DISSERTATION REPORT

ON

"HYDROGEOCHEMISTRY OF BAZADA REGION OF TAPI BASIN,PART OF JALGAONDISTRICT, MAHARASTRA"

SUBMITTED
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CANDIDATE'S DECLARATION

I, hereby, certify that the report entitled **"HYDROGEOCHEMISTRY OF BAZADA REGION OF TAPI BASIN, PART OF JALGAON DISTRICT, MAHARASTRA"** has been prepared by the undersigned. This work carried out, during the period of **3rd March 2017** to **3rd May 2017**, is a record of my own work under the supervision of **Dr S.P Rai**, Scientist 'F', Hydrology Investigation Division, National Institute of Hydrology (NIH), Roorkee (Uttarakhand).

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Chapter-1

1.1 Introduction

Groundwater is a primary source of freshwater in large parts of the world, but depletion of groundwater resources is now a very significant international problem and unsustainable exploitation of groundwater resources requires urgent attention. Since, groundwater resources play a major role in ensuring livelihood security across the world, especially in economies that depend on agriculture. The socio-economic dependency on groundwater is explained over a range of factors by Burke and Moench (2000). Groundwater systems have become the "lender of last resort" and depletion of renewable groundwater stocks is taken as the first indicator of water scarcity (Shah and Indu 2004).

Groundwater is considered to be less vulnerable than surface sources and can therefore help to stabilize agricultural populations and reduce the need for farmers to migrate when drought threatens agricultural livelihoods (Moench 2002). In other words, groundwater resources provide a reliable drought buffer in large regions of the world (Calow et al 1997). The ability to access groundwater plays a major role in reducing risk and increasing incomes (Moench 2003), especially when other modes of irrigation are absent.

India is now the biggest user of groundwater for agriculture intheworld.Groundwater irrigation has been expanding at a very rapid pace in India since the 1970s. The data fromthe Minor Irrigation Census conducted in 2001 shows evidence of the growing numbers of groundwater irrigation structures (wellsand tube wells) in the country. Their number stood at around 18.5million in 2001, of which tube wells accounted for 50%. It is believed that the number of groundwater irrigation structures is now around 27 million with every fourth rural household owning at least one such irrigation structure (Shah 2009).Though groundwater overuse was recognized as a serious problem for quite some time (Dhawan 1995; Moench 1992; Macdonaldet al 1995), conventional approaches to groundwater in India until the mid-1990s have involved a clear focus on the "development" of groundwater resources. The mid-1990s saw a slow and reluctantchange in thinking, from a development to a managementmade.

Access of safe drinking water remains an urgent necessity as 30% of urban and 90% of the rural. Indian population still depend completely on saturated surface or Groundwater resources (Kumaret al.2005). While access to drinking water in India has increased over the past decade the tremendous adverse impact of unsafe water for health continues. It is estimated that about 21% of the communicable diseases in India are water born (BradonandHomman 1995). Through recent years CENTRAL GROUNDWATER BOARD has taken up several studies in the district. They are – (Toppo et al., 2003-2004; Jain &Nain 2004)

According to the hydrological survey in March 2012 the conditions of water level as- out of the 120 wells drilling between depths of 198 to 204.35 mbgl, Discharged varied from traces to 7.76 lps. Staticwater levels inthese wells variesfrom 12.00 to 200.00 mbgl depths. Granular zones encountered and screened at various depths in alluvial parts of the district , particularly in Tapi Basin area . Bazada part of Jalgaon has a varied climate. It is hot and dry in summer, with temperatures reaching 47 °C (117 °F) from late May to mid-June; the record high, in May 2010, was 49.2 °C (120.6 °F). Bazada part of Jalgaon receives about 700 millimetres (28 in) of rainfall during the monsoon.Bazada part of Jalgaon District is located in the Western part of Indian peninsula and Northern side of Maharashtra State. In 1906, the District of Khandesh was divided into two Districts called West and East Khandesh with head quarters at Dhulia and Bazada part of Jalgaon District respectively. After the formation of the Maharashtra State in 1960, the two Districts are named after their headquarters as Dhulia and Bazada part of Jalgaon. Bazada part of Jalgaon District is known to the world, for its Gold market, Banana production, Cotton cultivation and emerging industrial and educational hub for the region. Cotton and Banana are the staple crops of the district. There are reports of hydro geochemical components at some different location of Bazada part of Jalgaondistrict.Demanding a detailed investigation of the water resources for its better utilization and management. The major objective of this study is primarily investigation and interpretation of the groundwater chemistry of Bazada part of Jalgaon district for understanding the water-rock interactions and solute acquisitions processes that control groundwater composition and to assess groundwater quality for drinking and irrigation purposes.

1.2 Objectives

i) To study the hydro-geochemistry of groundwater.
ii) To study the suitability of groundwater for drinking purposes.
iii) To study the suitability of groundwater for irrigation purposes.

Chapter 2

2.1 Study Area:

Bazada part of Jalgaon district lies in the northern part of Maharashtra between 20° and 21° north latitude and 74° 55' and 76° 28' east longitude (Fig. 1). The off-shoots of Western Ghats extend in the easterly direction, whereas the SatpuraMountain forms the northern limit separating from neighbouring state of Madhya Pradesh. Aurangabad and Buldhana districts are in its east, where as Nasik and Dhule districts constitute its western border. The district head quarters is located at Jalgaon Town. For administrative convenience, the district is divided into 15 talukas viz., Bazada part of Jalgaon, Bhusaval, Yaval, Raver, Muktainagar, Amalner, Chopda, Erandol, Pallor, Chalisgaon, Jamner, Pachora, Bhadgaon, Dharangaon and Bodwad. It has a total population of 4,224,442 as per 2011 census. The district has 20 towns and 1487 villages. Population density as per 2011 sensus is 359 persons/Sq.km. The major part of the district comes under Tapi basin. Tapi is the main river flowing through the district.

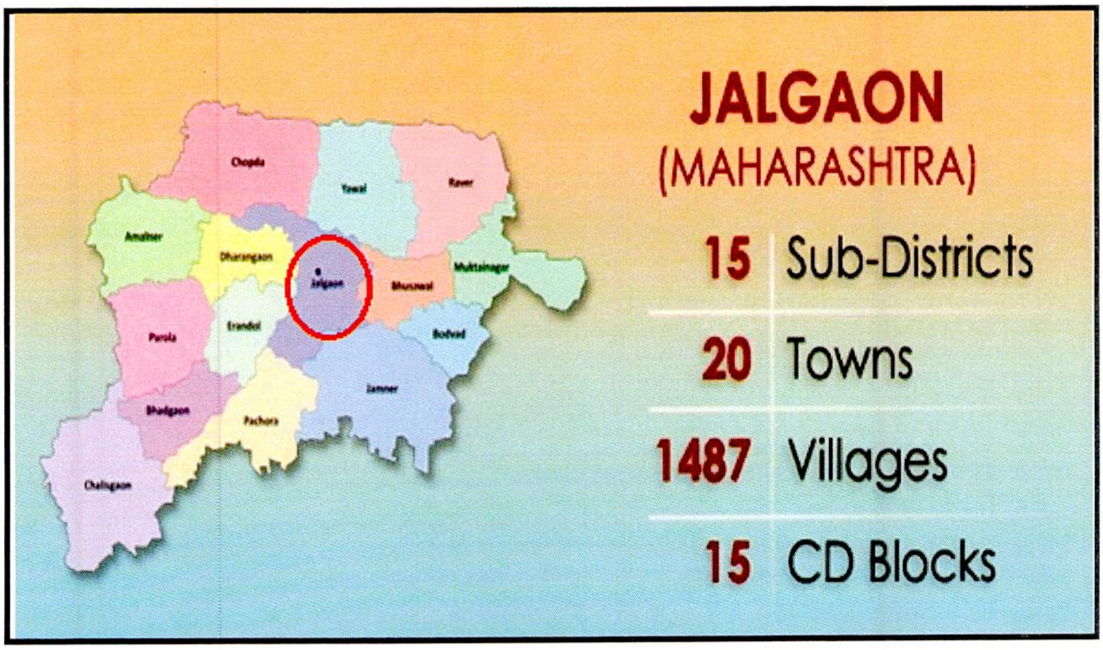


Figure 1: Major parts of Jalgaon district

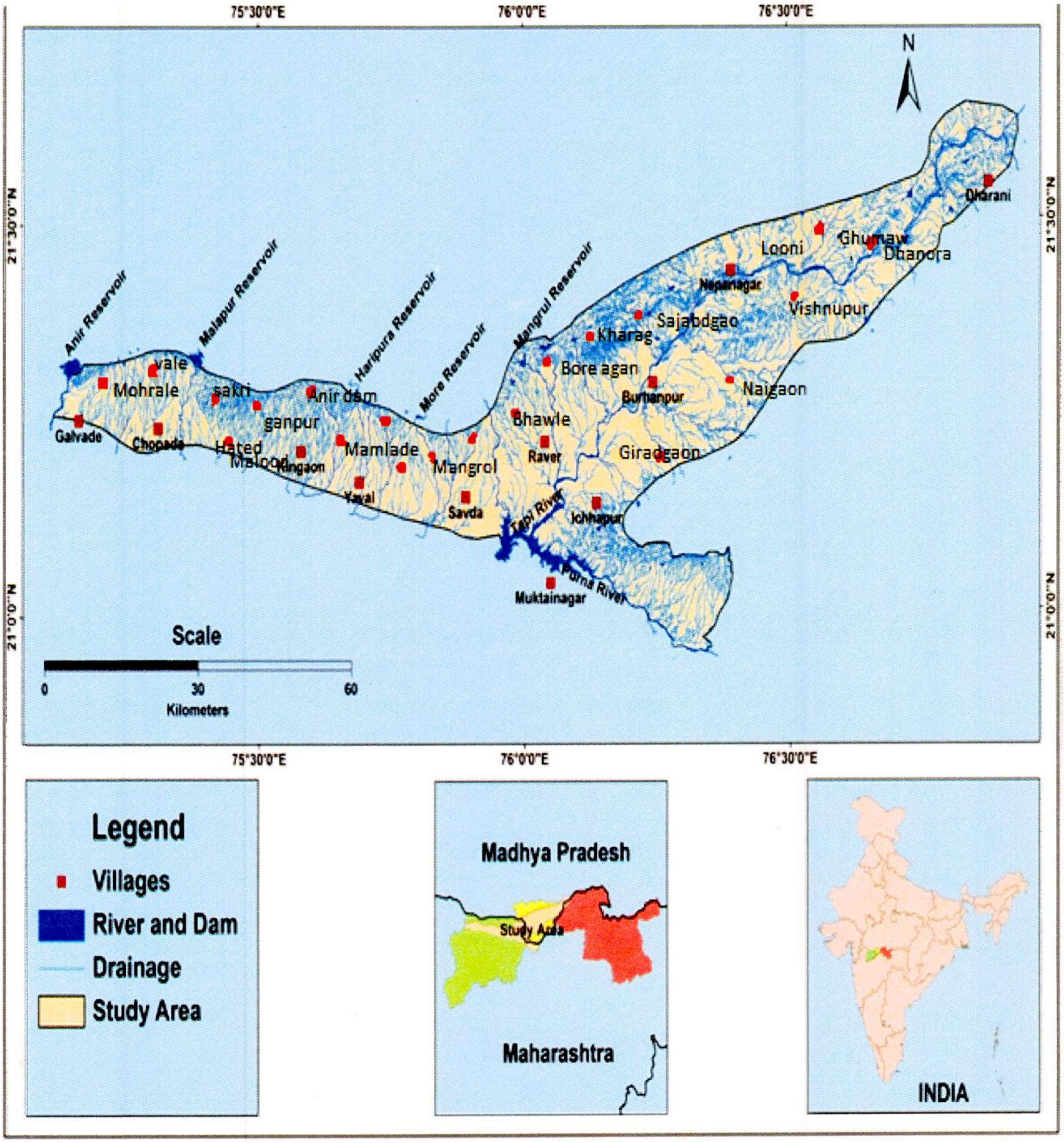


Figure-2: Location map of the study area

2.2 Geographical Location and Boundaries of Bazada part of Jalgaon District:

Bazada part of Jalgaon is one of the thirty five Districts of Maharashtra, situatedat the northern most border of the state. It is a part of erstwhile region of Bombay Presidency. Bazada part of Jalgaon District lies in the Tapi river basin stretching nearly 128 Kms. Alongtheriver and varying in the breadth from 112 Kms.To 144 Kms. It covers anarea of the Bazada part of Jalgaon District is 11765.00 Sq. Kms. Which constitute 3.82% of the total area of the state. Administratively it has 15

Tahsils, viz., Chopda, Yawal, Raver, Muktainagar, Bodvad, Bhusawal, Bazada part of Jalgaon, Erandol, Dharangaon, Amalner, Parola, Bhadgaon, Chalisgaon, Jamner.

2.3 Physiography of Bazada part of Jalgaon District:

The Tapi and its tributaries drain the Bazada part of Jalgaon region to the west towards Arabian Sea. The landscape is typically that of the Deccan lavas with residual hill ranges and broad valley, with trap dykes introducing sharp local contrast as small chains of hillocks. Thus the region includes varied topographical features and landscapes consisting of wild hills, barren plain, low lying rocky hills and bad land topography near major river banks.

Regionally, at parallel with the Tapi, there are three well markedbelts.

i) The Northern Hilly Region of Satpuda.
ii) The Central Tapi Valley Region.
iii) Southern Ajantha Hilly Region

i. The Northern Hilly Region of Satpuda:

The Satpuda have hills of considerable heights. Some are aboutPanchPandu and Mondhiamal in the East which rise to over 1000 metersabove mean sea level. In the western part of Satpuda region, the altitude of the central crest is about 600 meters high above mean sea level. Intense erosion is predominant in Satpuda region. Much of this region is under forest cover; although severe depletion of forest is much in evidence.

ii.The Central Tapi Valley Region:

The main river of the District is the westward flowing Tapi whichflows for about 125 Kms. within the District. The whole Tapi valley from this District is flat and well tilled. The Tapi valley region is divided into two parts i.e. northern part of the Tapi and southern part of the Tapi. Spurs of the Satpudafrom the north, stretch close to the river bank and on the South rise some low barren hill ranges. The Tapi banks are high and bare. Tapi valley consists of avast alluvial plain.

iii.Southern Ajanta Hilly Region:

Ajanta hill range forms a divide between the Tapi-Purna and Godavari basins. The hill ranges of east of the Satmala are Ajanta hill ranges. The Ajanta range covers the southern part of the District for a distance for a distance of about 120 Kms. The altitude in the west ranges from 600 to 900meters. The altitude of much of the central and eastern part of the region is between 300 to 450 meters.

2.3 Geomorphology and Soil Types:

The district can be divided into three main physiographic divisions i.e.,Satpura hill ranges in the northern part with dense forest; Tapi valley consisting of alluvial plain in the central part of the district and Ajanta hill ranges, flanking the hill ridges and small valleys in the southern part of the district. Tapi is the main river flowing through the district and its major tributaries are Purna in the South and Bhokar, Suki, Morna, Harki, Manki and Gul in the north.The soils in Bazada part of Jalgaon district are essentially derived from the basaltic lava flows and are classified as,

a) Deep black soils,

b) Medium black soils,

c) Loamy and sandy soils

d) Forest soils

Deep black soils are observed in northern part of Amalner, Erandol, Bazada part of Jalgaon, Bhusaval and Edilabadtalukas. Medium black soils occur over large areas in the district viz.; the central belt of the wide Tapi valley and southern hills. In Tapi alluvial basin, soils are black alluvial clay occurring in the southern parts of Yaval, Raver, Chopda, Bazada part of Jalgaon, Bhusaval, Chalisgaon,Amalner,andBhadgao,Loamy soils are observed in the southern-most part of Amalner, Erandol, Bazada part of Jalgaon and Bhusaval. Sandy soils are observed on the foothills of Satpura ranges and near southern hillocks. Forest soils are dark brown and occuron slopes mainly in the Satpura ranges.

2.4 Soil Types

The Bazada part of Jalgaon District belongs to the deccan uplands ofMaharashtra. The variety of soil of the study region are essentially derivedfrom under lying basalt, though older alluvium soil has a deep cover all alongthe broad Tapi valley. The fertility of these types of soil largely dependsontheir position vis-a-vis relief and their nearness to stream courses.

The types of soil in the region are classified in to three broad groups.

i. Deep Black Soil.

ii. Medium Black Soil.

iii. Course Shallow Soil.

i. Deep Black Soil:

This type of soils is grey black and dark brown coloured. Theyare highly sticky. This type of soil is suitable for growing the crops like cotton,banana, wheat, jawaretc.Deep black soil is found in the northern parts of Amalner,Muktainagar, Bazada part of Jalgaon and Bhusawaltahsils.

ii. Medium Black Soil:
These are similar to medium black soils of Deccan. They are clayloam to clay, brownish black in colour and the depth of it is 1 to 2 meters. Thistype of soil cover a large portion of the District and are found in the beltrunning in the east-west District in northern parts of the region between thefoothills of Satpuda and the Tapi river. It includes most of the cultivated area insouthern parts of Raver, Yawal and Chopdatahsils. Another belt in thesouthern parts in the region running in the east – west direction lies between theAjanta range and south of the Tapi valley. The type of soil of Chalisgaon,Erandol, Bhusawal, Bazada part of Jalgaon and Bhadgaontahsils belong to this type.

iii. Course Shallow Soil:

It includes different sub types of soil

.a) Loamy Soil:
These are deep grey in colour and respond well to irrigation.They consist mainly of deposits of river silt. This type of soil is very fertile andobserved on the banks of river Girna and Purna. They occur in a continuous trip in the southern most portion of Amalner, Erandol, Bazada part of Jalgaon, Bhusawal andMuktainagartahsils. Cotton, jawar and banana are the crops which are grownin this soil.

b) Sandy Soil:
The colour of this soil is reddish or yellowish red and depthvarying from few centimetres to 0.45 meters. Sandy soil occurs in largepatches on the slopes of the Satpuda ranges and near the southern hillocks inChalisgaon, Pachora, Jamner, Bhusawal, Parola, Erandol and Bhadgaontahsils.

c) Forest Soil:
These types of soil are black in colour, 5 to 15 centimetresindepth and rich in organic matter. These soils occur on the northern portion ofRaver, Yawal and Chopdatahsils. They occupy the slopes of Satpuda ranges ofhills but no erosion on account of forest cover exists.

2.5 Natural Vegetation:

The natural covering of the land surface of the earth is naturalvegetation. Natural vegetation is important because the soil erosion and soilfertility totally depends on it. The occurrence and proportion of rainfalldepends upon availability of proportion of natural vegetation.

2.5.1Forest area in Bazada part of Jalgaon District:

Forest areas in a study region can be grouped as follows.
i)Forests in Satpuda ranges.

ii) Forests in Middle East, east and south-east.

iii) Forests in south and south-west.

Product wise forests in the region can be grouped as follows.
i) Teak timber areas in northern slopes of Satpudas.

ii) Teak pole areas in forest of Chopda, Yawal, Chalisgaon and Muktainagaron flat or undulating areas.

iii)Babul areas on the banks of river Sur and Purna with species like Babul,Khair, Hiwar, Yelatur, Apta etc.

iv)Scrub forest are scattered throughout the region on the south of Tapivalley.

v) Inaccessible forests are situated in the hearts of Satpuda hills and Satmalaranges in Chalisgaon tehsil .Every tahsil has forest cover but proportion of forest cover varies from one tahsil to another tahsil.

2.6:Geology of Bazada part of Jalgaon District

No systematic geological work has been carried out in the studyregion. The information available on the geology of the region is meagre.Structurally most of the area of the District is covered by Deccantraps. The Deccan traps are made up principally of the most rocks of basalticand doleritic composition. These traps are the results of out pouring ofenormous lava flows which data back to the Mesozoic era. These are spread outin the form of horizontal sheets of beds. The hill ranges on the south of theTapi are covered with dark basalt. A few strips of thick alluvium covered landon both sides of the Tapi and its tributaries which probably caused by faulting,it consists of brownish, yellowish, coloured clay and silt with pebbles, gravelsand fine drained sand.The trap gives rise to deep black soil. Such belts of soil areobserved in northern parts of Amalner, Muktainagar, Bazada part of Jalgaon, Bhusawal andErandoltahsils. The sandstone and limestone are also found in the northwestern portion of Satpuda ranges.

2.7 Drainage System of Bazada part of Jalgaon District:

Drainage includes surface as well as underground flow of naturalwater. It is related to cloudiness, insolation, humidity, precipitation, windvelocity, wind direction, surface flow, and also related to nature of topography,vegetation, soil cover and its human utilization pattern.

Tapi is the main river in the Bazada part of Jalgaon District. It drains about 120Kms. of surface. The Tapi receives many tributaries from both sides. On theright bank of Tapi the tributaries are Bhokar, Suki, Mor, Manki, Guli, Hadki.

Aner while Purna, Bhogawati, Vaghur, Girna, Panzara and Bori tributariesare join the Tapi river on its left bank.The right bank tributaries of the Tapi river originate fromSatpudas on its southern slope and of little use for irrigation purpose.The left bank tributaries of Tapi flow the south and emanate fromSahyadris except for Purna and Vaghur. The Purna, Girna, Panjhara drain muchwider tracks. The Purna entering from the south-east flows in this District for40 Kms. and meets the Tapi near Changdeo in Muktainagartahsil. The Girnariver rising from Nasik District and flowing 120 Kms. to Bazada part of Jalgaon District, joinsto Tapi near village Nanded in Amalnertahsil. The Vaghurriver flows fromAjanta hills and meets to Tapi near Shelgaon in Bazada part of Jalgaontahsil. The river Boririses in Nasik District near Malegaon and joins the Tapi near village Bohoreinthe District. During the raining season all these tributaries flow with significantvolume of water and become almost dry during summer season.

2.8: Climate and Rainfall:

The average annual rainfall in the district is 740.7 mm. (29.16'). About 87 per cent of the annual rainfall is received during the monsoon months of June to September, July being the month with the highest rainfall. The central parts of the district comprising the talukas of Bazada part of Jalgaon, Bhusawal, Jamner and Pachora get a little more rain than the rest of the district. Jamner, the station with the highest rainfall in the district, gets annually 802 mm. (31.58") while Amalner, the station with the least rainfall gets 675 mm. (26.58"). The_ variation of rainfall over the district from year to year is large.

On an average on 45 days in the year the district gets rainfall of 2.5 mm. (10 cents) or more. This number varies from 48 at Jamner to 42 at Chopda, Amalner and Paiola.

Bazada part of Jalgaon has a varied climate. It is hot and dry in summer, with temperatures reaching 47 °C (117 °F) from late May to mid-June; the record high, in May 2010, was 49.2 °C

(120.6 °F). Bazada part of Jalgaon receives about 700 millimetres (28 in) of rainfall during the monsoon.

District receives an average rainfall of about 690 mm and the temperature varies from 10 to 48 degree Celsius.

Bazada part of Jalgaon has got pretty diverse climate. It is exceptionally hot and dry during summer with temperature reaching as high as 45 degrees Celsius. Bazada part of Jalgaon receives about 700 mm rainfall during monsoons, which is followed by pleasant temperature in winter.

Bazada part of Jalgaon's climate is a local steppe climate. During the year there is little rainfall. The climate here is classified as BSh by the Köppen-Geiger system. The average annual temperature is 27.2 °C in Bazada part of Jalgaon. The average annual rainfall is 785 mm.

Table 1:Climate data of Bazada part of Jalgaon

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Non**	**Dec**
mm	0	1	4	10	31	107	116	88	161	73	21	7
^{0}c	21.7	23.8	27.5	30.6	31.8	28.7	26.2	25.7	25.7	25.6	22.8	12.7
^{0}C(min)	13.1	14.6	18.5	22.5	23.9	22.9	21.9	20.8	19.5	15.2	21.2	12.7
^{0}C(max)	30.3	33.1	36.5	38.8	39.7	34.5	30.5	30.2	30.7	31.7	30.5	29.7
^{0}F	71.1	74.8	81.5	87.1	89.2	83.7	79.2	78.3	78.3	78.1	73.0	70.2
^{o}F(min)	55.6	55.8	65.3	72.5	75.5	75.0	73.2	71.4	70.2	69.4	67.1	59.4
^{o}F(max)	86.5	91.6	97.7	101.8	103.5	94.1	86.9	86.4	87.4	89.1	86.9	85.3

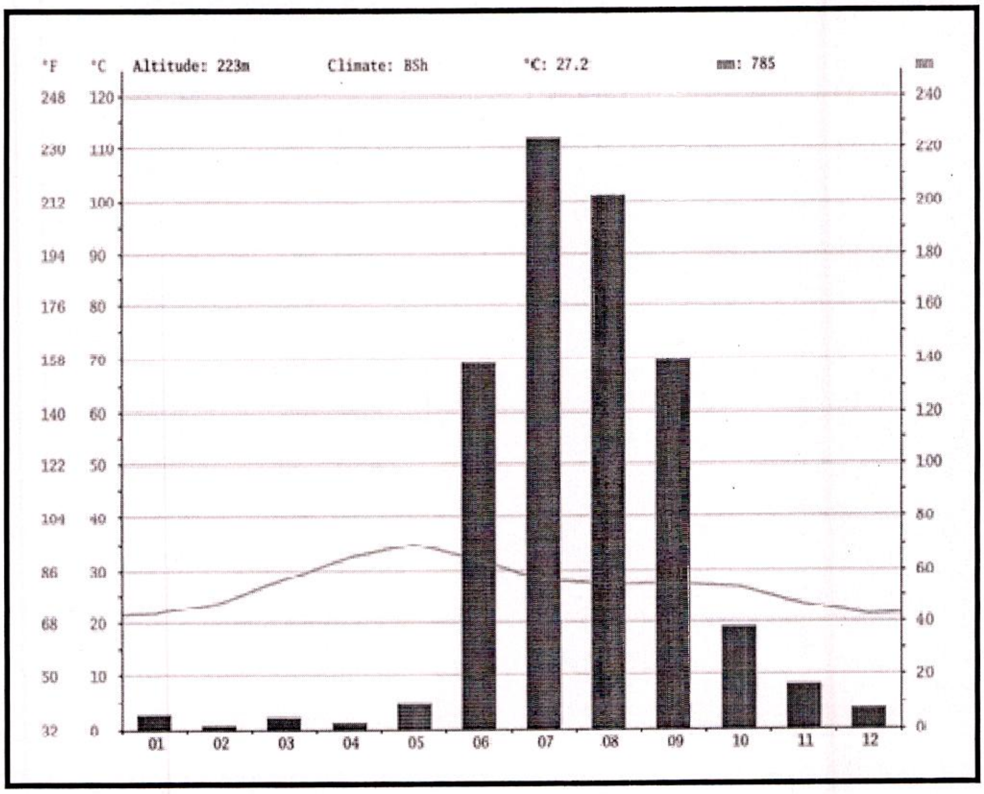


Figure-3:Climate Graph Bazada part of Jalgaon Showing Precipitation is the lowest in February, with an average of 1 mm. Most of the precipitation here falls in July, averaging 224 mm.

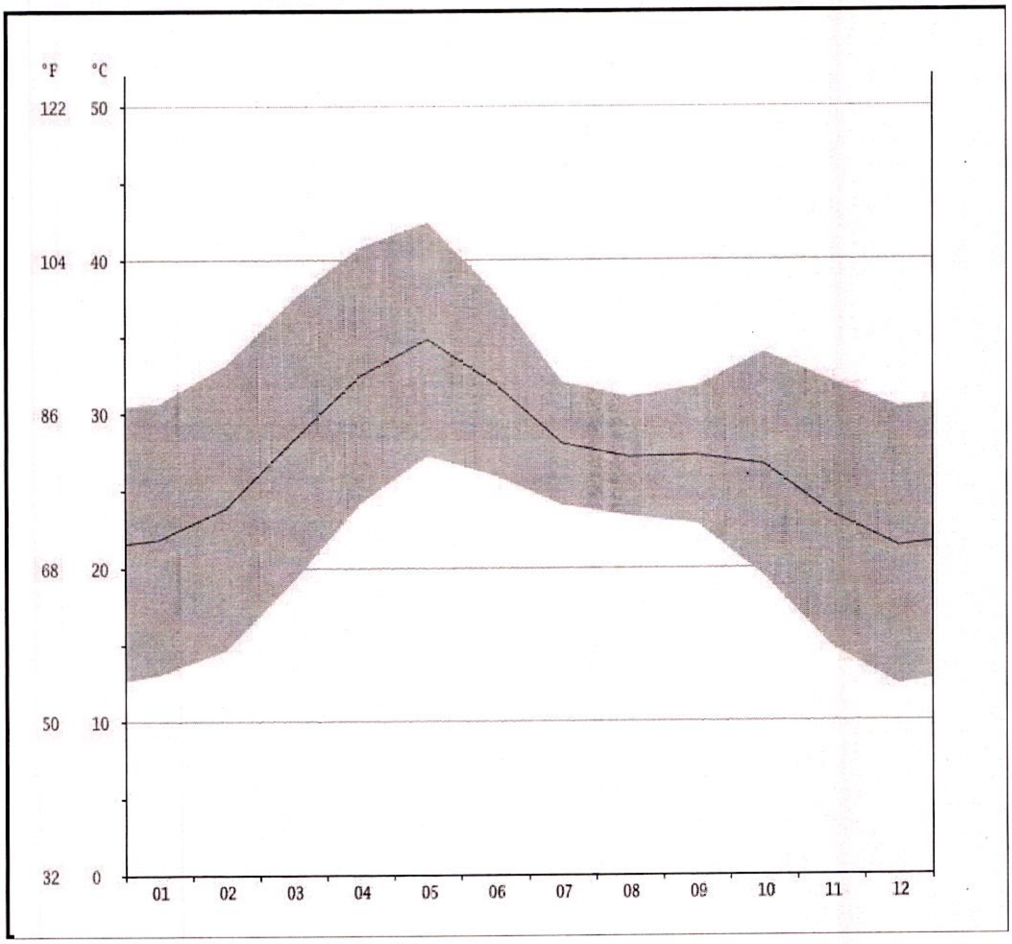


Figure-2:Temperature graph Bazada part of Jalgaon showing an average temperature alongwith maximum and minimum. The May with 34.8 °C, is the hottest month of the year. December is the coldest month, with temperatures averaging 21.3 °C.

Chapter 3

3.1 Hydrogeology

Other major aquifers in Maharashtra State are Archeans (32,235 sq km; 10.5% coverage) consisting mainly of granites, gneisses, and schist's followed by alluvium (14,526 sq km; 4.7%), Precambrian (Vindhyans, Cuddapahs, and Kaladgis) 6,217 sq km; 2% of area in the state consisting mainly of sandstones, limestones and shale's, Gondwana (4800 sq km; 1.6%) consisting of sandstone, conglomerate, shale, coal beds etc. Theaquifers are grouped under three major hydrogeological groups namely unconsolidated, semi-consolidated and consolidated and also nine different types of hydrogeological sub-groups based on geological age and hydrogeological characters.

3.2Seasonal Water Level Variations

Seasonal Water level variations were analysed and maps were prepared after everywater level measurement comparing the current water levels with that of the preceding seasonand pre-monsoon season. During the year water level Variation in August 2014 withreferenceto September 2015 were studied.TheseVariations were analysed to decipher the Groundwater situation with respect totime. Rise and fall in water level was observed. The rise in water level due to monsoonrainfall is natural phenomenon in the hydrologic cycle as natural dynamic recharge.However, the fall in water level is local phenomenon and many courses may be attributed tofall in water level.

Parts of the talukas like Pachora, Bazada part of Jalgaon, Bhusawal, BodwadandMuktainagar have shown Variation of 0-2 m. In entire district, rise in water levelhasbeen observed except in Muktainagartaluka where in some parts fall of 0-2 m was observed. Major parts of the district is characterised by Variations of 2-4 mviz. Chalisgaon, Bhadgaon, Parola, Erandol, Dharangaon, Bazada part of Jalgaon, Chopda, AmalnerYaval, Raver and Parts of Muktainagar (Edlabad). In parts of Bhadgaon, Chalisgaon, Yaval and Raver taluka, Variation more than 4 m is observed.

Table 2 Water Level of Bazada part of Jalgaondistrict

Village	Latitude	Longitude	Date	Monsoon (Water Level)

Village	Latitude	Longitude	Date	Monsoon (Water Level)
Chahardi	21.23	75.24	14/09/2015	5.30
Galangi	21.26	75.13	14/09/2015	5.35
Ganpur	21.29	75.16	14/09/2015	20.73
Virvade	21.32	75.35	16/9/2015	14.90
Chopda	21.25	75.32	16/09/2015	18.50
Chopda	21.27	75.30	16/09/2015	17.70
BorAjanti	21.32	75.33	16/9/2015	11.20
Lasur	21.30	75.21	10-09-2015	22.50
Borkhede	21.25	75.36	16/09/2015	10.10
Chinchole	21.22	75.56	21 /09/2015	10.10
Adgaon	21.24	75.56	21/09/2015	11.38
Malod	21.23	75.58	21/09/2015	8.40
KingaonBudrukh	21.20	75.57	22/09/2015	12.00
Shirsad	21.17	75.64	23/09/2015	30.00
Viraoli	21.17	75.66	23/09/2015	35.20
Yaval	21.17	75.71	23/09/2015	24.00
ChikoraSiwar	21.18	75.74	23/09/2015	34.90
DongarKathora	21.20	75.74	23/09/2015	25.80
Hingona	21.20	75.77	23/09/2015	35.00
Nahavi	21.17	75.85	23/09/2015	38.10
Rajora	21.12	75.75	24/09/2015	45.40
Atrawal	21.20	75.83	24/09/2015	38.90
ChicklyBudukh	21.14	75.76	16/09/2015	50.00
Amoda	21.15	75.83	24/09/2015	44.40
Savda	21.16	75.89	25/09/2015	46.70
Rajora	21.33	76.04	25/09/2015	37.50

Village	Latitude	Longitude	Date	Monsoon (Water Level)
Kamoda	21.20	75.86	25/09/2015	34.20
Saokheda	21.22	75.90	25/09/2015	37.50
KhumbherKheda	21.23	75.94	25/09/2015	31.50

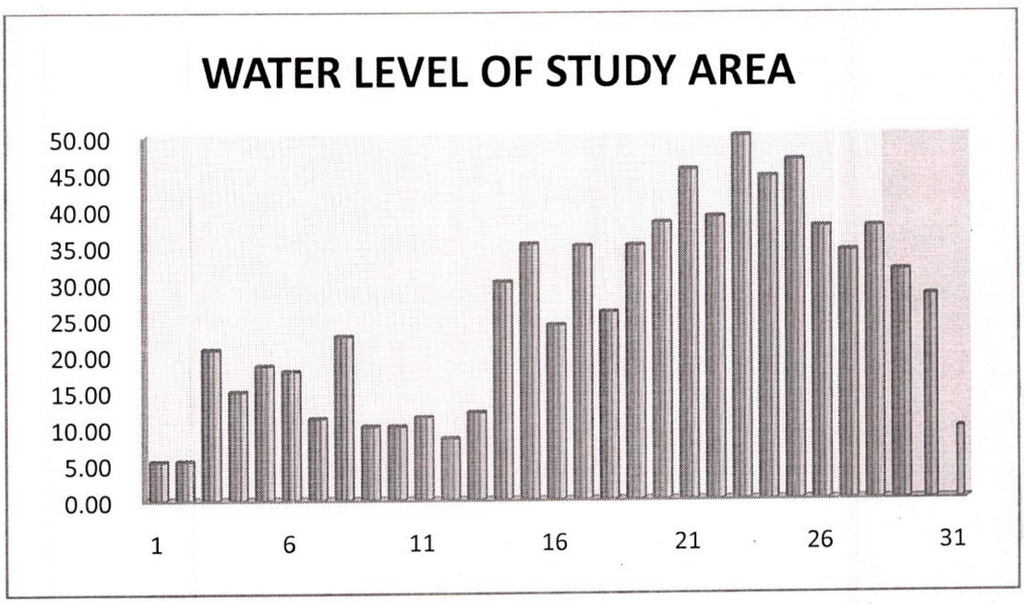


Figure -3; Water level graph of study area

3.3: Water Sampling Locations

Groundwater conditions of the study area were studied by carrying out water sampling. Water samples were collected from different sources of the study area such as river, Open well, Bore well and hand pump. Table 3includes the details of the sampling location of the collected samples from the study area.

Table 3 Details of sampling sites

S.No.	Sample Name	Source	Location	Longitude	Latitude

S.No.	Sample Name	Source	Location	Longitude	Latitude
1	J1	River	Mohrale	75.68	21.28
2	J2	River	Sakli	75.64	21.17
3	J3	OW	Naigaon	75.59	21.23
4	J4	HP	Vaghjira	75.60	21.28
5	J5	OW	Malood	75.59	21.25
6	J6	BW	Kingaon	75.58	21.21
7	J7	BW	Giradgaon	75.59	21.20
8	J8	BW	Hated	75.17	21.25
9	J9	BW	Anir Dam	75.15	21.31
10	J10	River	Ganpur	75.15	21.29
11	J11	River	Mamlade	75.26	21.29
12	J12	OW	Krishnapur	75.26	21.34
13	J13	HP	Bore Aganti	75.32	21.33
14	J14	OW	Mangrol	75.40	21.22
15	J15	BW	Vale	75.27	21.22
16	J16	BW	Bhawale	75.18	21.28
17	J17	BW	Aadagon	75.33	21.28
18	J18	BW	Malapur	75.37	21.33
19	J19	BW	Kharag	75.34	21.25
20	J20	BW	Vishnapur	75.39	21.30
21	J21	River	Akulkheda	75.27	21.25
22	J22	OW	Ghumawal	75.32	21.23
23	J23	HP	Looni	75.47	21.23
24	J24	OW	Looni	75.48	21.25
25	J25	BW	Mania basti	75.48	21.27
26	J26	HP	Dhanora	75.52	21.21
27	J27	BW	Devgaon	75.52	21.19
28	J28	OW	Dhanora	75.51	21.21
29	J29	BW	Dhanora	75.52	21.23
30	J30	OW	Sajabidgoan	75.52	21.25

Chapter-4

Methodology:

4.1:Sampling and preservation –

Representative groundwater samples were collected for physicochemical analysis in polyethylene bottles along with their GPS coordinates during July 2016 – August 2016 from 30 locations and preserved by adding an appropriate reagent (APHA, 2012). The handpumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. All the groundwater samples were collected from the sources, which are being used extensively. The details of groundwater samples collected for analysis of various parameters in provided in Table-5.

4.2 Methodology for Water Quality Parameters

In the present study, various water quality parameters as given in Table 4are described in detail as follows:

4.2.1 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).

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 is 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.

PROCEDURE: -

i) For detailed instructions, follow manufacturer's manual, Standardize 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.

4.2.2 Electrical Conductivity (EC)

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 demineralized water and total dissolved solids in boiler and cooling tower water. Electrical conductivity is generally measured in terms of μS/cm.

REAGENTS: -

i) **Conductivity water:** Pass distilled water through a mixed bed deionizer and discard first litre. Conductivity should be less than 1μmho/cm.

ii) **Standard potassium chloride solution, 0.01 N:** Dissolve 745.6 mg anhydrous KC1 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 μmho/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, Standardize 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 μmho/cm.

ii) Remove electrodes from KCL, rinse thoroughly with distilled water, and blot dry with a soft tissue. Immerse them in the sample. Let the reading stabilize. Read the EC value.

4.2.3 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 indices 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 fiber 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.

4.2.4 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.:

REAGENTS:-

1-Sulphuric Acid 0.02N:

Dilute 0.72 ml of concentrated sulphuric acid to 1000ml with distilled water and standardize against standard sodium carbonate.

2-Sodium carbonate solution (0.02N): Dissolve 0.27gm sodium carbonate in distilled water and make up to 250ml.

3-Phenolphthalein indicator: Dissolve 5gm of the indicator in 500ml of ethanol and dilute to 1000ml with distilled water.

4-Methyl orange indicator: Dissolve 0.5gm of the indicator (acid free type, in 1000ml distilled water.

PROCEDURE:-

1- Pipette 20ml of the water sample into a 250 ml clean conical flask.

2- Add two drops of phenolphthalein indicator. If a pink colourdevelops, carbonate is present.

3- Titrate this against 0.02N sulphuric acid till the pink colour disappears.

4-To the sample in the conical flask, add 1 or 2 drops of methyl orange indicator.

5- Continue the titration till the straw yellow color changes to pinkish red.

Calculations:

Volume of water sample taken= 20ml.

Volume of 0.02N H_2SO_4 used for phenolphthalein end point = Xml

Volume of 0.02N H_2SO_4 used for methyl orange indicator.

HCO_3^- (mg/l) = (Y-2X) *0.02 *61/20 *100.

4.3Chemicals and Reagents

All chemicals used for analysis were of analytical reagent grade (Merck/BDH). Standard solutions of metals ions were procured from Merck, Germany. Pesticide standards were procured from Sigma-Aldrich, USA. Bacteriological reagents were procured from HiMedia, India. De-ionized water was used throughout the analysis work. All glassware and other containers used for trace metal analysis were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48 hours and finally rinsed with de-ionized water several times prior to use. All glassware and reagents used for bacteriological analysis were cleaned and sterilized before use. All glassware for pesticide analysis was rinsed with chromatography grade solvents prior to use.

4.4Analytical Methodology

The samples were analyzed as per Standard Methods for the Examination of Water and Wastewater (APHA, 2012; Jain and Bhatia, 1988). The details of analytical methods and equipment used in the study are given in Table 3. Ionic balance was calculated and the error in the ionic balance for majority of the samples was within 5%.

The major cations and anions in the samples were analyzed with the help of Dionex IC-5000 Ion Chromatograph. Ion chromatography is a form of liquid chromatography, in which ion exchange resins are employed to separate atomic and molecular ions for analysis. IC involves the retention of ions from the sample being retained based on ionic interactions. Quantification of cations and anions in the sample is based upon calibration curve of standard solutions of respective cations/anions.

Table 4 Details of Analytical Methods and Equipment's

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	Conductivity Method	Ion Chromatography
6	Chloride		
8	Calcium		
9	Magnesium		
10	Sodium		
11	Nitrate		
12	Hardness	Titration by EDTA	Titration

4.5:Ion Chromatography

Ion chromatography is used for water analysis. The measurement of concentration of major anions such as fluoride,chloride, nitrate,nitrite and sulfate as well as major cations such as lithium, sodium , ammonium , potassium, calcium and magnesium in the parts-per-billion.

The analyzer, suppressor, column, detector are the component of ion chromatography. In ion chromatography,. As an ion extraction liquid runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentration in the sample.

Figure 4 :Working with Ion chromatograph

Working:

In ion chromatography, the sample is passed through analyzer where the mixture of sample is injected into a carrier fluid (eluent). Then the solutions are passed to suppressor where the conductance of eluent is reduced and at the same time it enhances the conductance of the sample. Then the sample solutions passed through a pressurized chromatographic column where ions are absorbed by column constitutes i.e. adsorbent. Different materials are andhere to adsorbent with different forces. As the eluent are flows through column the components of analyte are moved down the column at different speed and therefore they separate from one another. As the analyte are emerge from the column, the detector gives the output at the end of column.

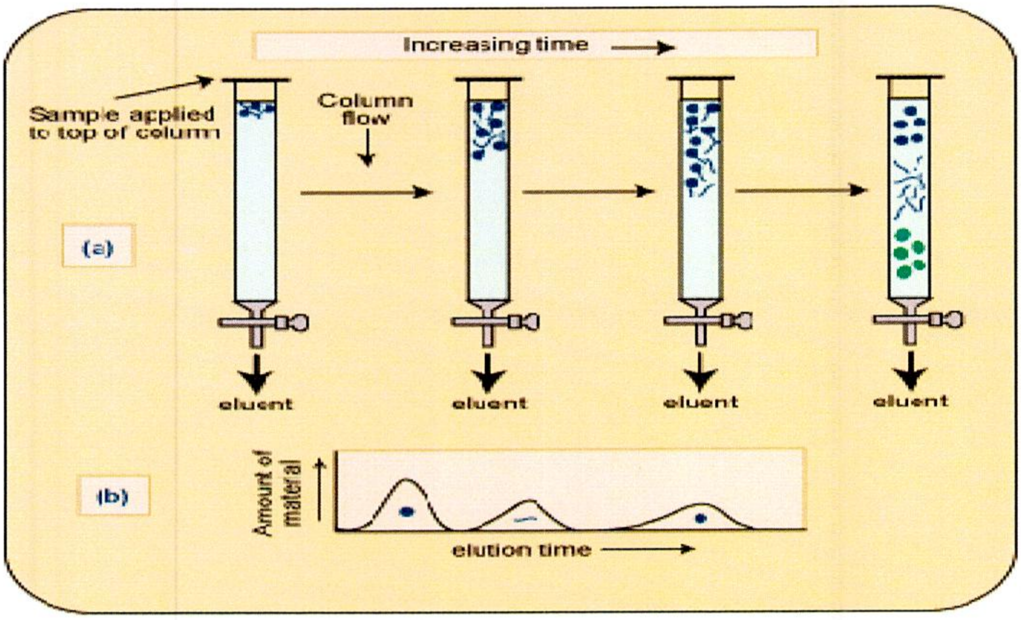


Figure 5:Working of component of ion chromatograph

Outcome of ion chromatography:

The outcome of ion chromatography is given by detector. Detector generates a measurable signal when the analyte are emerges from the column. These signals are represented as the peaks on the chromatogram.

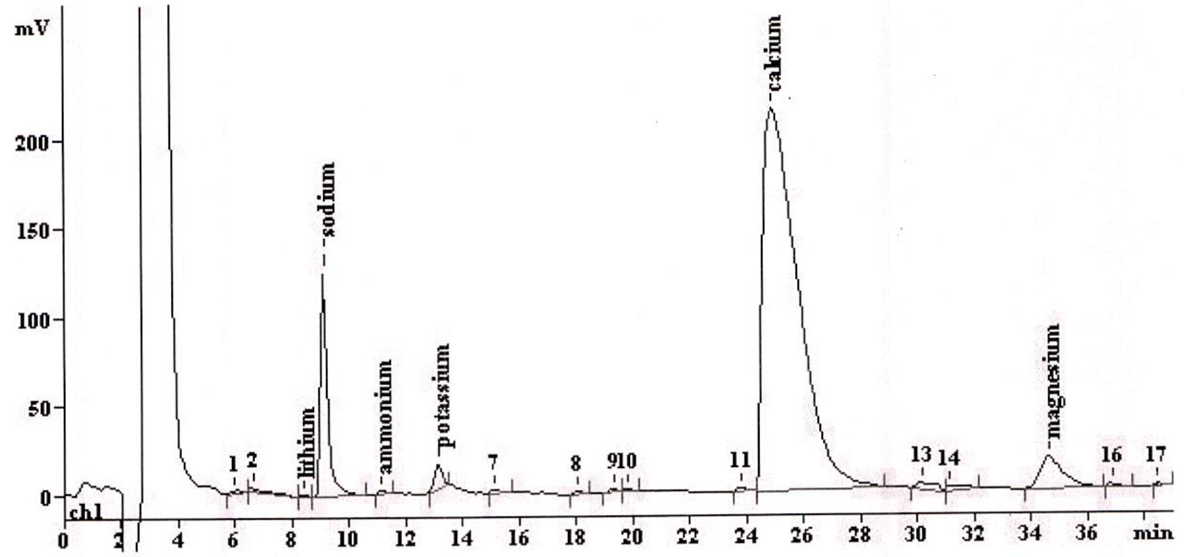


Figure 6: Representation of peaks in chromatograph

Chromatogram is the record of the outcome of detector as in the form of electrical conductivity versus time of the analyte passes through the chromatographic system.

Chapter-5

Results and Discussion

5.1 Groundwater Quality

The objective behind the Groundwater quality monitoring is to develop an overall picture of the Groundwater quality of theBazada part of Jalgaon District. During the year 2015,the team has carried out the Groundwater quality monitoring of 30 monitoring wells. These wells largely consist of the dug-wells representing the shallow aquifer. The sampling of Groundwater from these wells was carried out in the month of June (Pre-monsoon period) 2016 throughout the state. The district wise collection of groundwater samples is summarised in Table-5. The Groundwater quality data of Groundwater monitoring wells in Bazada region of tapi basin and Bazada part of Jalgaon district.

The water samples after collection were immediately subjected for the analysis of various parameters in the Regional Chemical Laboratory of the NIH at Roorkee. The general parameters analyzed in the collected samples of Groundwater are pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS). The samples were also analysed for major cations viz. Magnesium(Mg^{2+}), Calcium (Ca^{2+}), Sodium (Na^+), Potassium (K^+) and anions viz. Carbonate (CO_3^{2-}), bicarbonate(HCO_3^-), Sulphate (SO_4^{2-}), Chloride (Cl-), Nitrate (NO_3^-) and Fluoride (F-). The samplecollection, preservation, storage, transportation and analysis were carried out as per the standardedmethods given in the manual of American Public Health Association for the Examination ofWater and Wastewater (APHA, 1998). The results of the chemical analysis of Groundwater samples were checked and validated through standard checks. Subsequently, the interpretation of data was carried out to develop the overall picture of Groundwater quality in Maharashtra and Bazada part of Jalgaon district.

Table 5: Area wise collection of Groundwater samples (June 2016)

S.No.	Sample	Source	Location	Longitude	Latitude	EC	TDS	PH

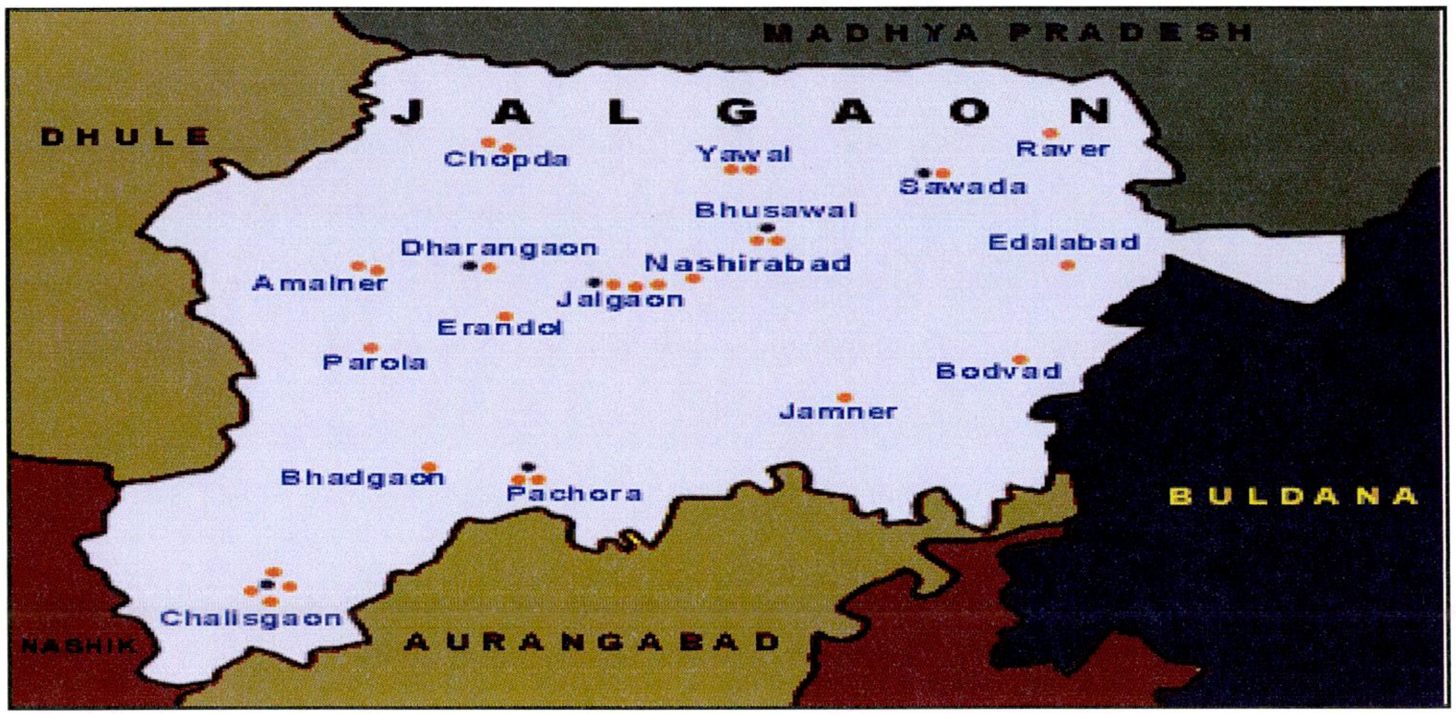
	Name							
							mg/l	
1	J1	River	Mohrale	75.68	21.28	380	88.3	7.5
2	J2	River	Sakli	75.64	21.17	1128	476.3	7.61
3	J3	OW	Naigaon	75.59	21.23	542	148.9	7.8
4	J4	HP	Vaghjira	75.60	21.28	458	102.6	7.69
5	J5	OW	Malood	75.59	21.25	500	103.4	7.62
6	J6	BW	Kingaon	75.58	21.21	647	212.3	7.39
7	J7	BW	Giradgaon	75.59	21.20	899	318.4	7.21
8	J8	BW	Hated	75.17	21.25	1345	241.5	7.11
9	J9	BW	Anir Dam	76.55	21.31	343	84.6	7.48
10	J10	River	Ganpur	75.15	21.29	1076	270.6	7.16
11	J11	River	Mamlade	75.26	21.29	566	142.2	7.22
12	J12	OW	Krishnapur	75.26	21.34	615	165.3	7.2
13	J13	HP	Bore Aganti	76.32	21.33	602	168.5	7.22
14	J14	OW	Mangrol	75.40	21.22	1008	321.3	7.19
15	J15	BW	Vale	75.27	21.22	1707	548.7	6.83
16	J16	BW	Bhawale	76.18	21.28	1338	422.5	7.31
17	J17	BW	Aadagon	75.33	21.28	766	264.1	7.41
18	J18	BW	Malapur	76.37	21.33	258	60.8	7.99
19	J19	BW	Kharag	75.34	21.25	865	384.0	7.29
20	J20	BW	Vishnapur	75.39	21.30	519	180.0	7.39
21	J21	River	Akulkheda	75.27	21.25	683	170.0	7.32
22	J22	OW	Ghumawal	75.32	21.23	736	158.1	7.39
23	J23	HP	Looni	75.47	21.23	770	277.7	7.81
24	J24	OW	Looni	76.48	21.25	577	166.1	7.64
25	J25	BW	Mania basti	75.48	21.27	384	210.7	7.75
26	J26	HP	Dhanora	75.52	21.21	870	151.5	7.48
27	J27	BW	Devgaon	76.52	21.19	718	254.7	7.5
28	J28	OW	Dhanora	75.51	21.21	1007	401.1	7.54
29	J29	BW	Dhanora	75.52	21.23	730	289.1	7.56
30	J30	OW	Sajabidgaon	76.52	21.25	530	176.6	7.6

Table 6:Ground water quality data of Samples of District

S.No.	Sample Name	Source	Location	Longitude	Latitude	F-	Cl-	HCO3-	SO42-	NO3-	Ca2+	Mg2+	Na+	K+
						mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	J1	River	Mohrale	75.68	21.28	0.0	3.8	260.00	6.8	5.0	40.9	20.3	13.6	1.0
2	J2	River	Sakri	75.64	21.17	0.0	103.5	338.50	23.2	144.3	31.3	86.4	85.5	2.0
3	J3	OW	Naigaon	75.59	21.23	0.0	12.0	296.1	7.1	20.0	42.9	34.5	27.3	1.1
4	J4	HP	Vaghjira	75.60	21.28	0.0	6.3	283.2	3.0	2.8	42.4	30.3	15.2	1.9
5	J5	OW	Malood	75.59	21.25	0.0	3.8	289.9	2.5	2.7	54.1	23.9	15.4	1.0
6	J6	BW	Kingaon	75.58	21.21	0.0	32.6	285.7	15.6	42.8	52.4	43.3	24.8	0.8
7	J7	BW	Giradgaon	75.59	21.20	0.0	70.1	389	11.9	63.9	59.5	64.6	47.5	1.0
8	J8	BW	Hated	75.17	21.25	0.0	90.9	73	49.9	5.3	15.2	8.3	71.0	0.9
9	J9	BW	Anir Dam	76.55	21.31	0.0	9.9	189	5.6	5.2	40.3	8.3	13.7	1.7
10	J10	River	Ganpur	75.15	21.29	0.0	58.6	490.2	6.7	7.4	15.3	52.3	129.4	0.9
11	J11	River	Mamlade	75.26	21.29	0.0	7.6	345	5.6	0.0	14.2	19.9	92.8	1.3
12	J12	OW	Krishnapur	75.26	21.34	0.4	19.7	370	7.2	0.0	38.7	27.1	70.6	1.3
13	J13	HP	Bore Aganti	76.32	21.33	0.3	27.3	367	4.5	0.0	24.0	49.2	53.2	1.9
14	J14	OW	Mangrol	75.40	21.22	0.0	42.6	650	9.2	0.0	15.0	55.7	176.5	3.9
15	J15	BW	Vale	75.27	21.22	0.0	81.6	900	15.9	19.1	15.8	19.0	393.8	1.6
16	J16	BW	Bhawale	76.18	21.28	0.0	50.1	785	43.8	0.0	19.8	55.9	247.1	5.8
17	J17	BW	Aadagon	75.33	21.28	0.0	66.2	354	10.7	9.2	36.0	12.3	127.5	2.2
18	J18	BW	Malapur	76.37	21.33	0.0	3.8	187	2.8	0.0	31.0	10.8	10.9	1.6
19	J19	BW	Kharag	75.34	21.25	0.0	96.8	320	21.0	6.5	40.4	13.3	133.7	2.7
20	J20	BW	Vishnapur	75.39	21.30	0.2	42.6	219	18.2	9.8	20.9	23.8	61.3	1.2
21	J21	River	Akulkheda	75.27	21.25	0.5	21.3	298	8.7	0.0	4.3	3.9	130.9	0.4
22	J22	OW	Ghumawal	75.32	21.23	0.0	20.2	324	3.2	14.5	37.7	26.6	55.0	0.8
23	J23	HP	Looni	75.47	21.23	0.0	59.7	327	6.6	61.4	22.3	53.9	72.6	1.1
24	J24	OW	Looni	76.48	21.25	0.0	18.5	345	5.0	27.9	29.0	51.2	33.6	0.9
25	J25	BW	Mania basti	75.48	21.27	0.0	49.9	145	7.9	63.7	42.9	27.9	17.6	0.9
26	J26	HP	Dhanora	75.52	21.21	0.0	15.2	345	5.1	21.0	28.7	48.0	32.8	0.7

S.No.	Sample Name	Source	Location	Longitude	Latitude	F-	Cl-	HCO3-	SO42-	NO3-	Ca2+	Mg2+	Na+	K+
						mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
27	J27	BW	Devgaon	76.52	21.19	0.0	76.8	234	13.8	41.1	42.0	47.0	32.9	1.0
28	J28	OW	Dhanora	75.51	21.21	0.0	98.5	290	10.9	141.3	38.9	67.7	42.8	0.9
29	J29	BW	Dhanora	75.52	21.23	0.0	58.4	347	26.8	69.8	41.4	57.9	34.4	0.4
30	J30	OW	Sajabidgoan	76.52	21.25	0.0	23.9	248	9.7	39.0	42.1	31.3	29.6	1.1

Figure 7: Physical map show the location of water samplesofBazada part of Jalgaon district



5.2 Physico-Chemical Characteristics of Groundwater

The concentrations of various gases and ions dissolved in water from the atmosphere, soil strata and minerals and rocks with which it comes are the characteristics of water. This ultimately decides the quality of Groundwater. The concentration of CO_3^{2-}, HCO_3^-, OH- and H^+ ions and dissolved CO_2 gases in water decide the acidic or basic nature of water while the salts of ions like Ca^{2+} and Mg^{2+} in water makes it soft or hard. Water with high Na^+ and Cl^- concentration can make the water saline. Nitrate ions percolated from anthropogenic sources can become predominant major anion in Groundwater. The excess fluoride concentration in GroundwaterFrom fluoride bearing minerals may be related to the concentration of Ca^{2+}, Na^+ and HCO_3^- ions present in Groundwater. Minimum, maximum and the average values of the chemical parameters analysed in the 30Groundwater samples collected from wells representing shallow aquifer are summarized below in Table-7.

Table 7 :Minimum, Maximum and average values of parameters in groundwater

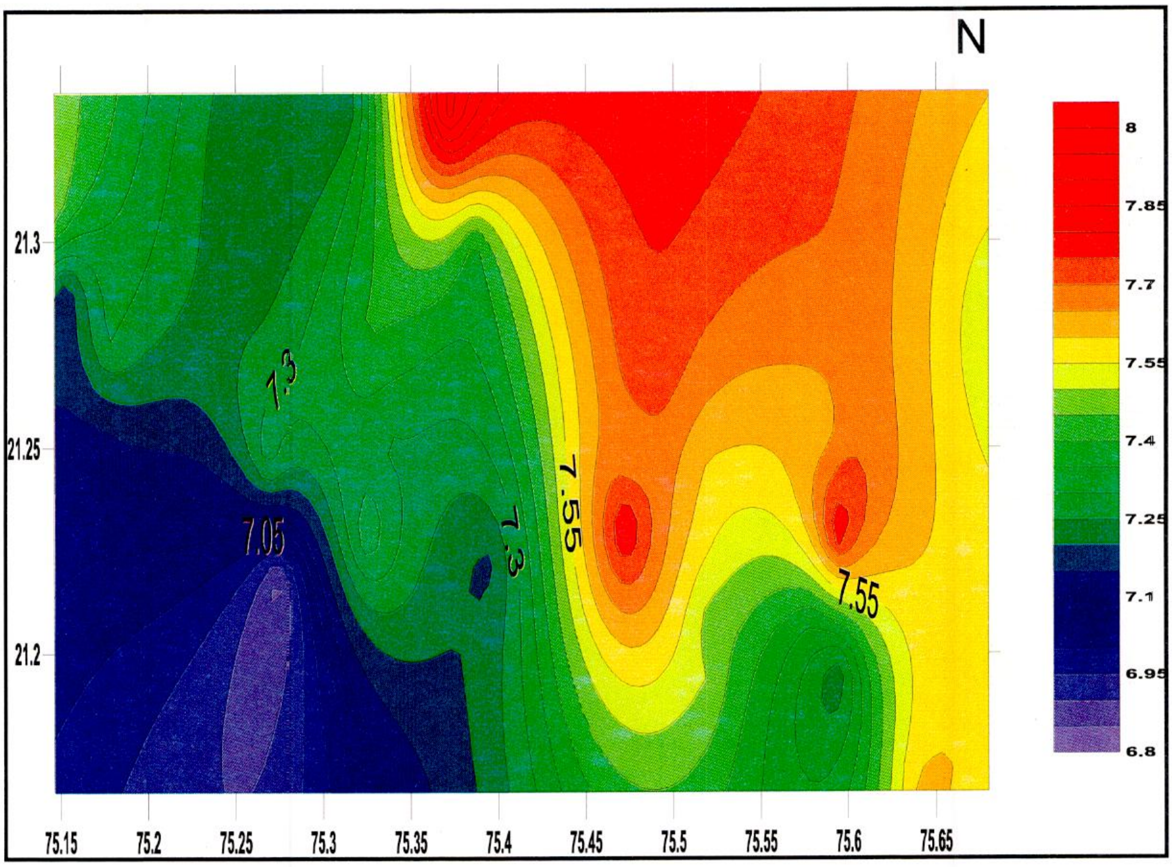
Sl.No.	Parameters	Minimum	Maximum	Average
1.	pH	6.83	7.99	7.44
2.	EC (µS/cm)	258	1707	752.23
3.	TDS (mg/L)	60.8	548.7	232.0
4.	TH as $CaCO_3$(mg/L)	26.57	432.64	228
5.	Ca^{2+} (mg/L)	4.3	59.5	32.6
6.	Mg^{2+} (mg/L)	3.9	86.4	35.8
7.	Na^+(mg/L)	10.9	343.8	27.5
8.	K^+ (mg/L)	0.4	5.8	1.5
9.	HCO_3^- (mg/L)	73	900	343.15
10.	Cl- (mg/L)	3.8	103.5	42.4
11.	SO_4^{2-} (mg/L)	2.5	49.4	12.3
12.	NO_3^- (mg/L)	0.0	144.3	27.5
13.	F- (mg/L)	0.0	0.5	0.0

The preliminary results of water quality parameters are discussed below:

5.2.1 pH

pH is one of the most important parameter in water chemistry and is defined as log[H+], and is measured as intensity of acidityor alkalinity on a scale ranging from 0-14. In natural water, pH is governed by the equilibrium between carbon dioxide, bicarbonate and carbonates ions and in general, ranges between pH 4.5 to 8.5. Although pH has no direct impact on the health of consumers, it is one of the most important operational water quality parameter. BIS (2012) have prescribed pH value in the range of 6.5 to 8.5 for water used for drinking purpose.The pH of the analysed water samples of study area varies from 6.83 to 7.99(Table 4)with an average value of 7.44 ,andwere well within the limits prescribed by BIS (2012) and WHO (2011) for various uses of water including drinking and other domestic supplies.

Figure 8 Map shows distributions of pH value of water samples



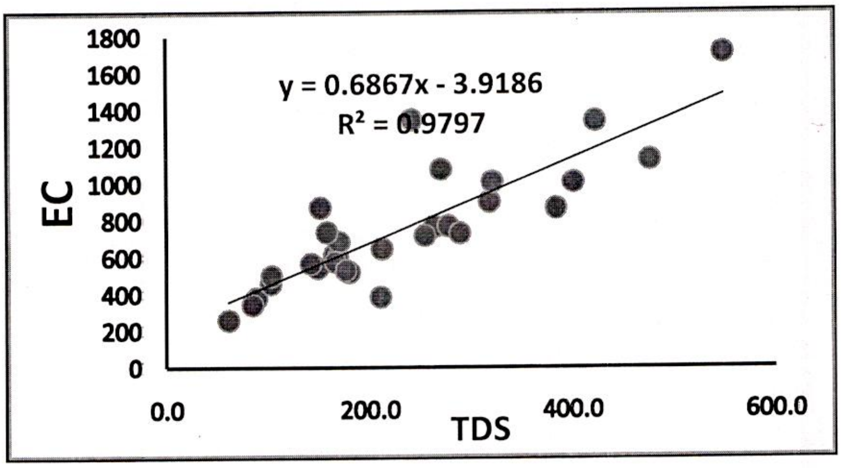
5.2.2: Electrical Conductivity (EC)

Electrical conductivity (EC) is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, miobility, and valence; and on the temperature of measurement. The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The electrical conductivity (EC) values varied from 258 to 1707 μS cm-1with an average value of 752.23 μS cm-1. The groundwater at some places indicated high salinity due to which it is unsuitable even for irrigation uses. The spatial differences between the EC values may reflect the wide variation in the activities and processes prevailing in the region.

5.2.3:Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

The measurement of EC of water gives an idea about the ions concentration in the water. As the concentration of dissolved ions increases, the water becomes more conductive and also showsrise in TDS values. EC and TDS are interrelated as mostly inorganic substances are dissolved inGroundwater. The TDS is computed as sum of ions concentration in Groundwater. It is also animportant parameter to assess the quality of water. The distribution of EC and TDS in groundwater of theBazada part of Jalgaon district is shown in Table -4respectively.The average values of EC of the samples suggest that the groundwater in the monitoringwells is fresh in nature .It is observed that the EC of Groundwaterofshallow aquifer in majority of the areas of the state is well within the maximum permissible limitsas prescribed by BIS, i.e. below 2000 μS/cm. In western part of Maharashtra especially in westerncoastal tract of the State, EC in the Groundwater is less than 500 μS/cm at 25°C and TDS is alsoless than 500 mg/L in the districts ofKingaon, Dhanora and Giradgaon. This is due to thephysiographical, climatic and hydrogeological conditions existing in the area. This area is mainlyhilly and receives maximum rainfall in the State and is covered by porous laterite capping overBasalts. Due to steep gradient existing in the area, the Groundwater gets minimum residence timeand the flushing of aquifer is regularly going on due to the heavy rainfall. The high values of TDSin few wells from Valedistrict may probably due to the intrusion of sea water. The low TDS ingroundwater in some parts of Bazada and Jalgaon is mainly in the hilly and forest area.Sakri ,Giradgaon , Hated , Ganpur, Mangrol, Vale , Bhawle, Dhanora , Devgaon , Ghumawal and Looniaretheareas where the Groundwater is highly saline i.e. Electrical Conductivity is more than 1707µs/cm.

Figure 9:Interrelation graph of EC and TDS



5.2.4:Total Dissolved Solids (TDS)

Total Dissolved Solid (TDS) in water includes all dissolved material in solution, whether ionized or not. TDS is numerical sum of all mineral constituents dissolved in water and is expressed in mg/l. TDS in drinking-water originates fromnatural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological region sowing to differences in the solubilities of minerals.The palatability of water with a total dissolved solids (TDS) level of less than about600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.No health-based guideline value for TDS has been proposed (WHO, 2011). BIS (2012) has prescribed 500 mg/l as the acceptable limit and 2000 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. The total dissolved solids concentration in the groundwater of the study area ranged from 60.8 to 548.7 mg\l with an average value of 232.0 mg/l.

Based on TDS contents, water can be classified in to four categories as fresh, brackish, saline and brine water (Table 7). TDS of the 100% of analyzed water samples fall in the category of fresh water.

Table 8:Classification of water based total Dissolved Solids

TDS (mg/l)	Water Quality	% Samples
0 – 1,000	Fresh Water	100%
1,000 – 10,000	Brackish Water	Nil
10,000 – 100,000	Saline Water	Nil
>100,000	Brine	Nil

5.2.5:Distribution of Total Alkalinity(HCO_3)

The total alkalinity of water is its acid neutralizing capacity and primarily a function ofcarbonate, bicarbonate and hydroxide content of water. It is expressed in terms of CaCO3. Therange and average concentrations values of carbonate and bicarbonate ions indicate that thealkalinity of Groundwater is mainly due to the bicarbonate ion. The distribuition of total alkalinityas shown in Graph indicates that the total alkalinity in few patches of Bhawle and Manglordistrict is more than 600 mg/L. In majority of the areas of the state the total alkalinity is less than300 mg/L and then the areas where total alkalinity lies in the range of 73-900 mg/L standssecond.

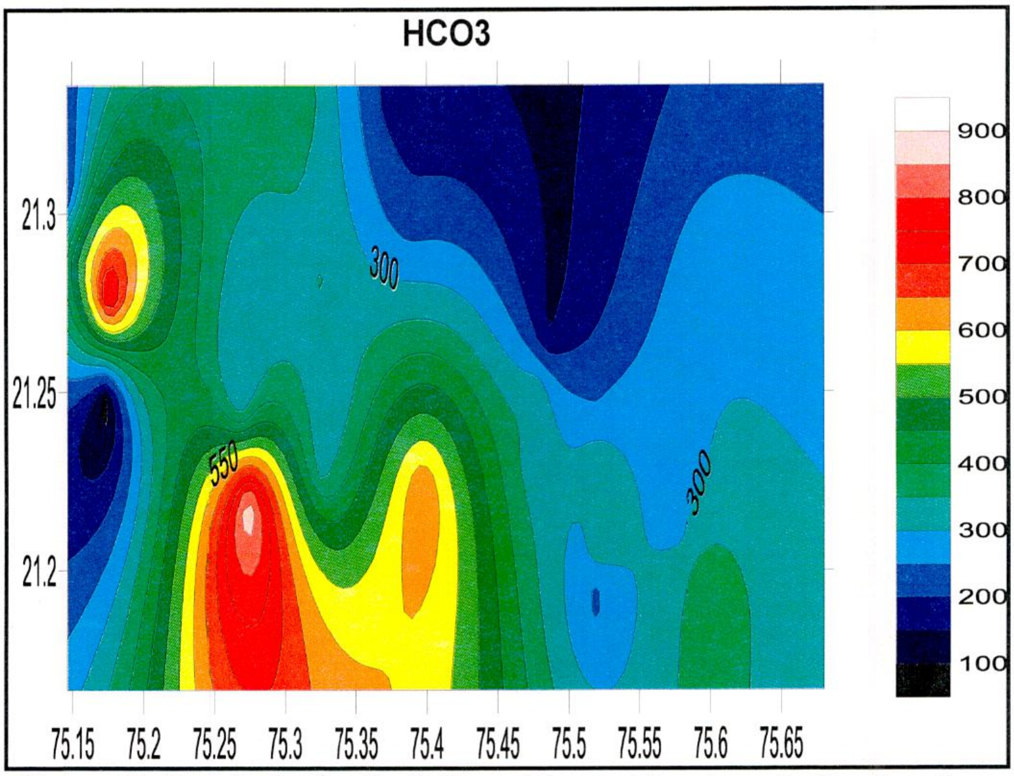


Figure-10:Graph shows alkalinity patches in bhawle and other locations

5.2.6 Total Hardness (TH)

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per litre.The degree of hardness of drinking-water is important for aesthetic acceptability by consumers. Hardness is the property of water which prevents the lather (foam) formation with the soap and increased the boiling point of the water. Hardness is classified in four categories as soft water, hard water, moderately hard water and very hard water (Table 8).

Table 9:Hardness Classification of water

Hardness (mg/l)	Water Class	% Sample
0-75	Soft	6.66 %
75-150	Moderately hard	23.33 %
150-300	Hard	53.31 %
>300	Very hard	16.66 %

Drinking-water can be a contributor to calcium and magnesium intake and could be important for those who are marginal for calcium and magnesium. Consumers are likely to notice changes in hardness. Public acceptability of the degree of hardness of water may vary considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500 mg/l. BIS (2012) has prescribed 200 mg/l as acceptable limit and 600 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. No health-based guideline value is proposed for hardness in drinking-water (WHO, 2011).

Total hardness of the groundwater samples of Bazada part of Jalgaon district varied between 26.57 to 432.64 mg/l. The average hardness of the analyzed samples was found as 228mg/l. 14% of the analyzed samples were having hardness less than 200 mg/l, 78% samples were having hardness between 200 - 600 mg/L, and 8% samples were having hardness above 600 mg/l. In general, groundwater of the Bazada part of Jalgaon district is hard to very hard in nature.

5.2.7. Major Anions (F^-, Cl^-, HCO_3^-, SO_4^{2-} and NO_3^-)

The anion chemistry of the analysed samples shows that HCO3-, Cl-, $NO_3$and SO_4^{2-} are the dominant anions in shallow groundwater and follows the abundance order of HCO_3- >Cl->NO_3->SO_4^{2-}>F- in majority of the groundwater samples. The plot of analysed data on anion diagram relating HCO_3-, Cl- and SO_4^{2-} shows that most of the plotted points fall in to bicarbonate zone (Fig. 11& 12).

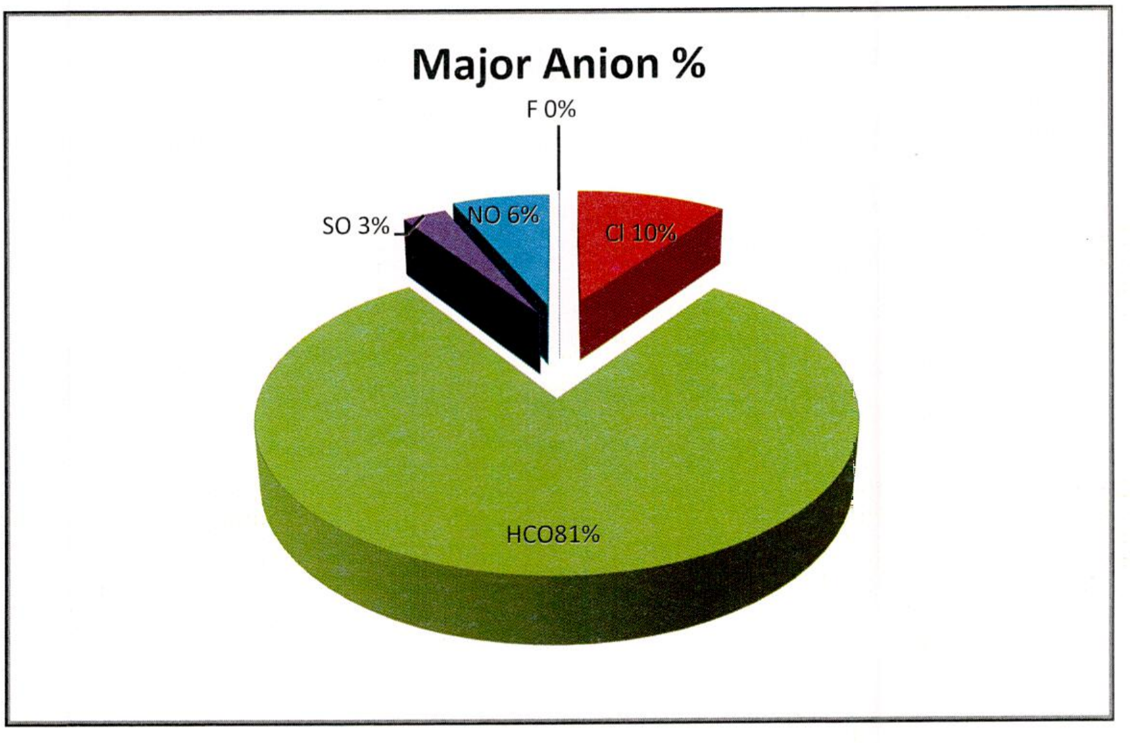


Figure 11: Contribution of the Anion the total Anions charge balance

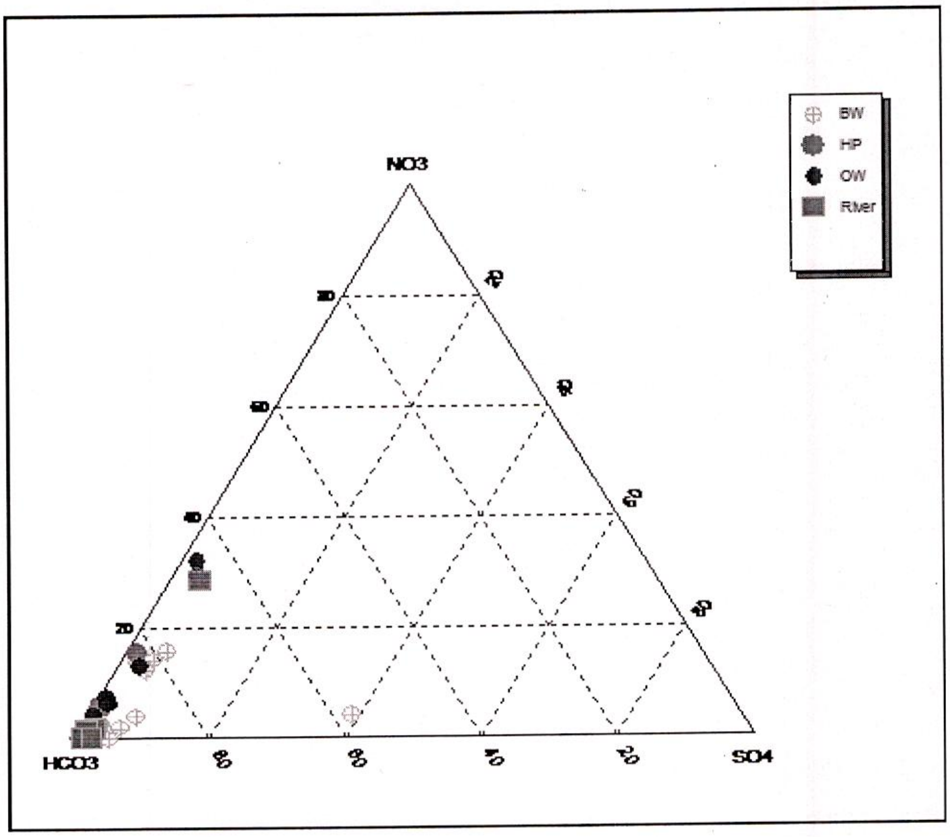


Figure 12: Ternary diagram for anions of groundwater samples

Concentration of bicarbonate (HCO_3^-) varies from a minimum of 73 mg/l to a maximum value of 900 mg/l (Avg. 343.0) and on an average it contributes 81.0% to the total anions (TZ-) in equivalent unit (Fig. 12). The bicarbonates are derived mainly from the soil zone CO2 and at the time of weathering of parent minerals. The soil zone in the subsurface environment contains elevated CO2 pressure (produce as result of decay of organic matter and root respiration), which in turn combines with rainwater to form bicarbonate. Bicarbonate may also be derived from the dissolution of carbonates and/or silicate minerals by the carbonic acid.Bicarbonates contribute to alkalinity (acid neutralizing capacity), and BIS (2012) has prescribed 200 mg/l as acceptable limit and 600 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. The alkalinty of samples collected from the study area were in the range of 77.9 – 658.7 mg/l as $CaCO_3$ and were well within the permissible limit in 98% of analysed samples and only 2% samples were having alkalinty above permissible limit (600 mg/l).

The chloride (Cl-) concentration in the analysed samples varies between 3.6 to 103.5 mg/l (Avg. 42.4 mg/l)and on an average chloride is contributing 10% of the total anionic balance. BIS (2012)have prescribed 250 mg/l as acceptable limit and 1000 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. Chloride concentrations in all the analysed samples were within the permissible limit prescribed by BIS. High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/l for sodium, potassium and calcium chloride. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste, but some consumers may become accustomed to low levels of chloride-induced taste. No health-based guideline value is proposed for chloride in drinking-water. Chloride is present in lower concentrations in common rock types, than any of the other major constituents of natural water and it is assumed that bulk of the chloride in Groundwater is primarily either from atmospheric source, sea water contamination or from anthropogenic sources. Abnormal concentration of chloride may result from pollution by sewage wastes. The large lateral variation in the chloride concentration and observed high concentration in some subsurface water indicate local recharge and may be attributed to the contamination by untreated industrial and domestic waste effluents from nearby area.

Sulfate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate. High sulfate levels in drinking water results in gastro-intestinal disorders, and hence, it is recommended that health authorities be notified of sources of drinkingwater that contain sulfate concentrations in excess of 500 mg/l (WHO, 2011). BIS (2012) has prescribed 200 mg/l as acceptable limit and 400 mg/l as permissible limit for sulfate in absence of alternate source for drinking and other domestic usage.Sulphate (SO42-) concentrationinBazada part of Jalgaon groundwater varies between 2.5 to 49.9mg/l (Avg. 12.3mg/l) and is contributing 3% to the total anions (TZ-).Sulphaten concentration werewell within the acceptable limit in 99% samples and exceeds the permissible drinking water limit of 400 mg/l only at <1% of the total analysed samples. The sulphate is usually derived from the oxidative weathering of sulphide bearing minerals like pyrite, gypsum or anhydrite. Apart from these natural sources, sulphate may be introduced through the application of sulphatic soil conditioners and fertilizers. The observed high concentration of (SO_4^{2-}) in some samples indicates the effects of industrial and anthropogenic activities in the area.

Nitrate and nitrite are highly soluble in water. Nitrate (NO_3-) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrite (NO_2-) is not usually present in significant concentrations except in a reducing environment, as nitrate is the more stable oxidation state. According to the Indian Standard for drinking water (IS 10500:2012), the maximum allowable nitrate concentration in drinking water is 45 mg/L as NO3. The guideline value for nitrite of 3 mg/l as NO_2 (WHO, 2011).

Concentration of nitrate in theBazada part of Jalgaon groundwater ranges from 0.0 to 144.3 mg/l with the average concentration value of 27.5 mg/l. Nitrate concentration exceeds the prescribed drinking water limit of 45 mg/l at 6% of the total locations.

Fluoride is found in all natural waters at some concentration. Seawater typically contains about 1 mg/L while rivers and lakes generally exhibit concentrations of less than 0.5 mg/L. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. Fluoride occurs as fluorspar (fluorite), rock phosphate, triphite, phosphorite minerals etc in nature. Among the factors, which control the concentration of fluoride includes climate of the area and the presence of accessory minerals in the rock mineral assemblage through which the groundwater is circulating. Concentrations in water are limited by fluorite solubility. It is the absence of calcium in solution which allows higher concentrations to be stable. High fluoride concentrations may therefore be expected in groundwater from calcium-poor aquifers and in areas where fluoride-bearing minerals are common (Nanyaro et al., 1984; Gaciri and Davis, 1993; Kundu et al., 2001). Many epidemiological studies have shown that fluoride in drinking water has a narrow range between intakes that cause beneficial and detrimental health effects. Fluoride intake to humans is necessary as long as it does not exceed the limits. The WHO (2011) and BIS (2012) estimates the maximum allowable limit for fluoride uptake to human's in drinking water as 1.5 mg/L. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis. White line striations followed by brown patches and, in severe cases, brittling of the enamel are common symptoms of dental fluorosis. Skeletal fluorosis first causes pain in the different joints, then limits joint movement and finally causes skeletal deformities, which become particularly acute if fluoride uptake occurs during growth. Since these ailments are incurable, fluorosis can only be mitigated by preventing intake of excess fluoride.

Concentration of fluoride in groundwater samples of Jhansi district varies between <1 and 2.2 mg/l and average concentration was found as 0.1 mg/l. On an average fluoride is contributing 0.1% of the total anionic balance. Concentration of fluoride exceedes the prescribed 1.5 mg/l drinking water requirement in about 62.2% of the total analysed groundwater samples (i.e., 700). In the Figure-11concentration of major anions (HCO_3-, Cl-, SO_4^{2-} , NO_3^{2-} and F-) are plotted against their sampling location; these concentration ranges were extraplotted to create a surface using different GIS interpolation techniques. These figures are giving a general pattern of concentration which exists in the study area.

5.2.8: Major Cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})

The major cations include Ca, Mg, Na and K. The water chemistry of the Jhansi district is dominated by alkali metals. On an average Ca alone constitute 41.0% of the total cations (TZ+) in the groundwater of the Bazada part of Jalgaon district. The plotted points of majority of the water samples falls in the Ca type and No dominated type water zone in cation triangle diagram and in general groundwater belong to Ca>Na >Mg >K water type(Fig. 13 & 14). The weathering and cation exchange processes normally control the levels of these cations in the water.

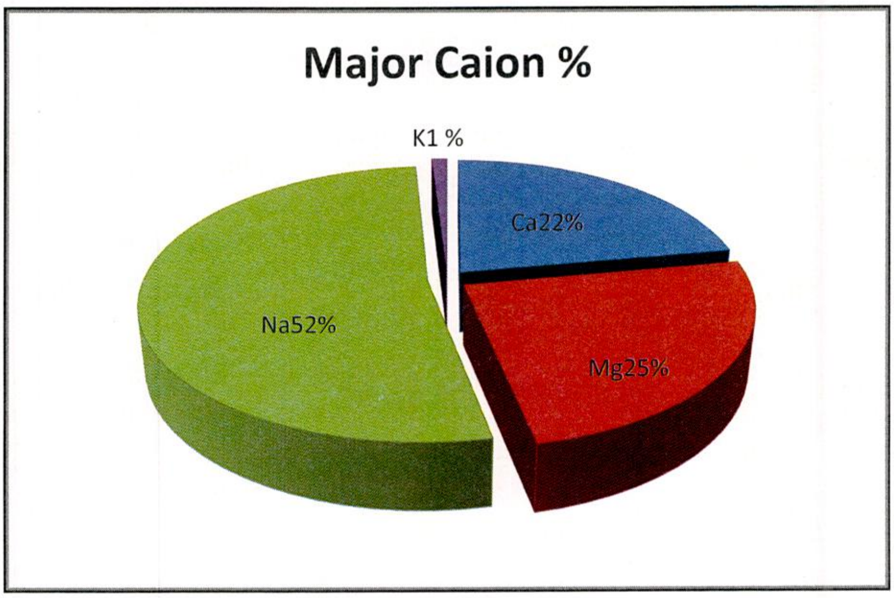


Figure 13:Contributions of cations towards the total cationic charges balance (TZ+)

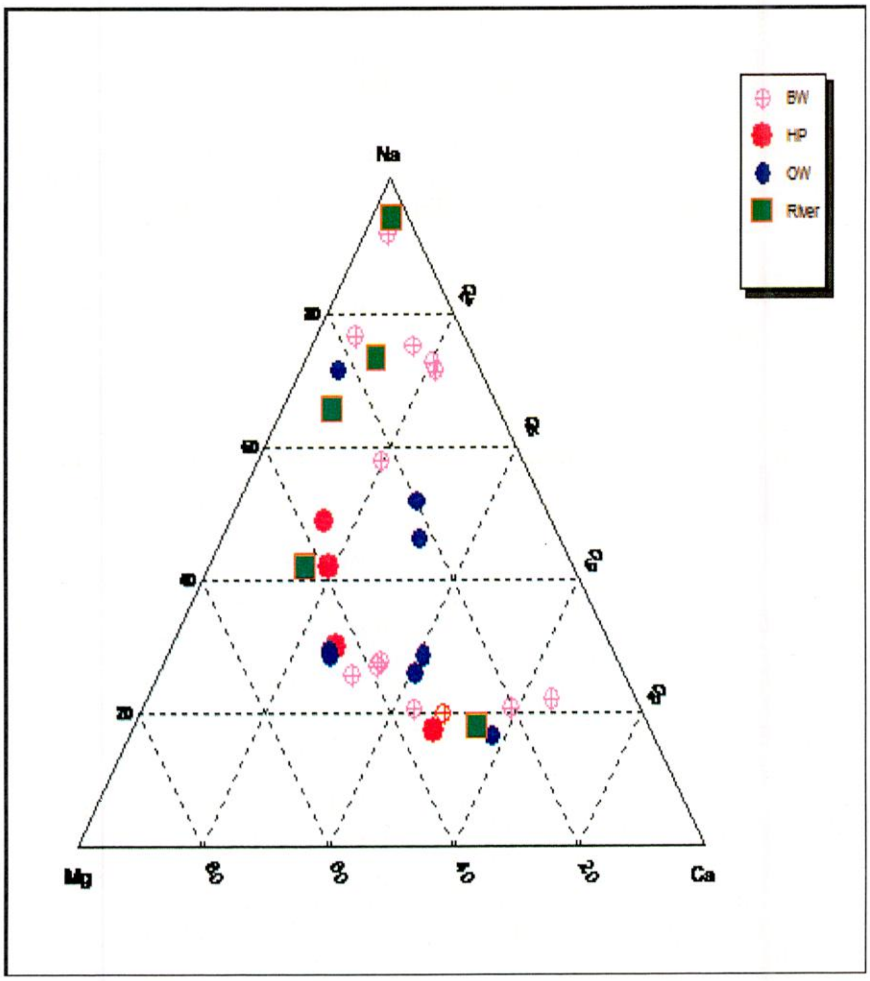


Figure 14: Ternary diagram for Cations of Bazada part of Jalgaon Groundwater samples

Calcium (Ca+) ion and calcium salt are among the most commonly encountered substances in water. Calcium in water arising mostly from dissolution of Ca bearing minerals of the aquifer formation and often it is the most abundant cation in aquatic water. Weathering and dissolution of calcium carbonate (limestone and dolomite) and calc-silicate minerals (amphiboles, pyroxenes, olivine, biotite etc) are the most common source of calcium is aquatic system. Concentration of calcium in the Bazada part of Jalgaon groundwater varied from 4.3 to 59.5 mg/l with an average concentration value of 32.6mg/l. Calcium is exceeding sodium, magnesium and potassium concentration in majority of groundwater samples of the area. In Bazada part of Jalgaon groundwater, Ca is contributing 22% of the total cationic mass balance (TZ+). BIS (2012)has prescribed 75 mg/l as acceptable limit and 200 mg/l as permissible limit for calcium in absence of alternate source for drinking and other domestic usage. 43% of samples exceeded the acceptable limit and 3% exceeded the permissible limit for drinking water.

The sodium in the aquatic system is derived from the atmospheric deposition, evaporate dissolution and silicate weathering. The evaporate encrustation's of sodium/potassium salts may also be developed due to cyclic wetting and drying periods causes the formation of alkaline/saline soils, which may also serve as a source of sodium and potassium. The weathering of Na and K silicate minerals like albite, anorthite, orthoclase and microcline are the major source of the Na and K in the aquatic system.Sodium concentration in the analysed samples was reported in the minimum range of 10.9mg/l to a maximum of 393.8 mg/l with an average concentration value of 76.4 mg/l. No health-based guideline value has been derived, as the contribution from drinking-water to daily intake is small (WHO, 2011). Based on taste threshold, the recommended concentration of sodium in the water should be less than 200 mg/land 52% of the total analysed sample were well within this category. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution.

Magnesium (Mg^{2+}) is abundant in earth crust and is a common constituent of natural water. Olivine, clay minerals, dolomite, pyroxenes are the common source minerals for magnesium in the waters. The carbonate, chlorides, hydroxides, oxides and sulphate of the magnesium are used in the production of magnesium metal, refractories, fertilizers, ceramics, and explosives and medicinal. Magnesium compounds are more soluble than their counterparts. As a result, large amount of magnesium are rarely precipitated. Magnesium carbonate and hydroxide precipitate at pH>10.

Magnesium concentration can be extremely high in certain closed saline lakes. Natural sources contribute more magnesium to the environment than all anthropogenic sources. The principle source of magnesium in natural water is ferromagnesian mineral in igneous rock and magnesium carbonate in sedimentary rock. The sulphate and chloride of magnesium are very soluble.In the analyzed groundwater samples; Mg constitutes 25% of the total cationic charge balance(Fig.14). Concentration of Mg varies from 3.9mg/l to 86.4 mg/l (Avg. 39.5 mg/l) during the sampling period. The presence of calcium and magnesium make the water hard. BIS (2012) have prescribed 30 mg/l as acceptable limit and 100 mg/l as permissible limit for magnesium in absence of alternate source for drinking and other domestic usage. 47% of samples exceeded the acceptable limit and 1.8% exceeded the permissible limit for drinking water.

Although potassium (K+) is nearly as abundant as sodium in igneous rocks and metamorphic rocks, its concentration in groundwater is one-tenth or even one-hundredth that of sodium. Parity in concentration of sodium and potassium is found only in waters with low mineral contents. Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance of potassium minerals to decomposition by weathering and the other the fixation of potassium in clay minerals formed due to weathering. In the analyzed30 groundwater samples of Bazada part of Jalgaon district, concentration of potassium ranged between 0.4mg/l and 5.8 mg/l with an average value of 1.5mg/l. The recommended daily requirement is greater than 3000 mg (WHO, 2011).In the Fig. 13 concentration of major anions (Ca^{2+}, Mg^{2+} Na+, K+) are plotted against their sampling location; these concentration ranges were extraplotted to create a surface using different interpolation techniques. These figures are giving a general pattern of concentration which exist in the study area.

5.3:Water Type and Hydrochemical Facies

The Hill and Piper plot is very useful in determining relationships of different dissolved constituents and classification of water on the basis of its chemical characters. The triangular cationic field of Piper diagram reveals that the groundwater samples fall into Catype class, whereas in anionic triangle majority of the samples fall into bicarbonate field.

The plot of chemical data(Fig. 15), on diamond shaped central field, which relates the cation and anion triangles revealed that the major water types in the studied locations wereCa-Mg-HCO_3, Na-Mg-HCO_3, Ca-Mg-SO^4-Cl and Na-K-HCO_3-Cl.In majority of the groundwater samples,alkaline (Ca+Mg) exceed alkali cations (Na+K). In general, the groundwater of the area exhibits the dominance of weak acid (HCO_3) over strong acid (SO_4+Cl).The facies mapping approach applied to the present study shows that Ca-Mg-HCO_3 is the dominant hydrogeochemical facies in the groundwater of the Bazada part of Jalgaon district.

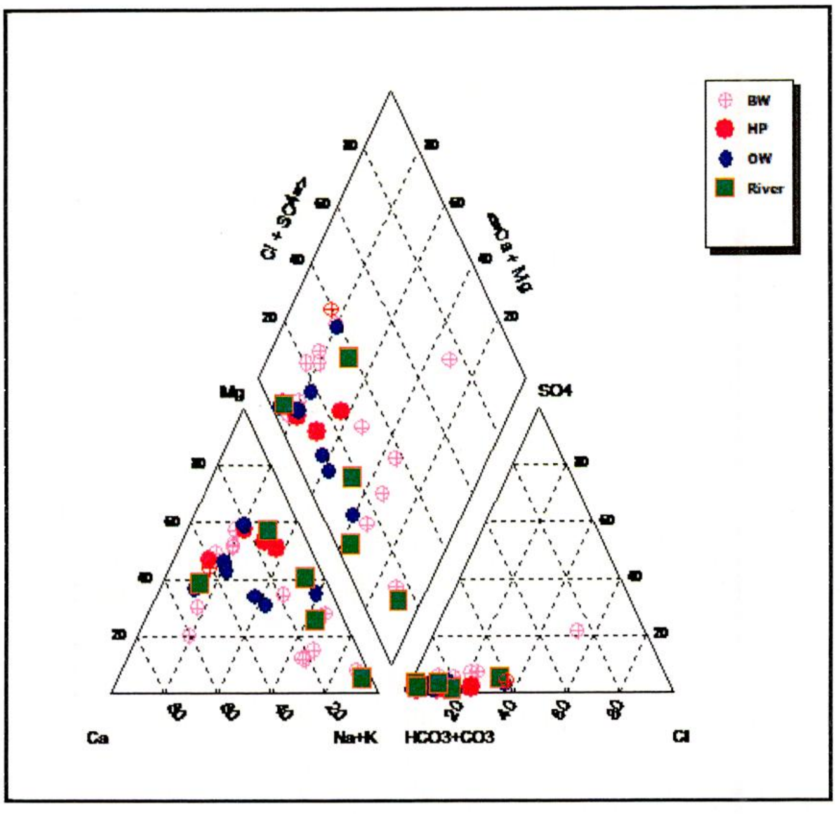


Figure 15: Hill and piperplot showing water type and hydrochemicalfacies

5.4:Suitability for Drinking and General Domestic Uses

To assess the suitability for drinking and public health purposes, the hydrochemical parameters of the groundwater of the Bazada part of Jalgaon district area were compared with the prescribed specification of Indian standard for drinking water (IS:10500, 2012). Table-9 shows that most of the water samples of the study area are marginally suitable for direct uses in drinking and domestic purposes.

pH of the groundwater samples (6.9 - 8.3) are well within the safe limit prescribed for drinking water.

The values of Total Dissolved Solid (TDS) exceeded IS-10500 (2012) desirable drinking water limit (500 mg/l) in 99% of the total samples. However, it is well below the maximum permissible limit of 2000 mg/l, except in <1% groundwater samples. The total hardness (TH) of the analysed sub-surface water of the study area varies between 26.57 mg/l and 432 mg/l (Avg. 228mg/l) indicating hard to very hard types of groundwater. The analytical data indicate that 25% groundwater samples have hardness higher than 300 mg/l and can be categorized as a very hard type of water. Hardness value exceeded the maximum permissible limit of 600 mg/l in 75% of the groundwater samples. Hard water prevents formation of lather with soap and increases the boiling point of the water. The high hardness may cause precipitation of calcium carbonate and encrustation on water supply distribution systems. The long term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, parental mortality and cardio-vascular disorders.

Fluoride (F-) is an essential element for maintaining normal development of healthy teeth and bones. However, higher F- concentration causes dental and skeletal fluorosis such as mottling of teeth, deformation of ligaments and bending of spinal cord. Concentration of F- exceeds the permissible limit of 1.5 mg/l in about 0%of the groundwater samples of the study area. Concentrations of SO_4^{2-} are also exceeding the drinking water the permissible level of 400 mg/lin0%of the total analysed samples. Cl- concentrations are found above the desirable levels of 250 mg/l for drinking water 0% of total samples, while in one sample Cl- concentration exceeded the permissible limit of 1000 mg/l as. Concentration of NO3- is higher than the recommended level of 45 mg/lfor drinking water 80% of total samples of the study area. Excessive NO_3 in drinking water can cause a number of disorders including methaemoglobinaemia in infants, gastric cancer, goiter, birth malformations and hypertensions.

Calcium is an essentials element for bone, nervous system and cell development. One possible adverse effect from ingesting high concentration of Ca^{2+} for long periods may be an increased risk of kidney stones. Among the cations, Na+ is most important ions for human health. A higher sodium intake may cause hypertension, congenial heart diseases, nervous disorder and kidney problems. The guideline value for sodium concentration in drinking water is 200 mg/l. Concentration of Na+ exceeds the recommended limit of 200 mg/l only in 0% of the total analysedgroundwater samples.

Table 10: Statistical summary of measured parameters in Bazada part of Jalgaongroundwater and its comparison to Indian standards for drinking water (IS-10500, 2012) (NR: No Relaxation)

Parameters	Min.	Max.	Avg.	Minimum permissible	Highest permissible	% Exceeded Desirable Limit	% Exceeded
General Parameters and Major Ions (mg/l)							
pH	6.83	7.99	7.44	6.5-8.5	8.5-9.2	100	Nil
EC (µS cm-1)	258	1707	752.23	-	-		
TH	26.57	432.64	228	300	600	75	25
TDS	60.8	548.7	232	500	2000	99	1
F-	0	0.5	1.7	1	1.5	Nil	Nil
Cl-	3.8	103.5	42.4	250	1000	100	Nil
HCO_3^-	73	900	263.7	-	-		
SO_4^{2-}	2.5	49.9	12.3	200	400	Nil	Nil
NO_3^-	0	144.3	27.5	45	NR	80	20
Ca^{2+}	4.3	59.5	32.6	75	200	100	Nil
Mg^{2+}	3.9	86.4	35.8	30	100	50	50
Na^+	10.9	393.8	76.4	-	-		
K^+	0.4	5.8	1.5	-	-		

In general, violation of IS-10500 drinking water standards in respect of TDS, fluoride, nitrate, calcium, magnesium have been evident in groundwater of Bazada part of Jalgaondistrict.

5.4:Suitability for Irrigation Uses

Water quality, soil types and cropping practices play an important role in assessing the suitability of water for irrigation. Total salt concentration (EC), sodium adsorption ratio (SAR), sodium percentage (Na%), residual sodium carbonate (RSC) and magnesium hazard (MH) are the important parameters which are widely used in assessing the suitability of water for irrigation uses. These parameters, which affects the quality for irrigation purposes were also computed and results are furnished in Table -10.

Table 11:Calculated parameters for irrigation uses

S.No.	Sample Name	EC	%Na	TH	SAR	RSC	MH
		µS/cm	mg/l	mg/l	meq/l	meq/l	%
1	J1	380	17.93	185.24	0.61	2.40	44.86
2	J2	1128	41.66	432.64	2.51	1.17	81.90
3	J3	542	25.79	248.62	1.06	2.34	56.88
4	J4	458	16.95	229.99	0.61	2.32	53.95
5	J5	500	16.30	233.21	0.62	2.40	41.96
6	J6	647	20.42	308.59	0.86	1.57	57.56
7	J7	899	27.53	413.70	1.43	2.20	64.02
8	J8	1345	74.44	71.89	5.13	0.47	47.15
9	J9	343	21.35	134.61	0.72	1.75	25.16
10	J10	1076	65.37	252.84	4.97	5.47	84.87
11	J11	566	72.40	117.22	5.24	4.47	69.76
12	J12	615	51.31	207.58	3.00	3.97	53.43
13	J13	602	41.47	261.51	2.01	3.37	77.09
14	J14	1008	70.28	265.93	6.61	7.96	85.87
15	J15	1707	91.54	117.22	22.24	13.57	66.35
16	J16	1338	75.18	278.89	9.04	10.04	82.23
17	J17	766	71.61	140.62	6.59	4.39	35.97
18	J18	258	20.03	121.61	0.60	1.84	36.31
19	J19	865	70.32	155.61	6.57	3.68	35.07
20	J20	519	57.17	149.96	3.06	2.07	65.13
21	J21	683	93.86	26.57	15.54	4.62	59.63
22	J22	736	45.80	203.52	2.36	3.26	53.67
23	J23	770	48.44	276.93	2.67	2.56	79.86
24	J24	577	29.26	282.47	1.22	2.80	74.35
25	J25	384	19.74	221.65	0.72	0.14	51.65
26	J26	870	29.76	268.38	1.22	2.94	73.26
27	J27	718	26.80	297.72	1.17	0.83	64.72
28	J28	1007	28.47	375.08	1.35	0.96	74.05

S.No.	Sample Name	EC	%Na	TH	SAR	RSC	MH
		μS/cm	mg/l	mg/l	meq/l	meq/l	%
29	J29	730	25.65	340.97	1.14	2.24	69.62
30	J30	530	28.42	233.41	1.18	1.71	54.94

5.6:Electrical Conductivity (EC) and Sodium Percentage (Na %)

Electrical conductivity (EC) and sodium concentration are very important in classifying irrigation water. Water used for irrigation always contains measurable quantities of dissolved substances as salts. It include relatively small but important amount of dissolved solids originating from the weathering of the rocks and soils and from the dissolving of lime, gypsum and other salt sources as water flows over or percolate through aquifer. The salts, besides affecting the growth of the plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth. The sodium percentage (Na %) in the water samples of sub-surface water is calculated by the equation :

$$Na\% = Na+K/(Ca+Mg+Na+K) \times 100$$

The sodium percentage (%Na) in the Bazada part of Jalgaon district area ranges between 1 and 93.86% (Avg. 44.17%). High %Na causes deflocculation and impairment of the tilth and permeability of soils. As per the Indian Standard (ISI 1993), maximum sodium of 60% is recommended for irrigation water. Plot of analytical data on Wilcox (1955) diagram relating electrical conductivity (EC) to sodium percent (%Na) shows that Na% are within the recommended values, and in general majority of groundwater samples of the Bazada part of Jalgaon district are falling in excellent to permissible quality region, which can be used for irrigation purposes (Fig.-16), while only 1% samples are falling in doubtful to unsuitable zone and >1% groundwater samples were found unsuitable for irrigation purpose.

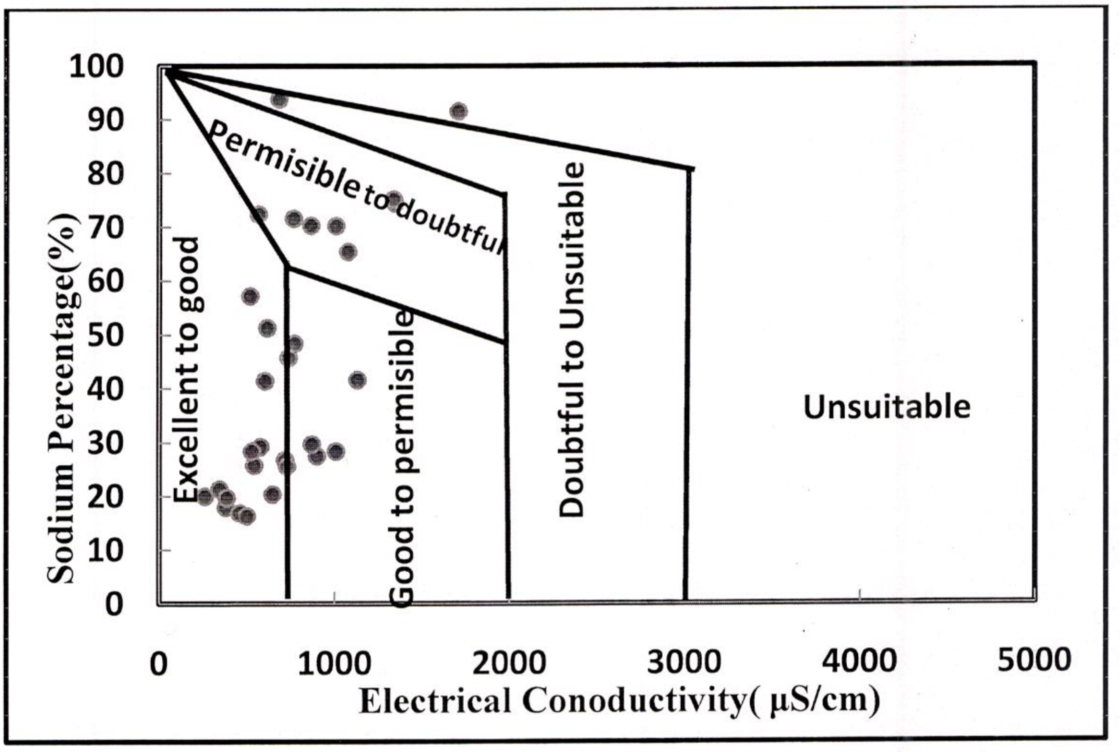


Figure 16: Plot of sodium percent (Na%) vs Electrical conductivity(EC)

5.7:Alkali and Salinity Hazard (SAR)

The total concentration of soluble salts in irrigation water can be expressed as low (EC =<250 µS cm-1), medium (250-750 µS cm-1), high (750-2250 µS cm-1) and very high (2250-5000 µS cm-1) salinity zone. While a high salt concentration (high EC) in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil. Excessive solutes in irrigation water are a common problem in semi-arid areas where water loss through evaporation is maximal. Salinity problem encountered in irrigated agriculture are most likely to arise where drainage is poor. This allows the water table to rise close to the root zone of plants, causing the accumulation of sodium salts in the soil solution through capillary rise following surface evaporation of water. The sodium or alkali hazard in the water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). It can be estimated by the formula:

$$SAR = Na/[(Ca+Mg)/2]^{0.5}$$

Table 12:Irrigation water classified into four categories on the basis of sodium adsorption ratio (SAR) and EC:

SAR	Water Category	% Sample	EC µS cm-1	Water Category	%Sample
0 – 10	Excellent (S-1)	99.0%	<250	Low (C-1)	0.1%
10 – 18	Good (S-2)	1.0%	250 – 750	Medium (C-2)	23.2%
18 – 26	Fair (S-3)	0.2%	750 - 2250	High (C-3)	74.6%
>26	Poor (S-4)	0%	>2250	Very High (C-4)	2.1%

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure due to dispersion of the clay particles. The calculated value of SAR in the study area ranged from 0.60 – 22.24 meq/l. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that most of the water samples fall in the category C1S1, C2S1, C3S2, And C3S3 indicating medium to high salinity and low medium alkali water. This water can be used for plants with good salt tolerance (Fig. 17).

High saline water cannot be used on soils with restricted drainage and requires special management for salinity control. Plants with good salt tolerance should be selected for such areas. Very high saline water is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and salt tolerance crops/plants should be selected.

Low sodium (alkali) water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity especially under low leaching conditions. This water can be used on coarse textured or organic soils with good permeability.

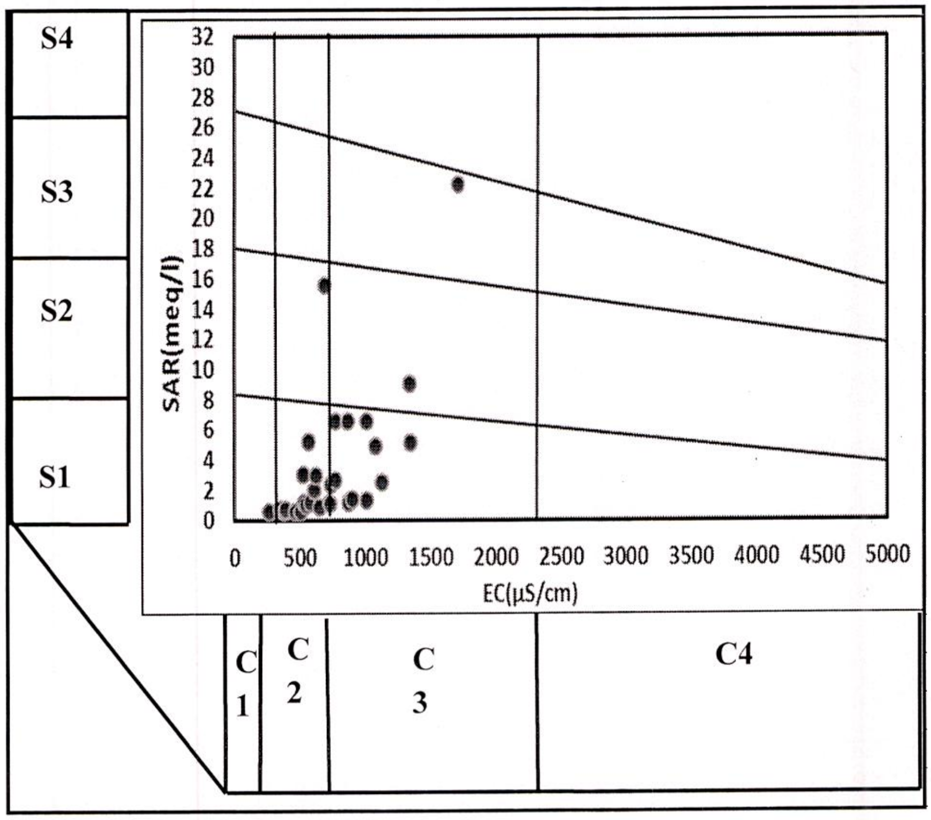


Figure 17: Salinity diagram for of irrigation water samples

5.8:Residual Sodium Carbonate (RSC)

The quantity of bicarbonate and carbonate in excess of alkaline earths (Ca+Mg) also influence the suitability of water for irrigation purposes. The excess of CO_3 + HCO_3over Ca + Mg may cause exchange of calcium ions fromsoil and is deleterious to the physical properties of the soils, leading to decrease in soil permeability. The effect of carbonate and bicarbonate and suitability of water for irrigation can be assessed by computing the residual sodium carbonate (RSC) values by the following formula.

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$ all concentration in meq/l

A high value of RSC in water leads to an increase in the adsorption of sodium on soil (Eaton 1950). Irrigation waters having RSC values greater than 5 meq/lhave been considered harmful to the growth of plants, while waters with RSC values above 2.5 meq/lare unsuitable for irrigation. A RSC value between 1.25 and 2.5 meq/lis considered as the marginal quality and value <1.25 meq/las the safe limit for irrigation. RSC values of study area indicated that 14.6% of analysed groundwater sample have RSC value between 1.25 - 2.5 meq/l and are in the category of suitable to marginally suitable for irrigation uses, while 8.7% of analysed water samples were having RSC values between 2.5 to 5.0 meq/land are unsuitable for irrigation. In the Bazada part of Jalgaon district only < 2.4% of total analysed groundwater samples having RSC values greater than 5 meq/l and could be considered harmful to the growth of plants.

CONCLUSION-8

Based on the analysis of Groundwater samples of the Bazada part of Jalgaon district, following conclusions are drawn-

1. The study area is located at Bazada in Jalgaon district of Maharashtra. The study area approximately extends from 20°N to 21°30□N latitudes and 74°54 □ E to 76°28′E longitudes. The 30 samples of water are collected from the Open well, Bore well,Handpump and river in which 5 samples are collected from river ,7 samples from Open well ,4 samples from handpump and 14 samples from Bore well for analysis of water chemistry.
2. In the study area overall pH varied from 6.8 to 8.0. Among all the samples of water of different sources, average value of pH of the River, Open well, Handpump and bore well is 7.36, 7.56, 7.55 and 7.39 respectively. Therefore, all the samples are in alkaline nature except sample no. J15 of Bore well with pH value 6.38 is acidic in nature.
3. TDS were found in overall study area between 60.8 mg/l to 548.7mg/l. TDS average value of theRiver, Open well, Handpump and bore well samples is 229.5mg/l, 205.1mg/l, 175.1mg/l and 265.2mg/l respectively. Therefore, all the samples are under the permissible limit (2000mg/l). Hence water is suitable for drinking purpose and fall under category of fresh water.
4. The groundwater chemistry of Bazada part of Jalgaon district is dominated by Ca, Mg, Na, and K. The dominance of these ions is in the order Na > Mg > Ca > K. Alkali cations dominate over alkaline earths (Ca and Mg) in many samples and on average Ca alone constitute 43% of the total cations (TZ+) in the groundwater of the area.
5. The anion chemistry of the analysed samples shows that HCO_3, Cl,$NO_3$and$SO_4^{2-}$are the dominant anions and follows the abundance order of HCO_3>Cl>NO_3>SO_4^{2-}>F in majority of the groundwater samples.
6. The Hill & Piper plot of chemical data revealed that the major water types of the study area are Ca-Mg-HCO_3, Na-Mg-HCO_3, Na-K-HCO_3 and Na-K-HCO_3-Cl. Among these facies Ca-Mg-HCO_3 is the dominant hydrogeochemical facies and the minor water types are Ca-Mg-SO_4 -Cl and Na-K-HCO_3.

7. On critical examination of the data, it can be seen that certain major ions concentration in groundwater exceeded 25% the desirable as well as permissible limit recommended for drinking water at many places. Most of the water samples of the study area are marginally suitable for direct uses in drinking purposes.
8. Application of Wilcox plot relating electrical conductivity to sodium percent. It was concluded that 80% samples of groundwater of the Bazada part of Jalgaon district is excellent to permissible quality, which can be used for irrigation purposes except 20% samples.
9. Based on US salinity diagram, it can be concluded that most of the water samples fall in the category C1S1, C2S1, C3S2, And C3S3 indicating medium to high salinity and low alkalinity.

Photographs

REFERENCES

- APHA (2012), Standard Methods for the Examination of Water & Wastewaters, American Public Health Association, 22th Edition, Washington DC.
- BIS (2001), Indian Standard – Guidelines for the quality of Irrigation water, IS 11624:1986, Bureau of Indian Standards, New Delhi.
- BIS (2012), Indian Standard – Drinking Water Specification (2nd Revision), IS 10500: 2012, Bureau of Indian Standards, New Delhi.
- WHO (2011), Guidelines for Drinking Water Quality – Fourth Edition, World Health Organization, Geneva.
- Golekar R. B., Patil S.N., Baride M.V. and Yeole D. R. (2012), Hydrogeochemistry of shallow and deep aquifers from Anjani and Jhiri river catchment Jalgaon district, northern Maharashtra, India IGWC Groundwater Research Series 5, 3 pp 740-757.
- Piper AM (1944), A graphic procedure in geochemical interpretation of water analyses. Trans Am Geophys Union 25, pp 914– 923.
- Dhawan 1995; Moench 1992; Macdonald et al 1995

Photographs