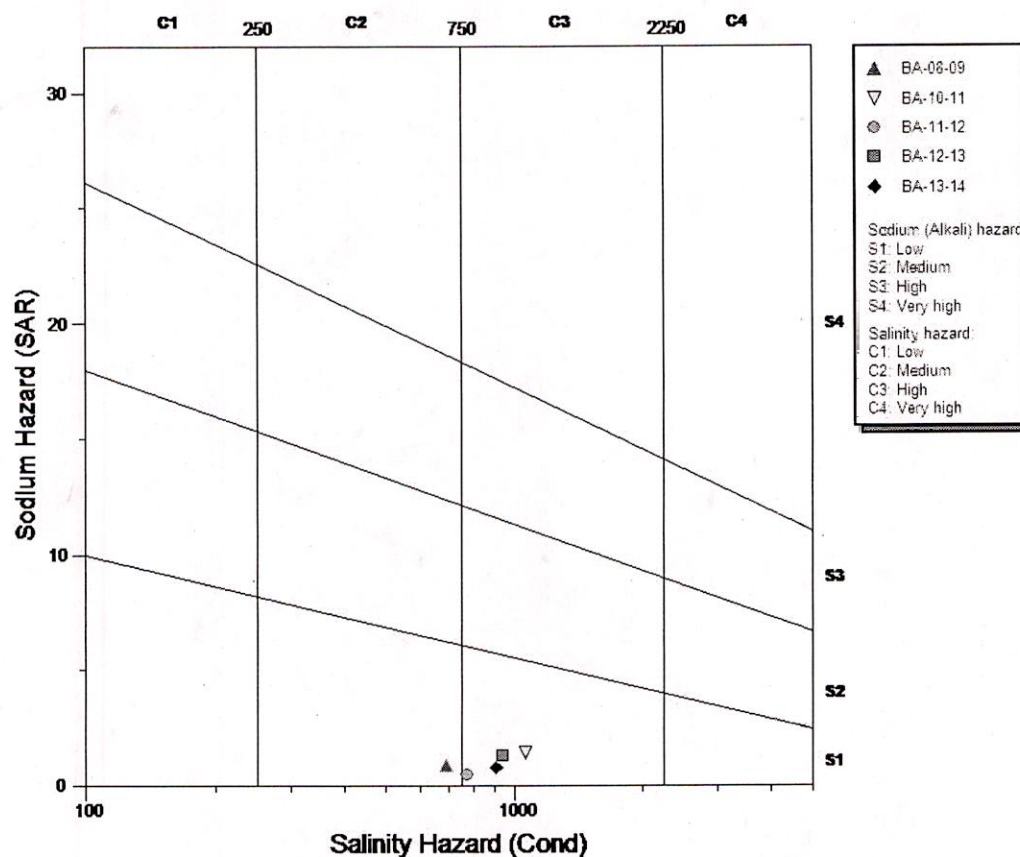


Figure 3.7. Wilcox diagram for Bah block of Agra district

It is seen from Figure 3.7 that water quality data for the period 2006-2014 falls under S1 categories of Sodium Hazard and has Low sodium. On the other hand, water sample data from 2008-14 have C2 to C3 Salinity Hazard indicating medium to high Salinity. In overall, the water of Bah block is characterized as C2S1 and C3S1.

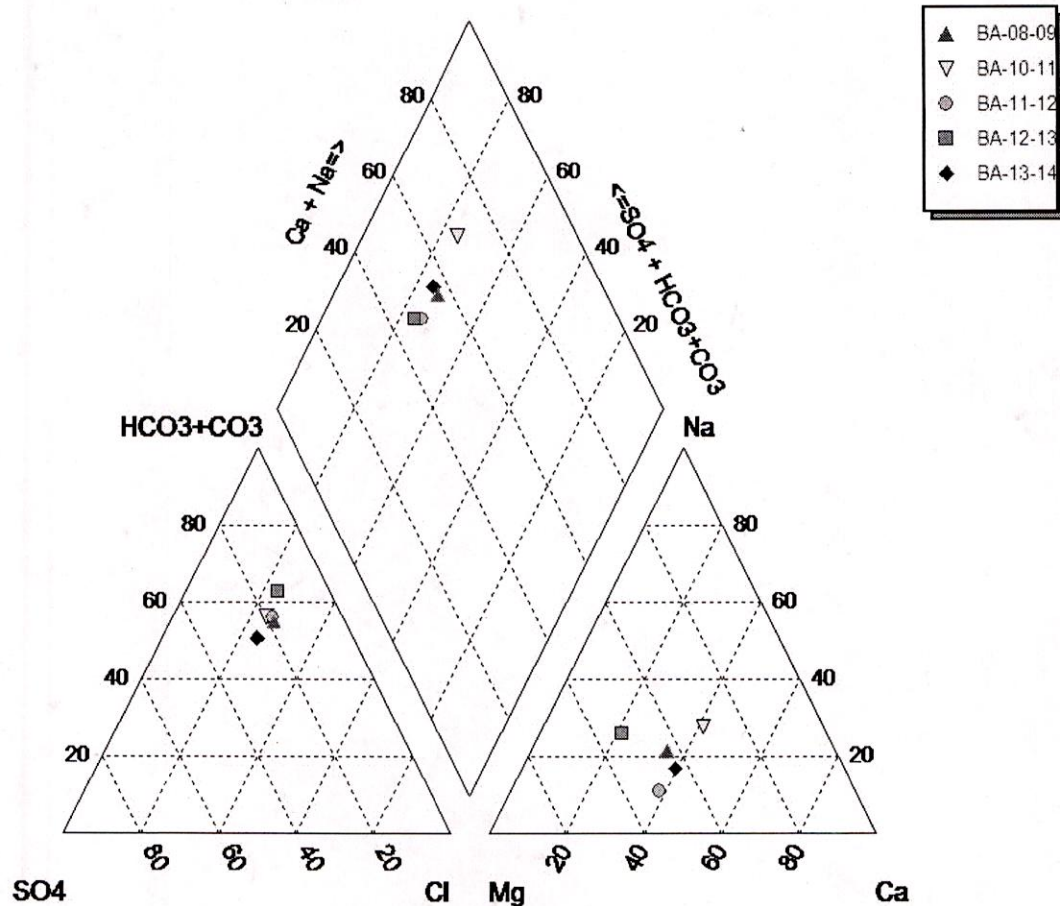


Figure 3.8. Piper diagram for Bah block of Agra district

The Piper diagrams for Bah block of Agra District are shown in Figure 3.8 based on the data from 2006-2014. It is seen from Figure 3.8 that for 2008-09 anions are 72% and cations are 58%, for 2010-11 anions are 78% and cations are 70%, for 2011-12 anions are 78% and cations are 50%, for 2012-13 anions are 78% and cations are 44%, and 2013-14 anions are 78% and cations are 58%.

In overall, data for the year 2008-14 is mixed and Ca²⁺-Mg²⁺-Cl⁻ is dominated.

Barauli Ahir Block

The Wilcox and Piper diagrams for Barauli Ahir block of Agra District are shown in Figure 3.9 and Figure 3.10 for 2006-2014 data.

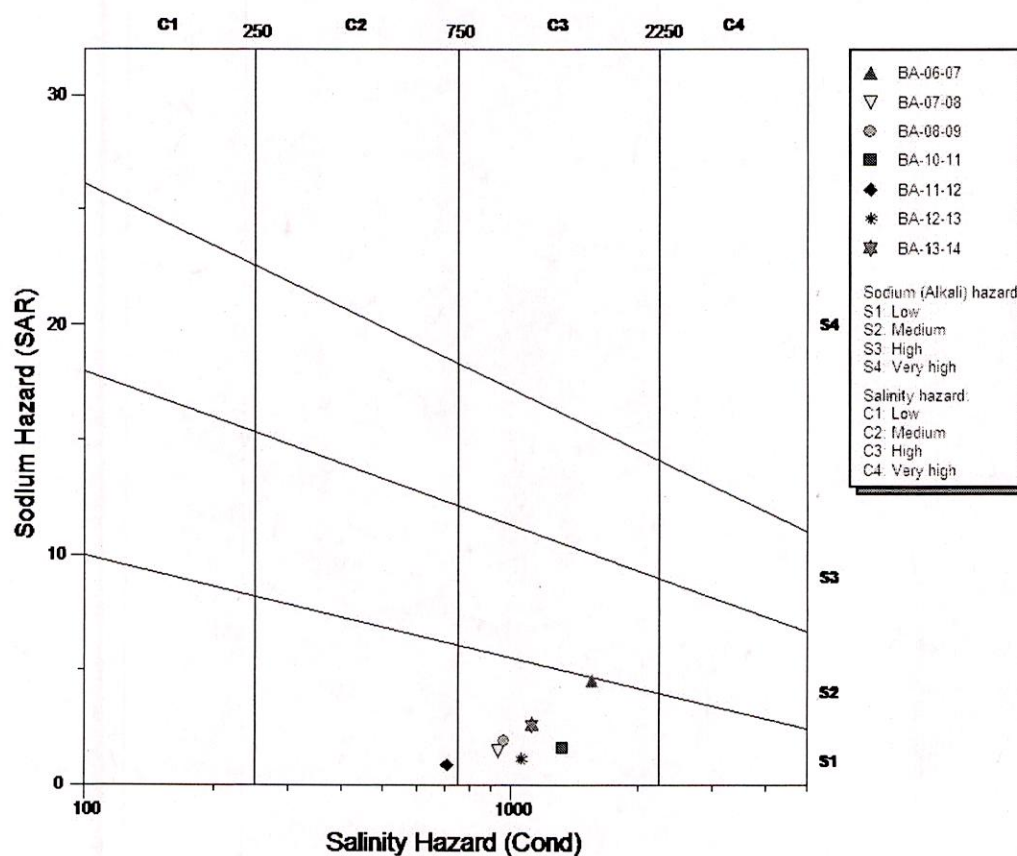


Figure 3.9. Wilcox diagram for Barauli Ahir block of Agra district

It is seen from Figure 3.9 that water quality data for the period 2006-2014 falls under S1 categories of Sodium Hazard and have Low sodium. On the other hand, water sample data for 2011-12 have C2 Salinity Hazard indicating medium Salinity, and for the year 2006-11 and 2012-14 have C3 category such that the samples have High Salinity. In overall, the water of Barauli Ahir block is characterized as C2S1 and C3S1.

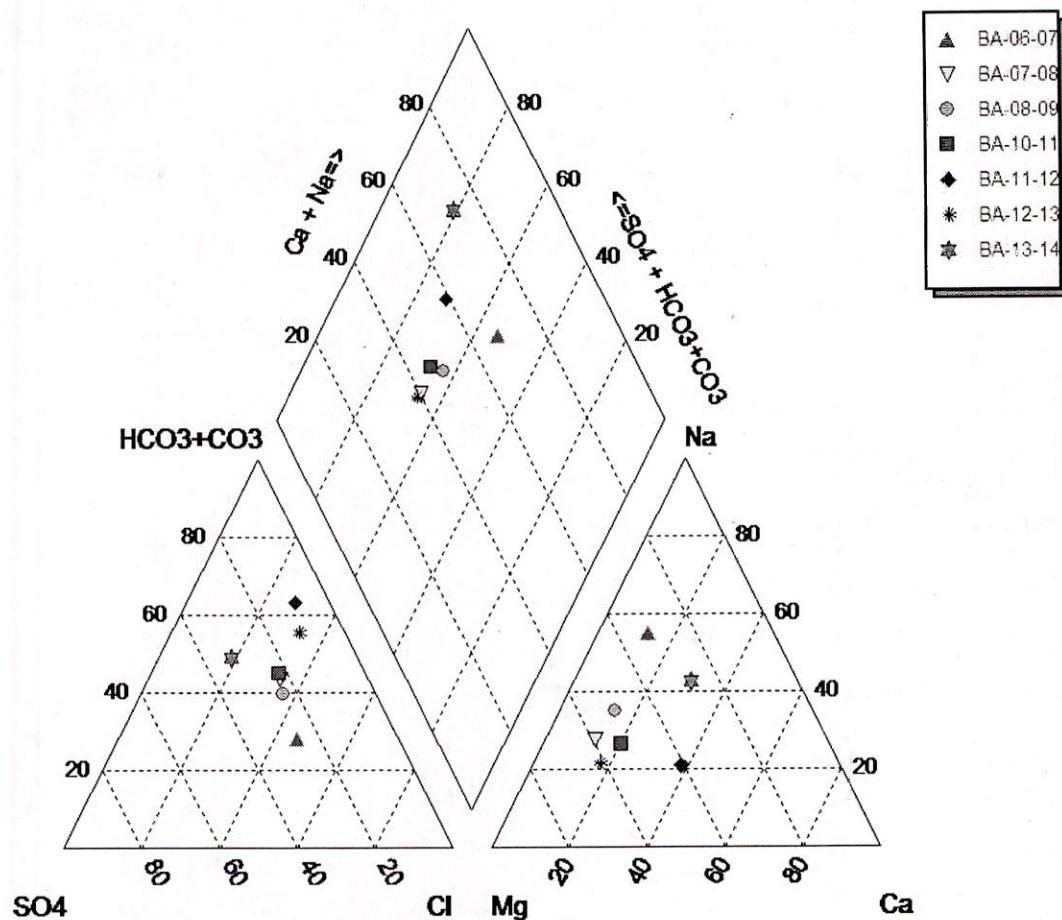


Figure 3.10. Piper diagram for Barauli Ahir block of Agra district

The Piper diagram for Barauli Ahir block of Agra District is shown in Figure 3.10 based on the data from 2006-2014. It is seen from Figure 3.10 that for 2006-07 anions are 58% and cations are 54%, for 2007-08 anions are 64% and cations are 42%, for 2008-09 anions are 62% and cations are 50%, for 2010-11 anions are 70% and cations are 45%, for 2011-12 anions are 72% and cations are 60%, and 2012-13 anions are 70% and cations are 40%, for 2013-14 anions are 80% and cations are 70%.

In overall, data for the year 2006-07, 2008-09 and 2010-12 are Mixed $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-Cl}^-$ Type, 2007-08 and 2012-13 are $\text{Ca}^{2+}\text{-HCO}_3^-$ Type and 2013-14 are $\text{Ca}^{2+}\text{-Cl}^-$ Type.

Bichpuri Block

The Wilcox and Piper diagrams for Bichpuri block of Agra District are shown in Figure 3.11 and Figure 3.12 for 2006-2014 data.

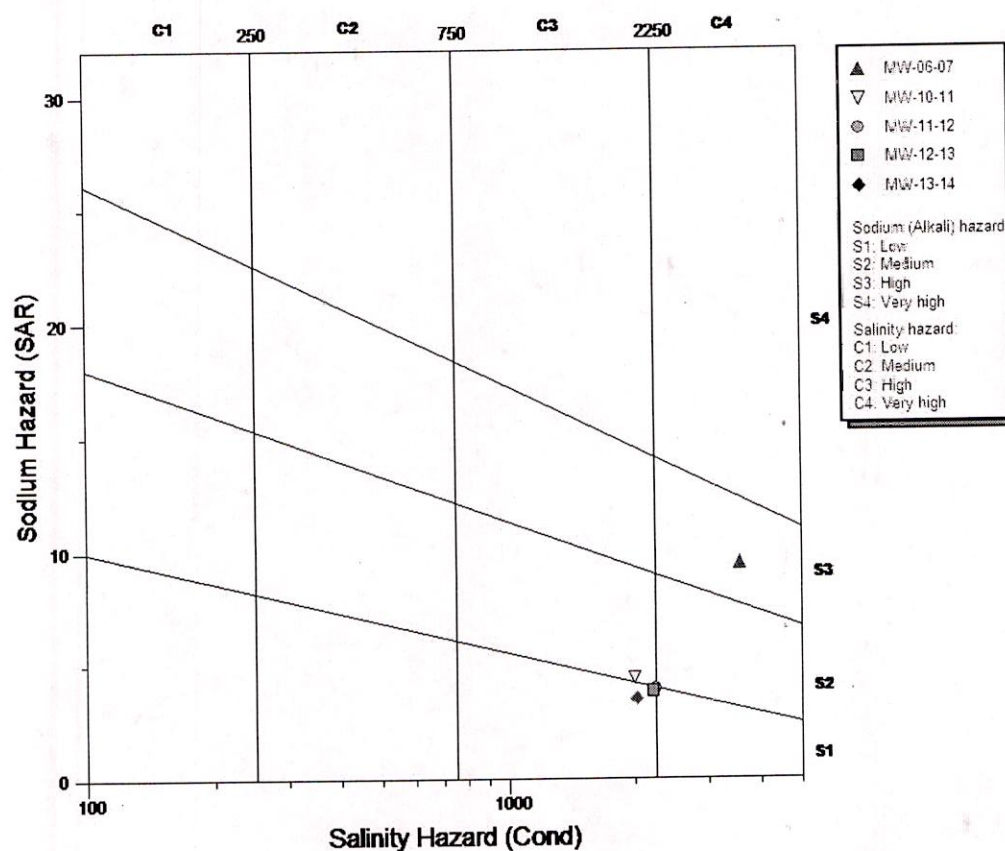


Figure 3.11. Wilcox diagram for Bichpuri block of Agra district

It is seen from Figure 3.11 that water quality data for the period 2006-2007 falls under S3 categories of Sodium Hazard and have High sodium, while data for all other years fall under S1 and S2 category which indicate Low to Medium Sodium hazard. On the other hand, water sample data for the year 2006-11 and 2012-14 has C3 category such that the samples have High Salinity, except for 2011-12 which has C4 Salinity Hazard indicating medium Salinity.

In overall, the water of Bichpuri block is characterized as C3S1, C3S2 and C4S3.

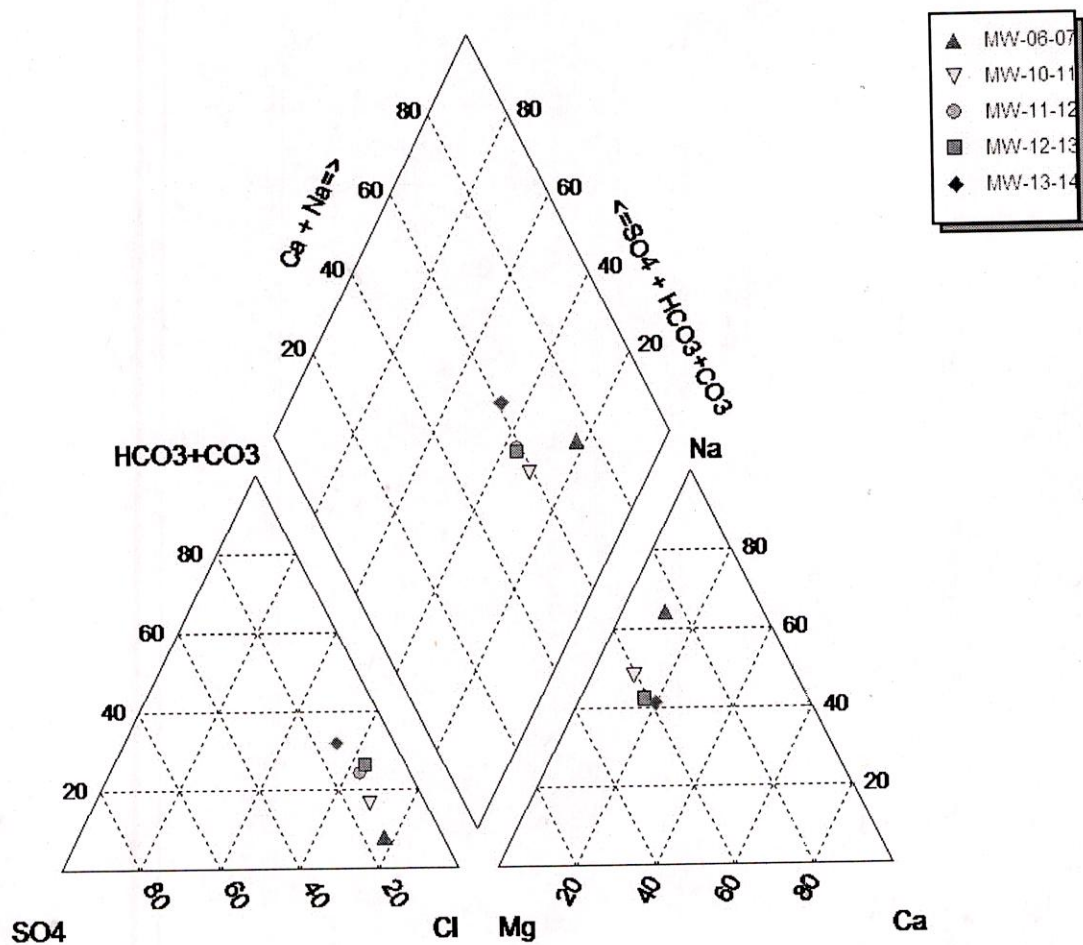


Figure3.12: Piper diagram for Bichpuri block of Agra district

The Piper diagram for Bichpuri block of Agra District is shown in Figure 3.12 for 2006-2014 data. It is seen from Figure 3.12 that for 2006-07 anions are 23% and cations are 75%, for 2010-11 anions are 25% and cations are 60%, for 2011-12 anions are 38% and cations are 60%, 2012-13 anions are 38% and cations are 60%, and 2013-14 anions are 48% and cations are 60%.

It is seen from Figure3.12 that for 2006-07 and 2010-14 water is $\text{Na}^+ - \text{Cl}^-$ Type.

Etmadpur Block

The Wilcox and Piper diagrams for Etmadpur block of Agra District are shown in Figure 3.13 and Figure 3.14 for 2006-2014 data.

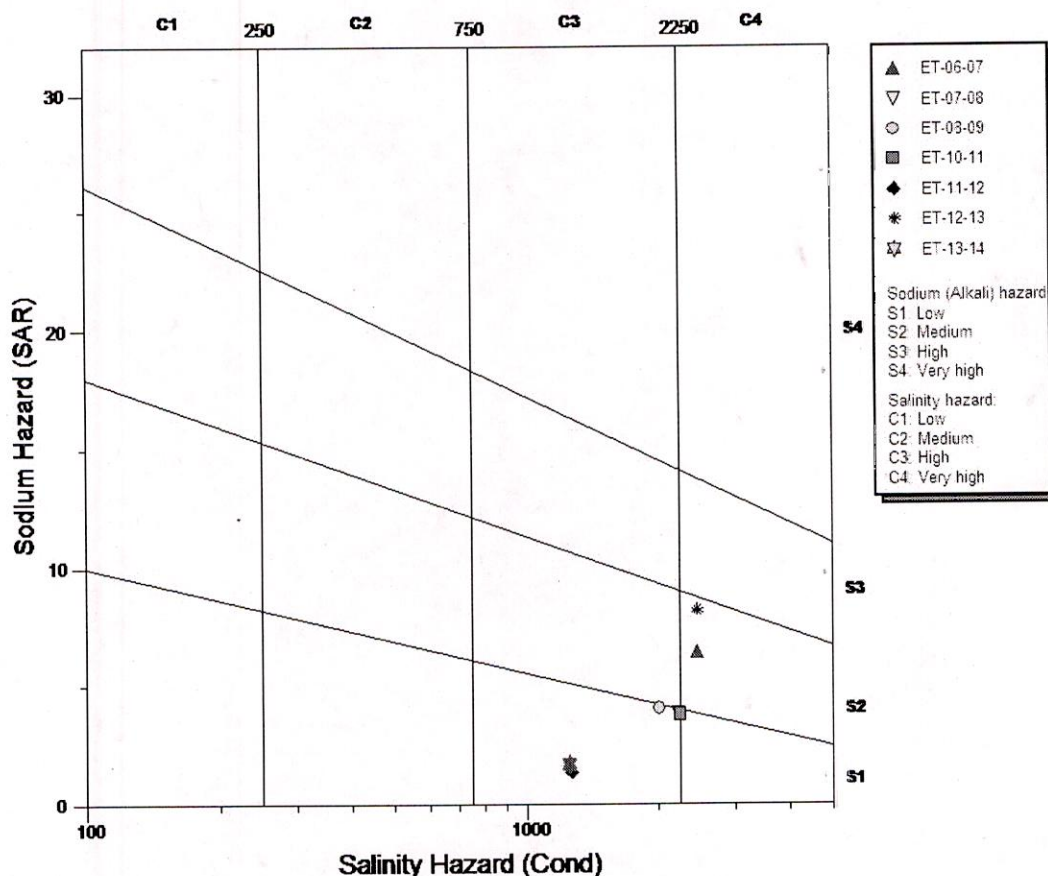


Figure 3.13. Wilcox diagram for Etmadpur block of Agra district

It is seen from Figure 3.13 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to Medium Sodium. On the other hand, water sample data for 2007-12 have C3 Salinity Hazard indicating High Salinity, except for the year 2006-07 and 2013-14 which have C4 category such that the samples have Very High Salinity.

In overall, the water of Etmadpur block is characterized as C3S1 and C4S2.

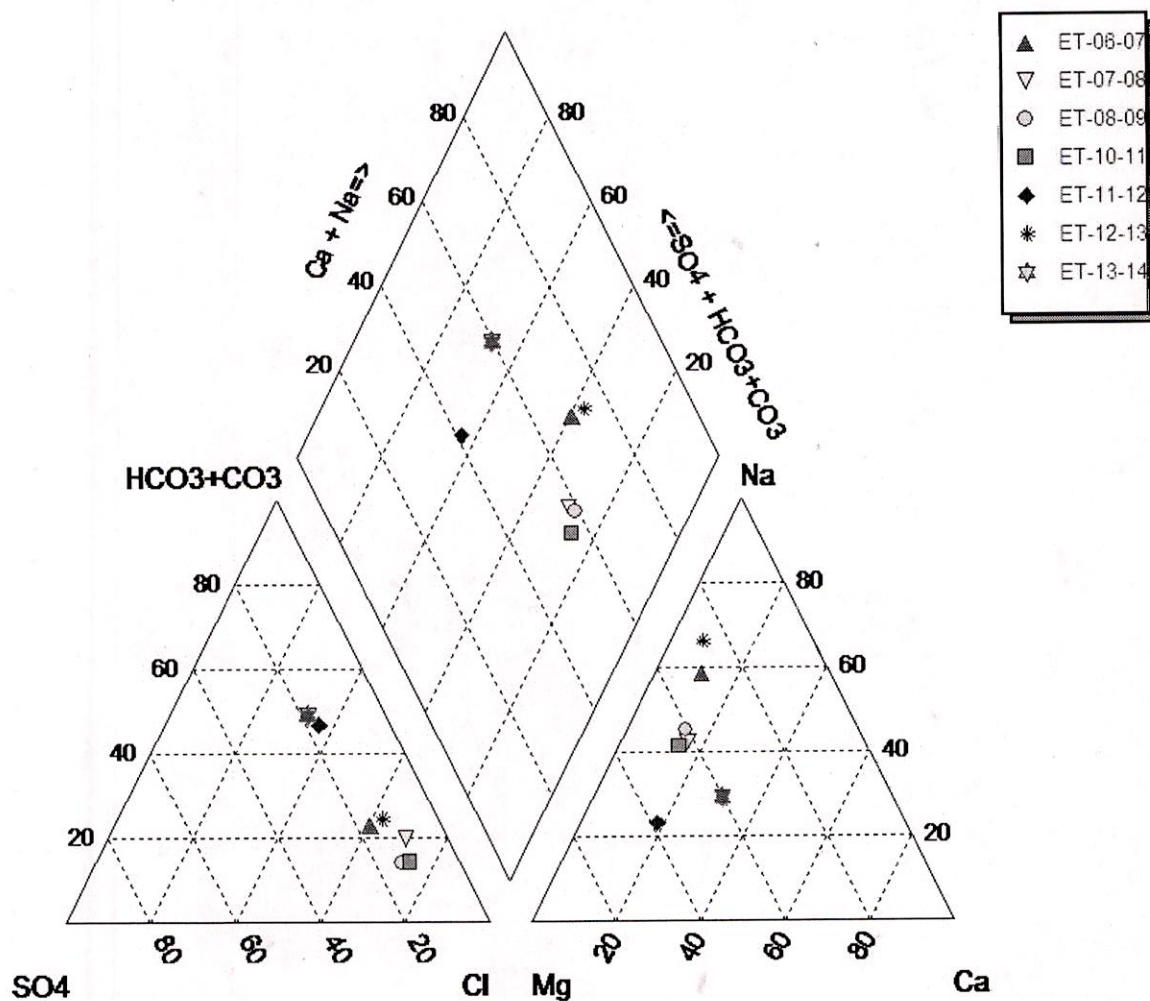


Figure 3.14. Piper diagram for Etmadpur block of Agra district

The Piper diagram for Etmadpur block of Agra District is shown in Figure 3.14 for 2006 to 2014. It is seen from Figure 3.14 that for 2006-07 anions are 39% and cations are 68%, for 2007-08 anions are 30% and cations are 59%, for 2008-09 anions are 28% and cations are 59%, for 2010-11 anions are 28% and cations are 58%, for 2011-12 anions are 65% and cations are 44%, for 2012-13 anions are 38% and cations are 72%, and 2013-14 anions are 68% and cations are 60%.

In overall, data for the year 2006-11 and 2012-13 are Na^+-Cl^- Type, for 2011-12 is $\text{Ca}^{2+}-\text{HCO}_3^-$ Type and for 2013-14 is $\text{Ca}^{2+}-\text{Mg}^{2+}-\text{Cl}^--\text{SO}_4^{2-}$ Type.

Fatehabad Block

The Wilcox and Piper diagrams for Fatehabad block of Agra District are shown in Figure 3.15 and Figure 3.16 for 2006-2014 data.

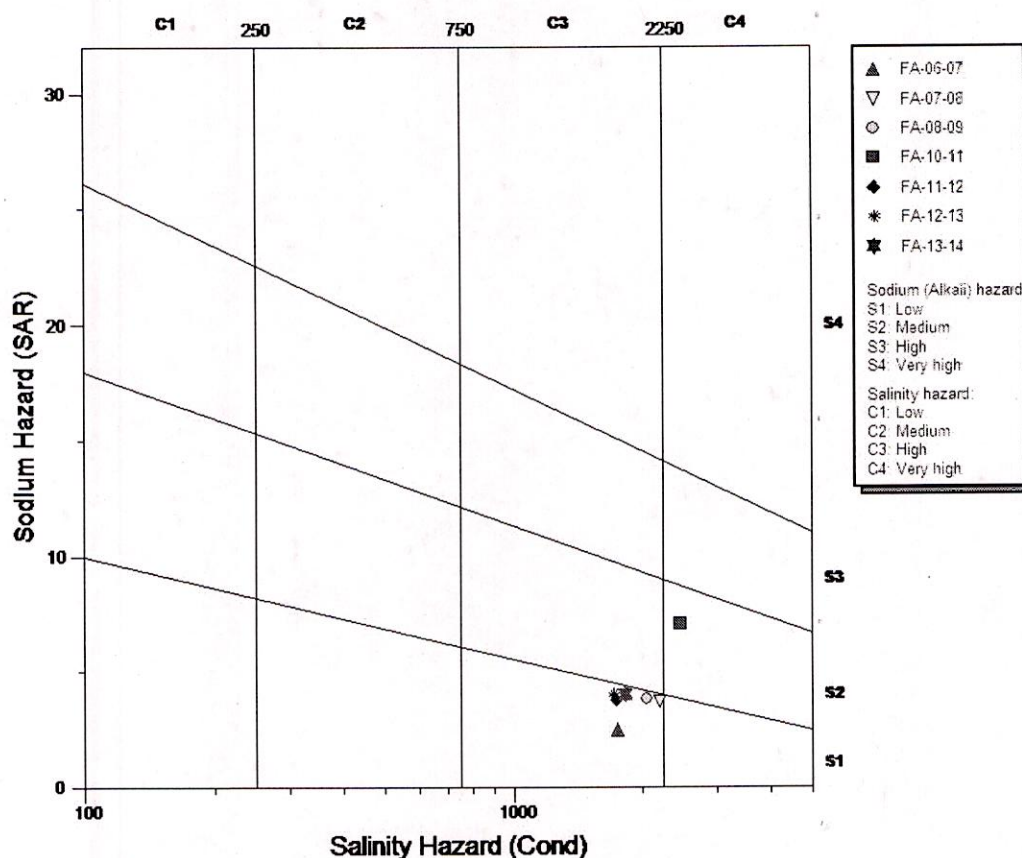


Figure 3.15. Wilcox diagram for Fatehabad block of Agra district

It is seen from Figure 3.15 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to Medium Sodium. On the other hand, water sample data from 2006-09 and 2011-14 have C3 Salinity Hazard indicating High Salinity, except for the year 2010-11 has C4 category such that the sample has Very High Salinity.

In overall, the water of Fatehabad block is characterized C3S1 and C4S2.

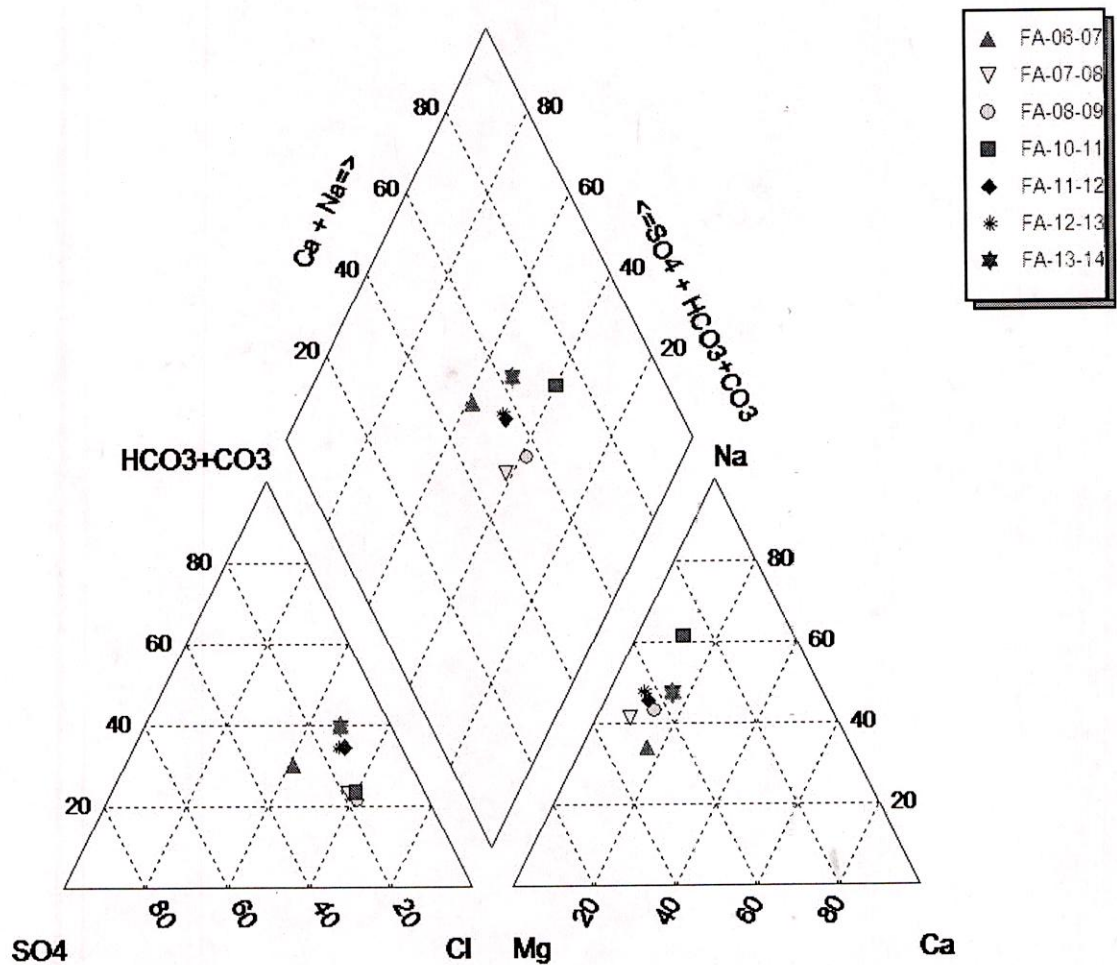


Figure3.16. Piper diagram for Fatehabad block of Agra district

The Piper diagram for Fatehabad block of Agra District is shown in Figure 3.16 based on the data from 2006 to 2014. It is seen from Figure 3.16 that for 2006-07 anions are 58% and cations are 50%, for 2007-08 anions are 42% and cations are 50%, 2008-09 anions are 40% and cations are 58%, 2010-11 anions are 40% and cations are 72%, for 2011-12 anions are 50% and cations are 58%, 2012-13 anions are 50% and cations are 58%, and 2013-14 anions are 54% and cations are 64%.

In overall, data for the year 2006-08 is $\text{Ca}^{2+}\text{-HCO}_3^-$ -Type, 2008-13 is $\text{Na}^+\text{-Cl}^-$ Type, and 2013-14 is $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-Cl}^- \text{-SO}_4^{2+}$ Type.

Fatehapur Sikari Block

The Wilcox and Piper diagrams for Fatehapur Sikari block of Agra District are shown in Figure 3.17 and Figure 3.18 for 2006-2014 data.

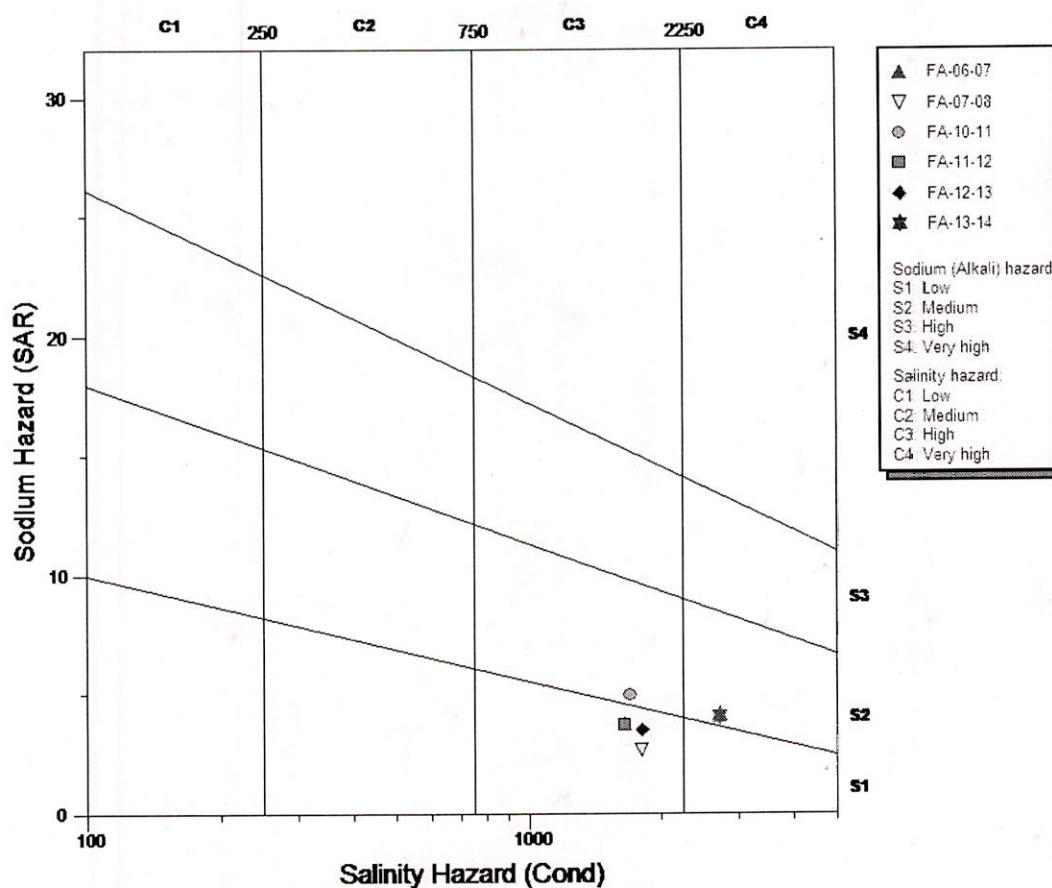


Figure 3.17. Wilcox diagram for Fatehapur Sikari block of Agra district

It is seen from Figure 3.17 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to Medium Sodium. On the other hand, water sample data from 2006-13 have C3 Salinity Hazard indicating High Salinity, except for the year 2013-14 which has C4 category such that the sample has Very High Salinity.

In overall, the water of Fatehapur Sikari block is characterized C3S1 and C4S2.

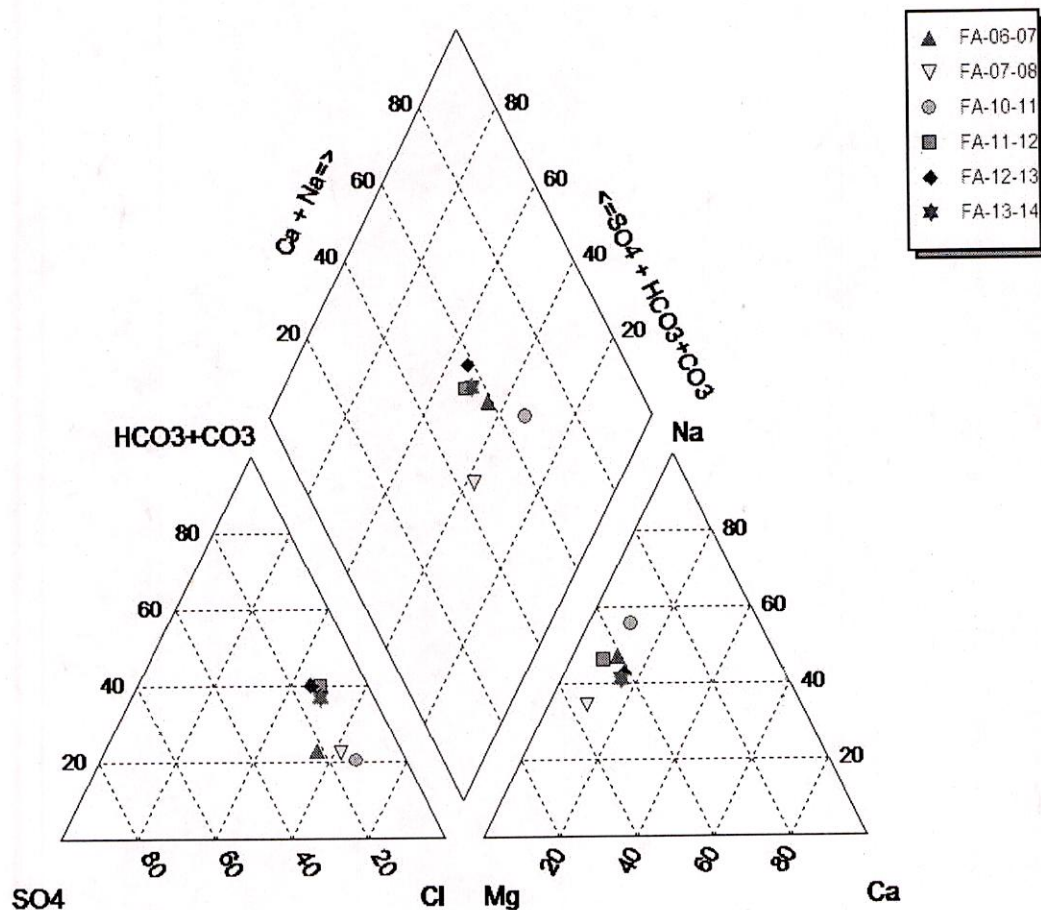


Figure3.18. Piper diagram for Fatehapur Sikariblock of Agra district

The Piper diagram for Fatehapur Sikari block of Agra District is shown in Figure 3.18 based on the data for the period 2006-2014. It is seen from Figure 3.18 that for 2006-07 anions are 44% and cations are 58% , for 2007-08 anions are 40% and cations are 44%, for 2010-11 anions are 38% and cations are 65%, for 2011-12 anions are 54% and cations are 54%, for 2012-13 anions are 58% and cations are 59%, and 2013-14 anions are 52% and cations are 58%.

In overall, data for the year 2006-07 and 2011-14 are Mixed $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-Cl}^-$ Type, 2007-08 is Mixed $\text{Ca}^{2+}\text{-Na}^+\text{-HCO}_3^-$ Type, and 2010-11 is $\text{Na}^+\text{-Cl}^-$ Type.

Jagner Block

The Wilcox and Piper diagrams for Jagner block of Agra District are shown in Figure3.19 and Figure 3.20 for 2006-2014 data.

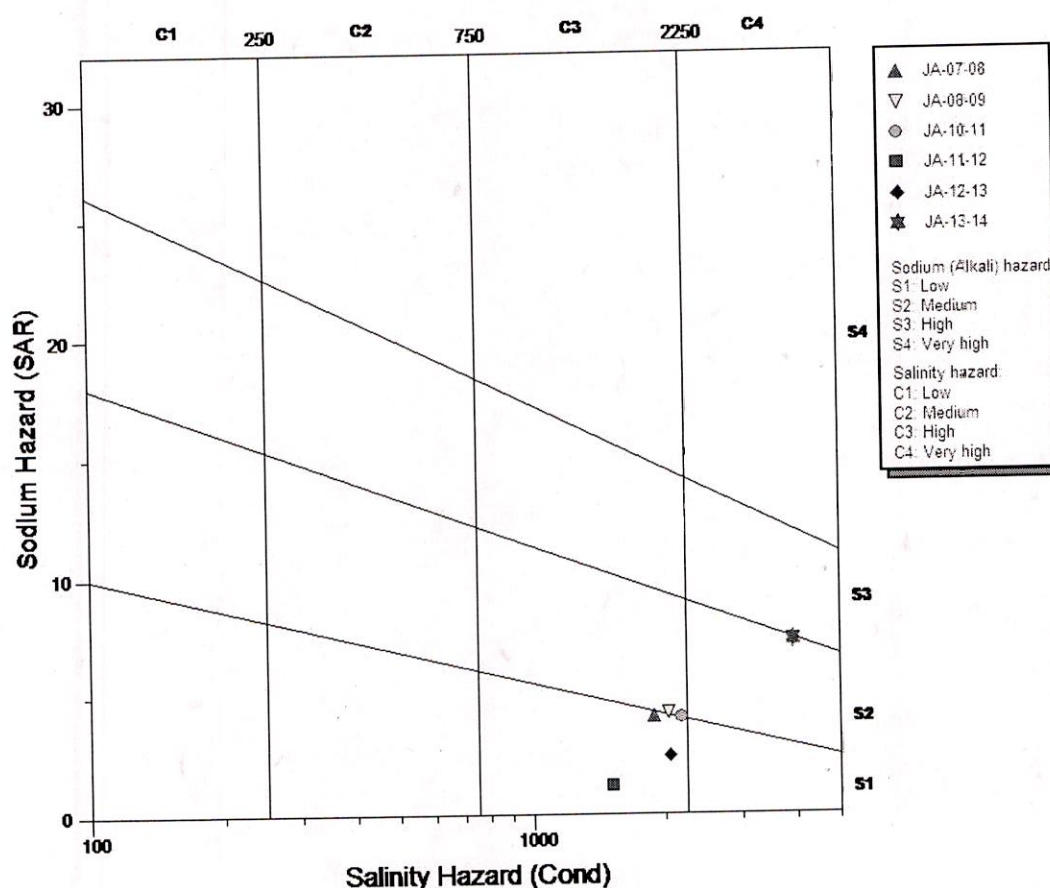


Figure3.19. Wilcox diagram for Jagner block of Agra district

It is seen for Figure 3.19 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to Medium Sodium. On the other hand, water sample data for 2007-13 have C3 Salinity Hazard indicating High Salinity, except for the year 2013-14 which has C4 category such that the sample has Very High Salinity.

In overall, the water of Jagner block is characterized C3S1 and C4S2.

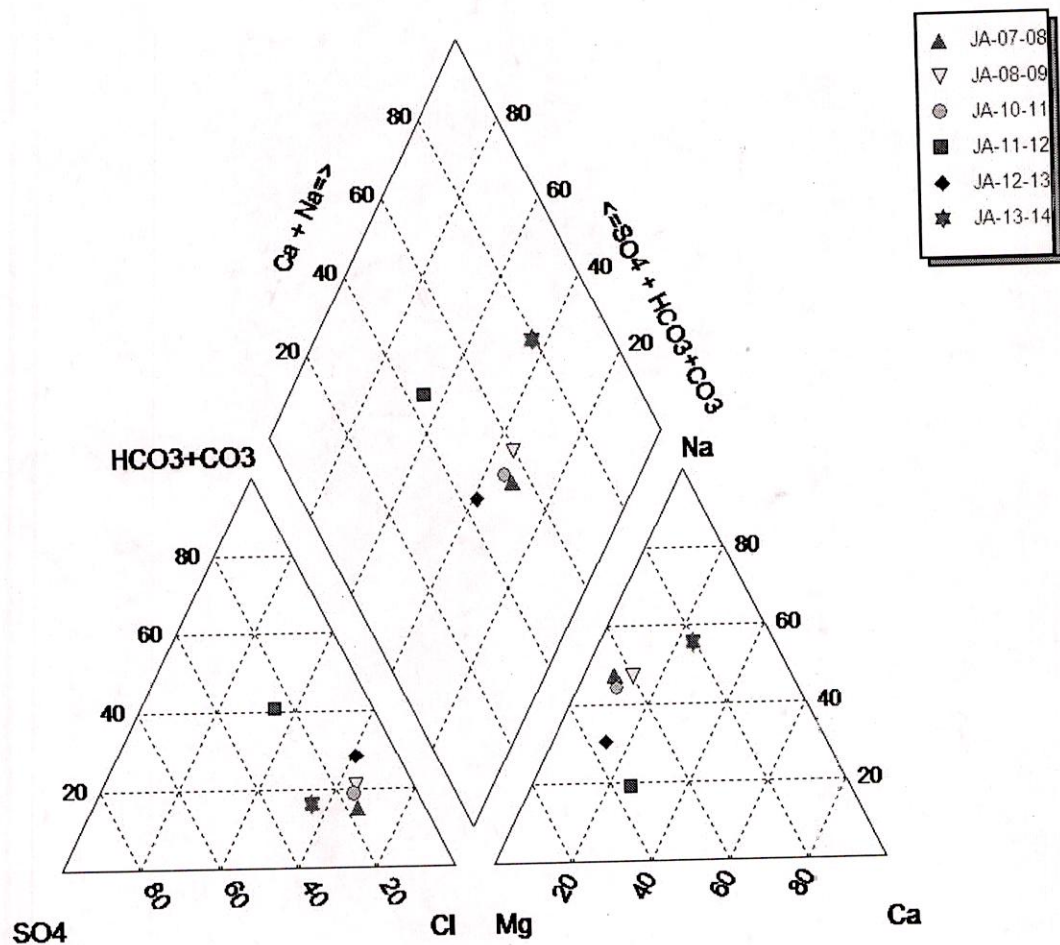


Figure3.20. Piper diagram for Jagner block of Agra district

The Piper diagram for Jagner block of Agra District is shown in Figure 3.20 based on the data from 2006 to 2014. It is seen from Figure 3.20 that for 2007-08 anions are 32% and cations are 58%, for 2008-09 anions are 38% and cations are 60%, 2010-11 anions are 38% and cations are 56%, for 2011-12 anions are 66% and cations are 44%, for 2012-13 anions are 39% and cations are 42%, and 2013-14 anions are 44% and cations are 80%.

In overall, data for the year 2007-09, 2010-11 and 2013-14 are $\text{Na}^+\text{-Cl}^-$ Type, 2011-12 is $\text{Ca}^{2+}\text{-HCO}_3^-$ Type, and 2012-13 is Mixed $\text{Ca}^{2+}\text{-Na}^+\text{-HCO}_3^-$.

Jaitpur Kalan Block

The Wilcox and Piper diagrams for Jaitpur Kalan block of Agra District are shown in Figure3.21 and Figure3.22 for 2006-2014 data.

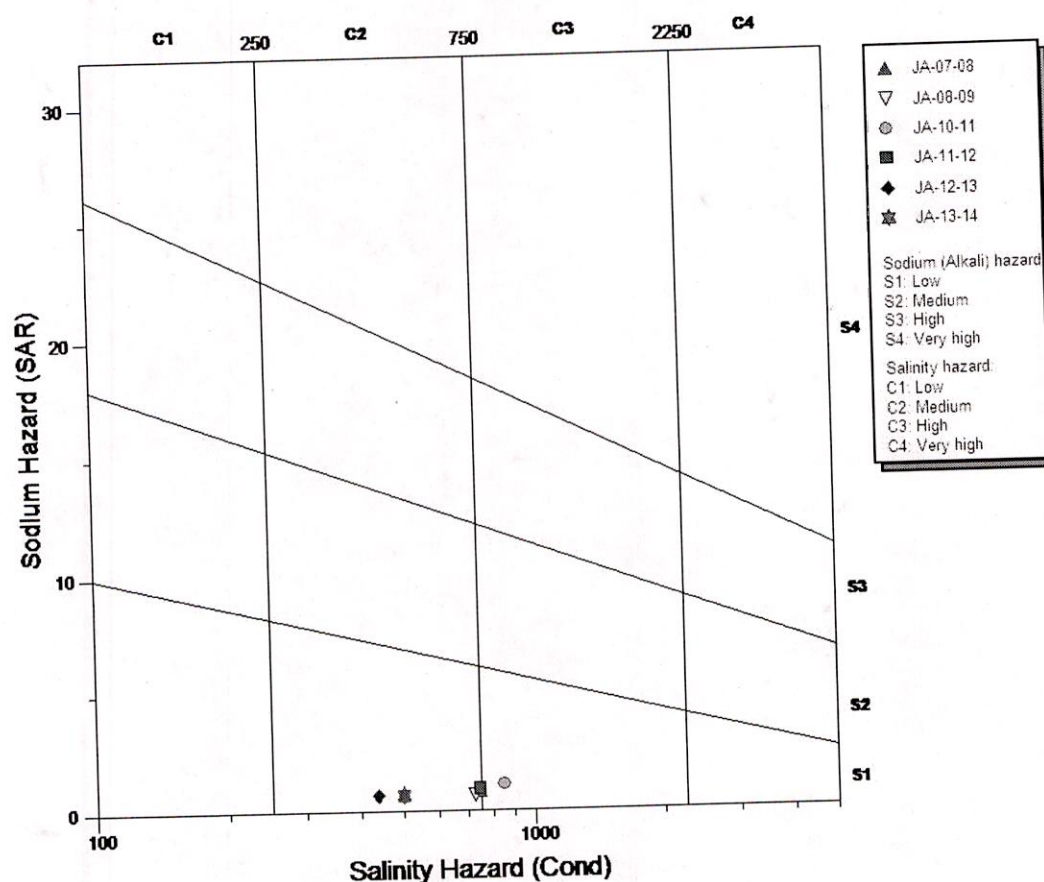


Figure3.21. Wilcox diagram for Jaitpur Kalan block of Agra district

It is seen from Figure 3.21 that water quality data for the period 2006-2014 falls under S1 categories of Sodium Hazard and have Low Sodium. On the other hand, water sample data for 2007-09 and 2011-14 have C2 Salinity Hazard indicating Medium Salinity, except for the year 2010-11 which has C3 category such that the sample has High Salinity.

In overall, the water of Jaitpur Kalan block is characterized as C2S1 and C3S1.

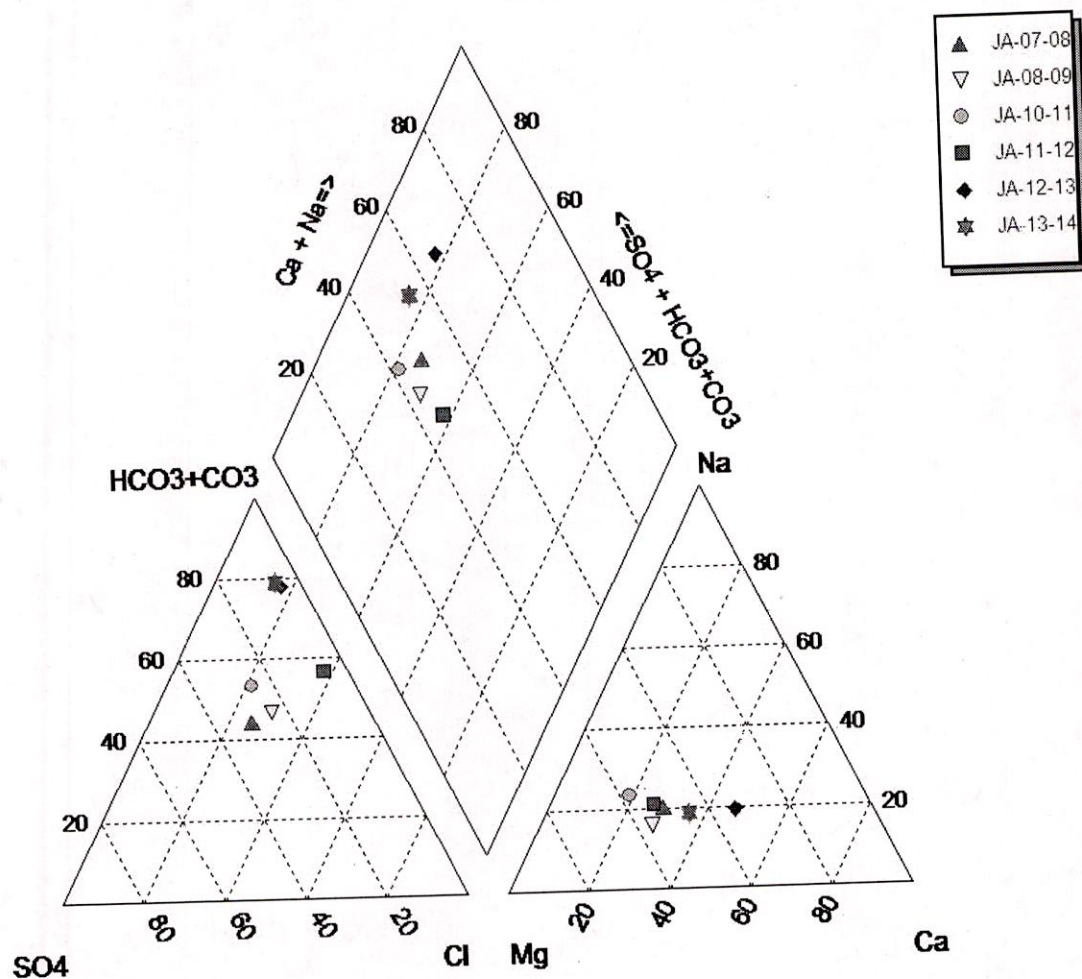


Figure 3.22. Piper diagram for Jaitpur Kalan block of Agra district

The Piper diagram for Jaitpur Kalan block of Agra District is shown in Figure 3.22 for 2006-2014 data. It is seen from Figure 3.22 that for 2007-08 anions are 72% and cations are 50%, for 2008-09 anions are 42% and cations are 70%, for 2010-11 anions are 80% and cations are 42% for 2011-12 anions are 62% and cations are 46%, for 2012-13 anions are 82% and cations are 65%, and 2013-14 anions are 82% and cations are 58%.

In overall, data for the year 2007-12 is $\text{Ca}^{2+} - \text{HCO}_3^-$ Type, 2012-13 is $\text{Ca}^{2+} - \text{Cl}^-$ Type, and for 2013-14 is Mixed $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^-$ Type.

Khairagarh Block

The Wilcox and Piper diagrams for Khairagarh block of Agra District are shown in Figure 3.23 and Figure 3.24 for 2006-2014 data.

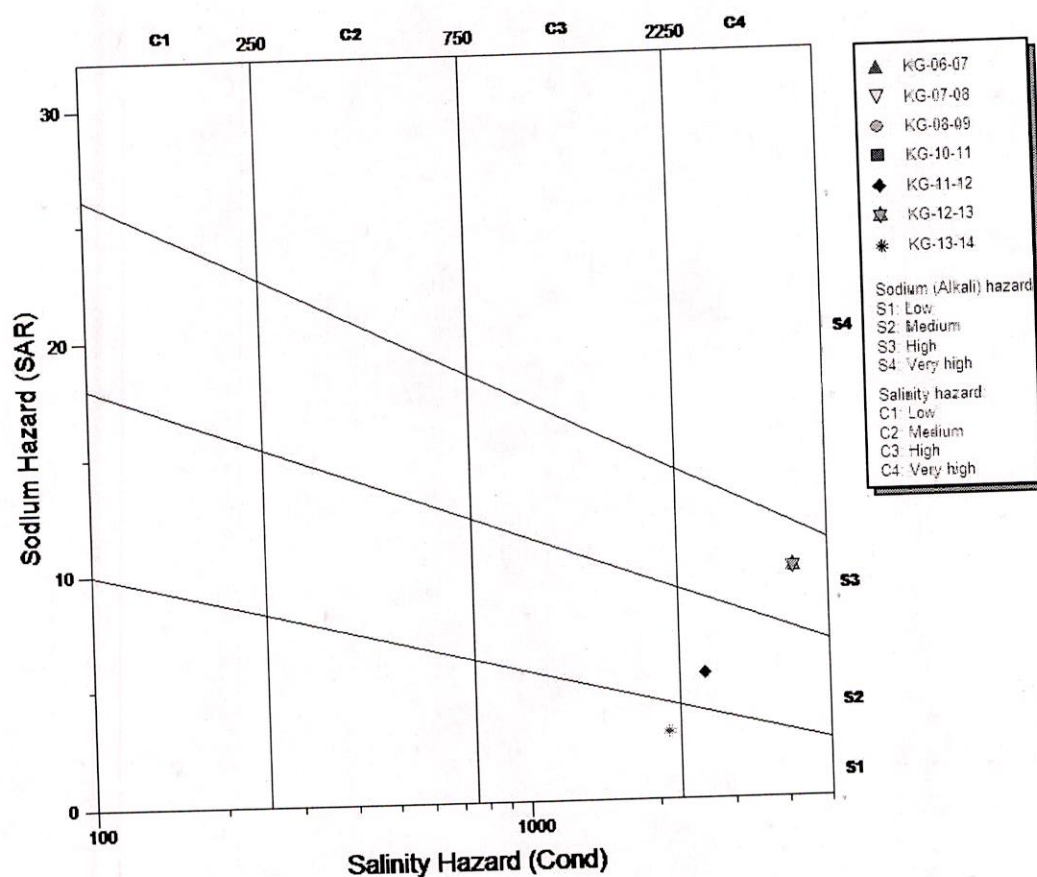


Figure 3.23. Wilcox diagram for Khairagarh block of Agra district

It is seen from Figure 3.23 that water quality data for period 2006-2014 falls under S1, S2 and S3 categories of Sodium Hazard and have Low to High Sodium. On the other hand, water sample data for 2013-14 have C3 Salinity Hazard indicating High Salinity, and for the years 2011-13 have C4 category such that the samples have Very High Salinity.

In overall, the water of Khairagarh block is characterized as C3S1, C4S2 and C4S3.

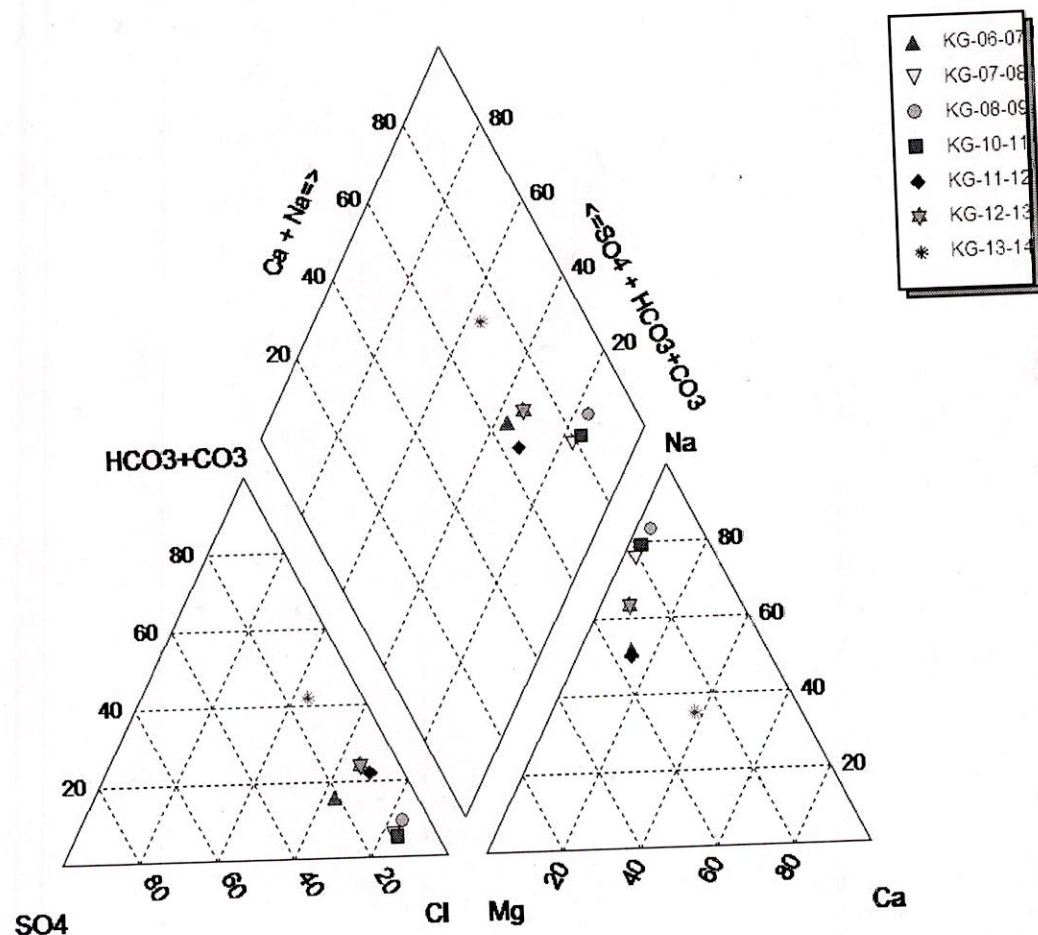


Figure 3.24. Piper diagram for Khairagarh block of Agra district

The Piper diagram for Khairagarh block of Agra District is shown in Figure 3.24 for 2006-2014 data. It is seen from Figure 3.24 that for 2006-07 anions are 38% and cations are 62%, for 2007-08 anions are 18% and cations are 80%, for 2008-09 anions are 18% and cations are 85%, for 2010-11 anions are 18% and cations are 85%, for 2011-12 anions are 30% and cations are 62%, for 2012-13 anions are 38% and cations are 70%, and 2013-14 anions are 58% and cations are 72%.

In overall, data for the year 2006-13 is $\text{Na}^+ - \text{Cl}^-$ Type and for 2013-14 is Mixed $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^-$ Type.

Khandouli Block

The Wilcox and Piper diagrams for Khandouli block of Agra District are shown in Figure 3.25 and Figure 3.26 for 2006-2014 data.

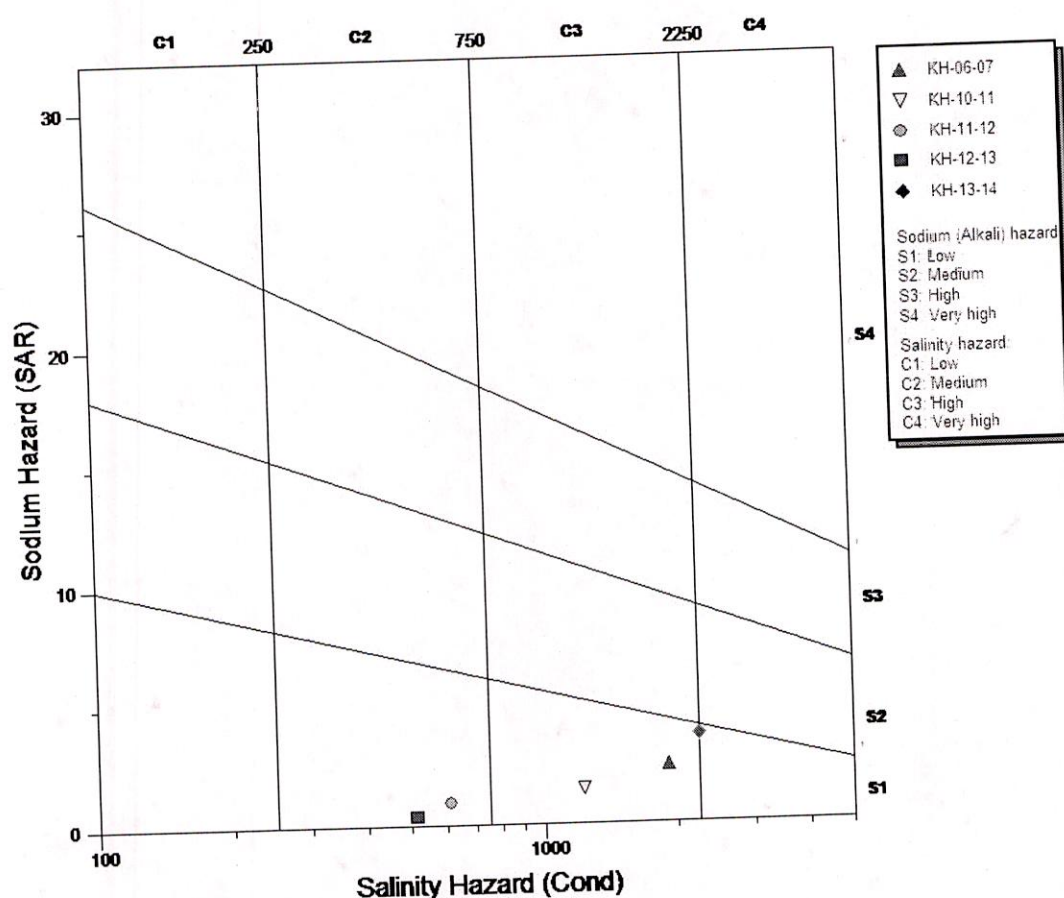


Figure 3.25. Wilcox diagram for Khandouli block of Agra district

It is seen from Figure 3.25 that water quality data for the period 2006-2014 falls under S1 categories of Sodium Hazard and have Low Sodium. On the other hand, water sample data for 2011-13 has C2 Salinity Hazard indicating Medium Salinity, and for the years 2006-07, 2010-11 and 2013-14 have C3 category such that the samples have High Salinity.

In overall, the water of Khairagarh block is characterized as C2S1 and C3S1.

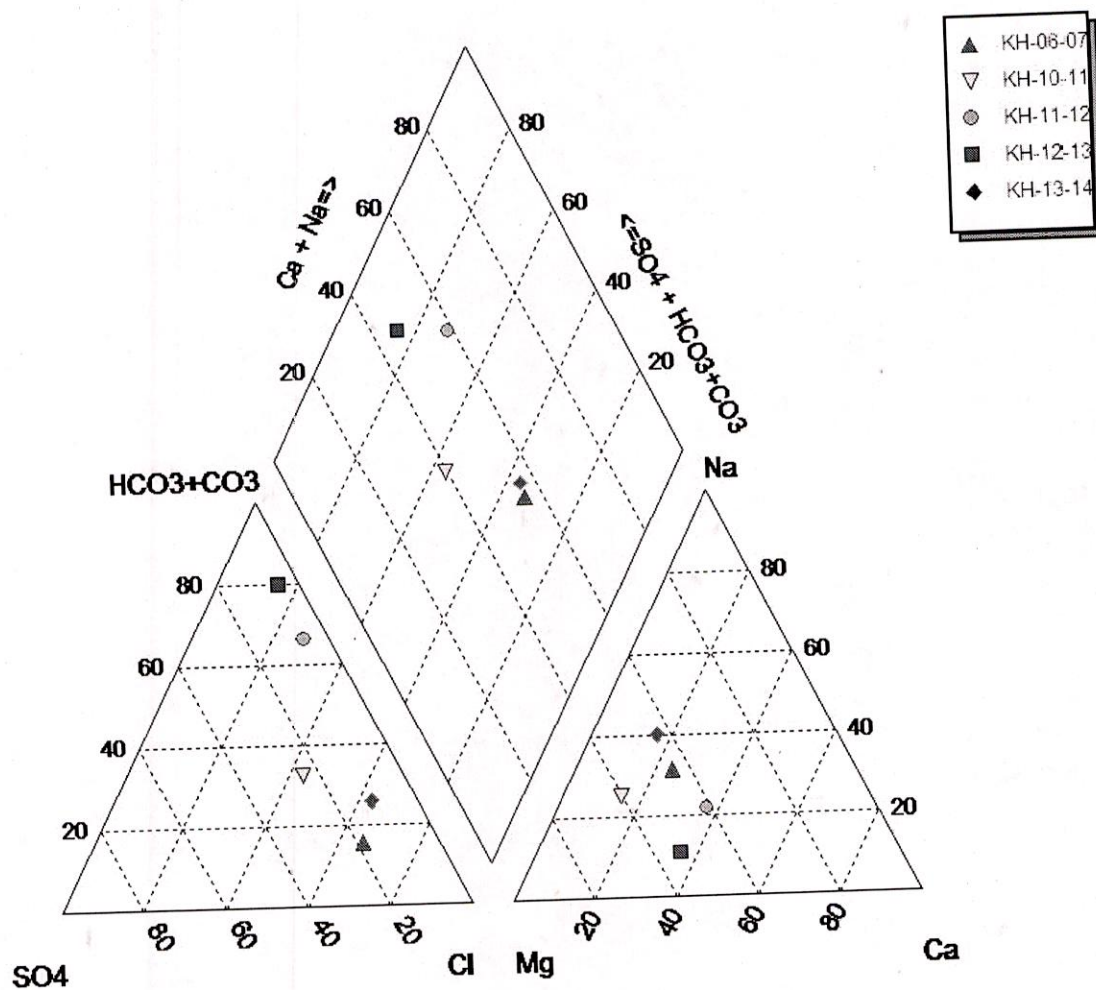


Figure 3.26. Piper diagram for Khandouli block of Agra district

The Piper diagram for Khandouli block of Agra District is shown in Figure 3.26 for 2006-2014 data. It is seen from Figure 3.26 that for 2006-07 anions are 36% and cations are 52%, for 2010-11 anions are 58% and cations are 40%, for 2011-12 anions are 72% and cations are 58%, for 2012-13 anions are 85% and cations are 45%, and 2013-14 anions are 38% and cations are 58%.

In overall, data for the year 2006-07 and 2014-14 are Na⁺ -Cl⁻ Type, for 2010-11 and 2012-13 are Ca²⁺ -HCO₃⁻ Type, and for 2011-12 is Mixed Ca²⁺ -Mg²⁺ -Cl⁻ Type.

Pinahat Block

The Wilcox and Piper diagrams for Pinahat block of Agra District are shown in Figure3.27 and Figure3.28 for 2006-2014 data.

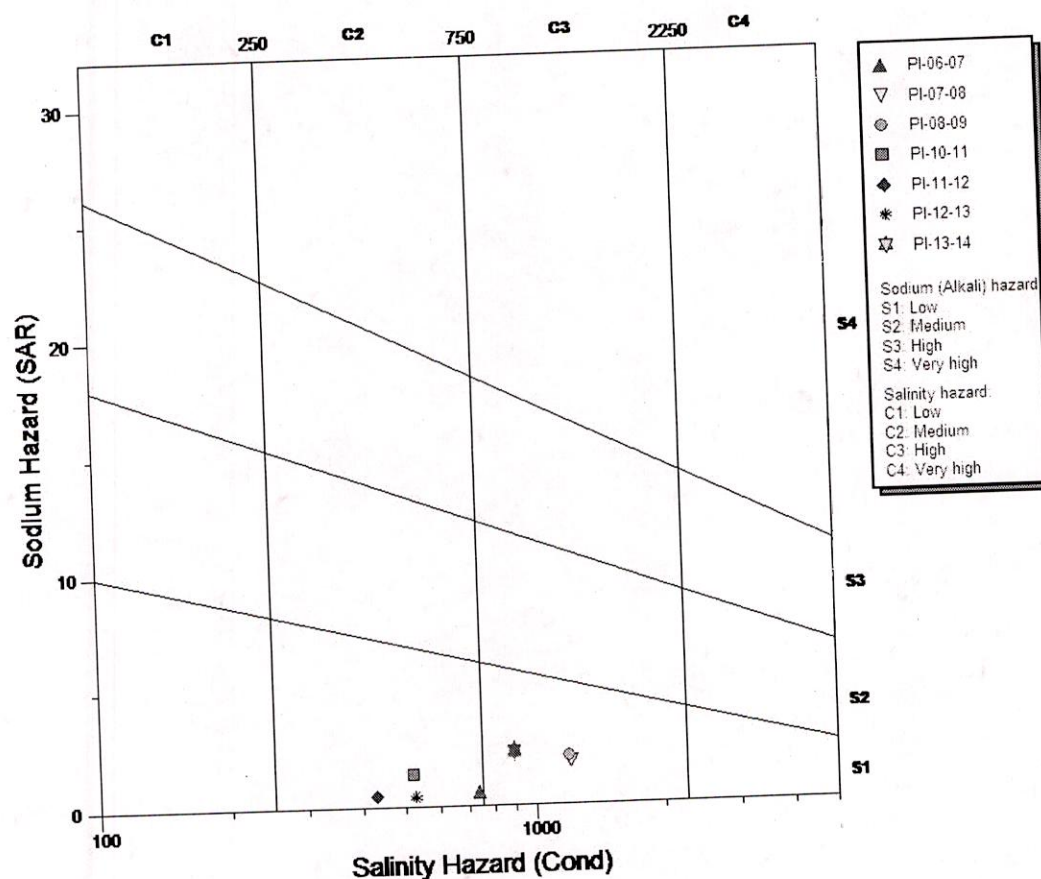


Figure3.27. Wilcox diagram for Pinahat block of Agra district

It is seen from Figure 3.27 that water quality data for the period 2006-2014 falls under S1 category of Sodium Hazard and has Low Sodium. On the other hand, water sample data for 2007-09 and 2013-14 have C2 Salinity Hazard indicating Medium Salinity, and for the years 2006-07 and 2010-13 have C3 category such that the sample has High Salinity.

In overall, the water of Pinahat block is characterized as C2S1 and C3S1.

Pinahat Block

The Wilcox and Piper diagrams for Pinahat block of Agra District are shown in Figure3.27 and Figure3.28 for 2006-2014 data.

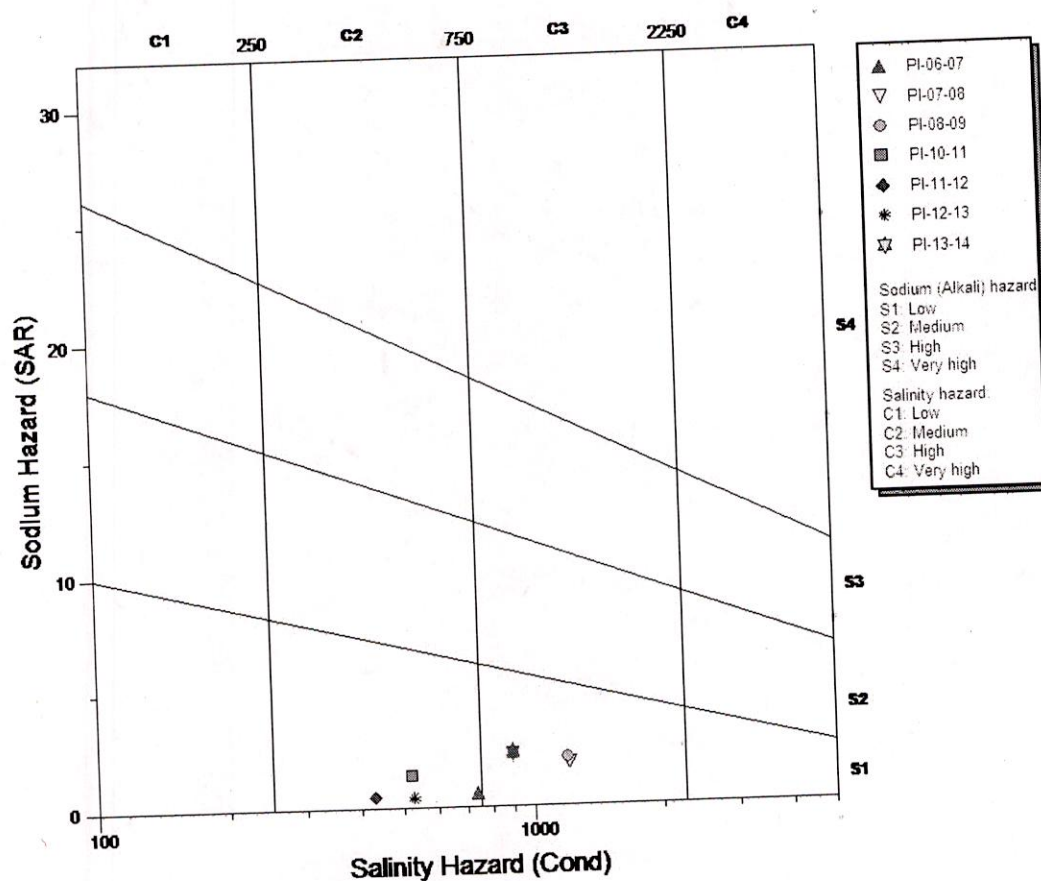


Figure3.27. Wilcox diagram for Pinahat block of Agra district

It is seen from Figure 3.27 that water quality data for the period 2006-2014 falls under S1 category of Sodium Hazard and has Low Sodium. On the other hand, water sample data for 2007-09 and 2013-14 have C2 Salinity Hazard indicating Medium Salinity, and for the years 2006-07 and 2010-13 have C3 category such that the sample has High Salinity.

In overall, the water of Pinahat block is characterized as C2S1 and C3S1.

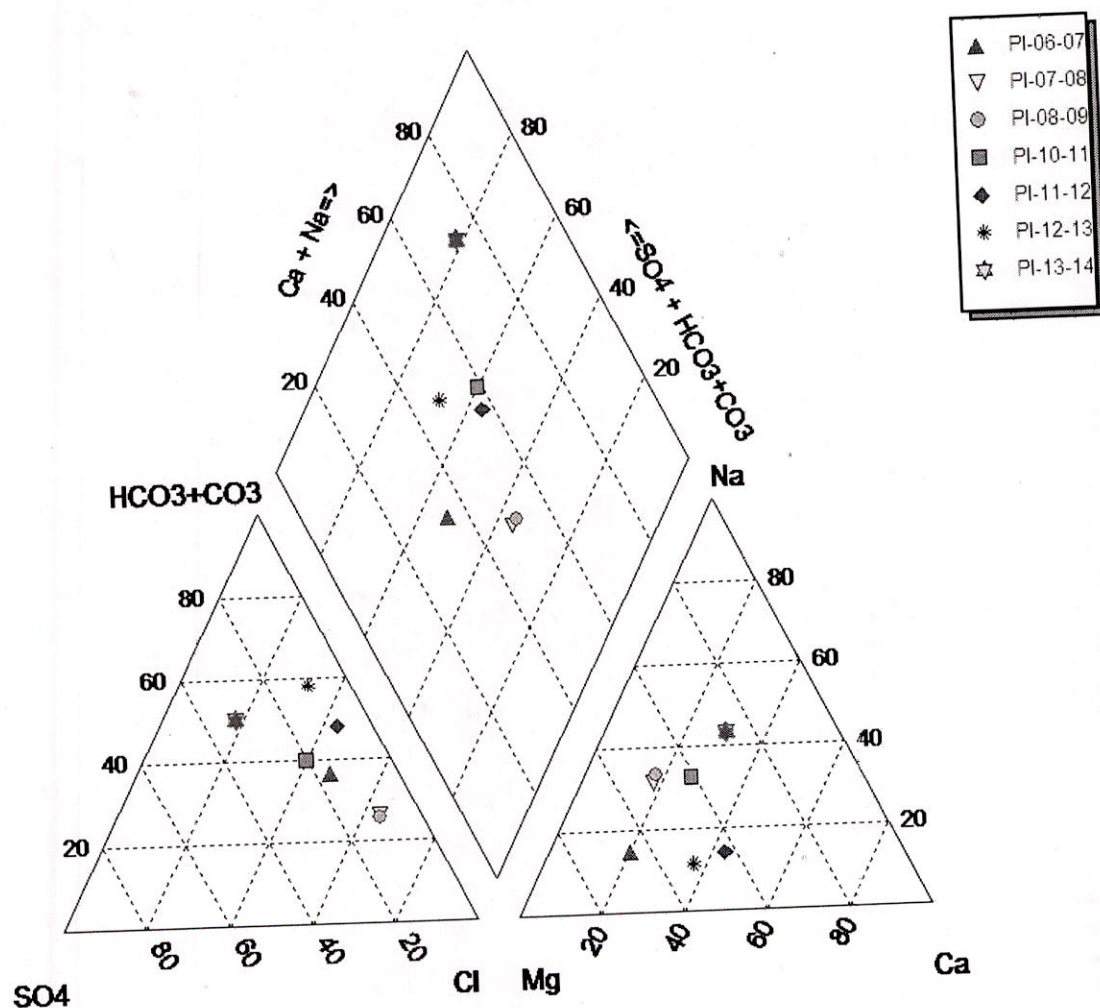


Figure 3.28. Piper diagram for Pinahat block of Agra district

The Piper diagram for Pinahat block of Agra District is shown in Figure 3.28 for 2006-2014 data. It is seen from Figure 3.28 that for 2006-07 anions are 52% and cations are 35%, for 2007-08 anions are 38% and cations are 48%, for 2008-09 anions are 38% and cations are 50%, for 2010-11 anions are 60% and cations are 60%, for 2011-12 anions are 58% and cations are 58%, for 2012-13 anions are 68% and cations are 48%, and for 2013-14 anions are 82% and cations are 72%.

In overall, data for the year 2006-07 and 2012-13 are Ca^{2+} - HCO_3^- Type, 2010-12 is Mixed Ca^{2+} - Mg^{2+} - Cl^- Type, 2007-09 is Na^+ - Cl^- Type, and 2013-14 is Ca^{2+} - Cl^- Type.

Saiyan Block

The Wilcox and Piper diagrams for Saiyan block of Agra District are shown in Figure 3.29 and Figure 3.30 for 2006-2014 data.

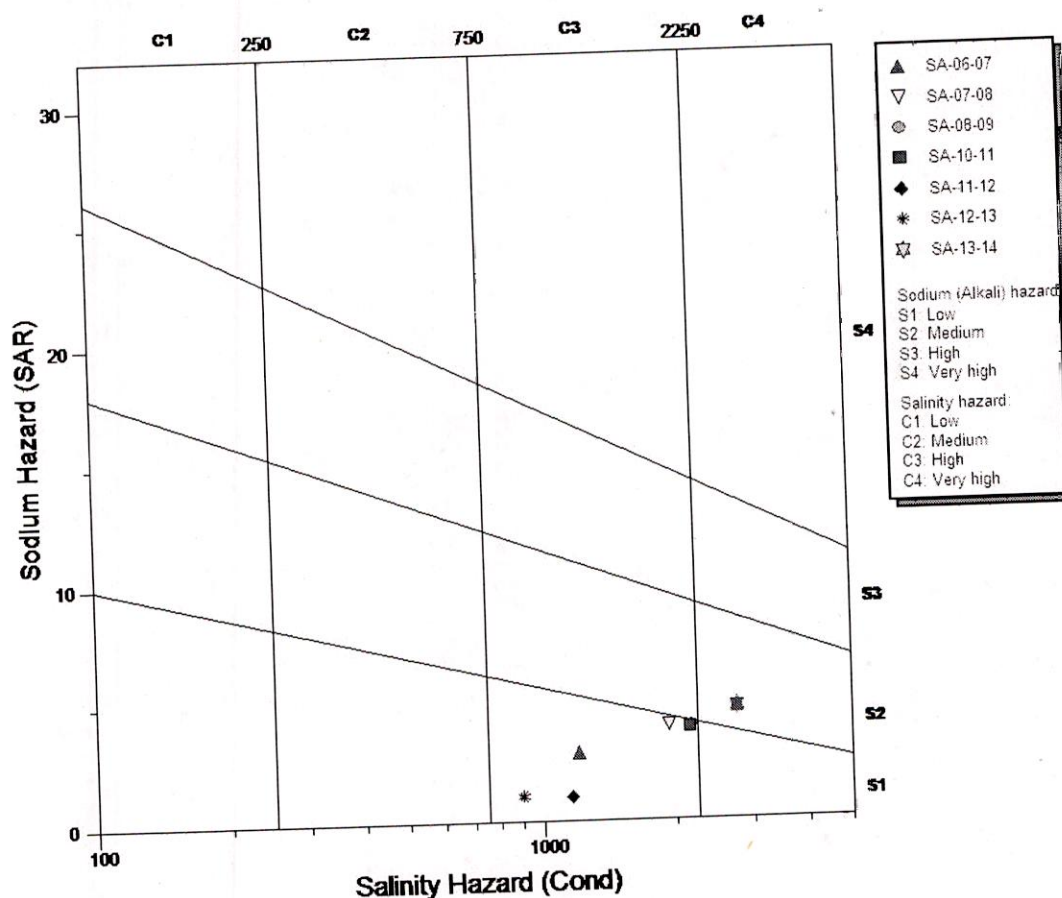


Figure3.29. Wilcox diagram for Saiyan block of Agra district

It is found that water samples for the period 2006-2014 fall under S1 and S2 categories of Sodium Hazard and have Low to High Sodium. On the other hand, water sample data from 2006-13 have C3 Salinity Hazard indicating High Salinity, except for the year 2013-14 which has C4 category such that the sample has Very High Salinity.

In overall, the water of Saiyan block is characterized as C3S1 and C4S2.

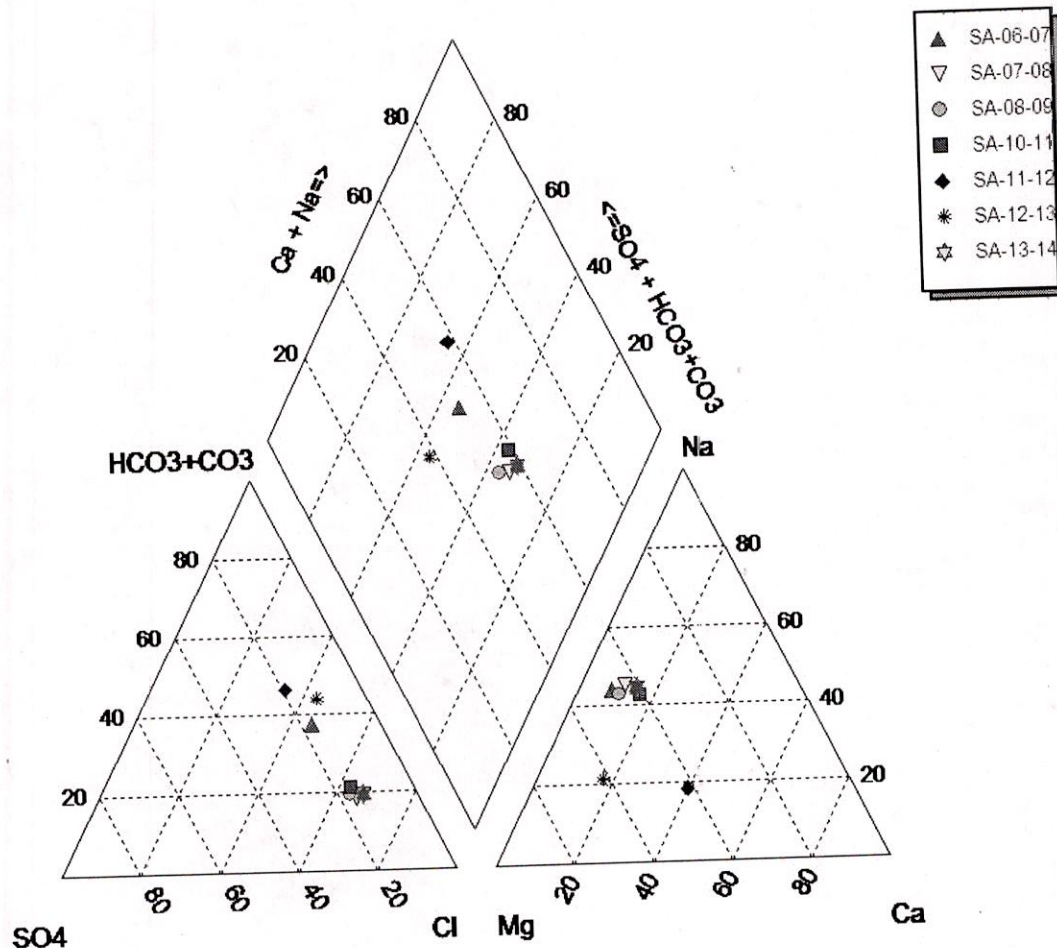


Figure3.30. Piper diagram for Saiyan block of Agra district

The Piper diagram for Saiyan block of Agra District is shown in Figure 3.30 for 2006-2014 data. It is seen from Figure 3.30 that for 2006-07 anions are 58% and cations are 52%, for 2007-08 anions are 38% and cations are 58%, for 2008-09 anions are 38% and cations are 58%, 2010-11 anions are 38% and cations are 60%, for 2011-12 anions are 68% and cations are 59%, 2012-13 anions are 58% and cations are 38%, and 2013-14 anions are 35% and cations are 60%.

In overall, the data for the year 2006-07 and 2011-12 are Mixed Ca^{2+} - Mg^{2+} - Cl^- Type, 2007-11 and 2013-14 are Na^+ - Cl^- Type, and 2012-13 is Ca^{2+} - HCO_3^- Type.

Shamsabad Block

The Wilcox and Piper diagrams for Shamsabad block of Agra District are shown in Figure 3.31 and Figure 3.32 for 2006-2014 data.

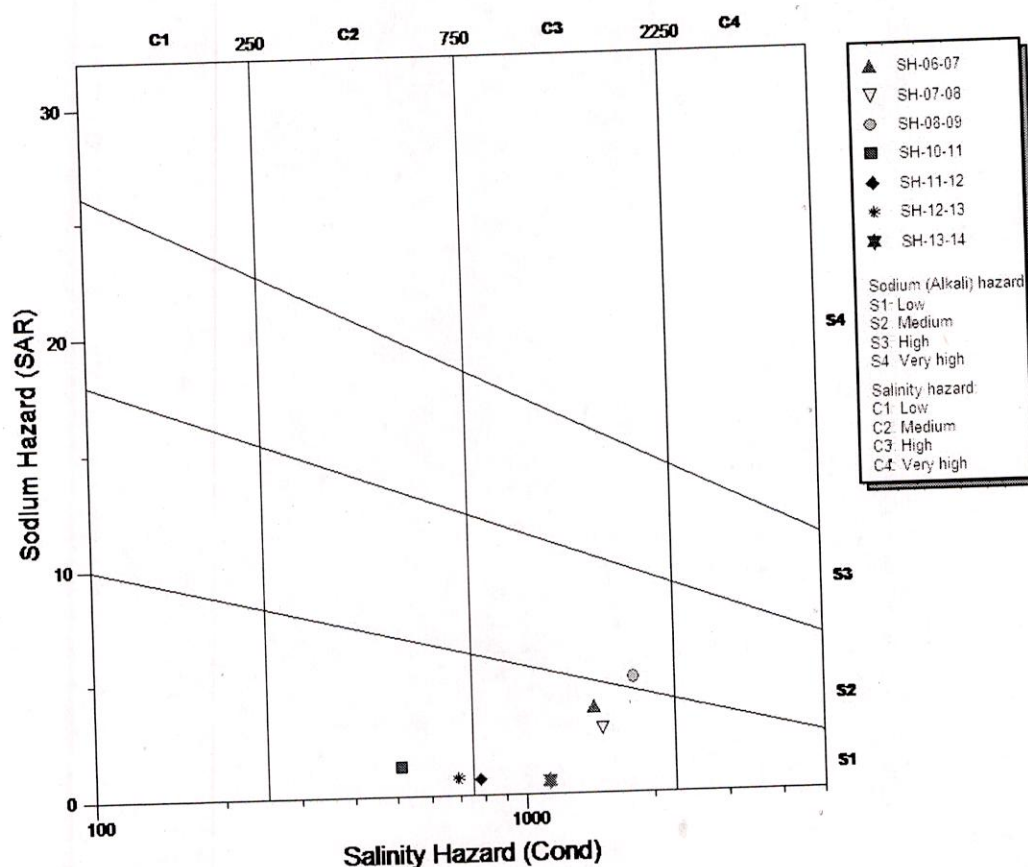


Figure 3.31. Wilcox diagram for Shamsabad block of Agra district

It is from Figure 3.31 that water quality data for the period 2006-2014 falls under S1 and S2 categories of Sodium Hazard and have Low to High Sodium. On the other hand, water sample data for 2010-09 and 2012-13 have C2 Salinity Hazard indicating Medium Salinity, and for the years 2006-09, 2011-12 and 2013-14 have C3 category such that the sample has High Salinity.

In overall, the water of Shamsabad block is characterized as C2S1, C3S1 and C3S2.

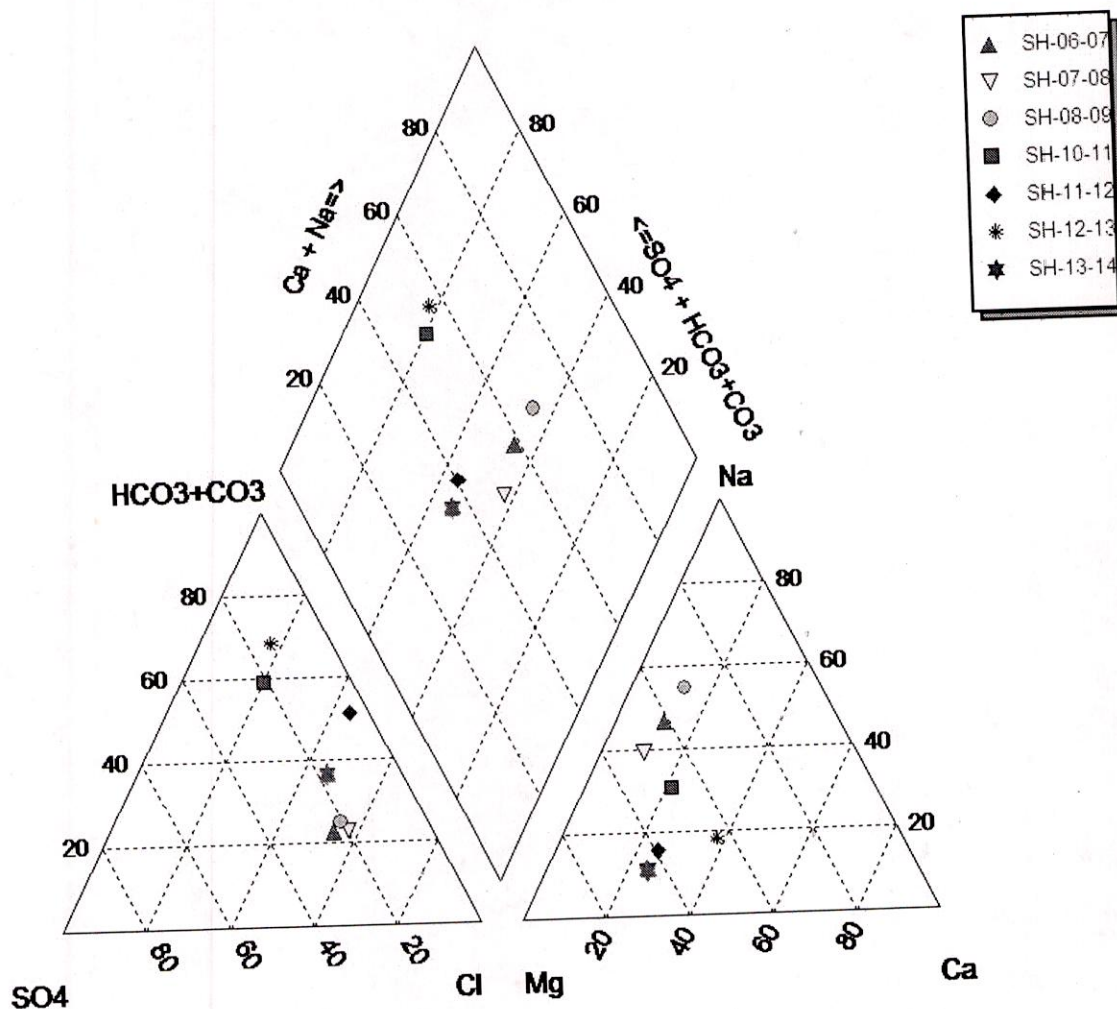


Figure 3.32. Piper diagram for Shamsabad block of Agra district

The Piper diagram for Shamsabad block of Agra District is shown in Figure 3.32 for 2006-2014 data. It is seen from Figure 3.32 that for 2006-07 anions are 48% and cations are 59%, for 2007-08 anions are 42% and cations are 50%, 2008-09 anions are 43% and cations are 68%, for 2010-11 anions are 80% and cations are 50%, for 2011-12 anions are 58% and cations are 40%, for 2012-13 anions are 82% and cations are 58%, and 2013-14 anions are 58% and cations are 38%.

In overall, data for the year 2006-09 is $\text{Na}^+ - \text{Cl}^-$ Type, 2011-13 is $\text{Ca}^{2+} - \text{HCO}_3^-$ Type, 2010-11 and 2013-14 are Mixed $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^-$ Type.

Suitability of Groundwater Quality for the Irrigation Purpose

The recommended classification criteria with respect to electrical conductivity, sodium content, Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are given by CGWB and CPCB (2000) as shown in Table 5.

Table 5. Guidelines for evaluation of irrigation water quality

Water class	Na (%)	EC ($\mu\text{S}/\text{cm}$)	SAR	RSC (meq/l)
Excellent	< 20	< 250	< 10	< 1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	> 26	2.5-3.0
Very bad	> 80	> 4000	> 26	> 3.0

It is obvious from Table 5 that if the value of above-mentioned parameters is less, the water will be more suitable for the irrigation use. Therefore, the groundwater quality has been assessed block-wise using Table 5 and is described as follows:

Bichpuri

For this block, the electrical conductivity varies from 2020 $\mu\text{mho}/\text{cm}$ to 3550 $\mu\text{mho}/\text{cm}$, which means that the quality of water is medium to bad. The Sodium % varies from 41.072 to 63.8, thus the quality of water under medium to bad. The SAR value range from 3.5 to 9.46, which indicates quality of water is in excellent class. RSC value is less than 1.25 and shows excellent water quality. In overall, the water quality of this block is not suitable for the irrigation purpose.

Akola

In this block the electrical conductivity varies from 1585 μ mho/cm to 6780 μ mho/cm, which means that the quality of water is very bad. The sodium % varies from 43.53 to 66.23, thus the quality of water under medium to bad. The SAR value range from 3.48 to 10.77 which indicates quality of water is in excellent class. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Barouli Ahir

In this block electrical conductivity varies from 708 μ mho/cm to 1560 μ mho/cm, which means that the quality of water is good to medium. The Sodium% varies from 20.78 to 54.76, thus the quality of water under good to medium. The SAR value range from 0.89 to 4.53, which indicates quality of water is excellent class. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is suitable for the irrigation purpose.

Fatehapur Sikari

In this block electrical conductivity varies from 1652 μ mho/cm to 2710 μ mho/cm, which means that the quality of water is medium to bad. The Sodium% varies from 34.25 to 55.34, thus the quality of water under good to medium. The SAR value range from 2.65 to 4.95 which indicates quality of water is excellent class. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Saiyan

In this block electrical conductivity varies from 900 μ mho/cm to 2170 μ mho/cm, which means that the quality of water is medium. The Sodium% varies from 18.32 to 44.7, thus the quality of water is excellent to medium. The SAR value range from 1.00 to 3.90, which indicates quality of water is excellent. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Fatehabad

In this block electrical conductivity varies from 1720 μ mho/cm to 2460 μ mho/cm, which means that the quality of water is medium to bad. The Sodium% varies from 33.75 to 47.4, thus

the quality of water is medium. The SAR value ranges from 2.48 to 7.04 which indicates excellent quality of water. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Achhanera

In this block electrical conductivity varies from 1656 $\mu\text{mho/cm}$ to 2140 $\mu\text{mho/cm}$. which means that the quality of water is medium. The Sodium% varies from 33.51 to 63.41, thus the quality of water is good to bad. The value of SAR value range from 2.76 to 7.79 which indicates quality of water is excellent. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Shamsabad

In this block electrical conductivity varies from 692 $\mu\text{mho/cm}$ to 1805 $\mu\text{mho/cm}$. which means that the quality of water is good to medium. The Sodium% varies from 11.06 to 46.46, thus the quality of water is excellent to medium. The value of SAR value range from 0.57 to 4.92 which indicates quality of water is excellent. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Khandouli

In this block electrical conductivity varies from 514 $\mu\text{mho/cm}$ to 1910 $\mu\text{mho/cm}$. which means that the quality of water is good to medium. The Sodium% varies from 10.85 to 39.96, thus the quality of water is excellent to good. The value of SAR value range from 0.4 to 3.63 which indicates quality of water is excellent. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Pinahat

In this block electrical conductivity varies from 428 $\mu\text{mho/cm}$ to 1210 $\mu\text{mho/cm}$. which means that the quality of water is good to medium. The Sodium% varies from 11.34 to 43.24, thus the quality of water is excellent to medium. The value of SAR value range from 0.4 to 2.3 which indicates quality of water is excellent. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Khairagarh

In this block electrical conductivity varies from 2110 μ mho/cm to 7330 μ mho/cm which means that the quality of water is medium to bad. The Sodium% varies from 34.76 to 82.95 thus the quality of water is good to very bad. The value of SAR value range from 2.84 to 23.79 which indicates quality of water is excellent to good. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Etmadpur

In this block electrical conductivity varies from 1250 μ mho/cm to 2450 μ mho/cm. which means that the quality of water is medium to bad. The Sodium% varies from 22.97 to 65.98, thus the quality of water is good to bad. The value of SAR value range from 1.37 to 8.16 which indicates quality of water is excellent. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Jaitpur Kalan

In this block electrical conductivity varies from 437 μ mho/cm to 853 μ mho/cm. which means that the quality of water is good to medium. The Sodium% varies from 15.85 to 23.31 thus the quality of water is excellent to good. The value of SAR value range from 0.65 to 1.09 which indicates quality of water is excellent. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

Jagner

In this block electrical conductivity varies from 1519 μ mho/cm to 391 μ mho/cm. which means that the quality of water is medium to bad. The Sodium% varies from 30.26 to 55.49, thus the quality of water is good to medium. The value of SAR value range from 1.18 to 5.02 which indicates quality of water is excellent. RSC value is less than 1.25 and show excellent water quality. In overall, the water quality of this block is not suitable for irrigation purpose.

Bah

In this block electrical conductivity varies from 692 μ mho/cm to 1062 μ mho/cm. which means that the quality of water is good to medium. The Sodium% varies from 11.05 to 27.69

thus the quality of water is excellent to good. The value of SAR value range from 0.61 to 1.55 which indicates quality of water is excellent. RSC value is less than 1.25, and show excellent water quality. In overall, the water quality of this block is suitable for irrigation purpose.

CHAPTER 6: SUMMARY AND CONCLUSIONS

In the present work, water quality characterization and assessment on suitability for the irrigation purpose has been carried-out for all blocks of the Agra district, which is located in the Northern part of the Uttar Pradesh state of India.

Summary:

The water quality data of all fifteen blocks of Agra district for the period 2006-2014 were used and analyzed using Wilcox and Piper diagrams, SAR and RSC. Accordingly the groundwater quality has been characterized and suitability is assessed for the irrigation purpose. The characterization of water quality and assessment on suitability for the irrigation purpose based on above-mentioned criteria has been discussed and presented in the Chapter 5.

Conclusions:

Based on the discussions made above, it is concluded that groundwater of various blocks of Agra district is $\text{Na}^+ - \text{Cl}^-$, $\text{Ca}^{++} - \text{Na}^+ - \text{HCO}_3^-$, $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^-$, $\text{Ca}^{2+} - \text{HCO}_3^-$, $\text{Ca}^{2+} - \text{Cl}^-$, $\text{Na}^+ - \text{Cl}^-$, $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{Cl}^- - \text{SO}_4^{2-}$, $\text{Ca}^{2+} - \text{Na}^+ - \text{HCO}_3^-$ Type. It is also concluded that the quality of water for the block Barouli Ahir, Fatehapur Sikari, Saiyan, Achhenera, Shamsabad, Khandouli, Pinahat, Jaitpur Kalan and Bah falls under Very Good to Medium category and can be used for the irrigation purpose. But, the quality of water for the blocks Bichpuri, Akola, Fatehabad, Khairagarh, Etmadpur and Jagner falls under Medium to Very bad category and hence cannot be used for the irrigation purpose.

Recommendations:

Based on the work carried-out under the present study, the following brief recommendations are made:

Boron is also an important parameter in water and in small quantity beneficial for plants. Thus this parameter must also be included in the water testing program.

There is one data for each block per year. Thus it is recommended that the water quality data from 3 to 4 locations in each block must be sampled and tested.

The sampling frequency must be increased to at least twice a year, i.e., pre-monsoon and post-monsoon.

The exact locations of the sampling points in the form of location Name, Latitude, Longitude and Reduced Level (R.L.) must be recorded.

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