“Characterization of Ground Water Quality of Depalpur tehsil of Indore, Madhya Pradesh’’

THESIS

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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior

In partial fulfilment of the requirements for the Degree of

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BY

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CERTIFICATE – I

This is to certify that the thesis entitled "**Characterization of Ground Water Quality of Depalpur Tehsil of Indore, Madhya Pradesh**" submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (DEPARTMENT OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bonafied research work carried out by **Mr. Vijay Gami**, under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has dully been acknowledged by him.

Place: Indore

Date:

(Dr. K. S. Bangar)

Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman : Dr. K. S. Bangar ………………………

Member : Dr. V. K. Khaddar ....

Member : Dr. N. S. Thakur ………………………

CERTIFICATE – II

This is to certify that the thesis entitled **"Characterization of Ground Water Quality of Depalpur Tehsil of Indore, Madhya Pradesh"** submitted by **Mr. Vijay Gami,** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Department of Soil Science & Agricultural Chemistry)** College of Agriculture, Indore, has been, approved after evaluation by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.

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Place : Indore

Date : / /

(VIJAY GAMI)

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ABBREVIATION

S. No.	Legends	Description
1.	Ca^{2+}	Calcium
2.	CO_3^{2-}	Carbonate
3.	HCO_3^-	Bi-Carbonate
4.	$dS\ m^{-1}$	Desi Siemen per meter
5.	EC	Electrical conductivity
6.	ESP	Exchangeable sodium percentage
7.	*et al*.	Alied (any other)
8.	*ham*	Hectare meter
9.	K^+	Potassium
10.	Kg	Kilogram
11.	L	Liter
12.	l	Liter
13.	mbgl	Meter below ground levels
14.	Cl^-	Chloride
15.	Me	Milli equivalent
16.	Mmol	Milli mol
17.	Mg^{2+}	Magnesium
18.	Na^+	Sodium
19.	POM	Post - Mansoon
20.	PPM	Part Per Million
21.	PRM	Pre - Monsoon
22.	RSC	Residual Sodium Carbonate
23.	SAR	Sodium Adsorption Ratio
24.	SD	Standard Deviation
25.	SO_4^-	Sulphate
26.	%	Percent
27.	TW	Tube well
28.	TDS	Total Dissolve Solids
29.	W	Well

CHAPTER - I
INTRODUCTION

Ground water is the most essential and vital component of our life support system. “Water is life's matter and matrix, mother and medium. There is no life without water.” The water present underground in the cracks and spaces in soil, sand and rock is known as groundwater. Ground water is the water that percolates through rocks and soil and stored below the surface. It is the important substance for the existence of life on the Earth. Rainfall is the chief source of water supply. All the water obtained as a result of rainfall is not available for further use because some of it is lost in evaporation, percolation and transpiration. Ground water is one of the sources of drinking water to the people of this planet.

Ground water is one of the earth’s most important, renewable and widely distributed resources. Chemical formula of water is H_2O. It exists in the three states namely solid, liquid and gas. Water is universal solvent used as media for bio-chemical as well as chemical reaction. Water is essential for all living organism. Life cannot run without water. On earth 97.2 % of water is salty and 2.8 % is fresh water from which about 20 % constitutes ground water (Rajesh Kumar, 2011). Groundwater also plays an important role in agriculture, for both watering of crops and for irrigation of dry season crops. It is estimated that about 45% of irrigation water requirement is meet from groundwater sources.

Indiscriminate use of water can lead not only to shortages, but also to the deterioration of crop yields and soils. Ground water resource of a region is one of the building blocks for balanced economic development of the area, especially in an agriculture based society. Dependence on ground water for irrigation and increasing water requirements in urban areas in Madhya Pradesh has necessitated judicious and planned uses of ground water resources in order to reach sustainability. Monsoon rainfall is the main source of natural recharge to ground water and rainfall pattern is an important factor which impact on groundwater levels in the phreatic aquifers of Madhya Pradesh. The normal rainfall of the Madhya Pradesh State is 952.3 mm.

Depth to Water levels ranges in Madhya Pradesh from 1.10 to 49.40 mbgl. Groundwater is the important source for the irrigation, domestic as well as industrial purposes in Madhya Pradesh. However, due to rapid growth of population, urbanization, industrialization and agriculture activities, ground water resources are under stress. There is growing concern on the deterioration of ground water quality due to geogenic and anthropogenic activities. The chemical alteration of the ground water depends on several factors, such as interaction with solid phases, residence time of ground water, seepage of polluted river water, mixing of groundwater with pockets of saline water and anthropogenic impacts (Umar and Absar 2003). So water quality standards are needed to determine its suitability for intended use.

The chemical comparison of the water that enters in the groundwater reservoir and reactions with the minerals present in the rocks and soils that may modify the water composition (Singh and Khare 2008).Ground water contains wide varieties of dissolved inorganic chemical constituents in various concentrations as a result of chemical and biochemical interactions between water and the geological materials through which it flows and to a lesser extent because of contribution from the atmosphere and surface water bodies. The cation and anion concentration depends upon the solubility of the minerals present in the formation and the time duration of water in contact with the rocks and the amount of dissolved CO_2 present in the water (Viessman *et al*. 1989).

Depalpur tehsil is one of the important tehsil located in the Indore district of Madhya Pradesh (India). It is located at latitude of 22° 51' 1" N and longitude of 75° 32' 45" E. It has an average elevation of 533 metres (1748 feet). There are 147 villages and 3 towns in Depalpur Tehsil. The total area of Depalpur is 796.60 sq. km. The climate of Depalpur tehsil as well Indore district is characterized by hot summer and well distributed rainfall during the southwest monsoon season. Monsoon arrives generally in the middle of June to end of june. The principal crops of tehsil are soybean and wheat. Normal annual rainfall of the district is 960.96 mm. Depth to water level data reveals that the water levels in the range of 10-20 mbgl occupy major part of the Depalpur Block. Tube well or bore well is the major source of irrigation in the Depalpur tehsil. Net ground water availability in this thesil is 13912 ham. The percentage of irrigated area to total cultivable area is 63.82 in Depalpur. The tehsil is covered by medium black soils. No work has been done regarding water quality of Depalpur tehsil. Therefore, the present study was framed to know the systematic characterization of ground water quality. A detailed ground water survey of the tehsil was carried out village –wise in tehsil during 2018-19. The work was performed under All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture, College of Agriculture Indore, Madhya Pradesh. The objectives of the study are as follows:

- To know the quality of ground water of study area with respect to pH, EC, SAR, RSC.
- To evaluate the suitability of ground water for agricultural purposes in study area.
- To assess the concentration of water soluble cations and anions.
- To study correlation among various parameters of ground water.

CHAPTER - II
REVIEW OF LITERATURE

The comprehensive of review of literature is the most essential part of any scientific study. This chapter contains various scientific literatures with respect to ground water quality performed in past in India and abroad.

2.1 Water quality related with pH

Subramani *et al*. (2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India. They concluded that the pH values of groundwater ranges from 6.9 to 9.2 with an average value of 8.2 and low alkaline in nature.

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh and obtained pH range of basin water is 7.75 to 8.09 with an average 7.97 and these range of pH is within the acceptable for crop production.

An investigation was carried by Vasanthavigar *et al. (*2012) in sub basin of Thirumanimuttar in Tamil Nadu on groundwater quality for determining its suitability for agricultural purposes. They investigated that water is neutral to alkaline in nature with pH ranging from 6.78 to 9.22 with an average of 7.37 in investigating area.

Obiefuna and Sheriff (2011) studied the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes and they found pH in between 5.1 and 8.2, with the mean value of 6.01 in study area.

Srinivasamoorthy *et al. (*2011) assessed groundwater quality in Salem district of Tamil Nadu for determining its suitability for drinking and agricultural proposes. The results showed that the groundwater is neutral to alkaline in nature with pH ranges 6.6 to 8.6 with an average of 8.0 in studied area.

Reddy (2013) evaluated groundwater quality of Bhaskar Rao Kunta watershed in Nalgonda District, India for its suitability for irrigation. He recorded pH values which lies between 7.7 to 9.0 with an average of 8.3 in the region.

A study of groundwater was carried out by Nag and Das (2014) in Suri Blocks of Birbhum District, West Bengal, India. They observed that the pH of the samples are well to moderately suitable for irrigation with pH range in between 7.1 to 8.4.

An investigation was carried out by Patil *et al.* (2014) for assessment of ground water quality in Ahmedpur tehsil of Latur district, Maharashtra and concluded that the water samples are alkaline in nature which has pH range from 7.18 to 8.81 with an average 7.9.

Singh *et al.* (2014) studied about the ground water quality in the township of Ranchi district of Jharkhand. Results showed that the groundwater is slightly alkaline in nature with the pH ranges from 7-8 and average of 7.4.

Toumi *et al.* (2015) collected groundwater samples from Al-Ula Region of Saudi Arabia and analysed pH of the samples which varied from 7.3 to 8.2 and results of analysis indicated slightly alkaline nature of the water in the region.

Venkateswarana and Deepa (2015) studied quality of ground water in the Vaniyar watershed of Dharmapuri district, Tamil Nadu. They concluded that the pH of the samples varied from 7.50 to 9.02 which are used for all types of crops.

Choudhary *et al*. (2016) investigated pH of the ground water in the part of central India and they found pH in between 6.2 and 8.3 with mean value 6.88 of water in the region. In some locations of investigated area water are slightly acidic in nature.

Bhat (2016) studied about the ground water quality in Gohana block of Sonipat, Haryana. Results of the study showed that the pH of ground water varied from 5.1 to 8.5 which indicate moderate suitability of groundwater for irrigation purpose.

Apraj *et al*. (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results of the study showed that the pH values of irrigation water samples from Palghar Tehsil varied from 7.14 to 8.38 with an average value of 7.63. While pH of samples from Dahanu tahsil ranges from 6.81 to 8.43 with an average value of 7.48.

A study was carried out by Kumar *et al.* (2017) for ground water quality in the high altitude areas of Himachal Pradesh, India. The resulted values of pH varied from 7.2 to 7.9 in the study area.

Singh *et al*. (2017) investigated the pH of groundwater in Gulha block of Kaithal district in Haryana which varied from 7.36 to 9.80 with a mean value of 8.1.

Rao (2018) collected groundwater samples from Prakasam district of Andhra Pradesh and they analysed pH of the samples which ranges from 7.2 to 8.3 with a mean of 7.81. The results of the analysis indicated that the groundwater is alkaline in nature.

2.2 Water quality related with EC

Subramani *et al. (*2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India. They concluded that the EC values ranges from 80 µS/cm to 3,740 µS cm^{-1} and groundwater in the area is generally high to very high saline in nature.

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh and obtained EC range of basin water is 0.64 to 1.06 dS m^{-1} and these EC range found within the acceptable range of crop production.

An investigation was carried out by Vasanthavigar *et al. (*2010) in sub basin of Thirumanimuttar in Tamil Nadu on groundwater quality for determining its suitability for agricultural purposes. They investigated that the electrical conductivity (EC) ranges from 473.31 to 2,210.56 (µS cm^{-1}) in the study area.

Obiefuna and Sheriff (2011) studied the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes and they found electrical conductivity range below 0.249 dS m^{-1} in the study area.

Srinivasamoorthy *et al*. (2011) studied groundwater quality in Salem district of Tamilnadu for determining its suitability for drinking and agricultural proposes. They concluded that the EC was ranging from 222.0 to 4,282.0

µS cm^{-1}. Higher electrical conductivity was observed during post-monsoon season in this study.

Reddy (2013) evaluated groundwater quality of Bhaskar Rao Kunta watershed in Nalgonda District of Telangana state, India for its suitability for irrigation. He recorded EC values which lies in between 650 and 1497 (µS cm^{-1}) with an average of 975 (µS cm^{-1}) and these values indicated that the 80% of the samples fall under medium to high salinity.

Nag and Das (2014) studied groundwater in Suri Blocks of Birbhum District, West Bengal, India. They observed that the EC of the samples are well to moderately suitable for irrigation with range in between 90 and 300 µS cm^{-1} and 55 to 552 µS cm^{-1} during POM and PRM, respectively.

An investigation was carried out by Patil *et al.* (2014) for the assessment of ground water quality in Ahmedpur tehsil of Latur district, Maharashtra and concluded that the most of the well water samples was moderately suitable for irrigation due to high salinity class. The EC values of ground water samples were 0.478 to 1.310 dS m^{-1} with the average value 0.812 dS m^{-1}.

Singh *et al*. (2014) studied about ground water quality in the township of Ranchi district of Jharkhand. They concluded that the EC exceed the desirable limit at few sites in the region with the range in between 238 and 1357 µS cm^{-1} and an average value of 666 µS cm^{-1}.

Venkateswarana and Deepa (2015) studied quality of ground water in the Vaniyar watershed of Dharmapuri district, Tamil Nadu. They concluded that the EC of the samples varied from 399 to 5163 µS cm^{-1} which belongs high to very high salinity class of waters. Soil must be permeable with adequate drainage facilities for satisfactory crop growth in the region.

Toumi *et al*. (2015) collected groundwater samples from Al-Ula Region of Saudi Arabia and they analysed EC of samples which ranged from 400 to 2575 µS cm^{-1}.

Bhat (2016) collected the ground water samples from Gohana block of Sonipat, Haryana. He analysed EC of samples which varied from 250 to 2250 (µS m^{-1}) and indicate the moderate suitability of groundwater for irrigation purpose.

Choudhary *et al. (*2016) investigated EC of the ground water in the part of central India and concluded that water of the region is extremely high electrical conductivity and ranged from 785 - 4589 µS cm^{-1}.

Apraj *et al*. (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results of the study showed that the water is slightly saline in reaction with EC values in Palghar tahsil ranged from 0.31 to 1.28 (dS m^{-1}) with mean 0.68(dS m^{-1}) and in Dahanu Tehsils ranged from 0.44 to 1.45(dS m^{-1}) with an average 0.79(dS m^{-1}).

Elmabrok *et al.* (2017) asserted the ground water quality in Alagilat Area, Libya and obtained EC values ranging from 1320 –10680 µS cm^{-1} with an average of 3940.31 µS cm^{-1} and these range of EC fall under doubtful and unsuitable category for crop production.

Kumar *et al.* (2017) studied ground water quality in the high altitude areas of Himachal Pradesh, India. The resulted value of EC varies from 495 to 3054 µS cm^{-1} in the study area.

Singh *et al.* (2017) investigated the EC of groundwater in Gulha block of Kaithal district in Haryana which varied from 0.30 to 2.31 dS m^{-1} with a mean value of 1.24 dS m^{-1}.

Rao (2018) collected groundwater samples from Prakasam district of Andhra Pradesh and they analysed EC of the samples which ranges from 1505 to 4980 µS cm^{-1} with a mean of 2983.50 µS cm^{-1}, the difference of it indicates a wide variation of salts present in the groundwater.

2.3 Water quality in relation to total Cations

Subramani *et al.* (2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India and they also observed the abundance of the major cations is as follows: $Na^+ \geq Ca^{2+} \geq Mg^{2+} > K^+$. The concentrations of various cations such as Na^+ (mg L^{-1}) 4 to 304 with an average 97, K^+ (mg L^{-1})

2 to 34 with an average 9.71, Ca^{2+} (mg L^{-1}) 10 to 176 with an average 63 Mg^{2+} (mg L^{-1}) 2 to 243 with an average 63 mg L^{-1} in water samples.

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh, they obtained concentration of cations in water samples such as Ca^{2+} from 0.67 to 6.29 (3.49) , Mg^{2+} from 0.23 to 0.59 (0.42), Na^{+} from 0.59 to 1.59 (1.03), K^{+} from 0.93 to 2.95 (1.66) mg L^{-1}.

Obiefuna and Sheriff (2011) studied the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes. They found concentration of cations like sodium (mg L^{-1}) 0.03 - 97 with mean 7.13, potassium (mg L^{-1}) 4 -12.10 with mean 7.35, calcium (mg L^{-1}) 18.07-73.76 with mean 34.17, magnesium (mg L^{-1}) 7.78 - 58.98 with mean 30.13 mg L^{-1} in water samples.

Srinivasamoorthy *et al. (*2011) studied groundwater quality in Salem district of Tamilnadu for determining its suitability for drinking and agricultural proposes. They obtained Calcium concentration in ground water ranges from 3.0 to 130.0 mg L^{-1}, potassium concentration 1.0 to 384.0 mg L^{-1} and sodium concentration from 33.0 to 834.0 mg L^{-1}. The abundance of major cations in the groundwater was in the order of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$.

An investigation was carried out by Vasanthavigar *et al.* (2012) in sub basin of Thirumanimuttar in Tamil Nadu on groundwater quality for determining its suitability for agricultural purposes. They found concentration of Ca^{2+} from 16.0-228.0 (mg L^{-1}), Mg^{2+} from 10.5-158.40 (mg L^{-1}), Na^{+} from 0.80-1497.0 (mg L^{-1}), K^{+} from 0.80-497.0 (mg L^{-1}) in the water samples. The order of concentration of major cations is $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$.

Reddy (2013) evaluated groundwater quality of Bhaskar Rao Kunta watershed, Nalgonda District of Telangana, India for its suitability for irrigation. He recorded concentration of cations in samples such as Ca^{2+} = 73 – 151 (107) (mg L^{-1}), Mg^{2+} = 53 –102 (81) (mg L^{-1}), Na^{+} = 63 –120 (86) (mg L^{-1}) and K^{+} = 0.6–1.5 (0.9) (mg L^{-1}).

An investigation was carried out by Patil *et al.* (2014) for the assessment of ground water quality in Suri Blocks of Birbhum District, West Bengal, India and they concluded that the Na^{+} is predominant cation followed by K^+ in water samples. The concentration of Na^+ varied from 7.92 to 24.10 (mg L^{-1}) with mean value 16.95 and K^+ conc. varied from 0.05 to 0.19 (mg L^{-1}) with mean value 0.115.

Singh *et al.* (2014) conducted studies on ground water quality in the township of Ranchi district of Jharkhand. The results showed that the concentration of Ca^{2+} in water from 21.8 to 164 mg L^{-1}, Na^+ from 14.2 to 75.2 mg L^{-1}, Mg^{2+} 9.8 to 46 mg L^{-1} and K^+ 1.9 to 19.3 mg L^{-1} The order of cations abundance was Ca^{2+}> Na^+>Mg^{2+}>K^+ in water samples.

Toumi *et al*. (2015) collected groundwater samples from Al-Ula Region of Saudi Arabia and they analysed total cations. They found calcium and magnesium contents in samples in between 50–301 and 5–105 mg L^{-1} respectively and sodium and potassium contents were in the range of 15–90 and 1.2–6 mg L^{-1} respectively.

Venkateswarana and Deepa (2015) studied quality of ground water in the Vaniyar watershed of Dharmapuri district, Tamil Nadu. They concluded that the concentration of major cations such as Ca^{2+} (mg L^{-1}) 1.25 to 17.02, Mg^{2+} (mg L^{-1}) 1.90 to 14.72, Na^+ (mg L^{-1}) 1.04 to 15.75 and K^+ (mg L^{-1}) 0.26 to 0.92 in water samples.

A study conducted by Choudhary *et al*. (2016) on the ground water quality in the part of central India and concluded that the depletion in the groundwater quality is gradually depends on overuse of groundwater . They also concluded that the mean concentration of Na^+, K^+, Mg^{2+}, Ca^{2+} and Fe^{++} in the water was 206 ± 25, 9.2 ± 2.3, 39 ± 6, 114 ± 19 and 1.7 ± 0.6 mg L^{-1}, respectively in water samples.

Apraj *et al*. (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results showed that the sodium concentration in irrigation water samples from Palghar tehsil varied from 4.98 to 109.26 me L^{-1} with a mean value of 31.92 me L^{-1} and that from Dahanu tehsil 6.14 to 104.70 me L^{-1} with a mean value of 29.12 me L^{-1}. Among all the cations Na^+ was dominant in water followed by Ca^{2+}, Mg^{2+} and K^+.

A study conducted by Kumar *et al. (*2017) on ground water quality in the high altitude areas of Himachal Pradesh, India. They concluded that the dominant cations are in the order of Na^+> Ca^{2+}> K^+> Mg^{2+}. The Na^+ concentrations are ranging from 79 to 140 mg L^{-1} with average of 105.38 mg L^{-1} is higher than that of K^+ (Average 74.03 mg L^{-1}). The concentration of Ca^{2+} varied in between 11 to 121 mg L^{-1}, while the concentration of Mg^{2+} varied from 39 to 89 mg L^{-1} in water samples.

The study was carried out by Singh *et al.* (2017) to assess the quality of groundwater in Gulha block of Kaithal district in Haryana. Results showed that the concentration of cations in water samples are Ca^{2+} (me L^{-1}) 0.20-2.00 (0.92), Mg^{2+} (me L^{-1}) 0.80-4.90 (2.69), Na^+ (me L^{-1}) 1.80-18.20 (8.30) and K^+ (me L^{-1}) 0.06-0.42 (0.15). The cations followed the order of abundance in the study area is - sodium > magnesium > calcium > potassium.

Rao (2018) collected groundwater samples from Prakasam district of Andhra Pradesh. He found the concentration of Ca^{2+} in between 55 and 90 (mg L^{-1}) with a mean of 65.67 mg L^{-1} while that of Mg^{2+} from 42 to 105 (mg L^{-1}) with a mean of 76.87 mg L^{-1}, Na^+ concentration from 185 to 823 mg L^{-1} with a mean of 444.73 mg L^{-1} and K^+ concentration observed to be low, which ranged from 12 to 121 with a mean of 54.33 mg L^{-1} in water samples.

2.4 Water quality in relation to total anions

Subramani *et al*.(2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India and the abundance of the major anions is as follows: Cl^- > HCO_3^- > SO_4^{2-} > NO_3^- > CO_3^{2-}. They found concentration of various anions such as Cl^- (mg L^{-1}) 7 to 1163 with an average 259, HCO_3^- (mg L^{-1})18 to 275 with an average 153, CO_3^{2-} (mg L^{-1}) 0 to 90 with an average 16, SO_4^{2-} (mg L^{-1}) 0 to 173 with an average 49 in water samples.

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh. They found concentration of anions such as HCO_3^- varied from 6.25 to 11.50 (8.07), Cl^- from 2.38 to 7.75 (5.13) me L^{-1}.

Srinivasamoorthy *et al*. (2011) studied groundwater quality in Salem district of Tamilnadu for determining its suitability for drinking and agricultural proposes. The results showed that the Cl^- concentration was ranging from 31 to 1,400 mg L^{-1}, SO_4^{2-} is highly variable from 1.0 to 184.0.The abundance of major anions in the groundwater was in the order of Cl^- > HCO_3^- > SO_4^{2-} > NO_3^- .

Vasanthavigar *et al.* (2012) assessed the groundwater quality in sub basin of Thirumanimuttar in Tamil Nadu for irrigation suitability. The concentration of various anions in water samples as HCO_3^- 73.22 - 893.84, Cl^- 86.85 - 1,602.27 and SO_4^{2-} 0.01 - 126.8. The order of abundance of anion concentration is HCO_3>Cl^->NO_3^-.

Reddy (2013) evaluated groundwater quality of Bhaskar Rao Kunta watershed, Nalgonda District, India for its suitability for irrigation. He found concentration of anions in water samples as HCO_3^- (mg L^{-1}) 165 – 260 (212), SO_4^{2-} (mg L^{-1})19 – 43 (30), Cl^- (mg L^{-1}) 30 -115 (71).

Patil *et al.* (2014) investigated quality of ground water in Suri Blocks of Birbhum District, West Bengal, India and concluded that the concentration of total anions is higher in summer (1.07) as compare to winter season(0.9) with this concentration water is moderately used (class C2) in irrigation. Concentration of SO_4^{2-} varied from 12.9 to 24.8 with mean value 19.24, Cl^- concentration varied from 5.2 to 11.5 with mean value 7.42 in water samples.

Singh *et al.* (2014) studied the ground water quality in the township of Ranchi district of Jharkhand. The results showed that the concentration of major anions as HCO_3^- 90–488 mg L^{-1}, Cl^- 30–176.3 mg L^{-1} and SO_4^{2-} 9.7–125.9 mg L^{-1}. The order of anions abundance in the groundwater was found as HCO_3^-> Cl^-> SO_4^{2-}.

Toumi *et al.* (2015) collected groundwater samples from Al-Ula Region, Saudi Arabia and analysed total anions in water samples. They found Chloride concentration varies from 73 to 770 mg L^{-1} and that of HCO_3^- 59 to 194 mg L^{-1} in groundwater.

Venkateswarana and Deepa (2015) studied quality of ground water in the Vaniyar watershed of Dharmapuri district, Tamil Nadu. They concluded that concentration of major anions such as HCO_3^- (ppm) 1.56 to 11.34, SO_4^- (ppm) 0.5 to 3.52, Cl^- (ppm) 0.45 to 11.56 in water samples.

Choudhary *et al*. (2016) studied the ground water quality in the part of central India and they concluded that the depletion in the groundwater quality is gradually depends on overuse of groundwater and also concluded that the mean concentration (n = 30) of Cl^- and SO_4^{2-} in the water was 98 ± 31and 56 ± 9 respectively.

Apraj *et al.* (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results showed that the concentration of carbonate varied from 0.0 to 6.0 me L^{-1} with a mean value of 1.02 me L^{-1} from Palghar tehsil, while in Dahanu tehsil it was varied from 0.0 to 6.0 me L^{-1} with a mean value of 2.50 me L^{-1}. There were no carbonate contents in majority of water samples. The order of anions in samples is $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-}$.

Kumar *et al.* (2017) studied ground water quality in the high altitude areas of Himachal Pradesh, India. They concluded that concentration of carbonate (CO_3^{2-}) varied from 57 to 198 mg L^{-1} and bicarbonate is varied from 139 to 276 mg L^{-1} and the content of SO_4^{2-} is observed from 23 to 65 mg L^{-1}. in water samples.

The study was carried out by Singh *et al.* (2017) to assess the quality of groundwater in Gulha block of Kaithal district in Haryana. The results showed that the concentration of total anions in water sample are CO_3^{2-} (me L^{-1}) 0.00-3.20 (1.00), HCO_3^- (me L^{-1}) 0.30-8.60 (4.72), Cl^{-1} (me L^{-1}) 1.40-10.90 (4.16), SO_4^{2-} (me L^{-1}) 0.04-7.13 (1.84) and anions followed the order in the study area is- $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{-2-} > NO_3^-$.

Rao (2018) collected groundwater samples from Prakasam district of Andhra Pradesh and analyzed for total anions like bicarbonate, chloride, sulphate. The HCO_3^- content is observed to be 480–1025 mg L^{-1} with a mean of 731.33 mg L^{-1}, Cl^- in between 215 and 1060 mg L^{-1} with a mean of 568.83 mg L^{-1} and SO_4^{2-} content is observed to be 22–125 mg L^{-1} with a mean of 71.47 mg L^{-1} in water samples.

2.5 Water quality in relation to SAR

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh. They obtained SAR values ranged below 1 i.e. 0.74 and SAR found within the acceptable range of crop production.

An investigation was carried out by Vasanthavigar *et al*.(2010) for assessment of groundwater quality in sub basin of Thirumanimuttar in Tamil Nadu for irrigation suitability. They investigated SAR values ranges from 0.010 to 26.07 and 0 to 11.49 during PRM and POM in water samples.

Obiefuna and Sheriff (2011) studied the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes and they found SAR range in between 0 and 0.035 me L^{-1} in water samples.

Srinivasamoorthy *et al*. (2011) studied groundwater quality in Salem district of Tamil Nadu for determining its suitability for drinking and agricultural proposes. They concluded that the majority of samples fall in C3S1 zone with the range of SAR 1 to 5 mg L^{-1} and an average 4 mg L^{-1} in water samples.

Reddy (2013) evaluated groundwater quality of Bhaskar Rao Kunta watershed, Nalgonda District, India for its suitability for irrigation. He recorded SAR in water samples is ranged from 1.15 to 2.25 me L^{-1} with an average 1.56 which indicated that the quality of groundwater was suitable for irrigation.

Sudhakar and Narsimha (2013) asserted ground water quality in Kushaiguda area of Ranga Reddy district in Andhra Pradesh, India. They found SAR ranges from 0.57 to 1.64 which shown 69% of groundwater is belongs to S3C1, indicating high salinity and low alkali water.

Nag and Das (2014) studied groundwater quality in Suri Blocks of Birbhum District, West Bengal, India. The results showed that the SAR values range from 0.18 to 2.07 in post monsoon and 0.24 to 3.24 during pre monsoon and all samples has low sodium hazard.

Singh *et al*. (2014) studied about ground water quality in the township of Ranchi district of Jharkhand. Present study investigated SAR ranges from 0.6 to 2.0 (avg. 1.0 (mmol $L^{-1})^{1/2}$ that shows majority of the groundwater samples are suitable for irrigation uses.

Bhat (2016) collected ground water samples from Gohana block of Sonipat, Haryana and found SAR ranges in between 4.03 and 24.16 (mmol $L^{-1})^{1/2}$. He classified samples as excellent (50.6%), good (44.4%) and rest in doubtful categories.

Apraj *et al.* (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu Tehsils of Coastal Konkan. The results showed that the SAR varied from 2.63 to 20.49(mmol $L^{-1})^{1/2}$ with a mean value of 10.53 (mmol $L^{-1})^{1/2}$ in Palghar tehsil. And in Dahanu tehsil the same ranged from 3.11 to 17.22 (mmol $L^{-1})^{1/2}$ with a mean value of 10.17 (mmol $L^{-1})^{1/2}$. The results of SAR 61% water samples were categorized under C1 class which is suitable for irrigation and 39% water samples were moderately suitable and categorized under C2 class.

Elmabrok *et al.* (2017) evaluated the ground water quality in Alagilat Area, Libya and found SAR ranges from 2.41 to 15.42 (mmol $L^{-1})^{1/2}$ with an average 4.84 (mmol $L^{-1})^{1/2}$ and SAR concentration to be within the safe limit and likely suitable for agricultural irrigation purposes.

The study was carried out by Singh *et al.* (2017) to assess the quality of groundwater in Gulha block of Kaithal district in Haryana. They analysed Sodium absorption ratio (SAR) which ranged from 2.55 to 14.39 (mmol $L^{-1})^{1/2}$ with mean value of 6.12 (mmol $L^{-1})^{1/2}$ in water samples.

2.6 Water quality in relation RSC

Sarkar and Hassan (2006) asserted the groundwater quality in Basin of Bangladesh and obtained RSC values higher (3.26 to 4.16 me L^{-1}) than the permissible limit (>2.5 me L^{-1}) in water of the study area.

Obiefuna and Sheriff (2011) studied the shallow groundwater quality of Pindiga Gombe area in Nigeria for irrigation and domestic purposes and found ranges of RSC from 0.35 to 3.02 me L^{-1}.

An investigation carried out by Vasanthavigar *et al*. (2012) in sub basin of Thirumanimuttar in Tamil Nadu for irrigation suitability. The results showed that the RSC in water samples ranges from 1 to 14 me L^{-1} and 3 to 18 me L^{-1} with an average of 7.2 and 10.6 me L^{-1} during PRM and POM.

Reddy (2013) evaluated quality of groundwater in Bhaskar Rao Kunta watershed, Nalgonda District of Telangana state, India for its suitability for irrigation. The results showed that the RSC values in water samples is < 1.25 me L^{-1} which indicated that the quality of groundwater was suitable for irrigation.

Sudhakar and Narsimha (2013) studied ground water quality in Kushaiguda area of Ranga Reddy district in Andhra Pradesh, India. They found that the RSC values ranges from -58.73 to 8.36 me L^{-1} and majority of the groundwater samples are suitable for irrigation uses.

Nag and Das (2014) studied the groundwater in Suri Blocks of Birbhum District, West Bengal, India. Results showed that the RSC values range in between -0.10 and 12.97 me L^{-1} and more than 80% of the water samples have RSC > 2.5 me L^{-1} which indicate an alkaline hazard to the soil.

Singh *et al.* (2014) studied the ground water quality in the township of Ranchi district of Jharkhand. They investigated RSC values < 2.5 me L^{-1} in water samples which are suitable for irrigation uses.

Bhat (2016) studied the ground water in Gohana block of Sonipat, Haryana.The results showed that the RSC of ground water varied from 0 to 9.2 me L^{-1} and majority of the samples are moderately suitable for irrigation purpose.

Apraj *et al*. (2017) studied quality of groundwater for irrigation in the areas of Palghar and Dahanu tehsils of Coastal Konkan. The results showed that the RSC values of irrigation water in Palghar tehsil is 0 to 3.80 with an average 0.74 and in Dahanu tehsil is 0 to 4.8 with an average 1.96.

Elmabrok *et al.* (2017) asserted the ground water quality in Alagilat Area, Libya and obtained RSC values ranges from -250.82 to 0.66 (me L^{-1}) with an average -33.73 (me L^{-1}) and RSC found to be within the safe limit and likely suitable for irrigation purposes.

Singh *et al.* (2017) investigated RSC of groundwater in Gulha block of Kaithal district in Haryana which ranged from nil to 5.80 me L^{-1} with mean value 2.20 me L^{-1} in water samples.

2.7 Correlation among various parameters of water quality

Khan et al. (2012) studied a correlation on the Ground Water of Vaiyampatti Village, Tiruchirappalli District. The result showed that the range from 0.003 to 0.870 for all water quality parameters and also a weak correlations were observed between pH and Chloride (r= -0.533).

Navneet and Sinha (2010) observed the correlation among parameters of ground water in Moradabad, India. They found that the correlation between conductivity and pH is 0.900, conductivity and calcium is 0.885 and conductivity and chloride is 0.918.

A study of correlation was carried out by Khan and Kumar (2012) on ground water in Tiruchengode taluk of Namakkal district, Tamil Nadu, India. They found that the correlation between EC and Chloride (R=0.969), EC and Ca^{2+}(R= 0.920). The value of correlation coefficient lies between -1 and +1.

Toumi *et al.* (2015) collected groundwater samples from Al-Ula Region of Saudi Arabia and correlate various parameters such as Ca^{2+} and SO_4^{2-} (r=0.29), SO_4^{2-} and Mg^{2+} (r=0.35). There is no significant relation between Ca^{2+} and Mg^{2+} versusHCO_3^- (r=−0.07,−0.06,respectively).

Subramani *et al*. (2005) observed the quality of groundwater in Chithar River Basin, Tamil Nadu, India. They found that the correlation between pH and EC is 0.0159, EC and Na^+ 0.8188, SO_4^{2-} and Na^+ 0.93191.

Bhoopathi *et al.* (2014) assessed ground water quality in Nacharam area of Ranga reddy district, Andhra Pradesh. They found that the correlation between pH and EC is -0.01, EC and Ca^{2+} is -0.13, Na^+ and k^+ is 1.0.

Choudhary *et al*. (2016) studied the ground water quality in the part of central India and they concluded that the correlation between Cl^- and SO_4^{2-} is -0.01, K^+ and Ca^{2+} is -0.05, Ca^{2+} and Mg^{2+} is 0.93.

CHAPTER - III

MATERIAL & METHODS

The chapter material and method provide detailed information about the methods of sampling and methods of analysis which is used in the Characterization of Ground Water Quality of the study area. The details of which are presented in the following manner

3.1 Collection of water samples

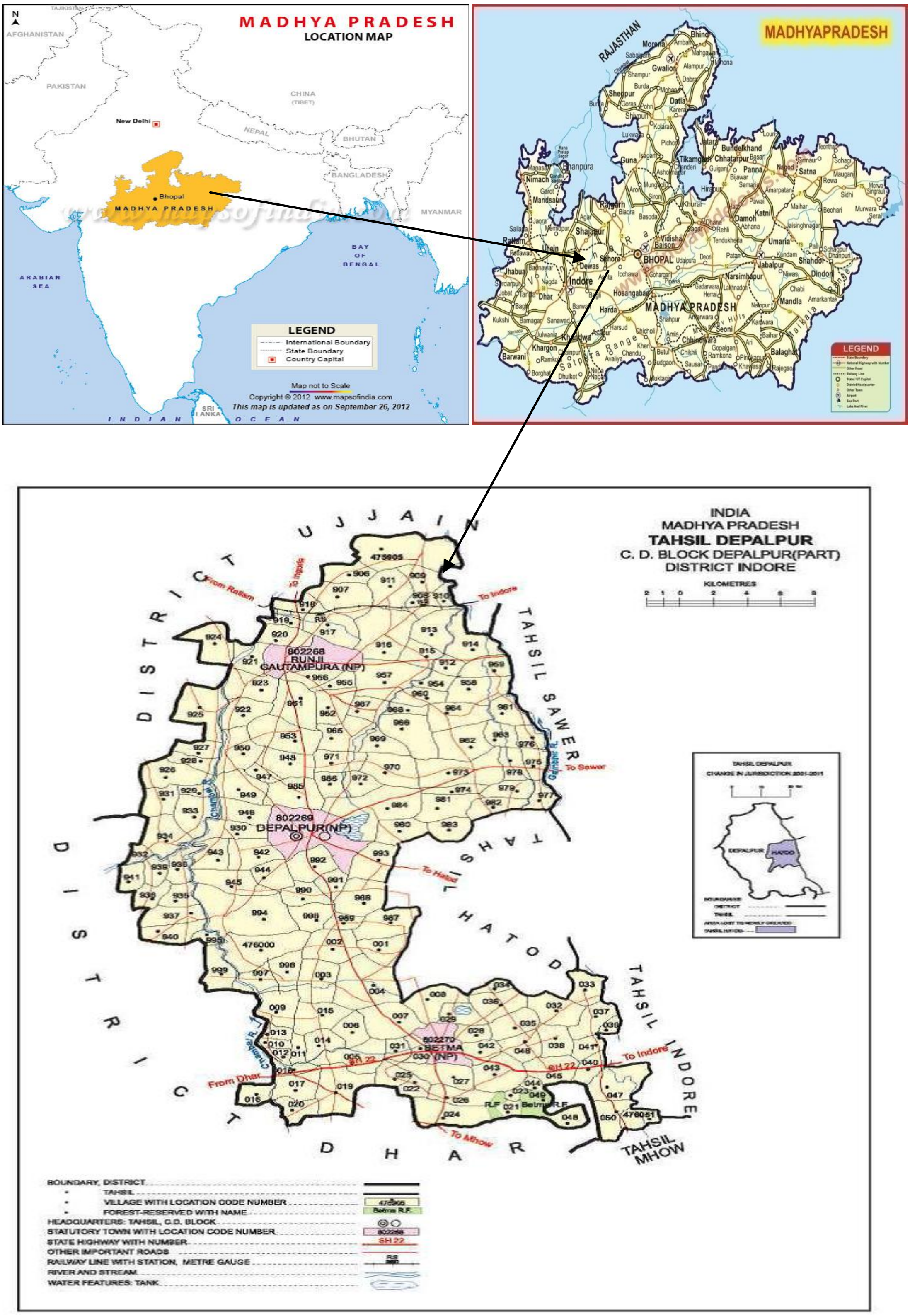
3.2 Methods of analysis

3.3 Methods of reporting

3.1 Collection of samples

A total of 200 groundwater samples were collected from dug and bore wells during May 2018 and cover the entire Depalpur tesil. The locations was recorded using hand held GPS (Global positioning system) Fig.3.1. General information about the water samples including farmer's opinion is given in Table 3.1. Samples were collected in 500ml capacity polyethylene bottles. Prior to collection, the bottles were thoroughly washed with distilled water in the laboratory before sample filling. Each bottle was rinsed to avoid any possible contamination in bottling and every other precautionary measure was taken. Collected samples were brought to the laboratory of salt Affected Soils Project, College of Agriculture, Indore for analysis to understand the characteristics of groundwater quality parameters using standard methods.

Fig. 3.1: Location of Depalpur tehsil in India and Madhya Pradesh.



3.2 Methods of analysis

3.2.1 Determination of pH

pH is defined as negative logarithm of the hydrogen ion (H^+) activity in a solution. The pH expresses the intensity of the acid or the alkaline condition of a solution. pH was determined with the help of glass electrode or pH meter (Richards,1954).

3.2.2 Determination of EC

The electric current in water is conducted by the ions present in it, so when the concentration of ions increases, conductivity augments as well. The salt content of the soil can be estimated roughly from an electrical-conductivity measurement in water. Scale of conductivity (desi Siemens per meter at 25° C.) The symbol “EC” is used to represent electrical conductivity. The EC values were measured in using a conductivity (EC) meter (Richards, 1954.)

3.2.3 Determination of cations

Calcium, magnesium, sodium, potassium etc are the main cations which is present in ground water. Concentrations of total cations in irrigation water affect its suitability for crop. Estimation of cation (Na^+ and K^+) was estimated by the procedure given by Tandan, (1993).Whereas, cations (Ca^{2+} and Mg^{2+}) was estimated by the method given by Richards (1954).

3.2.4 Determination of anions

Carbonates, bicarbonates, chloride, sulphate etc are the main anions present in ground water. Concentrations of total anions in irrigation water affect its suitability for crop .Estimation of anions in water by volumetric titration method as given by Richards (1954).

3.2.5 Determination of Sodium Absorption Ratio (SAR)

SAR is the ratio of sodium to calcium and magnesium. It is used to evaluate the suitability of ground water for irrigation as alkali hazard for crop. Calculation of SAR (mmol L^{-1}) with the help of following formula (Richards 1954).

$$SAR\ (mmol\ L^{-1})^{1/2} = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Classification of irrigation water based on the sodium hazard as Low - S1 [< 10], medium -S2 [10 – 18], high- S3 [18 – 26] and very high -S4 [>26].

3.2.6 Determination of Residual Sodium Carbonate (RSC)

RSC is the sum of carbonates and bicarbonates over the sum of calcium and magnesium. It influences the suitability of groundwater for irrigation. Calculation of RSC with the help of following formula (Richards 1954).

$$RSC\ (\text{me L}^{-1}) = [(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})]$$

More than 2.5 meq per litre RSC in water is unsuitable for irrigation.

3.3 Method of reporting

The results of the analysis of water samples were grouped as per the classification suggested by Richards (1954) as given in Table 3.1 and Fig. 3.1 and Minhas *et al*. (1998) of CSSRI, Karnal Haryana (Table 3.2).

Table 3.1 Classes of ground water quality as per Richards (1954)

Salinity classes (dS m^{-1})		Sodium Hazards (SAR) (mmol L^{-1})$^{1/2}$	
C1	<0.250	S1	<10
C2	0.250-0.750	S2	10-18
C3	0.750-2.250	S3	18- 26
C4	>2.250	S4	>26

Table 3.2: Criteria of ground water quality as per the Minhas *et al*. (1998) of CSSRI, Karnal Haryana

Water quality	EC (dS m^{-1})	SAR (mmol $L^{-1})^{1/2}$	RSC (me L^{-1})
A. Good	<2	<10	<2.5
B. Saline water			
1.Marginally Saline	2-4	<10	<2.5
2.Saline	>4	<10	<2.5
3.High SAR Saline	>4	>10	<2.5
C. Alkali waters			
1.Marginally Alkali	<4	<10	2.5-4.0
2.Alkali	<4	<10	>4.0
3. Highly Alkali	varialble	>10	>4.0

Correlation study

The correlation of coefficient was worked out for different parameters of ground water quality as per method suggested by Panse and Sukhatme (1978).

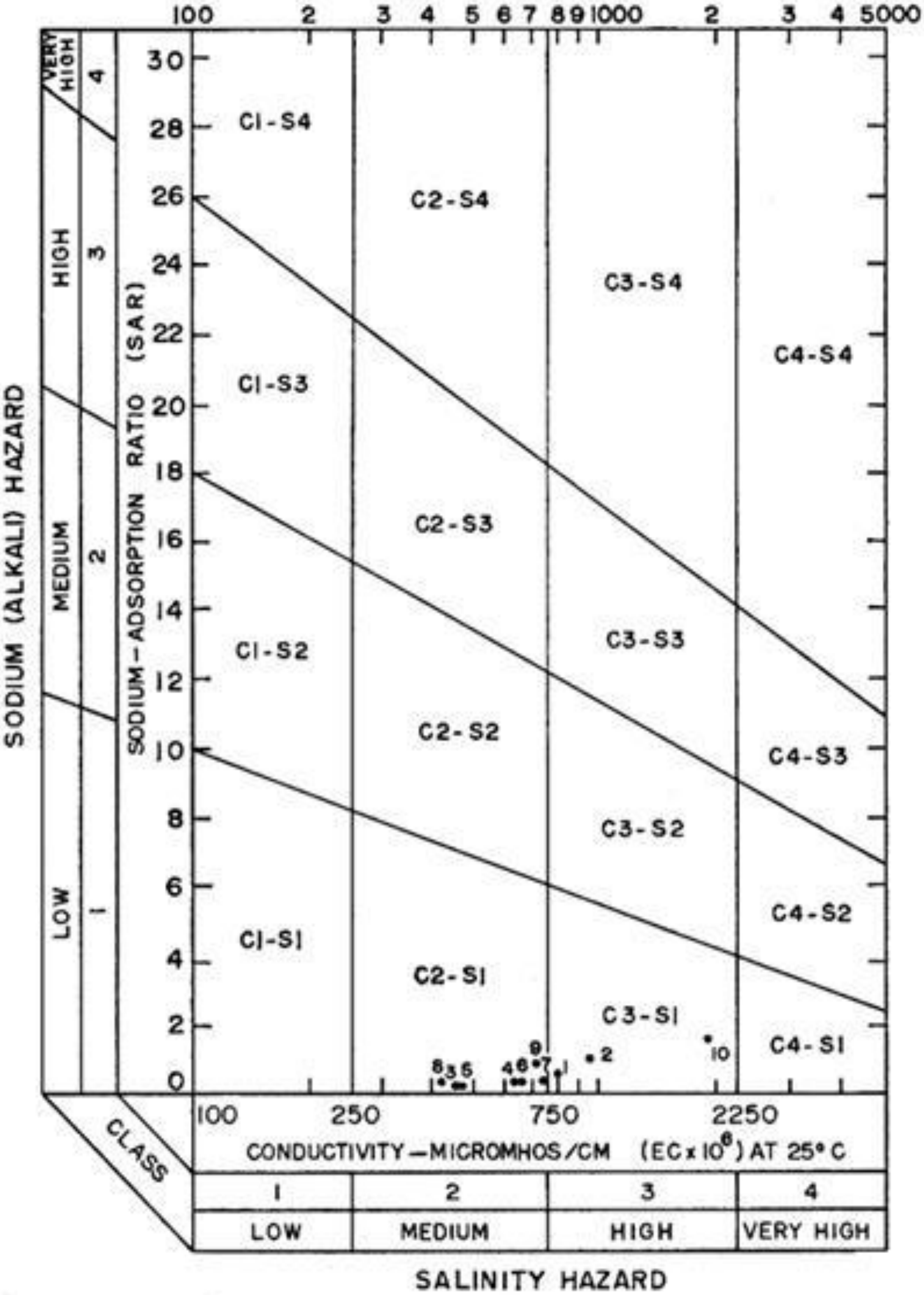


Fig. 3.2: Irrigation water classes (Richards, 1954)

Table 3.3: General information of ground water samples of Depalpur tehsil

S. No.	Village	Location	Source /Depth (m)	Years	Crop grown	Farmer' Rating
1.	Ushapura	22° 49' 7" N 75° 41' 5" E	TW 90	12	Soybean, wheat	Good
2.	Agra	22° 49' 33" N 75° 38' 18" E	TW 60	10	Soybean, chickpea	Good
3.	Gangajal Khedi	22° 51' 35" N 75° 37' 36" E	W 8	12	Soybean, wheat	Good
4.	Nandra	22° 52' 46" N 75° 37' 4" E	TW 45	15	Soybean, chickpea	Good
5.	Chiman Khedi	22° 51' 32" N 75° 35' 15" E	TW 55	8	Soybean, chickpea, vegetables	Good
6.	Goutampura	22°59' 32"N 75° 32' 36"E	TW 180	11	Soybean, chickpea	Saline
7.	Murkheda	22° 49' 57" N 75° 37' 3" E	TW 45	5	Soybean, chickpea, vegetables	Good
8.	Hasnabad	22° 49' 50" N 75° 35' 41" E	TW 30	9	Soybean, chickpea	Good
9.	Piploda	22° 48' 40" N 75° 36' 12" E	TW 40	3	Soybean, chickpea, vegetables	Good
10.	Banedia	22° 52' 26" N 75° 34' 14" E	TW 35	3	Soybean, chickpea	Good
11.	Betma Khurd	22° 40' 34" N 75° 39' 1" E	TW 45	20	Soybean, chickpea, vegetables	Good
12.	Banedia	22° 51' 19" N 75° 32' 25" E	TW 40	10	Soybean, wheat	Good
13.	Badoli Hoj	22° 49' 50" N 75° 34' 23" E	TW 110	12	Soybean, chickpea	Saline
14.	Khimalawda	22° 54' 11" N 75° 35' 30" E	TW 35	8	Soybean, chickpea, vegetables	Good
15.	Jalalpura	22° 54' 42" N 75° 33' 24" E	TW 55	7	Soybean, wheat	Good
16.	Jalalpura	22° 54' 35" N 75° 33' 18" E	TW 40	2	Soybean, Chick pea	Good

S.No.	Village	Location	Source /Depth (m)	Years	Crop grown	Farmer' Rating
17.	Agra	22° 49' 9" N 75° 38' 1" E	TW 60	10	Soybean, chickpea	Good
18.	Ahirkhedi	22° 50' 23"N 75° 38' 27"	TW 55	15	Soybean, chickpea	Good
19.	Gohan	22° 45' 8"N 75° 37' 46"E	TW 45	8	Soybean, wheat	Good
20.	Gohan	22° 45' 29"N 75° 37' 42"E	TW 40	5	Soybean, chickpea, vegetables	Good
21.	Atawda	22° 45' 43"N 75°36' 7"E	W 10	12	Soybean, chickpea	Good
22.	Atawda	22° 46' 15"N 75°35' 30"E	TW 45	6	Soybean, chickpea, vegetables	Good
23.	Rangwasa	22° 44' 32" N 75° 34' 16" E	TW 50	3	Soybean, chickpea, vegetables	Good
24.	Chiklonda	22° 46' 15" N 75° 32' 42" E	W 7	15	Soybean, wheat	Good
25.	Jalodia Gyan	23° 0' 37" N 75° 36' 48" E	TW 60	6	Soybean, chickpea	Good
26.	Barda Khedi	22° 57' 7" N 75°35' 56" E	TW 130	10	Soybean, chickpea, vegetables	Saline
27.	Jalodia Panth	22° 48' 39" N 75° 34' 25" E	TW 60	15	Soybean, chickpea	Good
28.	Giroda	22° 49' 14" N 75° 32' 53" E	TW 60	6	Soybean, chickpea	Good
29.	Barda Khedi	22° 57' 7" N 75°35' 56" E	TW 130	3	Soybean, wheat	Saline
30.	Takipura	22° 49' 46" N 75° 32' 41" E	TW 35	4	Soybean, wheat	Good
31.	Takipura	22° 49' 15" N 75° 31' 55" E	TW 40	2	Soybean, chickpea	Good
32.	Dansari	22° 45' 12"N 75° 38' 28"E	TW 55	5	Soybean, chickpea, vegetables	Good
33.	Barda Khedi	22° 57' 7" N 75°35' 56" E	TW 130	5	Soybean, chickpea	Saline

S.No.	Village	Location	Source /Depth (m)	Years	Crop grown	Farmer' Rating
34.	Karjoda	22° 55' 51" N 75° 38' 18" E	TW 40	7	Soybean, chickpea	Good
35.	Khandia	22° 53' 7" N 75° 40' 55" E	TW 60	12	Soybean, wheat	Good
36.	Machal	22° 40' 30" N 75° 40' 54" E	TW 35	3	Soybean, chickpea	Good
37.	Mothala	22° 41' 25" N 75° 35' 20" E	TW	5	Soybean, chickpea	Good
38.	Khajraya	22° 49' 40" N 75° 31' 31" E	W 7	13	Soybean, wheat	Good
39.	Khajraya	22° 49' 23" N 75° 30' 47" E	TW 40	10	Soybean, wheat	Good
40.	Chander	22° 47' 30" N 75° 29' 6" E	TW 45	5	Soybean, wheat	Good
41.	Sunala	22° 56' 38" N 75° 36' 53" E	TW 150	5	Soybean, wheat	Saline
42.	Aroda Kot	22° 48' 24" N 75°27' 38" E	TW 85	7	Soybean, chickpea	Good
43.	Pirpipliya	22° 40' 32" N 75° 35' 1" E T	TW 40	10	Soybean, wheat	Good
44.	Karki	22°50' 52"N 75° 28' 29"E	TW 150	2	Soybean, chickpea, vegetables	Saline
45.	Runawada	22° 49' 19" N 75° 25' 59" E	W 9	25	Soybean, wheat	Good
46.	Runawada	22° 49' 28" N 75° 25' 48" E	TW 65	12	Soybean, chickpea, vegetables	Good
47.	Ringanwas	22° 50' 28" N 75° 26' 20" E	TW 35	4	Soybean, chickpea	Good
48.	Khanpur	22° 45' 25" N 75° 31' 19" E	TW 50	6	Soybean, wheat	Good
49.	Phulan	23° 2' 23" N 75° 33' 24" E	TW 45	5	Soybean, wheat	Good
50.	Sikandri	22° 47' 43"N 75° 40' 20"E	TW 55	10	Soybean, chickpea, vegetable	Good
51.	Semda	22° 51' 19" N 75° 27' 7" E	TW 50	13	Soybean, wheat	Good
52.	Semda	22° 51' 25" N 75° 26' 48" E	TW 40	8	Soybean, wheat	Good

S.No.	Village	Location	Source /Depth (m)	Years	Crop grown	Farmer' Rating
53.	Palasiypar	22° 52' 52" N 75° 26' 57" E	TW 35	3	Soybean, chickpea	Good
54.	Palasiypar	22° 53' 1" N 75° 27' 7" E	TW 55	1	Soybean, chickpea, vegetables	Good
55.	Palasiypar	22° 53' 2" N 75° 26' 40" E	TW 70	9	Soybean, wheat	Good
56.	Limbodapar	22° 52' 18" N 75° 28' 20" E	TW 25	12	Soybean, Vegetables	Good
57.	Khatwadi	22° 51' 42" N 75° 29' 23" E	TW 80	6	Soybean, chickpea	Good
58.	Khatwadi	22° 51' 28" N 75° 29' 15" E	TW 60	4	Soybean, chickpea	Good
59.	Medat	22° 42' 20" N 75° 31' 3" E	TW 60	10	Soybean, chickpea, vegetables	Good
60.	Amli	22° 43' 29" N 75°31' 8" E	TW 35	15	Soybean, wheat	Good
61.	Murkheda	22° 50' 8" N 75° 36' 54" E	W 8	3	Soybean, chickpea	Good
62.	Murkheda	22° 49' 50" N 75° 36' 35" E	TW 40	17	Soybean, wheat	Good
63.	Birgoda	22° 53' 7" N 75° 32' 10" E	TW 40	13	Soybean, chickpea, vegetables	Good
64.	Birgoda	22° 53' 14" N 75° 32' 5" E	TW 55	7	Soybean, chickpea	Good
65.	Dhannad	22° 37' 25"N 75° 42' 44"E	TW 50	9	Soybean, wheat	Good
66.	Girota	23° 4' 2" N 75° 36' 12" E	TW 80	12	Soybean, chickpea	Good
67.	Kanwasa	22° 57' 56" N 75° 38' 18" E	TW 65	5	Soybean, wheat	Good
68.	Akolya	22° 42' 24" N 75° 23' 19" E	TW 55	3	Soybean, chickpea, vegetables	Good
69.	Banedia	22° 51' 19" N 75° 32' 25" E	TW 40	2	Soybean, wheat	Good
70.	Khireli	22° 48' 39" N 75°26' 36" E	TW 28	6	Soybean, wheat	Good
71.	Bahirampur	23° 1' 43" N 75° 31' 50" E	TW 65	10	Soybean, chickpea	Good

S.No.	Village	Location	Source /Depth (m)	Years	Crop grown	Farmer' Rating
72.	Farkoda	22° 55' 54" N 75° 31' 19" E	TW 70	10	Soybean, chickpea, vegetables	Good
73.	Farkoda	22° 56' 10" N 75° 31' 55" E	TW 70	5	Soybean, chickpea, vegetables	Good
74.	Ghadoda	23° 0' 30" N 75° 35' 28" E	TW 40	3	Soybean, chickpea	Good
75.	Keer Kheda	22° 51' 50" N 75° 32' 47" E	TW 65	5	Soybean, chickpea	Good
76.	Nogawan Khanjar	22° 59' 29" N 75° 30' 26" E	TW 30	12	Soybean, wheat	Good
77.	Nogawan Surf	22° 52' 34" N 75° 38' 49" E	TW 35	17	Soybean, wheat	Good
78.	Sanawda	22° 43' 38" N 75° 36' 46" E	TW 45	6	Soybean, chickpea, vegetables	Good
79.	Sanawda	22° 43' 39" N 75° 36' 33" E	TW 60	3	Soybean, wheat	Good
80.	Sironjya	23° 1' 14" N 75° 31' 23" E	TW 45	8		Good
81.	Aurangpura	22° 42' 45" N 75° 42' 19" E	TW 65	15	Soybean, wheat	Good
82.	Bajrangpura	22° 38' 43" N 75° 40' 13" E	TW 105	4	Soybean, chickpea	Saline
83.	Chitoda	22° 58' 25" N 75° 33' 56" E	TW 55	2	Soybean, chickpea, vegetables	Good
84.	Gangajal Khedi	22° 51' 23" N 75° 37' 30" E	TW 65	1	Soybean, chickpea	Good
85.	Pipliya Jhagdu	22° 41' 41" N 75° 41' 58" E	TW 55	20	Soybean, wheat	Good
86.	Karki	22°50' 37"N 75° 28' 44"E	TW 130	8	Soybean, wheat	Saline
87.	Pirpipliya	22° 40' 14" N 75° 35' 12" E	TW 40	7	Soybean, chickpea, vegetables	Good
88.	Rawad	22° 42' 57" N 75° 34' 48" E	TW 80	5	Soybean, wheat	Good

S.No.	Village	Location	Source	Years	Crop	Farmer'

			/Depth (m)		grown	Rating
89.	Piploda	22° 48' 40" N 75° 36' 12" E	TW 40	3	Soybean, chickpea	Good
90.	Ahirwas	22° 50' 22" N 75° 30' 5" E	TW 100	6	Soybean, wheat	Good
91.	Datoda	22° 34' 12" N 75° 53' 2" E	TW 70	12	Soybean, wheat	Good
92.	Gudar	22° 58' 21" N 75° 37' 4" E	TW 65	2	Soybean, chickpea	Good
93.	Shivgarh	22° 44' 26" N 75° 29' 8" E	TW 35	2	Soybean, wheat	Good
94.	Mendakwas	22° 57' 51" N 75° 31'34" E	TW 60	10	Soybean, wheat	Good
95.	Mendakwas	22° 57' 52" N 75° 31' 43" E	TW 50	15	Soybean, wheat	Good
96.	Mundipur	22° 53' 49" N 75° 33' 16" E	TW 85	9	Soybean, chickpea, vegetables	Good
97.	Ambalia	23° 3' 18" N 75° 33' 56" E	TW 30	3	Soybean, wheat	Good
98.	Chiman Khedi	22° 51' 24" N 75° 35' 30" E	TW 55	25	Soybean, chickpea, vegetables	Good
99.	Chiman Khedi	22° 51' 32" N 75° 35' 15" E	TW 45	10	Soybean, chickpea	Good
100.	Ujaliya	22° 54' 29" N 75° 40' 34" E	TW 50	4	Soybean, chickpea	Good
101.	Sejwani	22° 42' 55" N 75° 32' 32" E	TW 55	5	Soybean, wheat	Good
102.	Rayatpura	22° 41' 58" N 75° 40' 53" E	TW 45	5	Soybean, chickpea, vegetables	Good
103.	Jamgoda	22° 57' 35" N 75° 36' 23" E	TW 35	7	Soybean, chickpea, vegetables	Good
104.	Giroda	22° 49' 14" N 75° 32' 53" E	TW 60	9	Soybean, wheat	Good
105.	Bijepur	22° 41' 20" N 75° 38' 7" E	TW 65	10	Soybean, chickpea	Good
106.	Borsi	22° 44' 17" N 75° 42' 28" E	TW 50	15	Soybean, wheat	Good
107.	Ralayta	22° 57' 59" N 75° 31' 35" E	TW 35	2	Soybean, wheat	Good
108.	Shahpura	22° 53' 20" N 75° 39' 31" E	TW 55	3	Soybean, chickpea	Good
S.No.	**Village**	**Location**	**Source**	**Years**	**Crop**	**Farmer'**

			/Depth (m)		grown	Rating
109.	Mumdls Kalma	22° 53’ 37” N 75° 34’ 17” E	TW 90	7	Soybean, chickpea	Good
110.	Tajkhedi	22° 40’ 53” N 75° 31’ 0” E	TW 30	6	Soybean, wheat	Good
111.	Dhureri	22° 42’ 19” N 75° 33’ 35” E	TW 70	12	Soybean, chickpea	Good
112.	Galonda	22° 40’ 40” N 75° 42’ 19” E	TW 95	2	Soybean, chickpea, vegetables	Good
113.	Murkheda	22° 50’ 8” N 75° 36’ 54” E	W 8	14	Soybean, wheat	Good
114.	Goutampura	22°59’ 32”N 75° 32’ 36”E	TW 90	5	Soybean, wheat	Saline
115.	Goutampura	22°59’ 32”N 75° 32’ 36”E	TW 75	12	Soybean, chickpea	Good
116.	Khanpur	22° 45’ 25”N 75° 31’ 19”E	TW 65	8	Soybean, chickpea, vegetables	Good
117.	Sangvi	22° 38’ 39” N 75° 31’ 50” E	TW 55	5	Soybean, wheat	Good
118.	Ambapura	22° 38’ 38” N 75° 39’ 10” E	TW 65	2	Soybean, chickpea	Good
119.	Daultabad	22° 44’ 51” N 75° 32’ 42” E	TW 65	10	Soybean, chickpea, vegetables	Good
120.	Gokalpur	22° 54’ 20” N 75° 31’ 3|” E	TW 45	14	Soybean, chickpea	Good
121.	Gadihibillod	22° 39’ 58” N 75° 30’ 40” E	TW 50	9	Soybean, chickpea, vegetables	Good
122.	Kulala	23° 3’ 13” N 75° 36’ 43” E	TW 40	7	Soybean, wheat	Good
123.	Parinalwasa	23° 2’ 34” N 75° 35’ 30” E	TW 80	2	Soybean, chickpea	Good
124.	Bhidota	22°53’ 29” N 75° 29’ 44” E	TW 50	5	Soybean, wheat	Good
125.	Jalodia Gyan	23° 0’ 37” N 75° 36’ 48” E	TW 60	10	Soybean, wheat	Good
126.	Dharmat	22° 59’ 53” N 75° 38’ 28” E	TW 50	8	Soybean, chickpea	Good
127.	Chandan Khedi	22° 58’ 52” N 75° 38’ 49” E	TW 55	3	Soybean, chickpea, vegetables	Good
S.No.	**Village**	**Location**	**Source**	**Years**	**Crop**	**Farmer’**

			/Depth (m)		grown	Rating
128.	Ghehun Khedi	22° 53’ 26’ N 75° 37’ 41” E	TW 55	9	Soybean, wheat	Good
129.	Talawali	23° 1’ 3” N 75° 33’ 29” E	TW 45	12	Soybean, chickpea	Good
130.	Bachhoda	22° 58’ 25” N 75° 30’ 12” E	TW 100	14	Soybean, chickpea, vegetables	Saline
131.	Atyana	22° 54’ 19” N 75°36’ 54” E	TW 70	7	Soybean, wheat	Good
132.	Kadoda	22° 57’ 5” N 75° 34’ 38” E	TW 50	1	Soybean, chickpea, vegetables	Good
133.	Chiklonda	22° 46’ 15” N 75° 32’ 42” E	W 7	10	Soybean, chickpea	Good
134.	Chiklonda	22° 46’ 15” N 75° 32’ 42” E	W 7	20	Soybean, wheat	Good
135.	Pitawali	22° 57’ 29” N 75° 33’ 24” E	TW 70	2	Soybean, chickpea	Good
136.	Pitawali	22° 57’ 29” N 75° 33’ 24” E	TW 70	1	Soybean, wheat	Good
137.	Nandra	22° 52’ 46” N 75° 37’ 4” E	TW 45	5	Soybean, wheat	Good
138.	Osrod	22° 39’ 12” N 75° 30’ 5” E	TW 30	6	Soybean, chickpea	Good
139.	Rangwasa	22° 44’ 32” N 75° 34’ 16” E	TW 50	10	Soybean, chickpea, vegetables	Good
140.	Ataheda	22° 54’ 53” N 75° 37’ 12” E	TW 30	12	Soybean, wheat	Good
141.	Baroda Panth	22° 47’ 30” N 75° 32’ 21” E	TW 70	8	Soybean, chickpea	Good
142.	Gulawat	22°46’ 45”N 75° 41’ 24”E	TW 25	4	Soybean, wheat	
143.	Harnasa	22° 47’ 5” N 75° 33’ 19” E	TW 40	2	Soybean, wheat	Good
144.	Jalodia Panth	22° 48’ 39” N 75° 34’ 25” E	TW 60	3	Soybean, chickpea, vegetables	Good
145.	Khanjar Kheda	22° 59’ 5” N 75° 37’ 25” E	TW 75	10	Soybean, wheat	Good
146.	Mohna	22° 41’ 29” N 75° 39’ 52” E	TW 100	1	Soybean, chickpea	Saline

S.No.	Village	Location	Source	Years	Crop	Farmer’

			/Depth (m)		grown	Rating
147.	Palsoda	22° 58’ 41” N 75° 36’ 23” E	TW 65	5	Soybean, chickpea	Good
148.	Salampur	22° 38’ 53” N 75° 37’ 10” E	TW 35	3	Soybean, wheat	Good
149.	Kai	22° 56’ 11” N 75° 33’ 31” E	TW 60	5	Soybean, wheat	Good
150.	Kai	22° 56’ 11” N 75° 33’ 31” E	TW 60	2	Soybean, chickpea, vegetables	Good
151.	Kakwa	22° 55’ 41” N 75° 34’ 58” E	TW 45	11	Soybean, wheat	Good
152.	Kakwa	22° 55’ 41” N 75° 34’ 58” E	TW 45	2	Soybean, chickpea, vegetables	Good
153.	Agardi	22° 46’ 19” N 75° 34’ 53” E	TW 75	3	Soybean, chickpea	Good
154.	Bhama Kheda	22° 54’ 41” N 75° 28’ 14” E	TW 65	12	Soybean, chickpea	Good
155.	Chatwada	22° 47’ 26” N 75° 35’ 59” E	TW 50	10	Soybean, wheat	Good
156.	Jalodia Par	22° 53’ 22” N 75° 28’ 11” E	TW 70	2	Soybean, chickpea, vegetables	Good
157.	Kharsoda	23° 0’ 17” N 75° 31’ 29” E	TW 50	15	Soybean, wheat	Good
158.	Nolana	22° 57’ 35” N 75° 29’ 55” E	TW 160	6	Soybean, chickpea	Saline
159.	Tajkhedi	22° 40’ 53” N 75° 31’ 0” E	TW 30	5	Soybean, chickpea, vegetables	Good
160.	Singawda	22°45’ 27”N 75° 41’ 16”E	TW 70	20	Soybean, wheat	Good
161.	Sagdod	22° 45’ 33” N 75° 29’ 50” E	TW 50	10	Soybean, chickpea	Good
162.	Padlya	22° 59’ 41” N 75° 36’ 23” E	TW 55	15	Soybean, chickpea, vegetables	Good
163.	Bagoda	22° 38’ 11” N 75° 43’ 53” E	TW 50	8	Soybean, chickpea	Good
164.	Dhanya	22° 49’ 57” N 75° 26’ 39” E	TW 55	3	Soybean, wheat	Good
165.	Bhil badoli	22° 58’ 12”N 75° 35’ 20”E	TW 70	12	Soybean, chickpea	Good
S.No.	**Village**	**Location**	**Source**	**Years**	**Crop**	**Farmer’**

			/Depth (m)		grown	Rating
166.	Khadolya	22° 55' 51" N 75° 40' 13" E	TW 90	1	Soybean, wheat	Saline
167.	Muradpura	22° 50' 44" N 75° 49' 17" E	TW 50	6	Soybean, chickpea, vegetables	Good
168.	Rolai	22° 43' 29" N 75° 38' 49" E	TW 50	5	Soybean, wheat	Good
169.	Tamalpur	22° 52' 26" N 75° 30' 4" E	TW 50	2	Soybean, chickpea	Good
170.	Sater	22° 55' 4" N 75° 29' 55" E	TW 60	1	Soybean, wheat	Good
171.	Khatediya	22° 55' 24" N 75° 41' 3" E	TW 65	3	Soybean, wheat	Good
172.	Rambadodiya	22° 41' 52" N 75° 32' 32" E	TW 45	5	Soybean, chickpea	Good
173.	Kundhara	22° 55' 8" N 75° 28' 41" E	TW 70	10	Soybean, wheat	Good
174.	Gokalpur	22° 54' 20" N 75° 31' 3|" E	TW 45	15	Soybean, wheat	Good
175.	Badipura	22° 41' 31" N 75°35' 57" E	TW 55	10	Soybean, wheat	Good
176.	Betma Khurd	22° 40' 34" N 75° 39' 1" E	TW 45	5	Soybean, chickpea	Good
177.	Betma Khurd	22° 40' 34" N 75° 39' 1" E	TW 45	1	Soybean, chickpea, vegetables	Good
178.	Karwasa	22° 39' 49" N 75° 35' 56" E	TW 105	5	Soybean, chickpea	Saline
179.	Deora Khedi	22° 55' 45" N 75° 39' 29" E	TW 35	5	Soybean, wheat	Good
180.	Pelmalpur	22° 46' 58" N 75° 27' 18" E	TW 100	2	Soybean, wheat	Saline
181.	Katkoda	22° 56' 21"N 75° 36' 12"E	TW 80	2	Soybean, wheat	Good
182.	Katkoda	22° 56' 21"N 75° 36' 12"E	TW 80	10	Soybean, chickpea	Good
183.	Chirakhan	22° 38' 18" N 75° 41' 48" E	TW 40	3	Soybean, wheat	Good
184.	Begnda	22° 49' 16"N 75° 29' 23"E	TW 35	5	Soybean, chickpea	Good
185.	Gohan	22° 45' 8"N 75° 37' 46"E	TW 45	15	Soybean, wheat	Good

S.No.	Village	Location	Source	Years	Crop	Farmer'

			/Depth (m)		grown	Rating
186.	Gohan	22° 45’ 8”N 75° 37’ 46”E	TW 60	14	Soybean, wheat	Good
187.	Uttarsi	22° 44’ 36” N 75° 29’ 55” E	TW 65	6	Soybean, chickpea, vegetables	Good
188.	Rampuria	22° 44’ 16” N 75° 38’ 44” E	TW 50	3	Soybean, chickpea	Good
189.	Shahawda	22° 46’ 47” N 75° 28’ 22” E	TW 70	8	Soybean, wheat	Good
190.	Kalasura	22° 42’ 23” N 75° 38’ 7” E	TW 40	1	Soybean, chickpea, vegetables	Good
191.	Jalalpura	22° 54’ 42” N 75° 33’ 24” E	TW 55	2	Soybean, wheat	Good
192.	Jalalpura	22° 54’ 42” N 75° 33’ 24” E	TW 55	9	Soybean, chickpea	Good
193.	Khimalawda	22° 54’ 11” N 75° 35’ 30” E	TW 35	7	Soybean, wheat	Good
194.	Kalmer	22° 47’ 40” N 75° 27’ 18” E	TW 70	3	Soybean, chickpea, vegetables	Good
195.	Ektasa	22° 50’ 9” N 75° 27’ 38” E	TW 45	8	Soybean, wheat	Good
196.	Lalendipura	22° 42’ 42” N 75° 39’ 42” E	TW 65	2	Soybean, chickpea, vegetables	Good
197.	Manpura	22° 41’ 17” N 75° 31’ 3” E	TW 55	2	Soybean, chickpea	Good
198.	Banya Khedi	22° 54’ 38” N 75° 39’ 47” E	TW 70	1	Soybean, wheat	Good
199.	Chand Khedi	22° 41’ 49” N 75° 31’ 3” E	TW 65	10	Soybean, chickpea	Good
200.	Boriya	22° 43’ 28” N 75° 41’ 19” E	TW 35	8	Soybean, wheat	Good

CHAPTER - IV

RESULTS

This Chapter deals with the outcome of the findings on topic entitled **“Characterization of Ground Water Quality of Depalpur Tehsil of Indore, Madhya Pradesh”**. The experimental results are presented here under different headings.

4.1 Number of ground water samples

Ground water survey of Depalpur Tehsil was carried out during investigation period (2018) and total 200 samples were collected village wise with GPS locations.

4.2 Depth of wells / tube well

Ground water samples of Depalpur Tehsil were classified according to the depth of wells and tube wells (Table 4.1). The depth of wells/tubewell of Depalpur tehsil was less than 50 m and represented 32.5% of the total tube wells. About 63.5 % of wells/tubewell samples of the Depalpur tehsil were reported >50m (up to 200 m) depth.

Table 4.1: Distribution of ground water samples according to wells/ Tubwells depth of Depalpur tehsil

S. No.	Well / Tube well depth (m)	No. of Samples	% samples
1.	< 50	65	32.5
2.	>50 (up to 200)	135	67.5
3.	Total	200	

4.3 Water quality parameters of Depalpur Tehsil

The chemical analysis of each water sample, range and means of different water quality parameter of Depalpur tehsil are represented in Table 4.2 and 4.3. The pH values ranged from 7.12 to 8.48 with a mean of 7.65. The lowest pH in water samples was observed in village Tejkhedi (pH

7.12) at serial number 110 and highest value was recorded in village Gangajal Khedi (pH 8.48) at serial number 03. The EC values ranged from 0.32 to 3.9 with a mean of 1.28 dS m^{-1}. The lowest salt content (EC 0.32 dS m^{-1}) in water samples was observed in village Murkheda and Deora khedi at serial number 113, 179 respectively. The highest value of EC (3.9 dS m^{-1}) was recorded in village Karki at serial number 86. The SAR ranged from 0.07 to 0.95 $(mmolL^{-1})^{1/2}$ with a mean value of 0.45 $(mmolL^{-1})^{1/2}$. The lowest SAR value of 0.07 $(mmolL^{-1})^{1/2}$ was observed in village Semda at serial number 52 and highest value of 0.95 $(mmolL^{-1})^{1/2}$ in Badoli Hoj at serial number 13.

The calcium concentration in the samples had a wide range (1.4 to 28.2 me L^{-1}) followed by Mg^{2+} (0.78 to 13.8 me L^{-1}), Na^{+} (0.2 to 3.08 meL^{-1}) and K^{+} (0.01 to 0.14 me L^{-1}). Mean value of, Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were, 6.99, 4.49, 1.29 and 0.05 respectively. In case of anion, Cl^{-1} was the dominant ion with maximum value (30.1 me L^{-1}) observed in village Sunala at serial number 41. The highest value of HCO_3^- (8.3 meL^{-1}) recorded in Barda khedi village at serial number 33, while the minimum (0.7 me L^{-1}) observed in village Deora khedi at serial number 179. Mean value of SO_4^- were found to be 1.59 me L^{-1}.

Table 4.2: Chemical Composition of Ground water samples of Depalpur Tehsil

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		dS m^{-1}	me L^{-1}							$(mmol L^{-1})^{1/2}$	
1	8.19	0.65	2.00	3.80	0.80	3.60	2.20	0.85	0.01	0.39	A
2	8.01	0.64	3.20	2.90	0.50	4.00	1.60	0.72	0.10	0.33	A
3	8.48	1.23	4.40	7.20	0.70	8.00	3.80	1.64	0.08	0.52	A
4	7.52	1.43	3.60	9.40	1.30	8.20	4.40	1.60	0.09	0.50	A
5	7.35	2.45	1.10	10.10	0.30	13.90	8.90	1.66	0.02	0.39	B1
6	7.54	1.09	3.00	6.60	1.30	6.90	3.10	0.58	0.01	0.20	A
7	7.65	1.19	2.50	8.70	0.70	9.60	2.60	1.17	0.05	0.35	A
8	7.64	2.32	3.20	18.30	1.80	13.70	7.50	1.90	0.10	0.45	B1
9	7.58	0.70	2.20	4.00	0.80	3.20	2.50	1.30	0.01	0.62	A
10	7.77	0.48	1.10	2.80	0.90	2.20	1.50	1.10	0.07	0.64	A
11	7.62	1.14	3.70	6.70	1.60	6.60	2.80	1.90	0.03	0.67	A
12	7.85	0.51	1.70	3.10	0.30	2.40	1.70	1.00	0.02	0.55	A

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		dS m^{-1}	me L^{-1}							(mmol L^{-1})$^{1/2}$	
13	7.85	0.59	1.90	3.30	0.70	2.20	2.00	1.70	0.02	0.95	A
14	7.79	0.80	2.90	4.70	0.40	4.20	2.20	1.70	0.04	0.74	A
15	7.51	1.19	2.70	7.50	1.70	6.80	2.90	1.20	0.05	0.42	A
16	7.98	1.01	2.00	7.20	0.90	6.00	2.80	1.40	0.03	0.51	A
17	8.27	1.89	6.40	9.60	3.30	11.20	6.40	1.29	0.01	0.34	A
18	7.92	1.45	3.00	9.40	2.10	8.00	4.90	1.60	0.06	0.49	A
19	7.37	1.36	4.30	8.60	0.70	7.30	5.00	1.40	0.07	0.45	A
20	7.60	1.86	4.10	12.60	2.10	10.80	6.20	1.86	0.03	0.50	A
21	7.43	1.73	3.80	12.10	1.40	9.60	5.40	2.40	0.03	0.68	A
22	7.74	1.02	2.30	6.70	1.20	6.10	2.80	1.40	0.02	0.51	A
23	7.64	2.02	5.20	14.60	0.40	12.70	6.50	0.90	0.04	0.23	B1
24	7.20	2.68	4.00	19.40	3.20	15.40	10.0	1.40	0.06	0.31	B1
25	7.52	3.30	5.40	23.40	4.20	16.70	13.8	2.50	0.05	0.51	B1
26	7.65	2.33	5.90	14.60	2.80	15.50	5.70	2.10	0.07	0.49	B1
27	7.59	2.32	5.60	14.50	3.10	15.30	6.00	1.90	0.06	0.44	B1
28	7.57	1.09	2.80	7.10	1.10	5.80	3.30	1.70	0.06	0.62	A
29	7.59	1.21	4.30	6.10	1.80	6.30	3.80	2.00	0.07	0.70	A
30	7.94	0.47	1.30	2.40	0.80	2.10	1.90	0.70	0.06	0.40	A
31	7.70	1.02	2.10	7.10	1.00	6.20	2.70	1.30	0.04	0.47	A
32	7.56	0.98	1.40	6.40	2.10	4.50	3.70	1.60	0.02	0.63	A
33	7.54	2.87	8.30	18.10	2.30	17.40	9.10	2.20	0.03	0.47	B1
34	7.72	1.23	3.40	7.50	1.40	5.30	4.50	2.50	0.02	0.91	A
35	7.80	0.87	3.00	4.50	1.20	3.90	3.30	1.50	0.01	0.64	A
36	8.17	0.91	1.60	5.30	1.00	5.00	2.50	1.60	0.03	0.64	A
37	7.79	0.81	2.20	4.60	1.30	3.50	3.00	1.60	0.08	0.72	A
38	7.85	0.32	1.08	1.17	1.05	1.40	1.20	0.60	0.05	0.42	A
39	7.71	0.80	2.35	3.11	2.54	3.34	3.24	1.42	0.02	0.64	A
40	7.40	1.25	2.30	9.50	0.70	6.40	4.38	1.34	0.02	0.46	A
41	7.21	3.67	3.12	30.10	2.70	20.10	13.6	2.34	0.05	0.45	B1
42	8.03	1.13	2.40	7.30	1.36	5.90	3.90	1.48	0.03	0.53	A
43	7.34	1.43	2.70	10.30	1.30	7.10	5.90	1.30	0.20	0.41	A
44	7.49	1.74	3.20	11.80	2.40	7.90	7.60	1.90	0.03	0.56	A
45	8.17	0.62	1.70	4.00	0.50	3.40	1.90	0.90	0.02	0.43	A
46	7.67	0.82	2.30	4.80	1.10	4.20	2.87	1.16	0.02	0.49	A
47	7.73	1.05	3.10	5.80	1.70	5.40	3.70	1.40	0.02	0.52	A
48	7.38	1.05	2.80	5.90	1.80	5.70	3.90	0.90	0.04	0.33	A
49	7.28	0.78	3.10	3.80	0.90	3.70	3.40	0.70	0.01	0.30	A
50	7.48	1.16	2.90	7.30	1.45	6.20	4.80	0.60	0.03	0.20	A
51	7.48	1.27	2.70	7.95	1.90	6.12	5.40	1.23	0.03	0.41	A
52	8.02	1.21	2.40	8.40	1.25	6.30	5.70	0.21	0.02	0.07	A
53	7.88	1.15	3.12	7.60	0.80	7.40	3.30	0.80	0.02	0.27	A
54	8.18	0.72	1.30	5.13	0.77	4.10	2.90	0.20	0.08	0.08	A
55	7.64	1.06	3.80	5.20	1.75	5.30	4.70	0.60	0.06	0.22	A
56	7.59	0.68	1.40	5.30	0.20	3.60	2.90	0.28	0.07	0.12	A
57	7.33	0.66	1.60	4.20	0.80	4.20	2.21	0.31	0.05	0.13	A

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		dS m^{-1}	me L^{-1}							(mmol L^{-1})$^{1/2}$	
58	7.72	0.69	1.31	4.85	0.70	3.40	2.30	1.12	0.01	0.53	A
59	7.52	1.06	2.40	7.10	1.30	5.53	3.40	0.63	0.07	0.23	A
60	7.93	1.07	3.10	6.40	1.20	5.04	4.35	1.33	0.06	0.50	A
61	7.58	0.49	1.04	3.57	0.37	2.84	1.80	0.39	0.03	0.20	A
62	7.55	0.62	1.15	4.60	0.45	3.60	2.30	0.38	0.06	0.17	A
63	7.34	0.59	1.23	3.70	1.10	3.12	2.10	0.67	0.01	0.33	A
64	7.80	0.84	2.20	5.40	0.90	4.37	2.75	1.33	0.02	0.55	A
65	7.61	0.74	1.80	4.45	1.12	3.41	2.86	1.10	0.03	0.50	A
66	7.33	1.47	3.05	9.95	1.75	7.93	5.49	0.82	0.09	0.25	A
67	7.57	1.55	3.40	10.4	1.80	9.71	3.97	2.02	0.09	0.59	A
68	7.47	0.92	1.20	7.10	0.95	5.40	3.19	0.63	0.03	0.24	A
69	7.64	1.98	4.40	13.0	2.41	8.83	7.80	3.08	0.09	0.86	A
70	7.51	1.24	2.54	7.80	1.90	7.09	4.01	1.14	0.04	0.38	A
71	7.63	0.60	1.70	3.70	0.60	3.91	1.72	0.46	0.02	0.21	A
72	7.97	0.54	1.14	3.42	0.85	2.40	2.64	0.36	0.02	0.19	A
73	7.53	0.73	1.67	4.74	0.93	4.70	1.54	1.11	0.02	0.47	A
74	7.94	0.79	1.54	5.34	1.09	4.01	3.01	0.93	0.05	0.40	A
75	7.99	0.72	1.37	5.40	0.91	3.76	2.30	1.20	0.02	0.54	A
76	7.65	0.85	2.31	5.20	1.03	4.40	3.10	0.98	0.03	0.40	A
77	7.63	0.93	1.59	6.47	1.23	4.24	4.16	0.99	0.07	0.39	A
78	7.15	0.68	2.07	4.17	0.64	4.39	1.82	0.60	0.02	0.26	A
79	7.34	0.71	1.50	4.98	0.78	4.36	2.30	0.51	0.03	0.22	A
80	7.45	1.39	2.60	8.90	1.80	7.30	5.10	0.97	0.05	0.31	A
81	7.50	0.93	1.64	6.98	0.89	4.46	2.93	1.85	0.01	0.76	A
82	7.78	1.55	4.00	9.40	2.13	7.40	5.30	2.61	0.05	0.82	A
83	7.41	1.75	3.62	11.4	2.46	9.15	7.21	1.22	0.06	0.34	A
84	7.14	1.55	3.40	9.38	2.80	10.6	3.10	1.87	0.12	0.54	A
85	7.43	1.36	2.90	8.50	2.30	6.93	4.86	1.76	0.07	0.58	A
86	7.57	3.90	7.40	24.0	8.40	28.2	9.30	2.44	0.09	0.43	B1
87	7.17	0.94	2.40	5.30	1.80	5.30	3.40	0.72	0.09	0.27	A
88	7.62	1.41	3.60	9.30	1.70	7.70	5.60	1.44	0.10	0.44	A
89	8.12	1.67	3.80	11.2	1.85	9.70	5.40	1.37	0.04	0.39	A
90	7.49	1.02	2.07	6.20	1.86	4.70	3.85	1.53	0.01	0.59	A
91	7.79	1.04	2.15	6.30	1.92	5.40	3.90	1.12	0.04	0.41	A
92	7.30	1.06	2.13	6.70	1.82	5.60	3.50	1.56	0.01	0.58	A
93	7.87	1.24	2.60	7.60	1.07	6.57	2.80	1.92	0.01	0.68	A
94	7.15	1.20	2.30	8.98	0.97	6.30	4.10	1.87	0.01	0.65	A
95	7.51	1.09	1.63	7.24	1.17	6.10	2.40	1.58	0.03	0.58	A
96	7.89	1.01	1.87	7.15	1.05	5.76	3.10	1.19	0.03	0.44	A
97	7.93	0.97	2.46	6.15	1.32	5.90	2.70	1.28	0.02	0.48	A
98	7.86	1.11	2.06	7.98	1.03	5.03	4.30	1.75	0.04	0.65	A

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		$dS\ m^{-1}$	me L^{-1}							$(mmol\ L^{-1})^{1/2}$	
99	8.02	1.04	1.72	7.36	0.98	4.78	3.67	1.68	0.03	0.65	A
100	7.18	1.47	3.40	9.80	1.50	7.80	4.70	2.10	0.04	0.66	A
101	7.46	1.07	3.64	5.08	1.32	5.17	3.10	1.86	0.03	0.72	A
102	7.57	1.91	4.30	12.4	2.40	9.50	6.80	2.78	0.05	0.77	A
103	7.65	2.71	5.20	20.4	2.10	16.3	8.80	2.03	0.08	0.45	B1
104	7.35	2.18	4.70	15.3	1.20	11.4	7.40	3.00	0.10	0.77	B1
105	7.58	1.56	3.90	9.20	2.40	8.20	5.60	1.85	0.01	0.56	A
106	7.61	0.97	2.75	5.78	1.19	4.91	3.80	1.02	0.03	0.39	A
107	7.65	0.76	1.98	4.89	0.82	3.94	2.80	0.94	0.02	0.41	A
108	7.98	0.70	2.17	3.87	0.93	3.20	2.31	1.53	0.01	0.73	A
109	7.40	0.85	2.50	4.70	1.40	4.10	3.69	0.79	0.02	0.32	A
110	7.12	1.62	4.01	9.40	2.70	8.70	6.40	1.52	0.08	0.44	A
111	7.68	1.35	3.70	7.30	2.30	6.10	5.10	2.15	0.06	0.73	A
112	7.35	1.08	2.90	6.50	1.40	5.40	4.30	1.11	0.07	0.40	A
113	7.62	0.32	0.90	2.01	0.40	1.60	1.20	0.40	0.05	0.27	A
114	7.84	0.32	0.84	2.09	0.52	1.78	0.78	0.67	0.03	0.45	A
115	7.67	2.07	2.90	15.7	1.69	11.8	6.80	1.44	0.01	0.37	B1
116	7.63	1.41	3.10	9.70	1.32	6.90	6.70	0.62	0.01	0.19	A
117	7.69	1.65	3.30	10.7	2.40	8.79	6.30	1.43	0.04	0.41	A
118	7.92	1.62	3.56	9.70	2.98	8.60	6.70	0.92	0.09	0.27	A
119	7.61	2.11	4.60	13.1	3.30	11.8	8.20	1.09	0.09	0.27	B1
120	7.56	1.15	2.80	6.30	1.91	6.03	4.10	1.04	0.12	0.37	A
121	7.58	1.90	3.48	13.9	2.06	11.0	7.01	0.94	0.07	0.25	A
122	7.63	1.82	3.12	12.8	2.18	10.7	6.58	0.89	0.04	0.24	A
123	7.25	1.74	2.96	12.3	2.14	8.40	7.20	1.88	0.03	0.54	A
124	7.48	1.52	4.21	9.40	1.64	7.94	6.52	0.71	0.06	0.21	A
125	7.61	1.68	3.78	10.7	2.38	7.89	7.30	1.24	0.01	0.37	A
126	7.72	1.79	4.57	10.4	2.70	8.80	7.96	1.14	0.05	0.32	A
127	7.69	1.51	3.40	9.30	2.37	8.74	5.01	1.30	0.09	0.39	A
128	7.79	2.23	4.31	15.1	2.95	12.3	8.36	1.58	0.04	0.39	B
129	8.09	1.46	2.70	10.1	1.83	7.61	5.94	1.11	0.02	0.34	A
130	7.65	0.98	2.30	6.30	1.23	4.70	3.90	1.25	0.14	0.48	A
131	7.24	1.61	3.70	10.00	2.40	8.89	6.34	0.89	0.08	0.26	A
132	8.15	2.34	4.87	15.60	2.94	12.3	9.40	1.68	0.10	0.41	B1
133	7.94	1.04	1.40	8.10	0.90	6.20	3.28	0.94	0.04	0.34	A
134	7.15	1.36	2.94	9.30	1.30	7.40	5.10	1.02	0.07	0.32	A
135	7.66	1.81	3.70	12.10	2.36	8.90	7.78	1.35	0.09	0.38	A
136	7.71	1.34	2.49	9.70	1.23	7.50	5.10	0.86	0.01	0.27	A
137	7.63	1.32	2.70	8.70	1.80	7.30	4.80	1.13	0.01	0.36	A
138	7.84	1.78	3.64	11.97	2.17	8.78	7.90	1.15	0.12	0.32	A
139	7.65	1.37	2.70	9.30	1.70	8.40	4.40	0.94	0.02	0.29	A

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		$dS\ m^{-1}$	me L^{-1}							$(mmol\ L^{-1})^{1/2}$	
140	8.10	1.30	2.60	9.10	1.34	7.10	4.90	0.99	0.07	0.32	A
141	7.68	1.75	3.40	12.10	2.10	9.70	6.90	0.98	0.01	0.27	A
142	7.52	1.43	3.20	9.30	1.75	7.90	5.12	1.36	0.09	0.42	A
143	7.65	1.19	2.70	7.96	1.14	6.50	4.38	1.01	0.01	0.34	A
144	7.85	0.51	1.18	3.07	0.97	2.24	1.25	1.57	0.06	0.93	A
145	7.98	1.01	1.94	7.20	0.89	5.70	3.01	1.32	0.05	0.49	A
146	7.60	1.86	2.30	15.20	1.12	9.70	8.10	0.86	0.02	0.23	A
147	7.64	1.73	2.70	12.40	2.13	9.17	7.14	1.06	0.02	0.30	A
148	7.20	0.64	1.56	4.12	0.74	3.23	2.19	1.04	0.03	0.50	A
149	7.48	1.16	3.40	6.93	1.34	6.45	4.13	1.09	0.11	0.37	A
150	8.02	1.12	2.40	6.94	1.84	6.10	4.21	0.93	0.06	0.32	A
151	7.64	1.06	2.80	6.10	1.70	5.87	3.62	1.17	0.03	0.42	A
152	7.33	0.66	1.63	4.18	0.87	3.34	2.24	1.07	0.02	0.51	A
153	7.72	0.69	1.54	4.42	0.91	4.30	1.70	0.92	0.09	0.41	A
154	7.55	0.62	1.34	3.82	1.03	3.63	1.34	1.25	0.08	0.60	A
155	7.34	0.59	1.24	3.70	0.94	2.74	1.97	1.25	0.04	0.65	A
156	7.47	0.92	1.34	6.78	1.04	6.13	2.28	0.78	0.04	0.29	A
157	7.51	1.24	2.03	9.01	1.40	6.47	4.70	1.02	0.02	0.34	A
158	7.57	1.09	1.50	8.42	0.94	5.90	4.10	0.86	0.06	0.31	A
159	7.94	1.23	1.67	9.60	1.08	6.30	4.80	1.25	0.09	0.42	A
160	7.54	2.87	4.37	21.60	2.89	16.3	10.9	1.69	0.14	0.36	B1
161	7.80	0.87	2.20	5.47	1.03	4.53	3.24	0.94	0.01	0.38	A
162	7.79	0.81	1.80	5.36	0.94	4.60	2.40	1.17	0.03	0.49	A
163	7.71	0.80	1.70	5.46	0.89	4.18	2.20	1.62	0.02	0.71	A
164	8.03	1.13	3.10	7.12	1.02	5.65	4.43	1.28	0.04	0.46	A
165	7.67	0.82	1.36	5.80	0.99	4.21	3.01	0.92	0.07	0.38	A
166	7.38	1.05	2.04	6.95	1.07	5.30	2.98	1.80	0.06	0.69	A
167	7.63	0.85	2.01	5.37	1.14	4.03	3.25	1.24	0.03	0.52	A
168	7.61	0.97	2.45	5.85	1.39	4.78	3.61	1.27	0.02	0.49	A
169	7.98	0.70	2.08	4.12	0.80	3.60	2.00	1.46	0.05	0.68	A
170	7.68	1.35	3.05	7.80	2.70	8.10	4.23	1.24	0.12	0.39	A
171	7.48	1.52	3.40	9.34	2.45	8.60	5.53	1.06	0.01	0.31	A
172	7.84	1.78	3.80	11.45	2.59	9.80	6.40	1.66	0.06	0.46	A
173	7.72	1.34	3.10	7.78	2.44	7.12	5.30	0.93	0.02	0.30	A
174	8.17	1.93	4.25	11.97	3.07	9.80	8.19	1.27	0.05	0.34	A
175	8.09	1.45	3.70	8.30	2.45	7.48	5.21	1.78	0.03	0.56	A
176	7.65	0.96	2.30	6.13	1.19	5.10	3.54	0.94	0.04	0.36	A
177	7.63	1.31	3.00	7.69	2.34	7.90	4.12	1.13	0.06	0.36	A
178	7.49	1.73	3.64	11.38	2.31	9.48	6.20	1.59	0.06	0.45	A
179	7.84	0.32	0.70	2.21	0.37	1.40	1.22	0.60	0.10	0.42	A
180	7.21	2.11	4.13	13.67	3.32	10.7	9.06	1.36	0.01	0.35	B1

S. No.	pH	EC	HCO_3^-	Cl^-	SO_4^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR	Category
		dS m^{-1}	me L^{-1}							(mmol L^{-1} $)^{1/2}$	
181	7.68	1.46	3.40	8.90	2.12	9.16	4.20	1.24	0.08	0.37	A
182	7.72	1.78	3.59	11.76	2.45	9.84	6.37	1.64	0.04	0.45	A
183	7.66	1.81	1.95	15.10	1.08	9.54	7.56	0.96	0.03	0.26	A
184	7.68	1.90	3.37	13.54	2.07	11.07	6.98	0.99	0.02	0.26	A
185	7.98	0.70	2.05	4.03	0.94	3.40	1.97	1.63	0.01	0.78	A
186	7.40	0.85	2.40	5.00	1.10	4.53	2.44	1.48	0.06	0.62	A
187	7.35	1.08	2.63	6.42	0.98	5.41	3.47	1.19	0.06	0.45	A
188	7.61	0.93	3.10	5.30	0.87	5.37	2.56	1.37	0.02	0.53	A
189	7.69	0.91	3.03	5.07	1.03	4.87	2.98	1.24	0.06	0.49	A
190	7.92	0.89	2.16	5.42	1.27	4.28	3.36	1.26	0.06	0.52	A
191	7.56	1.91	3.39	13.64	2.04	11.06	7.02	1.03	0.05	0.27	A
192	7.58	1.46	3.56	8.84	2.14	9.20	4.12	1.26	0.02	0.38	A
193	7.25	0.60	1.12	4.24	0.73	3.03	2.00	0.97	0.01	0.48	A
194	7.46	1.73	3.51	11.35	2.39	9.63	6.24	1.45	0.08	0.41	A
195	7.98	1.01	1.97	6.98	1.06	5.19	3.09	1.72	0.03	0.66	A
196	7.50	1.13	2.91	7.13	1.09	6.41	3.50	1.24	0.02	0.43	A
197	7.62	1.41	3.44	8.48	2.18	8.92	4.01	1.17	0.02	0.35	A
198	7.77	0.48	1.70	2.31	0.85	2.15	1.78	0.87	0.04	0.50	A
199	7.92	1.45	3.30	8.70	2.48	7.21	5.48	1.76	0.08	0.56	A
200	7.60	1.86	3.10	12.36	2.7	8.35	7.67	1.78	0.02	0.51	A

Table 4.3: Maximum, minimum, mean and SD value of ground water samples of Depalpur tehsil

S.No.	pH	EC	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR
		dSm^{-1}	me L-1							(mmol$L^{-1}$$)^{1/2}$
Maximum	8.48	3.90	8.30	30.10	8.40	28.20	13.80	3.08	0.86	0.95
Minimum	7.12	0.32	0.70	1.17	0.20	1.40	0.78	0.20	0.01	0.07
Mean	7.65	1.28	2.80	8.33	1.59	6.99	4.49	1.29	0.05	0.45
SD	0.25	0.59	1.17	4.29	0.89	3.61	2.27	0.51	0.06	0.16

4.4 Frequency distribution of ground water samples in to different category

The frequency distribution of ground water sample in to different categories in Depalpur tehsil of Indore district is presented in Table 4.4. Out of

200 ground water sample collected from the tehsil, 182 samples were reported in good water category designated A. while 18 samples belonged to the category of B1 indicating true representation of saline water in Depalpur tehsil.

Table 4.4: Frequency distribution of water samples into different categories of water quality in Depalpur tehsil

S.N.	Categories	No. of Samples	% samples
1.	A (Good)	182	91
2.	B1 (Marginally Saline)	18	9
3.	B2 (Saline)	0	0
4.	B3 (High SAR Saline)	0	0
5.	C1 (Marginally Alkali)	0	0
6.	C2 (Alkali)	0	0
7.	C3 (Highly Alkali)	0	0
TOTAL		200	

4.5 Ground water classification of Depalpur tehsil as per Richards (1954)

As per the classification of Richards (1954) about 76.0% water samples of Depalpur tehsil (Table 4.5 and 4.6) fell in class of C3S1 followed by C2S1 (37 samples as 18.5%) and C4S1 (11 samples as 5.5%).

Table 4.5: Classification of ground water samples of Depalpur Tehsil according to Richards (1954)

S.No.	EC dS m^{-1}	SAR (mmol $L^{-1})^{1/2}$	Class	S.No.	EC dS m^{-1}	SAR (mmol $L^{-1})^{1/2}$	Class
1	0.65	0.39	C2S1	14	0.80	0.74	C3S1
2	0.64	0.33	C2S1	15	1.19	0.42	C3S1
3	1.23	0.52	C3S1	16	1.01	0.51	C3S1
4	1.43	0.50	C3S1	17	1.89	0.34	C3S1
5	2.45	0.39	C4S1	18	1.45	0.49	C3S1
6	1.09	0.20	C3S1	19	1.36	0.45	C3S1
7	1.19	0.35	C3S1	20	1.86	0.50	C3S1
8	2.32	0.45	C3S1	21	1.73	0.68	C3S1
9	0.70	0.62	C2S1	22	1.02	0.51	C3S1
10	0.48	0.64	C2S1	23	2.02	0.23	C3S1
11	1.14	0.67	C3S1	24	2.68	0.31	C4S1
12	0.51	0.55	C2S1	25	3.30	0.51	C4S1
13	0.59	0.95	C2S1	26	2.33	0.49	C4S1

S.No.	EC dS m^{-1}	SAR $(mmol\ L^{-1})^{1/2}$	Class	S.No.	EC dS m^{-1}	SAR $(mmol\ L^{-1})^{1/2}$	Class
27	2.32	0.44	C4S1	72	0.54	0.19	C2S1
28	1.09	0.62	C3S1	73	0.73	0.47	C2S1
29	1.21	0.70	C3S1	74	0.79	0.40	C3S1
30	0.47	0.40	C2S1	75	0.72	0.54	C2S1
31	1.02	0.47	C3S1	76	0.85	0.40	C3S1
32	0.98	0.63	C3S1	77	0.93	0.39	C3S1
33	2.87	0.47	C4S1	78	0.68	0.26	C2S1
34	1.23	0.91	C3S1	79	0.71	0.22	C2S1
35	0.87	0.64	C3S1	80	1.39	0.31	C3S1
36	0.91	0.64	C3S1	81	0.93	0.76	C3S1
37	0.81	0.72	C3S1	82	1.55	0.82	C3S1
38	0.32	0.42	C2S1	83	1.75	0.34	C3S1
39	0.80	0.64	C3S1	84	1.55	0.54	C3S1
40	1.25	0.46	C3S1	85	1.36	0.58	C3S1
41	3.67	0.45	C4S1	86	3.90	0.43	C4S1
42	1.13	0.53	C3S1	87	0.94	0.27	C3S1
43	1.43	0.41	C3S1	88	1.41	0.44	C3S1
44	1.74	0.56	C3S1	89	1.67	0.39	C3S1
45	0.62	0.43	C2S1	90	1.02	0.59	C3S1
46	0.82	0.49	C3S1	91	1.04	0.41	C3S1
47	1.05	0.52	C3S1	92	1.06	0.58	C3S1
48	1.05	0.33	C3S1	93	1.24	0.68	C3S1
49	0.78	0.30	C3S1	94	1.20	0.65	C3S1
50	1.16	0.20	C3S1	95	1.09	0.58	C3S1
51	1.27	0.41	C3S1	96	1.01	0.44	C3S1
52	1.21	0.07	C3S1	97	0.97	0.48	C3S1
53	1.15	0.27	C3S1	98	1.11	0.65	C3S1
54	0.72	0.08	C2S1	99	1.04	0.65	C3S1
55	1.06	0.22	C3S1	100	1.47	0.66	C3S1
56	0.68	0.12	C2S1	101	1.07	0.72	C3S1
57	0.66	0.13	C2S1	102	1.91	0.77	C3S1
58	0.69	0.53	C2S1	103	2.71	0.45	C4S1
59	1.06	0.23	C3S1	104	2.18	0.77	C3S1
60	1.07	0.50	C3S1	105	1.56	0.56	C3S1
61	0.49	0.20	C2S1	106	0.97	0.39	C3S1
62	0.62	0.17	C2S1	107	0.76	0.41	C3S1
63	0.59	0.33	C2S1	108	0.70	0.73	C2S1
64	0.84	0.55	C3S1	109	0.85	0.32	C3S1
65	0.74	0.50	C2S1	110	1.62	0.44	C3S1
66	1.47	0.25	C3S1	111	1.35	0.73	C3S1
67	1.55	0.59	C3S1	112	1.08	0.40	C3S1
68	0.92	0.24	C3S1	113	0.32	0.27	C2S1
69	1.98	0.86	C3S1	114	0.32	0.45	C2S1
70	1.24	0.38	C3S1	115	2.07	0.37	C3S1
71	0.60	0.21	C2S1	116	1.41	0.19	C3S1

S.No.	EC dS m^{-1}	SAR $(mmol\ L^{-1})^{1/2}$	Class	S.No.	EC dS m^{-1}	SAR $(mmol\ L^{-1})^{1/2}$	Class
117	1.65	0.41	C3S1	162	0.81	0.49	C3S1
118	1.62	0.27	C3S1	163	0.80	0.71	C3S1
119	2.11	0.27	C3S1	164	1.13	0.46	C3S1
120	1.15	0.37	C3S1	165	0.82	0.38	C3S1
121	1.90	0.25	C3S1	166	1.05	0.69	C3S1
122	1.82	0.24	C3S1	167	0.85	0.52	C3S1
123	1.74	0.54	C3S1	168	0.97	0.49	C3S1
124	1.52	0.21	C3S1	169	0.70	0.68	C2S1
125	1.68	0.37	C3S1	170	1.35	0.39	C3S1
126	1.79	0.32	C3S1	171	1.52	0.31	C3S1
127	1.51	0.39	C3S1	172	1.78	0.46	C3S1
128	2.23	0.39	C3S1	173	1.34	0.30	C3S1
129	1.46	0.34	C3S1	174	1.93	0.34	C4S1
130	0.98	0.48	C3S1	175	1.45	0.56	C3S1
131	1.61	0.26	C3S1	176	0.96	0.36	C3S1
132	2.34	0.41	C4S1	177	1.31	0.36	C3S1
133	1.04	0.34	C3S1	178	1.73	0.45	C3S1
134	1.36	0.32	C3S1	179	0.32	0.42	C2S1
135	1.81	0.38	C3S1	180	2.11	0.35	C3S1
136	1.34	0.27	C3S1	181	1.46	0.37	C3S1
137	1.32	0.36	C3S1	182	1.78	0.45	C3S1
138	1.78	0.32	C3S1	183	1.81	0.26	C3S1
139	1.37	0.29	C3S1	184	1.90	0.26	C3S1
140	1.30	0.32	C3S1	185	0.70	0.78	C2S1
141	1.75	0.27	C3S1	186	0.85	0.62	C3S1
142	1.43	0.42	C3S1	187	1.08	0.45	C3S1
143	1.19	0.34	C3S1	188	0.93	0.53	C3S1
144	0.51	0.93	C2S1	189	0.91	0.49	C3S1
145	1.01	0.49	C3S1	190	0.89	0.52	C3S1
146	1.86	0.23	C3S1	191	1.91	0.27	C3S1
147	1.73	0.30	C3S1	192	1.46	0.38	C3S1
148	0.64	0.50	C2S1	193	0.60	0.48	C2S1
149	1.16	0.37	C3S1	194	1.73	0.41	C3S1
150	1.12	0.32	C3S1	195	1.01	0.66	C3S1
151	1.06	0.42	C3S1	196	1.13	0.43	C3S1
152	0.66	0.51	C2S1	197	1.41	0.35	C3S1
153	0.69	0.41	C2S1	198	0.48	0.50	C2S1
154	0.62	0.60	C2S1	199	1.45	0.56	C3S1
155	0.59	0.65	C2S1	200	1.86	0.51	C3S1
156	0.92	0.29	C3S1				
157	1.24	0.34	C3S1				
158	1.09	0.31	C3S1				
159	1.23	0.42	C3S1				
160	2.87	0.36	C4S1				
161	0.87	0.38	C3S1				

Table 4.6: Distribution of ground water samples according to EC (dSm^{-1}) and SAR ($(mmolL^{-1})^{1/2}$) of Depalpur tehsil

Class	S1 (SAR <10)	S2 (SAR 10-18)	S3 (SAR 18-26)	S4 (SAR >26)	% samples
C1 (<0.25)	0	0	0	0	0
C2(0.25-0.75)	37	0	0	0	18.5
C3(0.75-2.25)	152	0	0	0	76
C4(>2.25)	11	0	0	0	5.5
Total	200	0	0	0	

4.6 Classes of pH

The data presented in the Table 4.7 shows that 25.5% of water sample of Depalpur tehsil belongs to the < 7.5 pH class. Further, the 74.5 % sample of Depalpur tehsil found to be in the pH class 7.6-8.5. The pH of water of Depalpur tehsil ranged from 7.12 to 8.48 with a mean value of 7.65, standard deviation 0.25 (Table 4.3.2). Out of 200 water samples 51 water samples were neutral in pH and 149 samples were slightly alkaline in nature.

Table 4.7 Distribution of ground water samples according to pH of water

S. No.	Water pH class	No. of Samples	% Samples
1.	Neutral (6.6-7.5)	51	25.5
2.	Slightly alkaline (7.6-8.5)	149	74.5

General statistics

Range	7.12 - 8.48
Mean	7.65
SD	0.25

4.7 Classes of ground water based on electrical conductivity (dS m^{-1})

The data with reference to electrical conductivity (EC) of ground water of Depalpur tehsil is given in Table 4.8**.** This parameter of water quality is categorized into four classes (< 0.25, 0.25-0.75, 0.75-2.25 and >2.25 dSm^{-1}). The 18.5% of Depalpur tehsil ground water sample belongs to the EC 0.25-0.75 class. About 75.5% water samples of Depalpur tehsil fell in the EC range of 0.75-2.25 dS m^{-1}. Around 6.0% water samples fell in the rage of > 2.25 dSm^{-1} class of EC. Electrical Conductivity of water ranged from 0.32 to 3.9 dS m^{-1} with a mean value of 1.28 dS m^{-1}, standard deviation 0.59 (Table 3).

Table 4.8: Distribution of ground water samples according to Electrical Conductivity (EC)

S. No.	EC (dS m^{-1})	No. of Samples	% Samples
1.	< 0.25	Nil	Nil
2.	0.25-0.75	37	18.5
3.	0.75-2.25	152	76
4.	>2.25	11	5.5

General statistics

Range	0.32 to 3.9 dS m^{-1}
Mean	1.28 dS m^{-1}
SD	0.59

4.8 Classes of Sodium Adsorption Ratio (SAR)

The data depicted in the Table 4.9 shows four classes of Sodium Adsorption Ratio (SAR) for ground water quality classification of Depalpur tehsil. All the sample of Depalpur tehsil fell in the class of SAR <10. As the Depalpur tehsil is concerned about 100.0% samples belongs to the SAR class of <10.

The SAR ranged from 0.07 to 0.95 (mmol $L^{-1})^{1/2}$ with a mean value of 0.45 $(mmolL^{-1})^{1/2}$. The lowest SAR value 0.07 $(mmolL^{-1})^{1/2}$ was observed in village Semda and highest value of 0.95 $(mmolL^{-1})^{1/2}$ in Badoli Hoj.

Table 4.9: Distribution of ground water samples according to SAR

S.No.	Sodium Adsorption Ratio (mmol $L^{-1})^{1/2}$	No. of samples	% Samples
1.	<10	200	100
2.	10-18	0	Nil
3.	18-26	0	Nil
4.	>26	0	Nil
TOTAL		200	100

General statistics

Range	0.07 to 0.95 (mmol $L^{-1})^{1/2}$
Mean	0.45 (mmol $L^{-1})^{1/2}$
SD	0.16

4.9 Classes of Residual Sodium Carbonate (RSC)

The data with respect to residual sodium carbonate (RSC) of ground quality of Depalpur tehsil presented in table 4.10. The RSC of water quality was classified into three different classes (<1.25, 1.25-2.5, >2.50 me L^{-1}). As far as the Depalpur tehsil is concerned 100% sample belongs to the RSC class <1.25 me L^{1}.

Table 4.10: Distribution of ground water samples according to RSC

S.N.	Class	RSC (me L^{-1})	No. of Samples	% Samples
1.	Safe	<1.25	200	100
2.	Marginal suitable	1.25-2.5	0	0
3.	Not suitable	>2.5	0	0
TOTAL			200	0

4.10 Classes of ground water based on Sodium Concentration

The date presented in Table 4.11 with respect to sodium concentration in water samples were grouped in to four classes (0-5, 5-10, 10-15 and >15 me L^{-1}). It is obvious from the data that 100.0% of water samples of Depalpur tehsil fell in the class 0-5 me L^{-1} of Sodium.

The sodium concentration varied from 0.2 to 3.08 meL^{-1} with Mean value of 1.29 meL^{-1}. The maximum value of the sodium was found in the village Khajraya and minimum value of sodium was found in village Hasnabad.

Table 4.11: Distribution of ground water samples according to Sodium concentration

S. N.	Sodium (me L^{-1})	No. of Samples	% Samples
1.	0-5	200	100
2.	5-10	0	0
3.	10-15	0	0
4.	> 15	0	0
Total		200	0

General statistics

Range	0.2 to 3.08 me L^{-1}
Mean	1.29 meL^{-1}
SD	0.51

4.11 Classes of chloride (Cl^-) Concentration

The date pertaining to Chloride (Cl^-) concentration (me L^{-1}) in ground water samples are presented in Table 4.12. The samples were classified in to four different classes (0-4, 4-8, 8-16, >16). It is quite clear from the table that 21 (10.5%) of water sample belongs to the chloride class 0-4 me L^{-1}. Whereas 46.5% water samples of the Depalpur tehsil fell in the chloride (Cl^-) class 4-8 me L^{-1}. In class 8-16 me L^{-1} 78 (39.0%) water samples of Depalpur tehsil belongs to it. Only 8 (4%) water samples of total water sample belongs to the chloride class >16 me L^{-1}.

Table 4.12: Distribution of ground water samples according to Chloride concentration

S. N.	Chloride (me L^{-1})	No. of Samples	% Samples
1.	0-4	21	10.5
2.	4-8	93	46.5
3.	8-16	78	39.0
4.	> 16	8	4.0
Total		200	100

General statistics

Range	1.17 to 30.10 me L^{-1}
Mean	8.33 me L^{-1}
SD	4.29

4.13 Correlation Coefficient among different parameters of water quality

The data pertaining to Correlation Coefficient (r) among different parameters of ground water quality are given in the Table 4.14. Under different quality parameters of water Chloride (Cl^-) content of water shows positive Correlation with EC and HCO_3^- whereas negative Correlation with pH. The cation Ca^{2+}, Mg^{2+}, Na^+, K^+ shows positive and significant correlation with EC, HCO_3^-, Cl^- and SO_4^- content and negative correlation with pH. The Na^+ and K^+ also show positive & significant correlation with Ca^{2+} and Mg^{2+} also. SAR show positive & significant correlation with pH, HCO_3^- and Na^+. Whereas negative correlation with EC, Cl^-, SO_4^{2-}, Mg^{2+}, K^+.

Table 4.13: Descriptive Statistics

	Mean	Std. Deviation	N
pH	7.6507	0.25027	200
EC	1.2688	0.59158	200
HCO_3^-	2.7873	1.17761	200
Cl^-	8.2588	4.29823	200
SO_4^{2-}	1.5608	0.89415	200
Ca^{2+}	6.9140	3.61659	200
Mg^{2+}	4.4665	2.27479	200
Na^+	1.2866	0.51057	200
K^+	0.0456	0.02997	200
SAR	0.4452	0.16508	200

Table 4.14: Correlation Coefficient (r) among different parameters of water quality

	pH	EC	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR
pH	1									
EC	-.173**	1								
HCO_3^-	-.059	.786**	1							
Cl^-	-.179**	.971**	.687**	1						
SO_4^{2-}	-.109	.764**	.714**	.675**	1					
Ca^{2+}	-.164*	.973**	.783**	.940**	.758**	1				
Mg^{2+}	-.160*	.938**	.697**	.923**	.698**	.848**	1			
Na^+	-.058	.521**	.509**	.474**	.413**	.459**	.397**	1		
K^+	-.032	.239**	.246**	.225**	.252**	.252**	.205**	.118*	1	
SAR	.081	-.097	.008	-.127*	-.046	-.156*	-.183**	.768**	-.060	1
**. Test of significance of correlation at 198 DF for 1 % (r= 0.208).										
*.Test of significance of correlation at 198 DF for 5% (r=0.134).										

CHAPTER- V

DISCUSSION

An investigation entitled **"Characterization of Ground Water Quality of Depalpur Tehsil of Indore, Madhya Pradesh"** was carried out during the year 2018-19. The data regarding the chemical parameters obtained from the results are interpreted in this chapter with suitable diagram, reference and scientific reasoning.

5.1 Ground water samples and its quality parameters

The present study on ground water was carried out in Depalpur tehsil of Madhya Pradesh and around 200 ground water samples from different wells/tube wells were collected during the year 2018-19.

Ground water samples had been categorized according to depth of source into two classes; less than 50 and more than 50 m (Table 4.1). About 32.5% samples were found in < 50 m depth and only 67.5 % samples under the >50 m depth.

5.1.1 pH values of irrigation water

pH is an important parameter to determine the quality of the ground water and it is used to assess the acidity or basicity of the ground water. The pH values of the ground water collected from the different location of the Depalpur tehsil were neutral to alkaline. It ranged from 7.12 to 8.48 with the mean value of 7.65 (Table 4.3 & Fig. 4.1). Out of 200 samples 75.5 % were found in the range 7.6 to 8.5, whereas 25.5% samples had pH <8.5. It is evident from the data of ground water samples of various locations which contained the higher amount of chloride and SAR recorded the higher pH. Correlation coefficient data between these parameters viz. SAR confirmed these findings. Divekar *et al.* (2005) also observed that the higher concentration of bicarbonate in water samples responsible for the development of alkalinity and thereby the higher pH values. This is because of the fact, that the pH of water samples reflects the dissolved CO_3^{2-} that originate either from the dissolution of atmospheric CO_2 or from the weathering of carbonaceous rocks. The pH of good water category (A) shows the lower pH as compared to other category of water. The application of water (B category) in soil may create salinity problem in soil after continuous use in the long run. Raghav *et al.* (2005) observed that the poor quality water and its adverse effects on soil physical properties were in arid and semi arid regions of the country.

5.1.2 Electrical Conductivity (EC)

The most influential water quality parameter on crop productivity is the water salinity hazard as measured by electrical conductivity (EC) and represented in dSm^{-1}. The primary effect of high EC water on crop productivity is the ability of the plant to compete with ions in the soil solution for water (physiological drought). If the EC quite high the water is less available to plants, even though the soil may appear wet. Because plants can use only transpire "pure" water, the usable plant water in the soil solution decreases dramatically as EC increases. The electrical conductivity has been accepted now as the water quality standard parameter for evaluating ground water because of its reliability and ease in determination. The classes as per USDA classification & based on electrical conductivity (Salinity hazards) are classified as low (0-0.25 dS m^{-1}), medium (0.25-0.75 dS m^{-1}), high (0.75-2.25 dS m^{-1}) and very high (>2.25 dS m^{-1}) and SAR values Sodium hazards as low (<10), Medium (10-18), high (18-26) and very high (>26). The total concentration of soluble salts expressed as electrical conductivity in ground water of Depalpur tehsil varied from 0.32 to 3.9 dSm^{-1} (Table 4.3 & Fig. 4.2). As per the classification given by Richards (1954), 152 (76%) samples belonged to class of medium to high conductivity (Table 4.6). Only 11 (5.5%) samples had EC more than 2.25 dS m^{-1} of very high conductivity class. The higher electrical conductivity (EC) in ground water samples was also observed by Bathusha and Saseetharan (2007) in Coimbatore city and Shahid *et al*. (2008) Julana block of Jind district of Haryana. Continuous application of higher electrical conductivity water may create soil salinity and deteriorate physical properties of soil.

It is evident from the results that most of the water samples show medium to high EC. This is mainly due to the presence of neutral salts of chloride and sulphate in ground water samples. Electrical conductivity was found to be positively correlated with Na^+ (r=0.52**), Cl^- (r=0.97**), Ca^{2+} (r=0.97**), K^+(r=0.23**) Mg^{2+} (r=0.93**) and HCO_3^- (r=0.78**). Bharambe (2001) observed soil salinity due to irrigation with good quality water in Jayakwadi command area of Maharastra was higher as compared to uncommand area. On the other hand, Verma *et al.* (2003) obtained an increasing trend in soil solution due to irrigation with high SAR and TDS water. The study conducted by Dubey *et al.* (1988) also revealed that irrigation water containing chloride and sulphate helped in exchangeable calcium build up in soil and counteracted the deleterious effect of high SAR of irrigation water.

5.1.3 Soluble Sodium Concentration (me L^{-1})

Sodium ($Na^{+)}$ is one of the common cations present in the water of well or tube well sources. Out of four different classes of sodium concentration (0-5, 510, 10-15 and >15 me L^{-1}), the 0-5 meL^{-1} class was the dominant one as compared to rest of the three classes (Table. 4.11). All 100% samples of the tehsil were grouped to this class. Brar *et al.* (2006) also observed the dominance of Na^+ cation in all the tube well samples of Bathinda district of Punjab. The major source of this sodium is weathering of feldspar prevailing in igneous rocks of the district. Similar findings were made by Sharma and Jain (2006). Use of such high concentration of sodium in irrigation water may pose the problem of soil sodicity and alkalinity hazards.

5.1.4 Residual Sodium Carbonate (RSC)

The soluble bicarbonates in ground water samples of Depalpur tehsil varied from 0.7 to 8.3 me L^{-1} (Table 4.3 and 4.10) and there were no soluble carbonates found in the water samples of the tehsil. The concentration of bicarbonate anion is impotent because they affect the precipitation of calcium and thereby result in excessive sodium saturated in soil. The carbonate and bicarbonate concentrations are very useful to judge the temporary hardness and alkalinity. There is no RSC values found in ground water samples of Depalpur tehsil. The continuous and indiscriminate use of higher RSC (>1.25 me L^{-1}) underground water may be expected to build excessive sodium in soil solution and exchange complex and clog the soil pores which mat leads to drainage problem. Vasanthavigar *et al.* (2012) observed that the continued usage of high RSC waters will affect the yields of crop. Naseem *et al.* (2010) reported that pH, EC and SAR of the irrigation water are significantly influenced by RSC. Tek Chand *et al.* (1993) reported that 52% water samples were sodic in nature and were found in Asalwas village of Mehenderagarh district of Haryana. Similarly, Sood *et al*. (1998) obtained soluble sodium concentration in the range of 3.0 to 90 meL^{-1} and it was the dominant cations in irrigation water samples of Bathinda district, Punjab. On the other hand Sharma and Minhas (1998) obtained an increasing trend in soil pH with increasing RSC values of irrigation water. Dubey *et al.* (1993) observed a decreasing trend in crop yield with increasing RSC of ground water.

5.1.5 Sodium Adsorption Ratio (SAR)

Electrical conductivity (EC) is an assessment of all the soluble salts in water sample while sodium hazard is defined separately because of its specific detrimental effect on soil physical properties. The sodium hazard is typically expressed as sodium adsorption ratio (SAR) in $(mmol\ L^{-1})^{½}$. This index quantifies the proportion of sodium (Na^{+}) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) in a sample. Calcium flocculates, while sodium disperses (pushes apart) soil particles. This dispersed soil readily forms crust and creates water infiltration and permeability problems.

It is evident from the results that the total ions concentration in the collected ground water samples was low and within the safe limits. All samples of the tehsil had SAR values < 10 (Table 4.9). The SAR of ground water was significantly correlated (r= 0.08**), (r= 0.08) and (r= 0.76**) with pH, HCO_3^{-} and Na^{+} of water respectively. Parvathappa *et al*. (1990) also obtained a significant positive correlation between pH and SAR of irrigation water through their study to determine the impact of irrigation water quality on soil properties under semi-arid tropics. Similar finding were also made by Dragovic *et al*. (1998). Soil ESP and pH increased and g rain yield of wheat decreased with an increase in SAR of irrigation water as reported by Khandelwal *et al.* (1990) and Khandelwal and Lal (1991).

5.2 Use of different qualities water in Agriculture

Most of the ground water of Depalpur tehsil (91%), which belongs to ‘A’ category known as good quality water can be used safely for all the crops including wheat and leguminous crops as well as vegetables (Table 4.4). The water which is characterized as marginally saline (B1 category) can be used for mustard and pearl millet in part of the area having a light textured soil. The ground water rated as high SAR saline (B3 category), marginally alkali (C1 category) and high alkali (C3) were unfit for irrigation and their indiscriminate use may cause secondary salinization and sodification to some extent and consequently the growth of the crop may also be affected severely.Such type of water was not found in Depalpur tehsil. Continuous use of water having RSC > 2.5 meL^{-1} is expected to build excessive Na^+ saturation in soil solution and exchange complex also. This situation may hinder the movement of air and water by clogging the soil pores and deteriorating physical condition of the soil.

5.3 Frequency distribution of ground water

The ground water samples from different sources were collected from Depalpur tehsil and assessment for their chemical parameters. The analyses were performed according to the standard methods for ground water samples (Richards, 1954). The ground water samples were classified into different categories as referred by Minhas *et al.* (1998). On the basis of EC, SAR and RSC values, the collected water samples were categorized as good quality (A), marginally saline (B1), saline (B2), high SAR saline (B3), marginally alkali (C1), alkali (C2) and very high alkali (C3). Out of 200 ground water samples, 182 (91%) and 18 (9%) samples came under category – A and B1 respectively. Bangar *et al.* (2008) also reported that the out of 712 ground water samples, 80% samples indicated good water quality, whereas 14% were found saline (marginally saline -9%, saline-4% & high SAR saline-1%) and 6% as alkali (marginally alkali-5% and alkali-1% categories) in Ujjain district of Madhya Pradesh.

5.4 Distribution of ground water samples

The classification of irrigation water respect to EC and SAR was based on the effect of soluble salts and exchangeable sodium on the physico-chemical properties of soil. Generally, C1S1 and C2S1 are said to be of good quality water as per the criteria fixed by Richards (1954). The class belonging to C1S2, C2S2 and C3S2 are of tolerable quality and the rest are of bad quality. Water samples of the present study area of Depalpur tehsil showed (Table 4.6) that most of the ground water samples 76% (152 samples) fell in C3S1 class followed by 37 (18.5%) in C2S1 , 5.5% (11 samples) C4S1. The results reported by Divekar *et al*. (2005) are in agreement with the present findings.

5.5 Coefficient of Correlation

A Correlation study (Table 4.14) among different parameters of ground water was made by following equation as suggested by Panes and Sukhatme (1978). Correlation study revealed that pH and SAR, EC and all cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO^{-}, Cl^{-}, SO_4^{2-}) of ground water samples were significantly and positively Correlated with each other. While pH and EC showed negative correlation with each other. Verma *et al*. (2003) obtained a good correlation between EC and SAR of irrigation water. Similar relationship was also obtained by Lal *et al.* (1998).

CHAPTER – VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

Ground water is the most significance source of supplemental irrigation water supply. For the sustainable growth in agriculture, crops require different water qualities thus analysis of ground water is prior to effective management and necessitating monitoring of ground water qualities. With this objective in view, a study entitled **"Characterization of Ground Water Quality of Depalpur Tehsil of Indore, Madhya Pradesh"** was conducted during 2018-19 in the Department of Soil Science, College of Agriculture, Indore (M.P.). Depalpur tehsil is one of the important tehsil located in the Indore district of Madhya Pradesh state (India). It is located at latitude of 22° 51' 1" N and longitude of 75° 32' 45" E. Normal annual rainfall of the tehsil is 960.96 mm. In this view around two hundred ground water samples were collected from the every village of tehsil. These water samples were analysed in the laboratory of Salt Affected Soils Project, College of Agriculture, Indore for different quality parameters such as pH, EC, total cations (Ca^{2+} , Mg^{2+} , Na^{+} , K^{+}) and total anions (CO_3^{2-} , HCO_3^{-} , Cl^{-} , SO_4^{-}). The values of SAR and RSC were also worked out by the formula given by the Richards (1954).

6.1 The salient findings of the experiment are summarized below:

- The ground water samples from different sources were collected from Depalpur tehsil and assessment for their chemical parameters. The analyses were performed according to the standard methods for ground water samples (Richards, 1954). The ground water samples were classified into different categories as referred by Minhas *et al*. (1998). On the basis of EC, SAR and RSC values, the collected water samples were categorized as good quality (A), marginally saline (B1), saline (B2), high SAR saline (B3), marginally alkali (C1), alkali (C2) and very high alkali (C3). Out of 200 ground water samples, 182 (91%) and 18 (9%) samples came under category good quality (A) and marginally saline (B1) respectively.

- In Depalpur tehsil, the pH of 200 water samples were neutral to slightly alkaline in nature (7.12 to 8.48) with the mean value of 7.65, whereas EC varied from 0.32 to 3.9 dS m^{-1}. Out of 200 samples 75.5 % were found in pH range 7.5 to 8.5, whereas 25.5% samples had pH <7.5. As per the classification given by Richards (1954), 188 (94%) samples belonged to class of medium to high conductivity. Only 12 (6%) samples had EC more than 2.25 dS m^{-1} of high conductivity class.
- The values of SAR varied from 0.07 to 0.95 with the mean value of 0.45 $(mmol\ L^{-1})^{1/2}$. Whereas RSC were totally absent in ground water samples of Depalpur tehsil.
- Among the different cations calcium are dominant followed by magnesium, sodium and potassium. In different wells / tubewell, , Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 1.4 to 28.2, 0.78 to 13.8, 0.2 to 3.08 and 0.01 to 0.14 with mean value of 6.99, 4.49, 1.29 and 0.05 meL^{-1}, respectively.
- Among the different anions chloride are dominant followed by bi-carbonate and sulphate. In different wells / tube wells, Cl^{-}, HCO_3^{-} and $SO4^{2-}$ varied from 1.17 to 30.1, 0.7 to 8.3, 0.2 to 8.4 with mean value of 8.33, 2.80, 1.59 me L^{-1}, respectively.
- Under different quality parameters of water, chloride (Cl^{-}) content of water show significantly positive Correlation with EC and HCO_3^{-} whereas negative correlation with pH.

6.2 Conclusion

1. By the overall study on ground water quality of Depalpur tehsil of Indore district, it has been concluded that most of the water are of good quality (91%) and remains fall in the category of marginally saline (9%) as per the CSSRI, Karnal classification.
2. On the basis of Richards (1954) classification, the ground water of Depalpur tehsil are belong to medium to high salinity hazard (94%) and remaining samples belong to very high salinity hazard (6%).

6.2 Suggestion for further work:

1. Continuous monitoring of ground water quality season wise in areas of poor quality water will be helpful to take immediate steps in minimizing further deterioration of the quality of soils.
2. Effect of poor quality water should be monitored in soil at different length of time. This will be helpful in formulating proper management practices in the affected areas.
3. Regular monitoring of ground water should be done for assessing the possible damage to the crop from soil salinity and alkalinity.

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