Seasonal Variation of Groundwater Quality of Jalalabad (West) Block of the District Fazilka, Punjab, India

काशी हिन्दू विश्वविद्यालय

BANARAS HINDU UNIVERSITY

THESIS

Submitted in partial fulfilment of the requirements
for the award of the degree of

Master of Science (Agriculture)

in

Soil Science - Soil and Water Conservation

Submitted by

Ashish Kumar

Supervisor

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ID. No. 17430SAC001 **2020** **Enrolment No. 398765**

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To,
The Registrar,
Banaras Hindu University,
Varanasi-221 005

Dear Sir,

I have great pleasure in forwarding the thesis entitled **'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab, India'** submitted by **Mr. Ashish Kumar (I. D. No. 17430SAC001 and Enrolment No. 398765)** in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in **Soil Science - Soil and Water Conservation**, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University.

I certify that the entire scheme of investigation reported herein, was planned and carried out by the candidate under my guidance. To the best of my knowledge and belief, the data presented in the thesis are genuine and original. No part of the work has been submitted for any degree or distinction.

Forwarded **Forwarded** **Yours faithfully,**

(Head) **(*Course Coordinator*)** **(Dr. Triyugi Nath)**
Chairman of the Advisory Committee

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Dated: .....

Dear Sir,

I, Ashish Kumar (I. D. No. 17430SAC001 and Enrolment No. 398765) have great pleasure in the submitting of the thesis entitled 'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab, India' in the fulfilment of the requirements for the award of the degree of Master of Science (Agriculture) in Soil Science -Soil and Water Conservation, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Rajiv Gandhi South Campus, Barkachha, Mirzapur.

I certify that the entire scheme of investigation reported herein, was planned and carried out by the me under guidance of the Chairman of my advisory committee, Dr. Triyugi Nath and the members.

The data presented in the thesis is genuine and original and I did the research work as per supervision and valuable suggestions given my advisory committee. It is true in the best of my knowledge and belief and no part of the work has been submitted for any degree or distinction.

Yours faithfully,

(Ashish Kumar)

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By

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Date: ***(Ashish Kumar)***
Place: Varanasi

ABBREVIATIONS

%	-	Per cent
cm.	-	Centimeter
mm.	-	Millimeter
et al.	-	*Et alia,* and others
Fig.	-	Figure
sq. km	-	Square Kilometer
i.e.	-	*Id est,* that is
dS m^{-1}	-	Desi simen per meter
mg L^{-1}	-	Milligram per liter
meq L^{-1}	-	Milli equivalent per liter
No.	-	Number (s)
^{o}C	-	Degree Celcious
Cmol $(P^{+})kg^{-1}$	-	Centimol per Kilogram
S.N	-	Serial number
EDTA	-	Ethelene di amine tetra acetic acid
M ha	-	Million hectare
DTPA	-	Diethylene triaminepenta acetic acid
Temp.	-	Temperature
viz.,	-	Vide licet, namely
Max.	-	Maximum
Min.	-	Minimum
J	-	Journal
Soc.	-	Society
Sci.	-	Science
Dept.	-	Department
Agri.	-	Agriculture
Univ.	-	University
pH	-	Puissance de hydrogen
EC	-	Electrical conductivity
K	-	Potassium
Ca	-	Calcium
Mg	-	Magnesium
TDS	-	Total Dissolved Solid
Na	-	Sodium
Co3 I	-	Carbonate
HCO3	-	Bi-carbonate
Cl	-	Chloride
SAR	-	Sodium Adsorption Ratio
RSC	-	Residual Sodium Carbonate
PI	-	Permeability Index
KR	-	Kellys Ratio
SSP	-	Soluble Sodium Percentage
IWQI	-	Irrigation Water Quality Index
Pre_Mon	-	Pre monsoon
Dur_ Mon	-	During monsoon
Post_Mon	-	Post monsoon

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Chapter: 1

INTRODUCTION

Water is a unique resource on the planet earth. It is very essential for sustaining all forms of life. Groundwater is defined as water that is present beneath the water table under earth's exterior. Water in the ground passes through soil and rock pores, through fractures and weathered areas of the bedrock. Groundwater account for about 98% of the world's use of fresh water and is estimated 60 times as plentiful as fresh water found on lakes and streams and has a major effects on the habitats of rivers and wetland for crops, animals and aquatic life. As the groundwater is not visible that's why it is often ignored in the consideration of all the waters on earth, yet groundwater is a valuable resource available and it should be use judicially. Water is also seen as a universal solvent to dissolve multiple things that are essential for the ecosystem's survival in turn, water is most important in many geological processes and can also be used for different use from the rainfall. The groundwater in India, which helps to regulate the quantity and quality needed for the survival of all species of life.

India is the biggest consumer of groundwater in the world due fastest evergrowing population, with an estimated consumption of around 230 cubic kilometers per year and more than one quarter of the world's total. Particularly in India, groundwater is a vital resource, with more than 60 percent of irrigated agriculture and 85 percent of drinking water supply dependent on it. Water contains many minerals like calcium, magnesium and flouride and sulphate etc. in the form of valuable cations and ions.

In addition to surface water bodies, groundwater is usually less prone to pollution. Also, natural rain water impurities, which replenish groundwater systems, are removed when infiltrated through soil strata. In India, where groundwater is intensively used for irrigation and industrial purposes, a range of land and water-based operations reason pollutions of this valuable resource. The

overexploitation causes water contamination in particular areas of the aquifer, for example in the field of drinking, domestic and industrial purposes.

In the some cases, its inadequate scientific development with insufficient knowledge of groundwater flows has led to its mineralization, dynamically and geo-hydrochemically (Kumar and Shah, 2006). The river basins are highly variable in hydrogeological and groundwater occurrences and within the basins due to large changes in topographical, drainage, pluvial and geological arrangements of groundwater recharge. Groundwater is contaminated in many cities and industrial clusters in India due to industrial effluents and municipal waste in the water bodies. The hydrogeologically and occurrence of groundwater greatly varies from one river-basin to another and within the basins, in the red to a great variations in topography, drainage, rainfall and geological setup. Pollutions of the groundwater are due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in the India.

Punjab is a state in a northern India. The state is bordered by the Indian states of Jammu and Kashmir to the north, Himachal Pradesh to the east, Haryana to the south, Rajasthan to the southwest (Chopra, RPS and Krishan, G., 2014) and the Pakistani province of Punjab to the west. The state covers an area of 50,362 square Kilometers' which is 1.53% of India's total geographical area. Punjab extends from the Latitudes 29.30° North to 32.32° North and Longitudes 73.55° East to 76.50° East. Chandigarh is capital city of Punjab, its north, Sri Muktsar Sahib to its east and Sri Ganganagar to the south and Pakistan to its west. There are 3 Tehsils in the district which are named as Jalalabad and Fazilka. Fazilka is located at south-western part of the Punjab. It is bounded by district of Ferozpur to abohar. Fazilka is also known as Bangla. Fazilka district has a total area of 3113 km^2. Fazilka has population density of 380 people per km^2. Its height above mean sea level is 180 meter. The important river of district is Satluj. The climate of the area is semi-arid. The area receive rainfall from south - west monsoon lasting from June to September with a average annual rainfall of **349 mm** out of which 78 to 80% received during June to September. Rest 22% of the annual

rainfall occurs as erratic of the year in the form of thunder storm and western disturbances. The average temperature of the area is 37.4° C (Central Groundwater Board, 2017). The district area forms a part of Upper Indo-Gangetic plain and Sutlej Sub basin of main Indus basin. The area as a whole is almost flat with a gentle slope towards the south westerly direction. The soil is predominantely sodum, developed beneath hot and arid to semi-arid climatic conditions. The pH value ranges from 7.8 to 8.5, which shows that the soil is normal in reaction. Mostly grey and red desert, calsisol, regosol and alluvial soils are found in this zone (file:///C:/Users/dc/Downloads/water%20quality%20of%20ferozpur.pdf).

Geographical area of district is 585000 ha and the total cultivable area is 475000 ha. Net sown area of district is 475000 ha. Area under forest is 12000 ha and land under non agricultural use is 39000 ha. The cropping intensity of the district is 184% and gross cropped area is 876000 ha. The area irrigated by canals is 161000 ha followed by borewells is 313000 ha. The total net irrigated area is 474000 ha crops grown during *Rabi* season are wheat, barley, rapeseed, mustard and gram. Mainly crops growing during *Kharif* season are rice, cotton, moongbeen and horticultural crops like kinnow, orange, malta, guava and ber are also grown. The kinnow crop is grown on 17.5000 ha area (Agriculture Contingency Plan for ICAR) (file:///C:/Users/dc/Downloads/fazilka%20data%20icar.pdf).

There are no major industries in the area except Agro and sugar mill industries in Fazilka area. The groundwater quality of shallow aquifer is assessed based on the chemical data of the ground water observation monitored regularly by CGWB on annual basis (central ground water board). Ground water at shallow depth occurs under unconfined to semi confined and confined conditions are in the deeper aquifers. Block is categorized as over exploited as per Dynamic Groundwater Resources, 2013 assessment, the deeper aquifers are marginal to highly saline and it is not suitable for irrigation purpose so that all users are tapping at shallow aquifers only. State government drinking water supply wells tapped at shallow aquifers and canal supply water are used for domestic and irrigation purpose (http://cgwb.gov.in/Documents/Dynamic%20GWRE-2013.pdf).

The Water Quality Index (WQI) is one of the most efficient, easy to understand to assess the quality of water for different purposes. The Water Atlas presents the WQIs for three-month periods (Jan to Mar, Apr to Jun, July to Sep and Oct – Dec). WQI is used in streams, in black waters (natural waters of tea and coffee) as well as in springs. The WQI of a water body is resolute on quarters by quarter basis, based on the mean value for a chosen water quality parameter. WQI ranges for a general water body classification have been set. The index is accompany by the 'confidence value' that reflects the degree to which the index is complete. The research sciences from the 1970 (Ning and Chang, 2002) focused on the problems relating to the optimal design of water quality surveillance and the improvement in effectiveness. In India, various organizations and institutions for water monitoring and water supplies are more anxious with the more precise monitoring of water resources and across a wider geographical area, thereby strengthening their monitoring system. Precipitation (rain and snow, stream flow, soil, ponds and reservoirs as well as the water quality of multiple bodies of water are being monitored by such organizations and scientists (Singh et.*al*, 2016) are cconsidering the above mentioned aspects and uplifting questions of groundwater quality and their impact on soil, animal and plant systems and this study representing numerous geohydrological and land use circumstances.

The groundwater quality of south west Punjab and stated that pH, EC, TDS and cationic parameter *i.e.* Na, K, Ca and Mg and anionic parameters *i.e.* carbonate, bicarbonate and chloride and irrigation water quality parameters *i.e.* SAR, RSC, PI, KR, SSP and IWQI in the different seasons are fluctuating and pre, during and post monsoon periods was varied. The IWQI is depends on said parameters' and groundwater quality is ditoriating very fast and affecting soil quality, plant biota and eventually human and animals health (Diana *et. al.,* 2016; Gurjar *et.al.,* (2017); Navdeep *et. al.,* (2013).

Keeping view of above facts and the importance of water in the human and animal nutrition, this research work planed entitled **'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab,**

India' and conducted for the awards of the Master of Science (Agriculture) in Soil Science-Soil and Water Conservation. The study was done at the Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur. The course running under auspices of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi with following objectives:

1. Determination of different chemical parameters for groundwater quality of Jalalabad block of Fazilka district, Punjab, India.
2. Evaluation of water quality of the groundwater samples using water quality index.
3. To study the pair of correlations and standard deviation between different quality parameters.

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Chapter : 2

REVIEW OF LITERATURE

Groundwater is a key part of our livelihood system. So the wetlands, swamps, streams, ponds and rivers must be protected in the atmosphere and in the world during droughts. It can be used when groundwater is available in order to recycle and replenish these essential habitats.. However, when the groundwater is tainted or not accessible, these parts of the ecosystem suffer considerably. In general, this can have major global consequences, but groundwater is treated more than surface water. A healthy consumption of human beings and less chemical treatments are required. For starters, it can be integrated over time in groundwater, pesticides and fertilizers. Road salt, radioactive miners and motor oil may also penetrate groundwater, which could affect the quality of the groundwater. Furthermore, the nature of the underwater may be compromised by unregulated waste from septic tanks and chemical products from underground storage tanks and leached areas.

The WHO estimates that almost 75% to 80% of human diseases are caused by drinking water, because most drinking water comes from groundwater and a small portion from surface water in India. Soil water, depending on the chemical structure of the stratum from rock falls, is usually rich with minerals such as calcium and magnesium salt, fluorine, and iron.

The related work in India and abroad on important criteria for water quality, irrigation and drinking, groundwater quality and groundwater quality recommendations have been reviewed Including the utility of the water and research work was planed entitled '**Seasonal variation of water quality of Jalalabad (West) block of the district Fazilka, Punjab, India'**and in this chapter, extensive literature has been studied and presented under following headings and subheadlines:

2.1: Chemical parameters of groundwater

Gurjar et. *al.* (2012) Studied the seasonal changes in Nangloi block hydro-chemical composition and confirmed that the pH of pre-monsoon season ground water ranges from 7.42 to 7.96, with a mean value of 7.72 and after monsoon, pH values for groundwater range from 7.38 to 7.86 and average pH values are 7.68. All pH levels are within the allowable limit for groundwater quality..

Islam and Shamsad (2009) studied the irrigation water quality in Bogra District of Bangladesh and reported that the pH of irrigation water of the area were under ranged between 6.7 to 7.9. they were reported that the average value of 7.22, which was within permissible limit for irrigation water quality. The EC values were reported that studied water quality was ranged from 0.317 to 0.769 ds m^{-1} for irrigation water, with an mean value of 0.55 dS m^{-1} and that was found' allowable for' the irrigation water quality range as per WHO permissible limits (1995) and BIS (2003) standard.

Brindha and Elango (2011) were carried out research work in Madhuranthakam, Tamil Nadu and reported that the hydro chemical parameters of groundwater quality for the pH and EC of the irrigation water was varied within the range 7.2 to 8.2 and 0.20-1.90 dSm^{-1} with an average values of 7.69 and 0. 80 dS m^{-1}, respectively and that was found' allowable for' the irrigation water quality ranged as per WHO permissible limits (1995) and BIS (2003) standard.

Jalal and Kamel (2011) were examined irrigation in the North Jordan country and reported a very mild alkaline affinity changed with pH values from 7 to 8.22 with an mean of 7.49. The electrical conductivity were ranged from 0.54–71 dS m^{-1} for collected samples of groundwater. The results showed that the irrigation limits allowable for almost all of the water samples.

Pourfallah *et. al.* (2014) investigated groundwater quality in Tehran, Iran and establish that the pH values ranged from 6.90 to 8.37 for all samples. In all water samples studied the total mean pH was 7.67±0.25. The pH is somewhat

alkalinic behaviour and the difference between pH and seasons were significant ($p<0.05$). There was a wide variations between 0.2 to 2.3 dS m^{-1} in electrical conductivity results from water samples. Most of the samples were limited.

Kerala, S. *et. al.* (2014) studied the excellence of groundwater and determined that the seasonal mean pH is 7.15 neutral. In post-monsoon pH ranges within 7.0 and 7.5 cover a wider area from the west to the east. In the periphery of the study area, the value was recorded between 7.4–7.6. The pH values of pre-monsoon in the majority of the west and east ranged from 7.0–7.3 to 6.6 to 8.1. The field of study in the South-East ranged from 6.6 to 7.0.. The values for EC were between 1.1 and 3 dSm^{-1} in post-monsoon season that was found' allowable for' the irrigation water quality range as per WHO allowable limits (1995) and BIS (2003) standard.

Ali *et. al.* (2015) studied the Groundwater Quality at Maytam Area in the City of Ibb, Yemen and recommended that the pH values of the groundwater samples was ranged from 7.0 to 7.8 with an average od7.37, indicating alkaline groundwater in nature. The quantity of minerals dissolved in water and their value for the samples tested was ranged from1.1 dS m^{-1} to 1.45 dS m^{-1} are found electrical conductivity (EC). The results showed, that groundwater quality was' suitable for the irrigation water quality range as per WHO permissible limits (1995) and BIS (2003) standard.

Pathak, H. *et.al.* In different months of the Pre-Monsoon, Monsoon and Post-Monsoon Seasons from June2009 to June2010 the of Sagar city of Madhya Pradesh was observed.and These samples ranged from 6.8 to 8.2 with an average value of 7.7 for the pre-Monsoon pH. The pH of the early monsoon was from 7.7 to 8.5 and averaged 8.2. The pH of the post-monsoon was from 7.5 to 8.4, with an average value of 8.1. This means that the pH is slightly alkaline.. This is showing a highly alkaline pH of pre-and post-monsoon. The results showed that the quality of groundwater was suitable in accordance with the permissible limits WHO (1995) and BIS (2003) of irrigation water quality standards.

Diana *et. al.* (2016) studied the pH and EC values for premonsoon duration ranged, for pH, EC respectively, from 6.19 to 8.69, from 1.74 to 4.01dS m^{-1} with mean values of 7.49, 1.33 dS m^{-1}.This showed that both the values are under the permissible limit. The value of pH and EC for post-Monsoon periods varies between 7 and 7,95. The average value of pH and EC varies between 0,25 and 3,806 dS m-1 and 7,33. Both values are within the allowed limit. That is therefore appropriate for irrigation.

Navdeep *et. al* .studied the seasonal variations of groundwater quality of adjoining region of Buddha Nallah, Punjab in the year 2013 and 2014 and stated that in pre monsoon period pH range from 7.75 to 8.47 with an average value of 8.09.This shows pH is very high alkaline due to anthropogenic behavior. In during and post monsoon season pH value range from 7.21 to 8.34, 7.15 to8.32 with an average values of 7.70 and 7.76 respectively. This showed pH is slightly alkaline. The results shows, that groundwater quality was' suitability for the irrigation water quality range as per WHO permissible limits (1995) and BIS (2003) standard.

Ramamohan *et. al.* (2013-2014) studied the water quality of the coastal area of Srikakulam district, Andhra Pradesh and suggested pH values of study area varies from 7.04 to 7.68 during post- monsoon and 7.2 to 8.2 during pre- monsoon. The pH values of all the stations indicated alkaline condition and under permissible limit as per Indian standards. The EC value of sampling water for winter and summer season varies from 0.94 to 4.4 , 1.2 to 4.5dS m^{-1}.EC values are higher in pre monsoon season than post monsoon season. The results showed, that groundwater quality was' suitable for the irrigation water quality range as per WHO permissible limits (1995) and BIS (2003) standard.

Sinha *et al* (2018) were studied the groundwater quality of Wakal river basin of Udaipur District, Rajasthan and suggested that pH and EC values of pre monsoon period varies from 6 to 8, 0.40 to 3.20 dS m^{-1} with an mean value of 6.98, 0.96 dS $m^{-1}$for pH, EC, respectively. The pH and EC value of post monsoon period varies from 6.5 to 7.6, 0.30 to 2.90 dS m^{-1} with a mean value of 7.1, 0.81 dS m^{-1} for

pH and EC respectively. 91.36 % area of Wakal river area has pH ranges from 6.75 to 7.25 during post monsoon period and 97.2 % area ranges from 6.5 to 7.5 during pre- monsoon period. The highest pH value was noticed near the village Bari in the Jhadol block during both pre and post monsoon period. 94.4 % study area during post-monsoon period and 47 % study area during pre-monsoon duration groundwater is not suitable for drinking purposes Because EC value is more than 0.75 dS m^{-1}.

2.2: Cationic parameters of groundwater

Diana *et. al.* (2016) studied the ground water quality of south west Punjab and stated that Na, K, Ca and Mg values of pre monsoon period varied from 3.6 to 570, 1.6 to 20.6, 1. 7 to 67.3, 0.98 to 351 mg L^{-1} with the mean values was 155, 5.76, 29.3, 77.2 mg L^{-1} for Na, K, Ca and Mg, in that order. The Na, K, Ca and Mg value of post monsoon period varied from 5.4 to 680, 1.2 to 13, 22 to 147, 15.1 to 226 mg L^{-1} with a mean values of 238, 6.47, 60.0, 91.2 mg L^{-1} for Na, K, Ca and Mg, respectively. All water is within permissible limit. They were reported that the 22% samples was found doughtful to unsafe category.

Gurjar *et.al.*(2017) Groundwater standard studied for the Delhi Nangloi Bloc pre-monsoon and post-monsoon.They stated that the Na, K, Ca and Mg content of pre monsoon period varied from 0.62 to 39.32, 0.06 to 0.85 , 0.48 to 9.26, 0.86 to 27.12 mg L^{-1} with an mean value of 18.70, 0.34 ,4.26,9.16 mg L^{-1} for Na, K ,Ca, Mg respectively. Na ,K, Ca and Mg value of post monsoon duration varied from 0.61 to 38.97, 0.05 to 0.83 ,0.45 to 9.18, 0.79 to 26.92 mg L^{-1} with an mean values of 18.45, 0.32 , 4.18, 9.08 mg L^{-1} for Na, K , Ca, Mg respectively . All cations content was in decreasing trend due to decrease in salinity of water. So quality of water improves in post monsoon period.

Navdeep *et. al.* (2013) studied the ground water quality of adjoining regions of Buddha Nallah, Punjab for various seasons of the year and stated that Na, K, Ca and Mg values of pre monsoon period varied from 51 to 211, 3.5 to 17.9, 34.0 to

125.8, 7.7 to 71.5 mg L^{-1} with mean value of 127, 12.3,73, 50.5 mg L^{-1} for Na, K, Ca and Mg, respectively. The Na, K, Ca and Mg value of during monsoon period varied from 65.3 to 234, 3.2 to 17, 34.6 to 125.2, 6.3 to 67.8 mg L^{-1} with mean values of 150.5, 11.0, 72.2, 47.8 mg L^{-1} for Na, K, Ca and Mg, respectively. The Na, K, Ca and Mg values of post monsoon period varied from 55 to 218.3, 2.6 to 16.9, 33.6 to 126.3, 7.6 to 69.6 mg L^{-1} with an mean value of 131.2, 10.8 , 73.1, 48.6 mg L^{-1} for Na, K , Ca, Mg respectively .Percolation of water during monsoon season leads to increase in sodium in ground water as compared to other seasons. Concentration of parameters was above the prescribed limit .so it affect the suitability for irrigation activities.

Abdul *et. al*. were studied the ground water quality of Gulbarga city at different seasons and stated that Na, K, Ca and Mg values of pre monsoon period varies from 26 to 273, 1 to 20 , 46 to 307, 11 to 148 mg L^{-1} with an mean value of 134.35, 6.45 ,134.05,63.67 mg L^{-1} for Na, K ,Ca, Mg respectively. Na ,K, Ca and Mg value of During monsoon period varies from 41 to 164, 1 to 46 , 61 to 216, 21 to 82 mg L^{-1} with an mean value of 83.09, 12.69 , 117.05, 46.29 mg L^{-1} for Na, K , Ca, Mg respectively . Na ,K, Ca and Mg value of Post monsoon period varies from 23 to 214, 1.0 to 38 ,40 to 272, 8 to 123 mg L^{-1} with an mean value of 102.87, 4.13, 103.44, 48.31mg L^{-1} for Na, K, Ca and Mg, respectively. Majority of ground water samples are below permissible limit for irrigation. So water can be used for irrigation purpose.

Ramamohan *et. al.* (2013-2014) studied the water quality of the coastal region of Srikakulam district, Andhra Pradesh and Na, K, Ca and Mg values of pre monsoon period varies from 5.2 to 51.2 , 43 to 97, 12.9 to 26 ,100 to 709 mg L^{-1} respectively. Na ,K, Ca and Mg value of Post monsoon period varies from 4 to 48.66, 42.5 to 96 ,11 to 23, 19.6 to 690 mg L^{-1} respectively. It is observed that Na, K, Ca, Mg values was higher during pre monsoon than post monsoon. All parameters concentration was below the desirable limit.

Sinha *et. al.* (2018) studied the ground water quality of Wakal river basin of Udaipur District ,Rajasthan and suggested that Na, K, Ca and Mg values of pre monsoon period varies from 0.2 to 12.1 , 0.0 to 1.2, 1.6 to 7 ,0.8 to 14 mg L^{-1} with an mean value of 2.98, 0.13 ,3.10,3.25 mg L^{-1} for Na, K ,Ca, Mg respectively . Na ,K, Ca and Mg value of Post monsoon period varies from 0.2 to 12.1 , 0.0 to 1.2 ,1.6 to 7, 0.8 to 14 mg L^{-1} with an mean value of 2.47, 0.01, 3.40, 1.94mg L^{-1} for Na, K , Ca, Mg respectively . It is observed that Mg and Ca are the most predominant cations followed by Na during pre monsoon period. whereas calcium and sodium are dominant in post monsoon period.99% of the investigated area is within permissible limit of Ca and Mg during both pre and post monsoon period. The highest Ca and Mg were found near the village Bira in Jhadol block during pre monsoon period and near to village kotra during post monsoon period. The highest Na was found in the village kotra during pre and post period and K was found in negligible amount during pre and post monsoon period.

2.3: Anionic parameters of groundwater

Islam and Shamsad (2009) investigated Bogra District's irrigation water quality in Bangladesh and proposed that the chloride content of the four samples of irrigation water in this field was considerably variable from 0.69 to 5.63 meq L^{-1} and a total of 1.57 meq L^{-1} averaged.Cl values for the study region are within the recommended limits and are acceptable for irrigation. The irrigation samples included a variety of Bicarbonates (HCO_{3-}) with an mean value of 5.12 meq L^{-1} between 3.17 and 6.94 meq L^{-1}.All water is suitable for irrigation.

Diana *et.al.* (2016) studied the ground water quality of south west Punjab and stated that Cl^- and HCO_3^- values of pre monsoon period varies from 14.2 to 1278.0 and 115.0 to 815.0 mg L^{-1} with an mean value of 288.0 and 413.0 mg L^{-1}, respectively. This shows that both the values are within permissible limit. Cl and HCO_3^- value of post monsoon period varies from 42.6 to 788, 150 to 780mg L^{-1} with a mean value of 293,423mgL^{-1} for Cl and HCO3- respectively .Both values are within permissible limit. So it is suitable for irrigation.

Gurjar *et.al.* (2017) studied quality of ground water for pre monsoon and post monsoon of Nangloi block of Delhi and stated that Cl and HCO3- values of pre monsoon period varies from 0.72 to 68.58, 4.52 to 12.26 mgL^{-1} with an mean value of 19.91, 8.66 mgL^{-1} for Cl andHCO3- respectively. Cl and HCO3- value of post monsoon period varies from 0.79 to 68.45, 4.58 to 12.32 mgL^{-1} with a mean value of 19.85, 8.70 mgL^{-1} for Cl and HCO3- respectively . All water is within permissible limit.

Navdeep *et.al.* (2013) studied the ground water quality of adjoining regions of Buddha nallah ,Punjab for different seasons of the year and stated that Cl values of pre monsoon period varies from 200 to 340 mgL^{-1} with an mean value of 269 mgL^{-1} for Cl . Cl value of During monsoon period varies from 195 to 328 mgL^{-1} with an mean value of 255.7 mgL^{-1}. Cl value of Post-monsoon period varies from 199 to 335 mgL^{-1} with an mean value of 263.3 mg L^{-1}. Concentration of Cl was above the prescribed limit .so it affect the suitability for irrigation purposes.

Abdul *et.al*. Studied the ground water quality of Gulbarga city at different seasons and stated that Cl and HCO_3- values of pre monsoon period varies from 87 to 557, 167 to 652 mgL^{-1} with an mean value of 279.22, 346.4 mgL^{-1} for Cl andHCO_3- respectively. Cl and HCO_3- value of During- monsoon period varies from 84 to 454 , 127 to 255 mgL^{-1} with a mean value of 191.05, 186.56 mgL^{-1} for Cl and HCO_3- respectively . Cl and HCO_3^- value of Post- monsoon period varies from 42 to 518, 147 to 480 mg L^{-1} with a mean value of 173.25, 313 mgL^{-1} for Cl and HCO_3^-, respectively .All water is within permissible limit for irrigation.

Ramamohan *et. al.* (2013-2014) studied the water quality of the coastal region of Sri Kakulam District, Andrapradesh and suggested that Values of chloride concentration ranges from 100 to 752 mg L^{-1} in post-monsoon and 125 to 699 mgL^{-1} in pre-monsoon period .All water samples except Devunalthada have concentration below the desirable limit and the values are higher in pre monsoon than post monsoon except Devunalthada.

Sinha *et. al.* (2018) Studied the ground water quality of wakal river basin of Udaipur District ,Rajasthan and suggested that Cl,CO_3 and HCO_3- values of pre monsoon period varies from 2.8 to 19.5, 0.0 to 4.2,0.0 to 5.2 mgL^{-1} with an mean value of 4.92,0.24, 1.58 mgL^{-1} for Cl,CO_3 andHCO_3- respectively. Cl ,$CO_3$and HCO_3- value of Post- monsoon period varies from 1.5 to 13.5 , 0.0 to 2.0,0.4 to 5.5 mgL^{-1} with a mean value of 3.69, 0.05,1.65 mgL^{-1} for Cl,CO_3 and HCO_3- respectively .The highest Cl value was found in village Bira in Jhadol block during pre monsoon period and village Kotra during post monsoon period. The highest HCO_3- value was found in village Nayawas in Kotra block during Both pre monsoon period and post monsoon period .99 % of study area have HCO_3- value less than 3.5mg $L^{-1}$for both pre and post monsoon season. The highest Cl value was found in village Bira in Jhadol block during pre monsoon and village Kotra during post monsoon period.

2.4: Irrigation water quality parameters

Abbas *et. al.* (2018) were conducted study to evaluate the groundwater quality and its suitability for irrigation purpose through GIS in villages of Chabahr city, Sistan and Baluchistan province in Iran. This cross-sectional study was carried out from 2010 to 2011 the 1-year-monitoring period. The water samples were collected from 40 open dug wells in order to investigate the water quality. Chemical parameters including EC, SAR, Na þ, Cl, pH, TDS, HCO 3 and IWQI were analyzed. In order to calculate the irrigation water quality index subsequent five water quality parameters (EC, SAR, Na þ, Cl, and HCO 3) were utilized. Among the total of 40 samples were analyzed for IWQI, 40% of the samples classified as excellent water, 60% of the samples in good water category.

Islam and Shamsad (2009) have researched water quality of the Bogra district in Bangladesh. Out of 44 water samples, the canal water near the village Bolua was categorized as ' C1-S1, ' while 43 other irrigation water samples were categorized as ' C2-S2. The value of soluble sodium percentage (SSP) ranged between 14.79% and 41.99% and the mean value varied by 24.42 %. 14 samples

were classified as "Excellent class" out of total 44 water samples and 26 samples were classifies as "good" based on the classification of Wilcox (1955) for SSP. The highest ground water RSC was 4.63. On the basis of Eaton (1950), 3 samples were classified as' good' from 44 water samples and 41 as' marginal' category and the average RSC values for the water samples collected were found to be 2.26. The Kelly proportion of water irrigation samples gathered was from 0.137 to 0.396 with an average of 0.27, all are acceptable and irrigational values (Kelly, 1953).

Anurika *et.al.* (2015) examined irrigation groundwater around Sanganer Tehsil, Jaipur, Rajasthan and found that the SAR of the ground water usually is less than 17 and falls under the C3S1 category that indicates low alkali and good water quality. SSP groundwater values are range from 16.38 to 82.82 in the studied area indicating low alkaline hazards and fair (Class III) to excellent irrigation water quality (Class I).The research region KR values ranged from 1.78 to 11.03. These show that KR is much greater than the permitted value 1.0 for groundwater samples and so it is not suited for irrigation. The PI range is between 10.36 and 43.91. These results of water samples falling into Class II and Class III and which is recognized as acceptable for irrigation.

Shreya and Nag (2015) evaluated the quality of groundwater of SuriI and II blocks in Birbhum, West Bengal during post-monsoon and pre-monsoon seasons in 2012 and 2013.It is found that SAR range varies from 0.18 to 2.07 for post-monsoon and from 0.24–3.24 for pre-monsoon. All samples have a low sodium hazard on the basis of the SAR values. The SSP values vary in post-monsoon between 5.62 and 47.31 and in pre-monsoon between 7.84 and 66.3 and fall under ' Very Good to Good ' category in post monsoon and ' Good to permissible' category in pre-monsoon season.In the post monsoon, the permeability index is between 23.07 and 90.06 and in the pre-monsoon between 18.20 and 66.09.During both post and pre-monsoon seasons, all water samples were fall under Classes I and II . This shows that water quality is moderately good. In this study where the RSC values ranges between -0.10 and 12.97 and > 80 percent of the water samples have RSC>2.5. The residual sodium carbonate values must preferably be less than 1.25 .which is permissible limit for irrigation. Water in this region is found to show an

alkaline hazard to the soil during monsoon. 76% of RSC values fall into the normal category during the pre-monsoon season, showing localized hazard.KR values range from 0.05 to 0.87 during post monsoon, and pre-monsoon values range from 0.08 to 1.95. According to the Kelly's ratio, water studied is appropriate for irrigation during both seasons, without two places in pre monsoon.

Guettaf *et. al.* (2017) examined the water quality status of Seybouse River, in the northeast of Algeria in the April and August 2010, January and April 2011.The amount of SAR in the region of Seybouse River varies from 0.44 to 0.94.The SAR values of irrigation water and the extent to which sodium is absorbed through soils are significantly linked to each other.RSC values observed are ranging from -9.60 to 1.60 meq L^{-1} for Seybouse River.

Dheeraj *et.al.* (2018) investigated groundwater quality in the Upper Berach Basin, Rajasthan and found that the value of SAR was found in the excellent category in 85 villages, good and unsuitable class of ground water samples were found in 9 villages and 1 village respectively during pre-monsoon period. Kelly's ratios value less than 1 is safe for irrigation. 43.89% samples are found safe for irrigation during pre monsoon and 52.36 % is found safe during post monsoon period.RSC value below 1.25 is found in 97.78 % samples in pre-monsoon and 98.92 % samples in post monsoon season. This shows that water is safe for irrigation in this region. Na % range between 20 and 40 was found in 9.44% area in pre monsoon and 10.18% area in post monsoon. This shows that this area's water falls into excellent irrigation category. In pre-monsoon and post monsoon period, 95.03 % and 91.97 % of basin area have excellent water quality for irrigation uses.

Sinha *et.al.* (2018) has analyzed groundwater quality from the Wakal River Basin in Udaipur, Rajasthan for pre- and post-monsoon period and has reported that the SAR values of both the pre and post-monsoon samples are below 10 and are therefore excellent for use in irrigation.RSC values are less than 1.25 (with the exception of one pre-monsoon sample) for all samples of study area, suggesting that the entire study area has a safe limit for both pre- and post-monsoon irrigation.

2.5: Water quality standards

Table 2.1: BIS Irrigation Water Standards (IS 10500 – 91, Revised 2003)

Sr.No.	Parameters	Desirable limit	Permissible limits in the absence of alternate source
1	pH	6.5 to 8.5	No relaxation
2	Colour (Hazen Unit)	5.0	25
3	Turbidity (JTU)	5.0	10
4	Odour	Unobjectionable	-
5	Total dissolved solids, ($mg\ L^{-1}$)	500	2000
6	Total hardness as $CaCO_3$, ($mg\ L^{-1}$)	300	600
7	Calcium as Ca, ($mg\ L^{-1}$)	75	200
8	Magnesium as Mg, ($mg\ L^{-1}$)	30	100
9	Chloride as Cl($mg\ L^{-1}$)	250	1000
10	Sulphate as SO_4, $mg\ L^{-1}$	200	400
11	Nitrate as NO_3,($mg\ L^{-1}$)	45	No relaxation
12	Iron as Fe, ($mg\ L^{-1}$)	0.3	1.0
13	Fluoride as F, ($mg\ L^{-1}$)	1.0	1.5
14	Arsenic as As, ($mg\ L^{-1}$)	0.01	0.05
15	Manganese as Mn, ($mg\ L^{-1}$)	0.1	0.3
16	Zinc as Zn, ($mg\ L^{-1}$)	5	15
17	Copper as Cu, ($mg\ L^{-1}$)	0.05	1.5
18	Chromium as Cr^{+6},($mg\ L^{-1}$)	0.05	No relaxation
19	Lead as Pb, ($mg\ L^{-1}$)	0.05	No relaxation
20	Mercury as Hg, ($mg\ L^{-1}$)	0.001	No relaxation
21	Cadmium as Cd, ($mg\ L^{-1}$)	0.01	No relaxation
22	Cyanide as Cn, ($mg\ L^{-1}$)	0.05	No relaxation
23	Minerals oil , ($mg\ L^{-1}$)	0.01	0.03
24	Phenolic compound,($mg\ L^{-1}$)	0.01	0.002
25	Coliform Organism , MPN 100ml	10.0	-
26	Residual free chlorine, ($mg\ L^{-1}$)	0.2	-
27	Pesticides , ($mg\ L^{-1}$)	Absent	0.001
28	Selenium as Se, ($mg\ L^{-1}$)	0.01	No relaxation
29	Aluminium as Al, ($mg\ L^{-1}$)	0.03	0.2
30	Boron as B, ($mg\ L^{-1}$)	1	5
31	Alkalinity ($mg\ L^{-1}$)	200	600
32	Anionic detergents ($mg\ L^{-1}$)	0.2	1.0

Table 2: Irrigation Water Standards (Prescribed by ICMR)

Sr.No	Parameters	Highest Desirable limit	Permissible limit in the absence of alternate source
1	pH	7.0 - 8.5	6.5 - 9.2
2	Colour (Hazen Unit)	5.0	25
3	Turbidity (JTU)	5.0	25
4	Odour	Unobjectionable	Unobjectionable
5	Total dissolved solids, ($mg\ L^{-1}$)	500	1500 – 3000
6	Total hardness as $CaCO_3$, ($mg\ L^{-1}$)	300	600
7	Calcium as Ca, ($mg\ L^{-1}$)	75	200
8	Magnesium as Mg, ($mg\ L^{-1}$)	50	-
9	Chloride as Cl, ($mg\ L^{-1}$)	200	1000
10	Sulphate as SO_4, ($mg\ L^{-1}$)	200	400
11	Nitrate as NO_3,($mg\ L^{-1}$)	20	100
12	Iron as Fe, ($mg\ L^{-1}$)	0.1	1.0
13	Fluoride as F, ($mg\ L^{-1}$)	1.0	1.5
14	Arsenic as As, ($mg\ L^{-1}$)	-	0.05
15	Manganese as Mn, ($mg\ L^{-1}$)	0.1	0.5
16	Zinc as Zn, ($mg\ L^{-1}$)	0.10	5
17	Copper as Cu, ($mg\ L^{-1}$)	0.05	1.5
18	Chromium as Cr^{+6},($mg\ L^{-1}$)	-	-
19	Lead as Pb, ($mg\ L^{-1}$)	-	0.05
20	Mercury as Hg, ($mg\ L^{-1}$)	-	0.001
21	Cadmium as Cd, ($mg\ L^{-1}$)	-	0.01
22	Cyanide as Cn, ($mg\ L^{-1}$)	-	0.05

***

Chapter : 3

MATERIALS AND METHODS

The present investigation entitled **'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab, India'.** For this random groundwater sample were collected from Jalalabad (west) block of the district Fazilka, Punjab, India and subsequently followed by the laboratory analysis of the water during 2017-2018 at the Rajiv Gandhi South Campus, Barkachha Mirzapur. This was done for the award of Master of Science (Agriculture) in the subject Soil Science- Soil and Water Conservation; the course is running under auspices of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India.

3.1: Site Selection and There Description

3.1.1: Hydrology of Punjab

The Punjab State is mainly underlain by unconsolidated quaternary alluvium of significant depth, which abuts against the rocks of Siwalik regions of mountain system towards North-East of Punjab. The alluvial deposits in common act as a single groundwater body except locally as unseen channels. The breadth of saturated permeable granular horizons occurs in the flood plains of rivers significantly, which are able of sustaining heavy duty tube wells. Water table is at shallow depth at several areas of the Muktsar, Ferozepur, Bathinda and Mansa districts where it ranges from 1.5 to 7.5 meter below ground level (Chopra R.P.S. and Krishan G., 2014) cause waterlogging at many places nearby cannels and deep water table at several areas of the Muktsar, Ferozepur, Bathinda and Mansa districts where it causing saline nature of water at plentiful places. The tubewells drilled in the area up to 60 m depth soil which reveals the predominance of fine sand soil. This occurs irregularly associated with "*Kankar*" and comprises of two main aquifer zones, each ranging in thickness from 4 m to 25 m removed by clay layers

of 3 m to 5 m soil thickness. Water table has been rising due to canal water supply in the area comprise blocks of Muktsar, Lambi, KotBhai, Khuiyan Sarwar, Abohar and Fazilka creating waterlogging at many places.

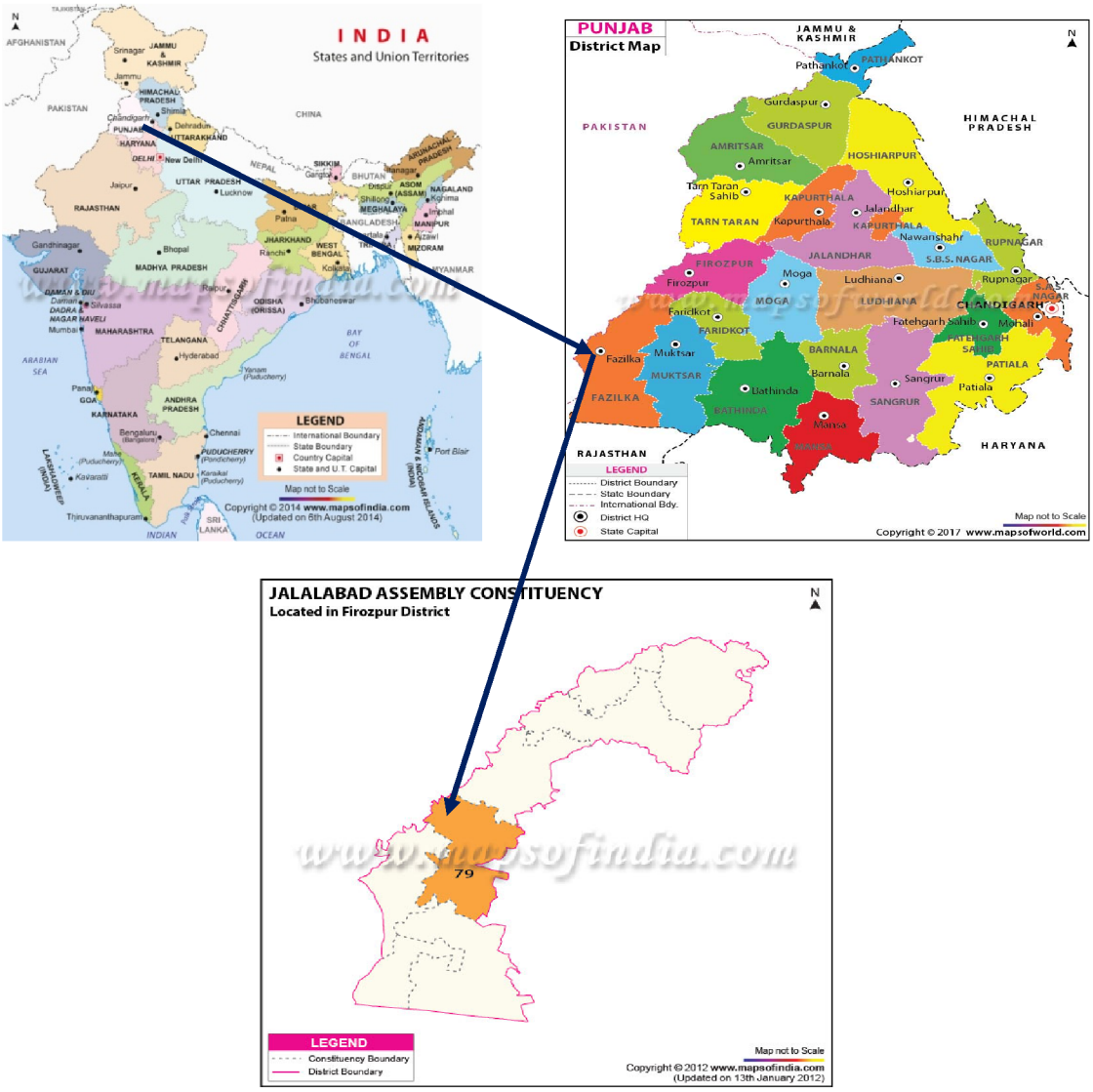
3.1.2: Hydrology of Fazilka district

The geological formations met within the district comprised of unconsolidated alluvial deposit of quaternary age. The alluvial deposit comprises of sand, silt, clay and often linked with '*Kankar'*. Fine to medium grained sand horizon form the potential aquifer in Fazilka.

The Fazilka district form a part of Sutlej River which is the major Indus basin and is interrupted by clusters of sand dunes. The district area is approximately a flat topography with a gentle slope towards south west direction. Physiographically, it is categorized by four distinct features *i.e.* the upland plain, sand dune tracts, younger flood plain and active flood plain. The river Sutlej that is of perineal nature mostly drains the area. River Sutlej showed both influent and effluent nature in the area. The area is traversed by a dense system of canals. In irrigation practices, input of tubewells are larger as compared to canal system *i.e* 137 % area irrigated by canal is being irrigated by tubewells (AQUIFER MAPPING AND MANAGEMENT PLAN, Central Groundwater Board, 2017).

3.1.3: Description of the block

Jalalabad west block, covering geographical area of 524.4 sq km and it is extend between Northan Latitude 30° 36' 60.573" N' and 30° 36' 20.6280" N and Eastern Longitudes '74° 15' 21.999" E and 74° 15' 21.611" E of the State, Punjab. The block is splited into 110 villages. Total population of Jalalabad was 173572 (Central Groundwater Board, 2017).The city has a historic name, after one of the Khans who ruled the area during the middle age epochs and graphical map of the site presented on next page.



3.2: Sampling and preservation

Groundwater samples were collected from different villages in Jalalabad west block. The samples were collected from deep tube well and it's collected before rainfall (May-June, 2018) and during rainfall (July-August, 2018) and after rainfall (September-October, 2018) from various locations and various depths (Figure 3.3). The hand pumps and tubewells were continuously pumped before to the sampling to ensure that ground water to be sampled were representative of ground water.

One liter of ground water samples were collected from different villages in Jalalabad west block. The locations and depth of sampling are given in Table 3.1. It was ensured that the concentration of different ions draft change in time that elapse

between drawing of samples analysis in laboratory. The water samples were collected in high density plastic bottles and preserved by toluene in laboratory for further analysis. All the samples were stored in sampling kits maintained temperature at between 4 to 5^{o}C.

Table 3.1: Details of the sampling site from different villages of the Jalalabad west of Fazilka District of Punjab

S. No	Site name	Block name	Source	Depth (feet)	GPS Location
1	Chak Kabarwala	Jalalabad	Tubewell	80	Lati.- 30^{0} 31.639″N Long.- 74^{0}16.727″E
2	Chak Panjkohi	Jalalabad	Tubewell	100	Lati.- 30^{0} 31.407″N Long.- 74^{0}17.093″E
3	Chak Tarewala	Jalalabad	Tubewell	70	Lati.- 30^{0} 30.629″N Long.- 74^{0}16.781″E
4	Chak Tambuwala	Jalalabad	Tubewell	85	Lati.- 30^{0} 30.772″N Long.- 74^{0}16.63″E
5	Chak Rohiwala	Jalalabad	Tubewell	110	Lati.- 30^{0} 29.973″N Long.- 74^{0}17.155″E
6	Kathgarh	Jalalabad	Tubewell	70	Lati.- 30^{0} 30.014″N Long.- 74^{0}15.39″E
7	Chak Gulam Rasool	Jalalabad	Tubewell	65	Lati.- 30^{0} 31.193″N Long.- 74^{0}15.993″E
8	Dhab Khushal Joyea	Jalalabad	Tubewell	55	Lati.- 30^{0} 31.156″N Long.- 74^{0}16.296″E
9	Chak Jand Wala	Jalalabad	Tubewell	77	Lati.- 30^{0} 31.415″N Long.- 74^{0}16.100″E
10	Ratakhera	Jalalabad	Tubewell	85	Lati.- 30^{0} 30.850″N Long.- 74^{0}16.200″E
11	Bahmniwala	Jalalabad	Tubewell	60	Lati.- 30^{0} 33.100″N Long.- 74^{0}13.719″E
12	Chak Lamochar	Jalalabad	Tubewell	40	Lati.- 30^{0} 34.009″N Long.- 74^{0}9.984″E
13	Laduka	Jalalabad	Tubewell	80	Lati.- 30^{0} 29.715″N Long.- 74^{0}7.591″E
14	Hojkhas	Jalalabad	Tubewell	90	Lati.- 30^{0} 28.079″N Long.- 74^{0}11.299″E

3.3: Chemicals and reagents

All general chemicals used in the study were of the grade of analytical reagent i.e. Merck, lobo chemical. During the entire study, doubled distilled water was used. All glassware and other containers used for analysis were carefully cleaned by soaking in detergent followed by soaking for 48 h in 10 percent chromic acid.

3.4: Chemical parameters analysis

The chemical analysis of the water samples was completed by using standard methods (APHA, 1992). The concise details of analytical methods and equipment used in the study are given in the Table-3.3 and the range of all parameters range in given in the Table-3.4.

3.4.1: Water reaction (pH)

Water reaction of the water samples was measured by using pocket pH meter (APHA, 1992).

3.4.2: Electrical Conductivity

Water samples have been measured for electrical conductivity by using pocket EC meter and expressed in dSm^{-1}.The EC can influence by temperature, therefore temperature correction was made after measuring the EC (APHA, 1992).

3.4.3: Total Dissolved Solids

Total dissolved solids (TDS) also referred to as filterable residue that represents the portion of the V sample that passes through a filter of a particular size. Generally, a pore size of 0.45 mm is considered to be adequate to differentiate between microscopic particulate and total disilvedissolved solid materials. The final result, after evaporation and drying to stable weight at 180^0C and represents the total dissolved solids. Most commonly, What-man filter paper was used for the filtration of the sample. A known volume of sample was filtered through the

prepared filter paper. The filtrate was collected in a clean flask and the filter was washed with three successive 10 mL portions of reagent grade chemicals and water which was added to the filtrate. A combination of TDS conductivity meter can provide an estimate of TDS concentration.

3.5: Cationic parameters analysis

3.5.1: Sodium (Na^+) and Potassium (K^+)

The sodium and potassium present in the water, since it is water soluble was measured easily by flame photometer method using sodium chloride and potassium chloride as standard respectively (APHA, 1992).

3.5.2: Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

The total calcium plus magnesium was determined by the titration method by using ethylene diamine tetra acetic acid (EDTA). The 10 mL of the water sample was pipette out into the conical flask and subsequently 5 mL of buffer ($NH_4OH + NH_4Cl$) solution (pH 8 to 10) and 5-6 drops of EBT (Erichrome Black-T) indicator was added and then titrated against standard EDTA (0.01 N) solution until colour changed from wine red to blue colour (APHA, 1992).

3.6: Anionic parameters analysis

3.6.1: Chloride (Cl^-)

The chlorides present in the water samples were estimated by using standard(0.02 N) silver nitrate and potassium chromate indicator (Mohr's titration method, APHA, 1992).The 10 mL of water sample was taken and transferred by pipette into conical flask which was diluted by doubled distilled water (approximately 100 mL) and added 5-6 drops of 5% K_2CrO_4 indicator. Thus, the titration of the sample prepared and was done with standard solution of 0.01 *N*

$AgNO_3$ from the burette. At the end point the colour of suspension changed from yellow to reddish brown due to presence of CrO_4^{2-} ions.

3.6.2: Carbonates (CO_3^-) and Bicarbonates (HCO_3^-)

Carbonates and bicarbonates were estimation done by a simple acidimetric titration method in water samples (APHA, 1992).The 10 mL of sample was taken in 100 mL conical flask. Thereafter, two drops of phenolphthalein indicator was added and titrated with standard H_2SO_4 (0.01 *N*) till the pink color just disappeared and the volume of standard acid was noted, and then two drops of methylred indicator was added.

Table 3.2: Chemical properties of water methods and equipment used in the study

S.N.	Parameters	Method followed	Equipment
1	pH	Electrometric	pH Meter
2	Conductivity	Electrometric	Conductivity Meter
3	Chloride	Titration by Ag NO_3 (0.01N)	Titration
4	Sodium	Flame emission spectroscopy	Flame photometer
5	Potassium	Flame emission spectroscopy	Flame photometer
6	Ca^{2+} + Mg^{2+}	Titration by EDTA (0.01 N)	Titration
7	CO_3^{--} / HCO_3^-	Titration by Std. H_2SO_4 (0.01 N)	Titration
8	SAR	Calculation	$= \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$
9	RSC	Calculation	$RSC\ (meq\ L^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$
10	KR	Calculation	$KR = \frac{Na+}{Ca^{2+} + Mg^{2+}}$
11	SSP	Calculation	$SSP = \frac{Na \times 100}{Ca + Mg + Na}$
12	PI	Calculation	$PI = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \times 100$
13	TDS	Electrometric	Pocket TDS Meter

Table-3.3: Characterization of water sample test values for different parameters

Parameter	Suitable	Moderately suitable	Not suitable
pH	6.5-8.4	0-5	>9.5
EC (dSm^{-1})	<0.7	0.7-3	>3
SAR	<10	10-18	>18
RSC($meq\ L^{-1}$)	<1.25	1.25-2.5	>2.5
HCO_3^- ($meq\ L^{-1}$)	>1.25	1.25-8.5	8.5
NO_3^-($meq\ L^{-1}$)	<5.0	5.0-30.0	>30
Cl^-($meq\ L^{-1}$)	<4.0	4.0-10.0	>10
Na^+($meq\ L^{-1}$)	<3	3-9	>9

(Source: FAO, 1994)

3.7: Quality parameters analysis

3.7.1: Sodium adsorption ratio (SAR)

SAR is a measure of alkali/sodium hazard to crops. SAR is calculated using the following formula where the concentration of all ions is in meq L^{-1}.

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

3.7.2: Residual sodium carbonate (RSC)

Water containing carbonate plus bicarbonate concentration better than the calcium plus magnesium concentration, prove as "Residual Sodium Carbonate" and calculated as under: given by Raghunath, 1987.

$$RSC\ (meq\ L^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

3.7.3: Soluble sodium percentage (SSP)

Wilcox (1955) has proposed classification scheme for rating irrigation water quality on the basis of soluble sodium percentage (SSP). The SSP was calculated by using following formula where the concentration of all ions is in meq L^{-1}:

$$SSP = \frac{Na \times 100}{Ca + Mg + Na}$$

The values of SSP less than 50 indicate good quality of water and higher values *i.e.*> 50 show that the water is unsafe for irrigation (USDA, 1954).

3.7.4: Permeability index (PI)

Permeability index was calculated by using the following formula:

$$PI = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \times 100$$

Where, all the values are in meq L^{-1} and the PI values >75 indicate excellent quality of water for irrigation. If, the PI values fall in between 25 and 75, that is indicator of good quality of water for irrigation purposes. However, if the PI values are <25, it reflect unsuitable nature of water for irrigation.

3.7.5: Kelly's ratio (KR)

Kelly's ratio was calculated by using the following expression:

$$KR = \frac{Na+}{Ca^{2+} + Mg^{2+}}$$

Where, concentrations are expressed in meq L^{-1}. The Kelly's ratio of unity or less than one is indicative of good quality of water for irrigation whereas above one is suggestive of unsuitability for agricultural purpose due to alkali hazards (Karanth, 1987).

3.7.6: Irrigation Water Quality Index (IWQI)

The various indices of water quality were derived from the primary parameters of water quality and Irrigation water quality refers to its suitability for

agricultural use. The water dissolved components concentration and composition determine their irrigation water quality. Quality of irrigation water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area. Good water quality has the potential to cause optimum yield under good soil and water management practices.

3.8: Statistical analysis

The data obtained from all the observation were statistically analyzed by using IBM-SPSS (25) statistical software. The correlation coefficient and standard deviation was also calculated by using above mentioned software.

The correlation matrix between pre monsoon, during monsoon and post monsoon periods were calculated and Figure prepared by using R Software of various parameters.

***

Chapter : 4

RESULTS AND DISCUSSION

The present investigation entitled **'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab, India'** conducted during the year 2017-18 for the awards of the Master of Science (Agriculture) in Soil Science-Soil and Water Conservation. The study was done at the Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur. The data of various characteristics have been presented in different tables and illustrated with suitable figures wherever possible. The observation recorded in the investigation, were analysed statistical and the result obtained have been presented under separate heads with suitable table and discussed critically.

4.1: Assessment of Groundwater Quality

Water containing high amount of soluble salts is unfit for irrigation. If the dominant ion is sodium, the frequently utilization of such water deteriorates soil's physical conditions which cause of soil dispersion, decreased infiltration and bad soil aeration. The excessive occurrence of soluble salts of calcium and magnesium creates a disruption in the mechanical uptake of water and plant nutrients by the osmotic pressure of the soil solution. The water samples of the study area were analyzed for pH, EC, TDS, ionic work including important cations (Calcium, Magnesium, Sodium, Calcium + Sodium and Potassium) and anions (Carbonate, Bicarbonate and Chloride), SAR, RSC, PI, KR, SSP and IWQI.

4.2: Chemical parameters of groundwater

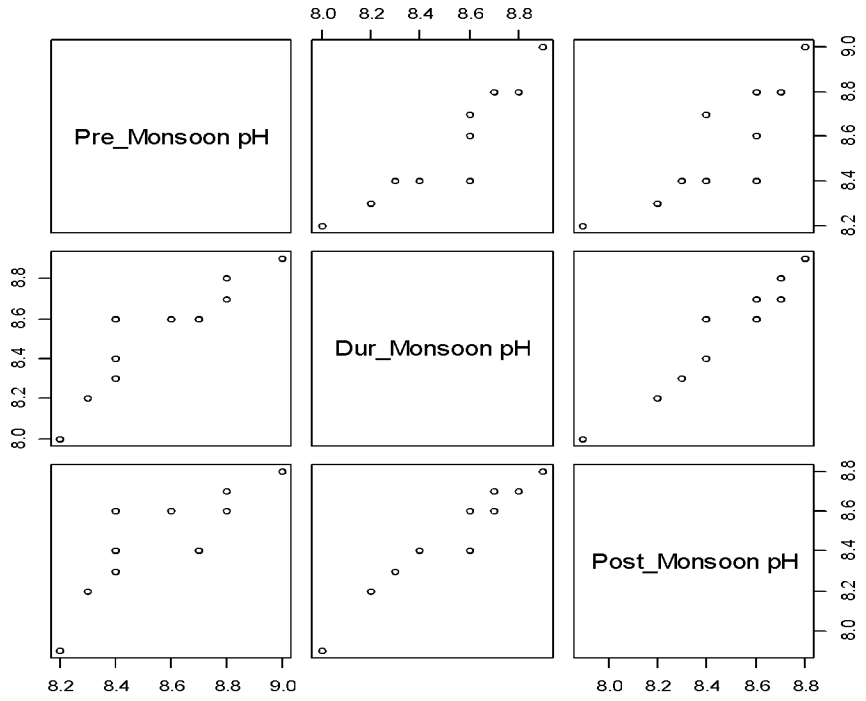
4.2.1: pH

A perusal of data presented in table 4.2 revealed that pH of groundwater of Jalalabad block varied from 8.2 to 9 with an average value of 8.54 and standard deviation was ± 0.24 during pre monsoon period. The pH of ground water during

Table 4.1: pH of groundwater of Jalalabad (West) block

Village	pH of groundwater		
	Pre Monsoon	During monsoon	Post monsoon
Chak Kabarwala	8.8	8.7	8.7
Chak Panjkohi	8.7	8.6	8.4
Chak Tarewala	8.4	8.4	8.4
Chak Tambuwala	8.4	8.3	8.3
Chak Rohiwala	8.8	8.7	8.6
Kathgarh	9.0	8.9	8.8
Chak Gulam Rasool	8.8	8.80	8.70
Dhab Khushal Joyea	8.4	8.6	8.6
Chak Jand Wala	8.4	8.4	8.4
Ratakhera	8.6	8.6	8.6
Bahmni wala	8.3	8.2	8.2
Chak Lamochar	8.2	8.0	7.90
Laduka	8.4	8.3	8.3
Hojkhas	8.4	8.4	8.2
Mean	8.54	8.49	8.44
Range	8.2 – 9.0	8.0-8.90	7.9-8.8
Standard deviation (±)	0.24	0.25	0.25
Permissible limit (WHO)		6.5 to 8.4	

Fig. 4.1: Correlation matrix of pH of groundwater of Jalalabad (West) block



monsoon varied from 8.0 to 8.9 with an average value of 8.5 and standard deviation was ± 0.25. The pH value of ground water varied from 7.9 to 8.8 with an average value of 8.44 and standard deviation was ± 0.25 during post monsoon period. Maximum value (9) was recorded in the groundwater of Kathgarh during pre monsoon period and the minimum value (7.9) was observed in Chaklamochar village during monsoon period. From the correlation matrix (Fig. 4.1) also indicated during monsoon pH of ground water reduced.

The pH of a solution is the negative common logarithm of the active hydrogen ion activity: pH = -log (H^+). In dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid –base equilibrium and, in most natural waters, is controlled by the carbondioxide -bicarbonate-carbonate equilibrium system. **Kerala, Satish *et al.* (2014)** studied the quality of groundwater and determined that the seasonal mean pH is 7.15 neutral. In post-monsoon pH ranges between 7.0 and 7.5 cover a wider area from the west to the east. In the periphery of the study area, the value was found between 7.4–7.6. The pH values of pre-monsoon were ranged of 7.0–7.3 and between 6.6 and 8.1 in most of the west and east. Similar result also coded by **Pourfallah *et al.* (2014) and they** investigated groundwater quality in Tehran, Iran and found that the pH values ranged from 6.90 to 8.37 for all samples. In all water samples studied the total mean pH was 7.67±0.25. The pH is somewhat alkalinic nature and the difference between pH and seasons were significant ($p<0.05$).

4.2.1: Electrical conductivity

A critical observation of the data presented in the table 4.2 revealed that EC of groundwater of Jalalabad block varied from 0.450 to 0.780 dS m^{-1} with an average value of 0.690 dS m^{-1} and standard deviation was ± 0.09 dS m^{-1} during pre monsoon period. EC of ground water during monsoon varied from 0.44 to 0.77 dS m^{-1} with an average value of 0.67 dS m^{-1} and standard deviation was ± 0.09 dS m^{-1}. The EC of ground water varied from 0.44 to 0.76 dS m^{-1} with an average value of 0.66 dS m^{-1} and standard deviation was ± 0.0.09 dS m^{-1} during post monsoon period. Maximum value (0.765 dS m^{-1}) was recorded in the groundwater of

Chakjandwala and Ratakhera during pre monsoon period. This showed that the EC value was found below the permissible limit which is clearly depicted in Fig. 4.2 that the EC was reduced during monsoon.

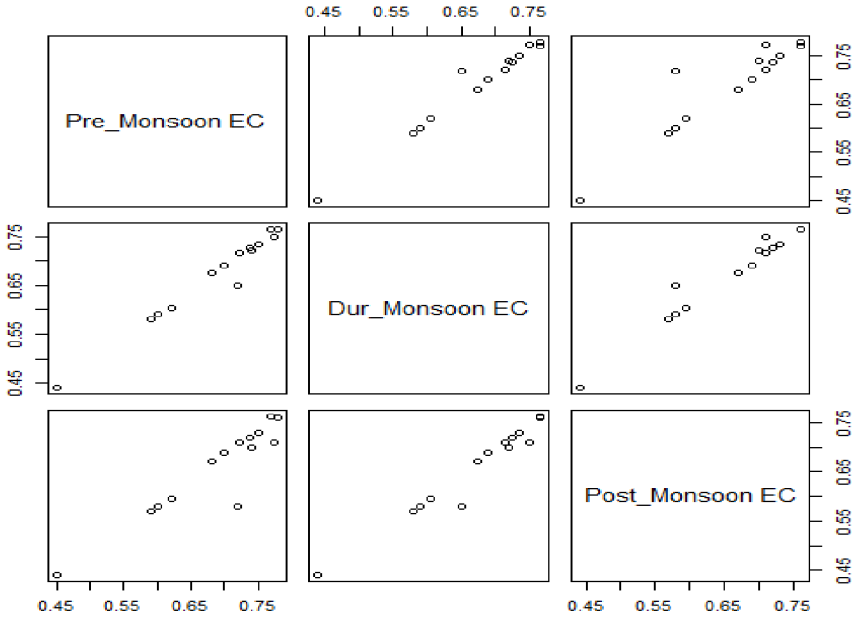
Sinha *et. al.* (2018) studied the ground water quality of Wakal river basin of Udaipur District ,Rajasthan and suggested that pH and EC values of pre monsoon period varied from 6 to 8, 0.40 to 3.20 dS m^{-1} with an mean value of 6.98, 0.96 dS $m^{-1}$for ph and EC, respectively. The .pH and EC value of post monsoon period varied from 6.5 to 7.6, 0.30 to 2.90 dS m^{-1} with a mean value of 7.1 and 0.81 dS m^{-1} for pH and EC, respectively. Around, 91.36 % area of Wakal river basin has pH ranges from 6.75 to 7.25 during post monsoon period and 97.2 % area ranges from 6.5 to 7.5 during pre monsoon period. The highest pH value observed near the village Bari in Jhadol block during both pre and post monsoon period.94.4 % study area during post monsoon period and 47 % study area during pre monsoon period ground water is not suitable for drinking purposes Because EC value is more than 0.75 dS m^{-1}.

Pathak, H. *et al.* examined the ground water quality of Sagar city of Madhya Pradesh during different months of the pre -monsoon, monsoon and post-monsoon seasons in June 2009 to June 2010 and suggested that the groundwater samples during pre- monsoon pH were ranged from 6.8 to 8.2 with an average value of 7.7. This showed that the pH is slightly alkaline and the pH of During-monsoon was ranged from 7.7 to 8.5 with an average value of 8.2. The pH of post-monsoon was ranged from 7.5 to 8.4 with an average value of 8.1.This shows pH of pre and post monsoon is highly alkaline. The data can be correlated by results of **Pourfallah *et al.* (2014)** and they investigated groundwater quality in Tehran, Iran and found that the there was a wide variation between 0.2 to 2.3 dS m^{-1} in electrical conductivity results from water samples. **Kerala, Satish *et al.* (2014)** studied the quality of groundwater and determined that the seasonal mean of the study area in the South-East was reneges between 6.6 and 7.0. The values for EC were between 1.1 and 3.0 dS m^{-1} in post-monsoon season that was found' allowable for' the irrigation water quality range as per WHO permissible limits (1995) and BIS (2003) standard.

Table 4.2: Electrical conductivity (dS m^{-1}) of groundwater of Jalalabad block

Village	EC of groundwater (dS m^{-1})		
	Pre- Monsoon	During monsoon	Post- monsoon
Chak Kabarwala	0.75	0.74	0.73
Chak Panjkohi	0.68	0.68	0.67
Chak Tarewala	0.72	0.65	0.58
Chak Tambuwala	0.70	0.69	0.69
Chak Rohiwala	0.72	0.72	0.71
Kathgarh	0.74	0.73	0.72
Chak Gulam Rasool	0.62	0.61	0.60
Dhab Khushal Joyea	0.77	0.75	0.71
Chak Jand Wala	0.78	0.77	0.76
Ratakhera	0.77	0.77	0.76
Bahmni wala	0.60	0.59	0.58
Chak Lamochar	0.45	0.44	0.44
Laduka	0.59	0.58	0.57
Hojkhas	0.74	0.72	0.70
Chak Kabarwala	0.69	0.67	0.66
Mean	0.69	0.67	0.66
Range	0.45-0.78	0.44-0.77	0.44-0.76
Standard deviation (±)	0.09	0.09	0.09
Permissible limit for irrigation		0.75-2.25	

Fig. 4.2: Correlation matrix of electrical conductivity (dS m^{-1}) of groundwater of Jalalabad block



Electrical conductivity is used for determination of total concentration of soluble salts in the groundwater. The importance of electrical conductivity is its measure of salinity which greatly affects the taste and thus has a significant impact on the user acceptance of the water as potable. The WHO permissible limit for EC in groundwater for irrigation is 0.600 dS m^{-1} and when this exceeds 3.000 dS m^{-1} it is harmful for all crops (effects on germination of seeds).

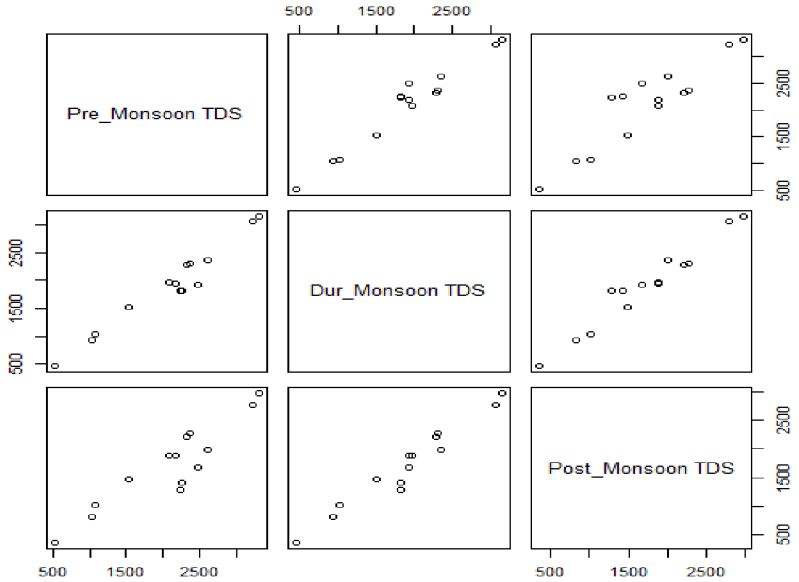
4.2.3: Total dissolved solids (TDS)

The data in the table 4.3 and Fig. 4.3 revealed that the TDS of groundwater of Jalalabad block during pre- monsoon period was ranged between 518 to 3320 meq L^{-1} with an average value of 2088.1 meq L^{-1}. The value of TDS is ranged from 460 to 3150 meq L^{-1} during monsoon season with an average value of 1899.29 meq L^{-1}. The TDS of groundwater was ranged from 350 to 2980 meq L^{-1} during post-monsoon period with an average value of 1628.07 meq L^{-1}. The lowest values of TDS between villages was observed in Chak Lamocharwala (518 meq L^{-1}) during post-monsoon season whereas highest mean value was observed in Dhab Khushal Joyea village (3320 meq L^{-1}) and all the groundwater samples was found above the standard (WHO and BIS) limit except in the Chak Gulam Rasool (1038.00, 820.00 and 935.00 meq L^{-1}) and Chak Lamochar (518.00, 350.00 and 460.00 meq L^{-1}) pre, during and post monsoon, respectively. Hence, exception rest groundwater was unfit for irrigation purpose. The standard deviation of all season was found ± 800.8, 752.07 and 666.53, respectively.

Table 4.3: TDS (meq L^{-1}) of groundwater of Jalalabad (West) block

Village	TDS of groundwater (meq L^{-1})		
	Pre- Monsoon	During monsoon	Post-monsoon
Chak Kabarwala	2360.00	2360.00	2310.00
Chak Panjkohi	1540.00	1480.00	1515.00
Chak Tarewala	2230.00	1280.00	1820.00
Chak Tambuwala	2320.00	2210.00	2280.00
Chak Rohiwala	2620.00	2620.00	2360.00
Kathgarh	2250.00	1420.00	1825.00
Chak Gulam Rasool	1067.00	1010.00	1035.00
Dhab Khushal Joyea	3320.00	2980.00	3150.00
Chak Jand Wala	2490.00	2490.00	1930.00
Ratakhera	2080.00	2080.00	1970.00
Bahmni wala	1038.00	820.00	935.00
Chak Lamochar	518.00	350.00	460.00
Laduka	2180.00	1890.00	1940.00
Hojkhas	3220.00	2780.00	3060.00
Mean	2088.10	1899.29	1628.07
Range	518-3320	460-3150	350-2980
Standard deviation (±)	800.80	752.07	663.53
Permissible limit for irrigation		500-1500	

Fig. 4.3: Correlation matrix of TDS (meq L^{-1}) of groundwater of Jalalabad (w) block



4.3: Cationic parameters of groundwater

A critical observation of the data in table 4.4 and 4.5 revealed that the cations of groundwater of Jalalabad block varied from place to place.

4.3.1: Sodium

The sodium content of groundwater of Jalalabad (West) block (Table 4.4) varied from 0.52 to 25 meq L^{-1} with an average value of 10.51 meq L^{-1} and standard deviation was ± 7.98 meq L^{-1} during pre- monsoon period. Sodium content of ground water during monsoon period was varied between 0.47 to 22.8 meq L^{-1} with an average value of 9.53 meq L^{-1} and standard deviation was ± 7.51 meq L^{-1}. Sodium content of ground water during post- monsoon period was varied from 0.43 to 20.65 meq L^{-1} with an average value of 8.03 meq L^{-1} and standard deviation was ± 6.78 meq L^{-1}. Maximum value (25 meq L^{-1}) was recorded in the groundwater of Dhab Khushal village during pre monsoon period. The permissible limit of Na in the groundwater is < 3 meq L^{-1} but several data founded more than this limit and this also clearly verified by correlation matrix depicted in the Fig. 4,4. Thus, it can say that the groundwater quality was not safe for irrigation purpose.

4.3.2: Potassium

The potassium content of groundwater of Jalalabad block (Table 4.4) varied from 0.31 to 0.92 meq L^{-1} with an average value of 0.69 meq $L^{-1}$and standard deviation was ± 0.17 meq L^{-1} during pre-monsoon period. Potassium content of groundwater during monsoon season was varied from 0.42 to 0.81 meq L^{-1} with an average value of 0.62 meq L^{-1} and standard deviation was ± 0.11 meq L^{-1}. Potassium content of ground water during post- monsoon varied from 0.26 to 0.66 meq L^{-1} with an average value of 0.52 meq L^{-1} and standard deviation was ± 0.11 meq L^{-1}. Maximum value (0.92 meq L^{-1}) was recorded in the groundwater of Chak kabar wala village during pre- monsoon period. The variability of K can also clearly verified by correlation matrix depicted in the Fig. 4.5 and all the sample was below the permissible limit (potassium < 2 meq L^{-1}).

Fig. 4.4: Correlation matrix of Na^+ content of groundwater (meq L^{-1}) of Jalalabad block

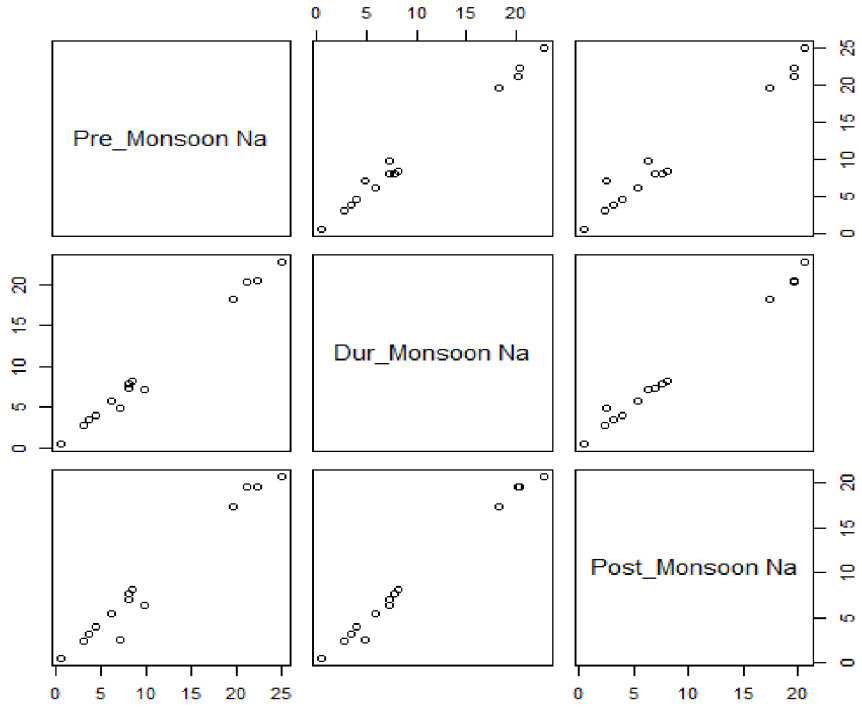
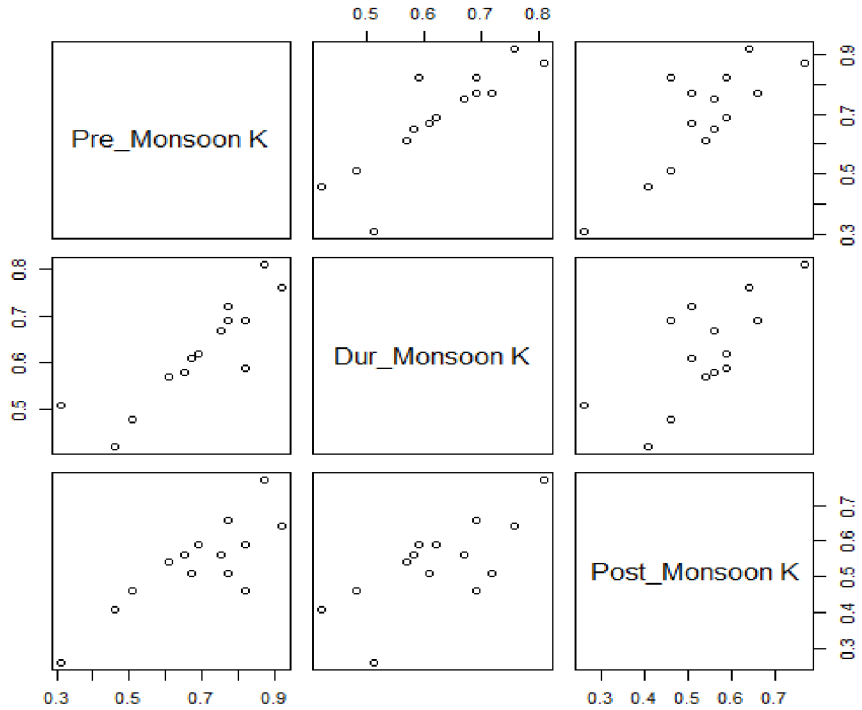


Fig. 4.5: Correlation matrix of K content of groundwater (meq L^{-1}) of Jalalabad block



4.3.3: Calcium

The calcium content of groundwater of Jalalabad block (Table 4.5 and Fig. 4.6) varied from 0.40 to 2.05 meq L^{-1} with an average value of 1.19 meq L^{-1} and standard deviation was ± 0.54 meq L^{-1} during pre-monsoon period. The Ca content of groundwater during monsoon varied from 0.3 to 1.7 meq L^{-1} with an average value of 1.04 meq L^{-1} and standard deviation was ± 0.47 meq L^{-1}. The Ca content of groundwater during post-monsoon varied from 0.25 to 1.55 meq L^{-1} with an average value of 0.89 meq L^{-1} and standard deviation of ± 0.44 meq L^{-1}. Maximum value (0.765 meq L^{-1}) was recorded in the groundwater of Chakjandwala and Ratakhera during pre- monsoon period and all the samples was below the permissible limit.

Table 4.4: Sodium and potassium content of groundwater (meq L^{-1}) of Jalalabad block

Cations	Sodium			Potassium		
Village	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon
Chak Kabarwala	21.13	20.28	19.57	0.92	0.76	0.64
Chak Panjkohi	6.09	5.80	5.35	0.82	0.59	0.59
Chak Tarewala	7.13	4.80	2.52	0.82	0.69	0.46
Chak Tambuwala	9.8	7.20	6.35	0.75	0.67	0.56
Chak Rohiwala	8.43	8.20	8.09	0.69	0.62	0.59
Kathgarh	8.04	7.80	7.57	0.61	0.57	0.54
Chak Gulam Rasool	4.48	4.01	3.91	0.67	0.61	0.51
Dhab Khushal Joyea	25.00	22.80	20.65	0.77	0.72	0.51
Chak Jand Wala	19.57	18.22	17.39	0.77	0.69	0.66
Ratakhera	8.00	7.30	6.96	0.65	0.58	0.56
Bahmni wala	3.70	3.40	3.22	0.51	0.48	0.46
Chak Lamochar	0.52	0.47	0.43	0.31	0.51	0.26
Laduka	3.04	2.75	2.39	0.46	0.42	0.41
Hojkhas	22.17	20.45	19.57	0.87	0.81	0.77
Mean	10.51	9.53	8.04	0.69	0.62	0.52
Range	0.52-25	0.47-22.8	0.43-20.65	0.31-0.92	0.42-0.81	0.26-0.66
Standard deviation (±)	7.98	7.51	6.51	0.17	0.11	0.10
Permissible limit	Sodium < 3 meq L^{-1}			Potassium < 2meq L^{-1}		

4.3.4: Magnesium

The magnesium content of groundwater of Jalalabad block (Table 4.5 and Fig. 4.7) varied from 0.4 to 2.5 meq L^{-1} with an average value of 1.40 meq L^{-1} and standard deviation was ± 0.53 meq L^{-1} during pre-monsoon period. The Mg content of groundwater during monsoon season was varied from 0.35 to 2.20 meq L^{-1} with an average value of 1.29 meq L^{-1} and standard deviation was ± 0.51 meq L^{-1}. The Mg content of groundwater during post-monsoon was varied from 0.30 to 2.05 meq L^{-1} with an average value of 1.12 meq L^{-1} and standard deviation was ± 0.45 meq L^{-1}. The maximum value (2.5 meq L^{-1}) was recorded in the groundwater of Hojkhas village during pre- monsoon period and the minimum value (0.30 meq L^{-1}) was observed in Chak Lamochar village during post- monsoon period.

4.3.5: Calcium + Magnesium

The calcium and magnesium content of groundwater of Jalalabad block (Table 4.5 and Fig. 4.8) varied from 0.45 to 3.40 meq L^{-1} with an average value of 2.03 meq L^{-1} and standard deviation was ± 0.81 meq L^{-1} during pre-monsoon period. The calcium and magnesium content of groundwater during monsoon season was varied from 0.71 to 3.75 meq L^{-1} with an average value of 2.33 meq L^{-1} and standard deviation was ± 0.90 meq L^{-1}. The calcium and magnesium content of groundwater during post-monsoon was varied from 0.60 to 3.40 meq L^{-1} with an average value of 2.03 meq L^{-1} and standard deviation was ± 0.70 meq L^{-1}.

Almost similar results for cations were also reported by various different scientists *i.e.* **Diana *et. al.* (2016) also** studied the ground water quality of south west Punjab and stated that the Na, K, Ca and Mg values of pre monsoon period varied from 3.6 to 570, 1.6 to 20.6, 1. 7 to 67.3, 0.98 to 351 mg L^{-1} with average values were 155, 5.76, 29.3, 77.2 mg L^{-1} for Na, K, Ca, Mg, respectively. The concentrations of Na, K, Ca and Mg values of post monsoon period varied from 5.4 to 680, 1.2 to 13, 22 to 14, 15.1 to 226 mg L^{-1} with mean values 238, 6.47, 60, 91.2 mg L^{-1} for Na, K, Ca and Mg, respectively. They reported that as per permissible limit, 22% samples are found doughtful to unsafe category. **Navdeep *et. al.* (2013)**

Fig. 4.6: Correlation matrix of Ca content of groundwater (meq L^{-1}) of Jalalabad block

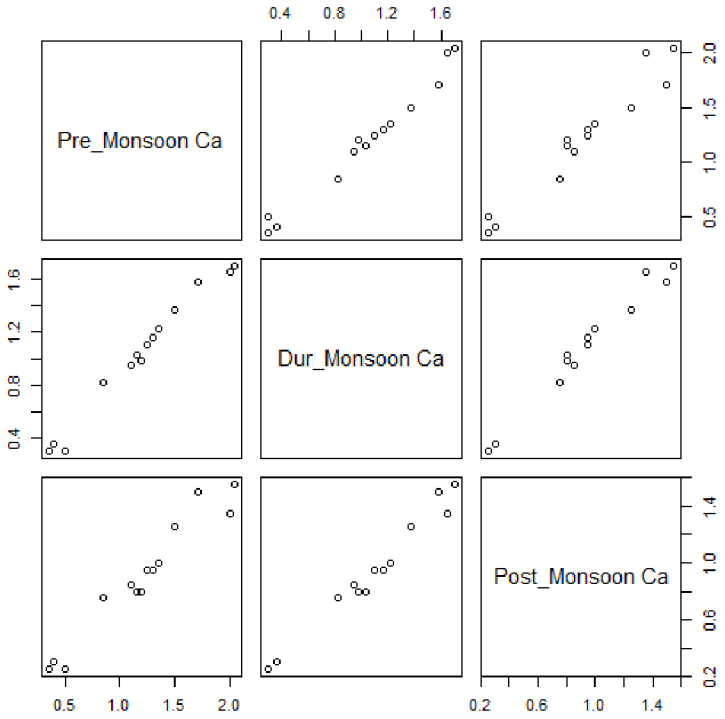


Fig. 4.7: Correlation matrix of Mg content of groundwater (meq L^{-1}) of Jalalabad block

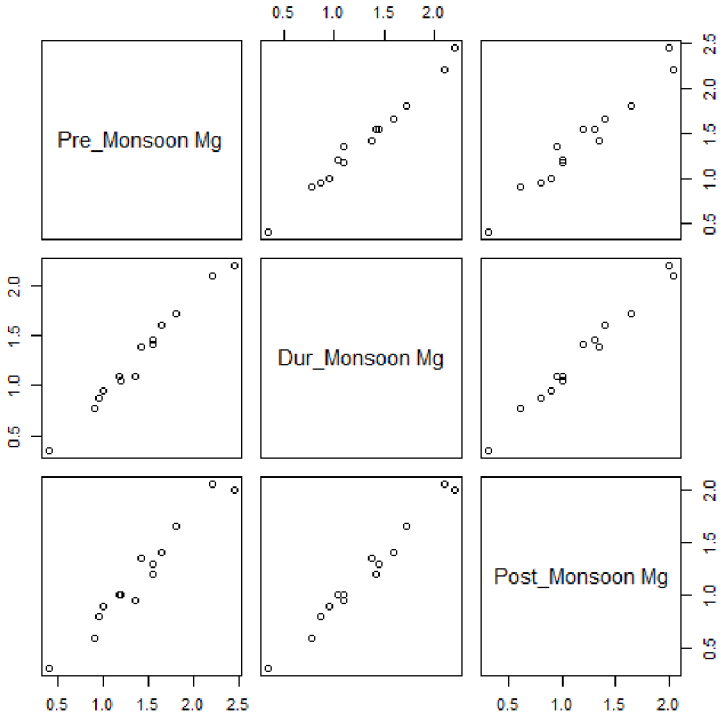
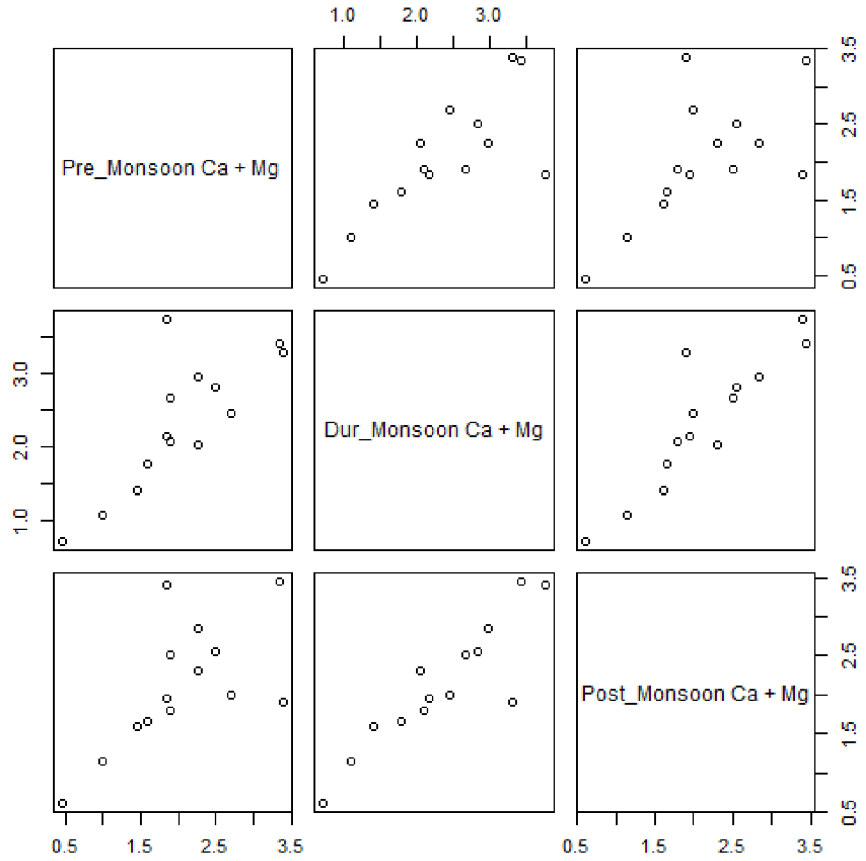


Table 4.5: Calcium, magnesi0um and calcium + magnesium content of groundwater (meq L^{-1}) of Jalalabad block

Village / Cations	Calcium			Magnesium			Calcium + Magnesium		
	Pre_Mon	**Dur_ Mon**	**Post_Mon**	**Pre_Mon**	**Dur_ Mon**	**Post_Mon**	**Pre_Mon**	**Dur_ Mon**	**Post_Mon**
Chak Kabarwala	1.30	1.16	0.95	0.95	0.87	0.80	2.25	2.03	2.30
Chak Panjkohi	1.25	1.10	0.95	1.20	1.05	1.00	1.85	2.15	1.95
Chak Tarewala	2.05	1.70	1.55	1.65	1.60	1.40	3.40	3.30	1.90
Chak Tambuwala	2.00	1.65	1.35	2.20	2.10	2.05	1.85	3.75	3.40
Chak Rohiwala	1.10	0.95	0.85	1.80	1.72	1.65	1.90	2.67	2.50
Kathgarh	1.50	1.37	1.25	1.55	1.45	1.30	2.50	2.82	2.55
Chak Gulam Rasool	0.85	0.82	0.75	1.00	0.95	0.90	1.60	1.77	1.65
Dhab Khushal Joyea	1.15	1.03	0.80	1.55	1.42	1.20	2.70	2.45	2.00
Chak Jand Wala	1.71	1.58	1.50	1.42	1.38	1.35	2.25	2.96	2.85
Ratakhera	1.20	0.98	0.80	1.18	1.10	1.00	1.90	2.08	1.80
Bahmni wala	0.40	0.30	1.50	0.90	0.78	0.60	1.00	1.08	1.15
Chak Lamochar	0.50	0.36	0.80	0.40	0.35	0.30	0.45	0.71	0.60
Laduka	0.50	0.30	0.25	1.35	1.10	0.95	1.45	1.40	1.60
Hojkhas	1.35	1.22	0.30	2.45	2.20	2.45	3.35	3.42	2.10
Mean	1.19	1.04	0.91	1.40	1.29	1.09	2.03	2.33	2.03
Range	0.4-2.1	0.30-1.70	0.25-1.55	0.4-2.5	0.35-2.20	0.30-2.05	0.45-3.40	0.71-3.75	0.60-3.40
SD (±)	0.54	0.47	0.43	0.53	0.51	0.44	0.81	0.90	0.70
Permissible limit	Calcium < 20 meq L^{-1}			Magnesium < 5 meq L^{-1}			*****		

Fig. 4.8: Correlation matrix of Ca + Mg content of groundwater (meq L^{-1}) of Jalalabad block



were also studied the groundwater quality of adjoining regions of Buddha Nallah, Punjab for different seasons of the year and stated that the Na, K, Ca and Mg values of pre- monsoon period varied from 51 to 211, 3.5 to 17.9, 34 to 125.8, 7.7 to 71.5 mg L^{-1} with mean values were found 127, 12.3, 73, 50.5 mg L^{-1} for Na, K ,Ca, Mg, respectively. Na , K, Ca and Mg concentrations during monsoon period varied from 65.3 to 234, 3.2 to 17, 34.6 to 125.2, 6.3 to 67.8 mg L^{-1} with mean values of 150.5, 11.0, 72.2, 47.8 mg L^{-1} for Na, K , Ca and Mg, respectively. The amount of Na, K, Ca and Mg values of post monsoon period varied from 55 to 218.3, 2.6 to 16.9, 33.6 to 126.3 and 7.6 to 69.6 mg L^{-1} with mean values of 131.2, 10.8, 73.1, 48.6 mg L^{-1} for Na, K , Ca and Mg, respectively. They were also reported that the percolation of water during monsoon season leads to increase in sodium in groundwater as compared to other seasons. The concentration of parameters was above the prescribed limit. So it

affect the suitability for irrigation purposes. **Sinha *et. al.* (2018)** were studied the ground water quality of wakal river basin of Udaipur District, Rajasthan and suggested that Na, K, Ca and Mg values of pre- monsoon period varied from 0.2 to 12.1, 0.0 to 1.2, 1.6 to 7, 0.8 to 14 mg L^{-1} with mean values 2.98, 0.13, 3.10, 3.25 mg L^{-1} for Na, K ,Ca, Mg, respectively. Na ,K, Ca and Mg values of Post - monsoon period varied from 0.2 to 12.1, 0.0 to 1.2, 1.6 to 7, 0.8 to 14 mg L^{-1} with mean values of 2.47, 0.01, 3.40, 1.94 mg L^{-1} for Na, K , Ca, Mg, respectively. They observed that the Mg and Ca are the most predominant cations followed by Na during pre- monsoon period. Whereas, calcium and sodium are dominant in post- monsoon period and 99% of the investigated area is within permissible limit of Ca and Mg during both pre and post monsoon period. **Gurjar *et. al.* (2017)** studied quality of groundwater for pre- monsoon and post-monsoon of Nangloi block of Delhi and stated that the Na, K, Ca and Mg values of pre monsoon period varied from 0.62 to 39.32, 0.06 to 0.85, 0.48 to 9.26, 0.86 to 27.12 mgL^{-1} with mean values of 18.70, 0.34, 4.26, 9.16 mg L^{-1} for Na, K ,Ca and Mg, respectively. The concentrations of Na ,K, Ca and Mg of post- monsoon period varied from 0.61 to 38.97, 0.05 to 0.83, 0.45 to 9.18 and 0.79 to 26.92 mg L^{-1} with mean concentration values of 18.45, 0.32, 4.18, 9.08 mg L^{-1} for Na, K , Ca and Mg, respectively. All cations concentration was in decreasing trend due to decrease in salinity of water.

4.4: Anionic parameters of groundwater

The anionic composition of groundwater of Jalalabad (West) block is presented in table 4.6.

4.4.1: Carbonate

The carbonate content of groundwater of Jalalabad west block (Table 4.6) varied from 1.2 to 5.6 meq L^{-1} with an average value of 2.92 meq L^{-1} and standard deviation was ± 1.44 meq L^{-1} during pre-monsoon period. The carbonate content of groundwater during monsoon period was varied from 1.1 to 3.80 meq L^{-1} with an average value of 2.41 meq L^{-1} and standard deviation was ± 1.07 meq L^{-1}. The carbonate content of

groundwater during post-monsoon was varied from 1.20 to 4 meq L^{-1} with an average value of 1.97 meq L^{-1} and standard deviation was ± 0.93 meq L^{-1}.

The maximum value (5.6 meq L^{-1}) was recorded in the groundwater of Chak Rohiwala village during pre-monsoon period and the minimum value (0.80 meq L^{-1}) was observed in Chak Lamochar village during pre- monsoon period. The variability of carbonate can also clearly verified by correlation matrix depicted in the Fig. 4.9 and all the sample was below the permissible limit, except some groundwater sample (carbonate < 3 meq L^{-1}).

4.4.2: Bicarbonate

The bicarbonate content of groundwater of Jalalabad west block (Table 4.6) was varied from 5.60 to 16 meq L^{-1} with an average value of 9.86 meq $L^{-1}$and standard deviation was ± 2.35 meq L^{-1} during pre-monsoon period. The bicarbonate content of groundwater samples during monsoon period varied from 4.80 to 15.4 meq $L^{-1}$with an average value of 9.01 meq L^{-1} and standard deviation was ± 2.45 meq L^{-1}. This content of groundwater during post-monsoon season was varied between 4 to 14.80 meq L^{-1} with an average value of 8.46 meq L^{-1} and standard deviation was ± 2.65 meq L^{-1}. The maximum value (16 meq L^{-1}) was recorded in the groundwater of Laduka village during pre-monsoon period. The variability of bicarbonate can also clearly verified from correlation matrix depicted in the Fig. 4.10 and most of the samples was below the permissible limit, except some groundwater sample (bicarbonate < 10 meq L^{-1}).

4.4.3: Chloride

The chloride content of groundwater of Jalalabad west block (Table 4.6) was varied between 2.4 to 46 meq L^{-1} with an average value of 20 meq L^{-1} and standard deviation was ± 12.95 meq L^{-1} during pre-monsoon period. The chloride content of groundwater during monsoon period was varied from 2.25 to 25.40 meq L^{-1} with an average value of 15.82 meq L^{-1} and standard deviation was ± 8.79 meq L^{-1}. Chloride content of groundwater during post-monsoon season was varied from 1.60 to 19.20 meq L^{-1} with an average value of 11.05 meq L^{-1} and standard deviation was ± 6.63 meq L^{-1}.

Maximum value (46 meq L^{-1}) was recorded in the groundwater sample of Dhab Khushal Joyea village during pre-monsoon period. The variability of chloride can also clearly verified from correlation matrix depicted in the Fig. 4.11 and most of the samples was above the permissible limit, except some groundwater sample (chloride < 4 meq L^{-1}).

From the data (Table 4.6), the anionic parameters of the selected site obviously showed that the carbonate, bicarbonate and chloride content was high during pre-monsoon and subsequently reduced during monsoon and post monsoon periods. In case of carbonate and bicarbonate, most of the samples was found within the permissible limit except some samples but chloride content was found very high in all the monsoon seasons. Similar results were also reported by different scientists as under:

Diana *et. al.* (2016) were studied the groundwater quality of south west Punjab and stated that the chloride and bicarbonate values of pre -monsoon period was varied from 14.2 to 1278.0 and 115.0 to 815.0 mg L^{-1} with an mean value of 288.0 and 413.0 mg L^{-1}, respectively. The chloride and bicarbonate value of post monsoon period was varied from 42.6 to 788.0 and 150.0 to 780.0 mg L^{-1} with a mean value of 293.0 and 423.0 mg L^{-1}, respectively.

Sinha *et. al.* (2018) were studied the groundwater quality of Wakal river basin of Udaipur District, Rajasthan and suggested that the Cl^-, CO_3^- and HCO_3^- contents was found during pre monsoon period between 2.8 to 19.5, 0.0 to 4.2, 0.0 to 5.2 mg L^{-1} with an mean value of 4.92, 0.24, 1.58 mg L^{-1}, respectively. The Cl^-, CO_3^- and HCO_3^- values of post- monsoon period was varied from 1.5 to 13.5, 0.0 to 2.0, 0.4 to 5.5 mg L^{-1} with a mean value of 3.69, 0.05, 1.65 mg L^{-1}, respectively. They were reported that the 0.99 % of study area have HCO_3^- value less than 3.5 mg L^{-1} for both the pre and post monsoon season. The highest Cl^- value was found in the village Bira of Jhadol block during pre monsoon and the village Kotra during post monsoon period.

Navdeep *et. al.* (2013) were studied the groundwater quality of adjoining regions of Buddha Nallah, Punjab for different seasons of the year and stated that chloride values of pre -monsoon period was varied from 200 to 340 mg L^{-1} with an

Table 4.6: Carbonate, bicarbonate and chloride content of groundwater (meq L^{-1}) of Jalalabad block.

Village /Anions	Carbonate			Bicarbonate			Chloride		
	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon
Chak Kabarwala	4.00	3.00	2.00	9.20	8.8	8.40	31.60	25.4	15.20
Chak Panjkohi	3.60	2.55	2.00	8.40	8.3	8.00	16.40	12.2	7.20
Chak Tarewala	2.00	1.80	1.60	8.80	6.9	5.60	30.40	15.4	5.60
Chak Tambuwala	1.80	1.70	1.60	9.40	8.3	7.60	9.60	7.3	15.60
Chak Rohiwala	5.60	4.20	3.60	9.60	9.3	8.80	30.00	22.8	18.40
Kathgarh	2.80	2.50	2.00	8.80	6.6	5.60	29.60	24.4	16.80
Chak Gulam Rasool	4.40	4.20	4.00	10.80	9.9	9.20	6.40	5.8	5.20
Dhab Khushal Joyea	2.80	2.30	2.00	11.60	10.4	9.60	46.00	32.3	19.20
Chak Jand Wala	5.20	3.80	1.20	9.65	8.9	8.40	25.60	22.2	17.60
Ratakhera	2.80	2.60	2.40	10.65	10.5	10.40	14.40	14.25	14.00
Bahmni wala	1.60	1.45	1.20	11.60	10.3	9.60	3.20	2.25	2.00
Chak Lamochar	1.20	1.10	0.80	5.60	4.8	4.00	2.40	9.9	1.60
Laduka	1.50	1.35	1.20	16.00	15.4	14.80	10.40	8.1	5.20
Hojkhas	1.60	1.20	0.80	8.00	7.8	7.60	24.00	19.2	16.00
Mean	2.92	2.41	1.93	9.86	9.01	8.44	20.00	15.82	10.79
Range	1.2-5.6	1.10-3.80	1.20-4.0	5.6-16	4.80-15.40	4-14.80	2.4-46	4.20-14.40	1.60-19.20
SD (±)	1.44	1.07	0.91	2.35	2.45	2.55	12.95	8.79	6.44
Permissible limit	Carbonate < 3 meq L^{-1}			Bicarbonate < 10 meq L^{-1}			Chloride < 4 meq L^{-1}		

Fig. 4.9: Correlation matrix of carbonate content of groundwater (meq L^{-1}) of Jalalabad block

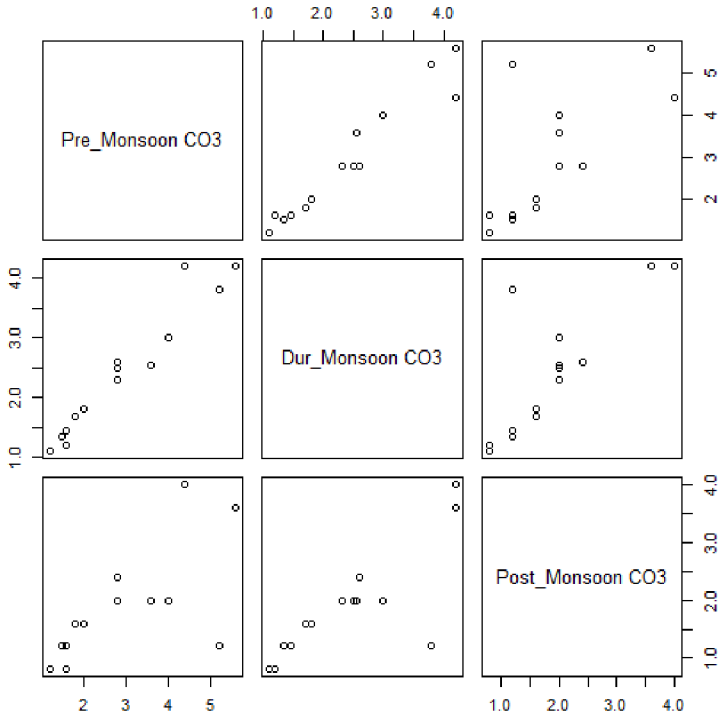


Fig. 4.10: Correlation matrix of bicarbonate content of groundwater (meq L^{-1}) of Jalalabad block

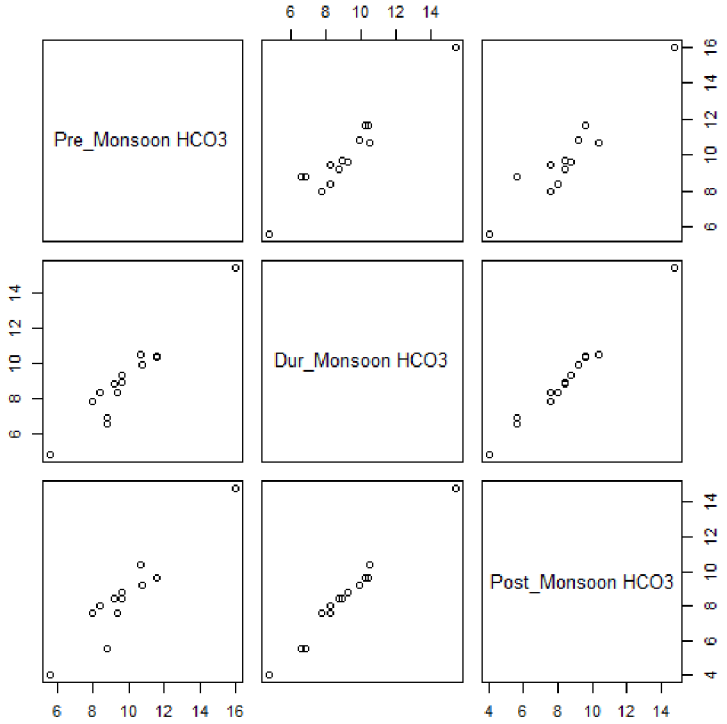
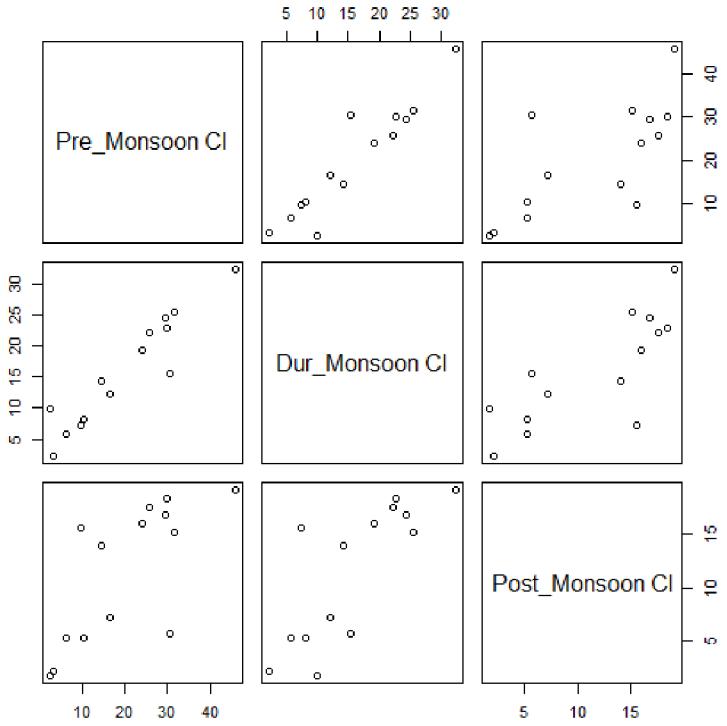


Fig. 4.11: Correlation matrix of Cl content of groundwater (meq L^{-1}) of Jalalabad block



mean value of 269.0 mg L^{-1} and during monsoon period was varied from 195.0 to 328.0 mg L^{-1} with an mean value of 255.7 mg L^{-1} and post-monsoon period was varied from 199.0 to 335.0 mg L^{-1} with an mean value of 26.0 mg L^{-1}. They reported the concentration of chloride was above the prescribed limit that is why it can affect the suitability for irrigation purposes.

Gurjar *et. al.* (2017) were studied the quality of groundwater for pre-monsoon and post- monsoon of Nangloi block of the Delhi and stated that Cl^- and HCO_3^- values of pre monsoon period was varied from 0.72 to 68.58, 4.52 to 12.26 mg L^{-1} with an mean value of 19.91 and 8.66 mg L^{-1}, respectively. The chloride and bicarbonate value of post monsoon period was varied from 0.79 to 68.45 and 4.58 to 12.32 mg L^{-1} with a mean value of 19.85 and 8.70 mg L^{-1}, respectively.

4.5: Irrigation water quality parameters

4.5.1: Sodium adsorption ratio

The SAR content of groundwater of Jalalabad west block (Table 4.7) was varied from 1.10 to 21.5 with an average value of 8.41 and standard deviation was ± 6.19 meq L^{-1} during pre-monsoon period. This SAR content of groundwater during monsoon period was varied from 0.79 to 20.6 with an average value of 8.55 and standard deviation was ± 6.46. The SAR content of groundwater during post-monsoon was varied from 0.79 to 20.65 with an average value of 7.66 and standard deviation was ± 6.21. The maximum value (21.5) was recorded in the groundwater of the Dhab Khushal Joyea village during pre monsoon period. Most of the samples was below the permissible limit, except some groundwater sample (SAR < 10). The variability of SAR also clearly verified from correlation matrix depicted in the Fig. 4.12.

4.5.2: Residual Sodium Carbonate

The RSC content of groundwater of Jalalabad west block (Table 4.7) was varied from 4.95 to 15.8 meq L^{-1} with an average value of 10.23 meq L^{-1} and standard deviation was ± 3.13 meq L^{-1} during pre- monsoon period. The RSC content of groundwater during monsoon period was varied from 5.19 to 12.28 meq L^{-1} with an average value of 9.09 meq L^{-1} and standard deviation was ± 3.02 meq L^{-1}. The RSC content of groundwater during post monsoon was varied from 4.20 to 14.40 meq L^{-1} with an average value of 8.41 meq L^{-1} and standard deviation was ± 2.97 meq L^{-1}. The maximum value (15.8 meq L^{-1}) was recorded in the groundwater of the Laduka village during pre monsoon period. Almost all the samples was above the permissible limit, except some groundwater sample (RSC <1.25 meq L^{-1}). The variability of SAR can also clearly verify from correlation matrix depicted in the Fig. 4.13.

4.5.3: Permeability index

The PI of groundwater of the Jalalabad west block (Table 4.7) was varied from 95.9 to 297.2 with an average value of 127.94 and standard deviation was ± 52.08 during pre monsoon period. The PI of groundwater during monsoon period varied from 91.7 to 225.5 with an average value of 119.18 and standard deviation

was ± 36.73. The PI content of groundwater during post monsoon was varied from 93.40 to 235.29 with an average value of 123.97 and standard deviation was ± 38.30. The maximum PI value (297.2) was recorded in the groundwater of the Chak Lamochar village during pre monsoon period and the minimum value (91.7) was observed in the Chak Tarewala village during monsoon period. All the samples was above the permissible limit (PI = 25-75). The variability of SAR can be also clearly verified from correlation matrix depicted in the Fig. 4.14.

4.5.4: Kellys ratio

The KR of groundwater of Jalalabad west block (Table 4.8) varied from 1.16 to 9.3 with an average value of 4.03 and standard deviation was ± 2.52 during pre monsoon period. KR of groundwater during monsoon period was varied from 0.66 to 9.99 with an average value of 3.92 and standard deviation was ± 2.87. The KR of groundwater during post monsoon was varied from 0.72 to 10.33 with an average value of 3.72 and standard deviation was ± 2.88. The maximum KR value (10.33) was recorded in the groundwater of Dhabkhushaljoyea village during post monsoon period. Almost all the samples was above the permissible limit, except some groundwater sample (KR <1.0). The variability of KR can be also clearly verified from correlation matrix depicted in the Fig. 4.15.

4.5.5: SSP (soluble sodium percentage)

The SSP of groundwater of the Jalalabad west block (Table 4.8) was varied from 53.69 to 90.25% with an average value of 75.59% and standard deviation was ± 11.02% during pre monsoon period. The SSP groundwater during monsoon period was varied from 39.83 to 90.90% with an average value of 73.50 % and standard deviation was ± 13.54%. The SSP of groundwater during post monsoon was varied from 42.02 to 91.17% with an average value of 72.20% and standard deviation was ± 13.76%. Maximum value (91.17%) was recorded in the groundwater of the Dhab Khushal Joyea village during post- monsoon period and the minimum value (39.83%) was observed in the Chak Lamochar village during monsoon period. Almost all the samples was above the permissible limit (SSP = 20-40%), except some groundwater sample. The variability of SAR can be also clearly verified from correlation matrix depicted in the Fig. 4.16.

4.5.6: IWQI (Irrigation water quality index)

The IWQI of groundwater of Jalalabad west block (Table 4.8) was varied from 175.67 to 359.52 with an average value of 226.19 and standard deviation was ± 44.12 during pre monsoon period. The IWQI of groundwater during monsoon period was varied from 161.54 to 271.97 with an average value of 214.24 and standard deviation was ± 30.23. The IWQI of groundwater during post monsoon season was varied from 171.06 to 283.03 with an average value of 215.35 and standard deviation was ± 29.65. Maximum value (359.51) was recorded in the groundwater of the Chak Lamochar village during pre monsoon period and the minimum value (161.54) was observed in the Chak Tare Wala village during monsoon period. The variability of IWQI can be also clearly verified from correlation matrix depicted in the Fig. 4.16.

On the basis of the data for IWQI parameter i.e. SAR, RSC, PI, KR, SSP and IWQI, it can say that the IWQI of the selected groundwater samples of the Jaladad west block is not safe for irrigation purpose, respectively. This is because, most of the samples was below the permissible limit, except some groundwater sample (SAR < 10), almost all the samples was above the permissible limit, except few groundwater sample (RSC <1.25 meq L^{-1}), all the samples was above the permissible limit (PI = 25-75), almost all the samples was above the permissible limit, except a little groundwater sample (KR <1.0), almost all the samples was above the permissible limit (SSP = 20-40%), except some groundwater sample. All the sample of groundwater of the Jalalabad west block of the district Fazilka, Punjab was not found suitable for irrigation purpose. This result can be correlated of different scientists similarly *i.e.* Sinha *et.al.* (2018) has analyzed groundwater quality from the Wakal River Basin in Udaipur, Rajasthan, Anurika *et.al.* (2015) were examined irrigation groundwater around Sanganer Tehsil, Jaipur, Rajasthan, Dheeraj *et.al.* (2018) investigated groundwater quality in the Upper Berach Basin, Rajasthan, Islam and Shamsad (2009) have researched water quality of the Bogra district in Bangladesh., Shreya and Nag (2015) evaluated the quality of groundwater of SuriI and II blocks in Birbhum, West Bengal and Guettaf *et. al.* (2017) examined the water quality status of Seybouse River, in the northeast of Algeria.

According to Abbas *et. al.* (2018) were conducted study to evaluate the groundwater quality and its suitability for irrigation purpose through GIS in villages of Chabahr city, Sistan and Baluchistan province in Iran. Groundwater quality parameter for irrigation purpose, if the IWQI within the limit, it can categorized as fallowing:

1. <50 Excellent for Irrigation
2. 50 to 99.99 Good for Irrigation
3. 100 to 199.99 Poor for Irrigation
4. 200 to 299.99 Very Poor for Irrigation
5. > 300.0 Not Suitable for Irrigation

In this study, it was found that the groundwater of the Jalalabad west block of the district Fazilka, Punjab comes under very deprived or not suitable for irrigation purpose.

Fig. 4.12: Correlation matrix of SAR content of groundwater (meq L^{-1}) of Jalalabad block

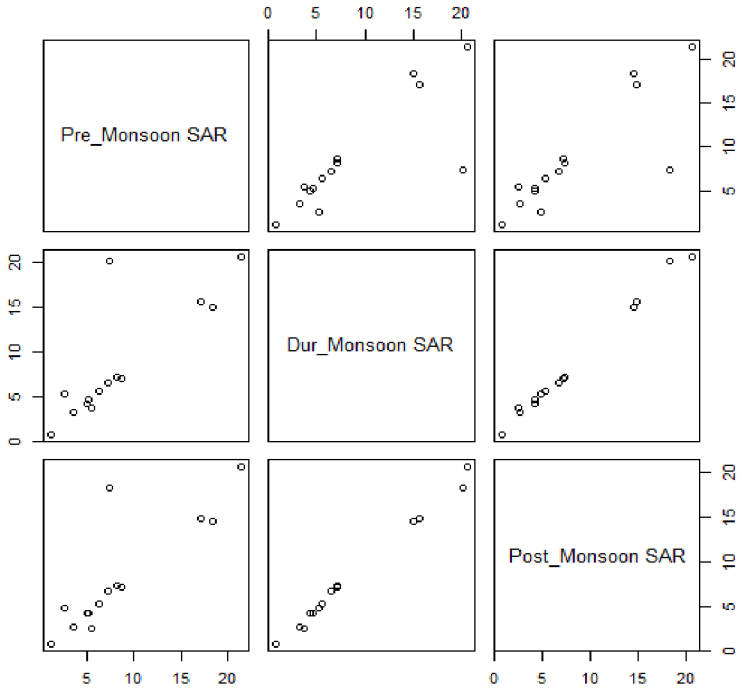


Fig. 4.13: Correlation matrix of RSC content of groundwater (meq L^{-1}) of Jalalabad block

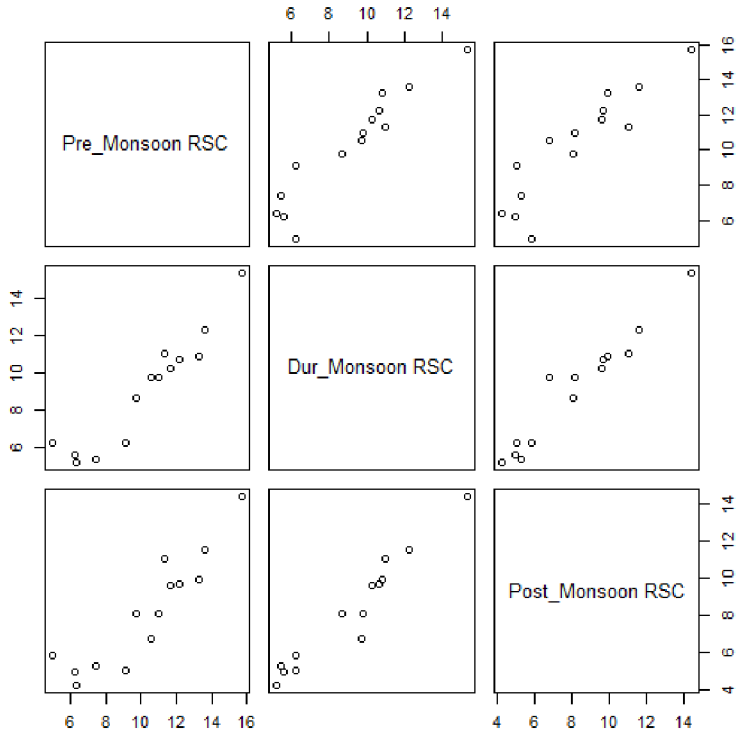


Fig. 4.14: Correlation matrix of PI content of groundwater (%) of Jalalabad block

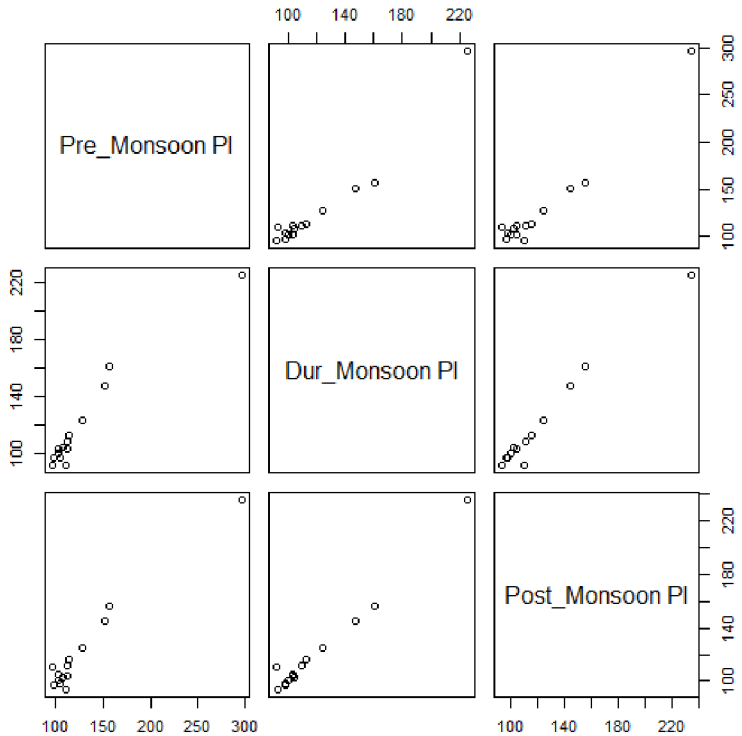


Table 4.7: SAR, RSC and PI of groundwater of Jalalabad west block

Village /IWQI Parameteres	SAR			RSC (meq L^{-1})			PI		
	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon
Chak Kabarwala	7.38	20.13	18.24	10.95	9.77	8.10	107.77	104.20	102.74
Chak Panjkohi	6.33	5.59	5.42	9.75	8.65	8.05	112.33	109.09	112.04
Chak Tarewala	5.47	3.74	2.59	7.40	5.40	5.30	95.88	91.69	110.55
Chak Tambuwala	2.53	5.26	4.87	4.95	6.25	5.80	110.04	92.06	93.40
Chak Rohiwala	8.65	7.10	7.23	13.30	10.83	9.90	111.60	103.49	104.41
Kathgarh	7.19	6.57	6.70	9.10	6.23	5.05	104.42	97.55	98.19
Chak Gulam Rasool	5.01	4.26	4.31	13.60	12.28	11.55	127.74	123.68	124.86
Dhab Khushl Joyea	21.52	20.60	20.65	11.70	10.25	9.60	102.55	103.07	104.85
Chak Jand Wala	18.45	14.98	14.57	10.55	9.74	6.75	102.32	100.11	100.24
Ratakhera	8.21	7.16	7.33	11.30	11.02	11.00	113.38	112.37	116.27
Bahmni wala	5.23	4.63	4.24	12.20	10.67	9.65	151.24	147.53	144.61
Chak Lamochar	1.10	0.79	0.79	6.35	5.19	4.20	297.22	225.50	235.29
Laduka	3.57	3.29	2.67	15.75	15.35	14.40	156.75	160.83	156.30
Hojkhas	17.13	15.64	14.90	6.25	5.58	4.95	97.96	97.37	96.99
Mean	8.41	8.55	7.84	10.23	9.09	8.38	127.94	119.18	123.15
Range	1.1-21.5	0.79-20.60	0.79-20.65	5-15.8	5.19-12.28	4.20-14.40	95.9-297.2	91.69-225.50	93.40-235.29
SD (±)	6.31	6.46	6.01	3.13	3.02	2.86	52.08	36.73	36.81
Permissible limit		SAR <10			RSC <1.25 meq L^{-1}			PI = 25-75	

Fig. 4.15: Correlation matrix of KR content of groundwater of Jalalabad block

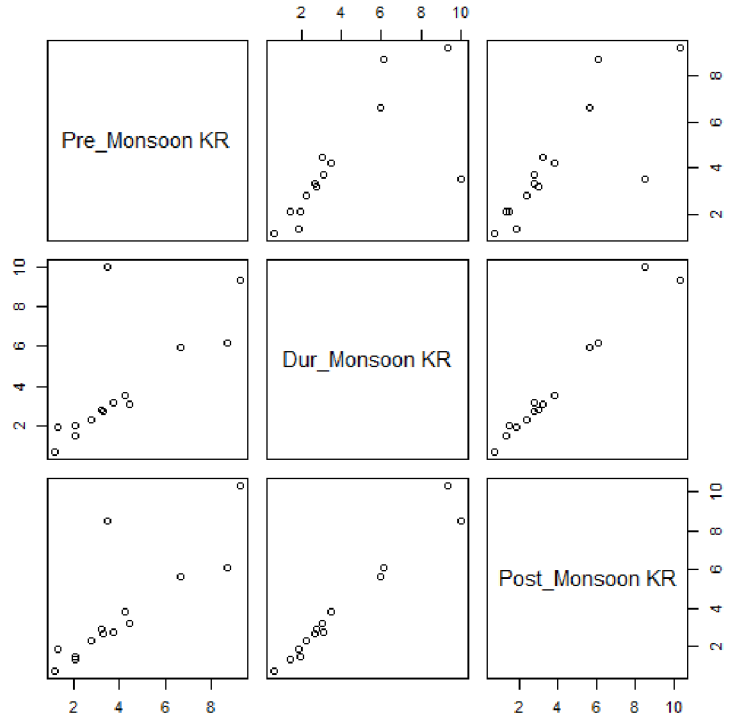


Fig. 4.16: Correlation matrix of SSP content of groundwater of Jalalabad block

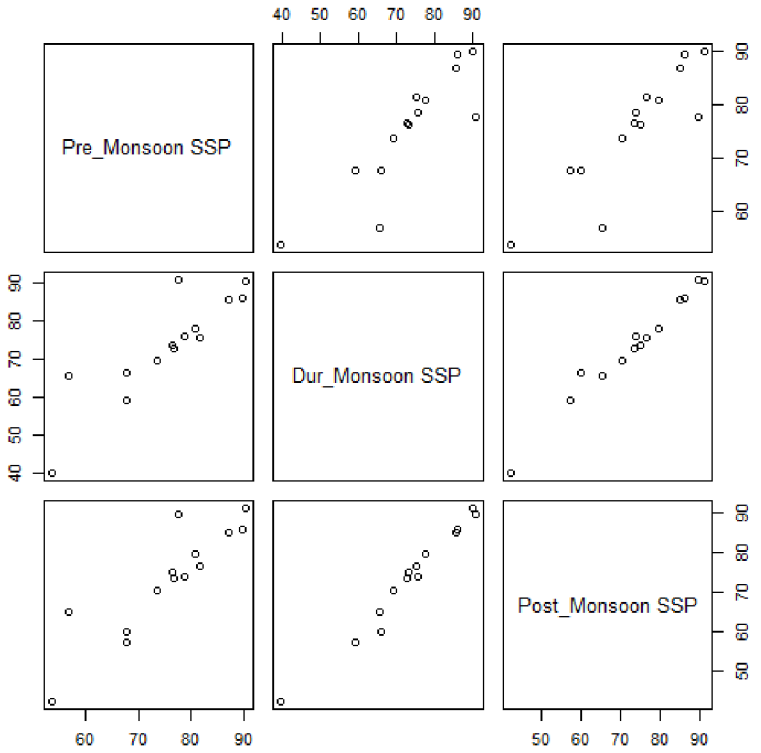
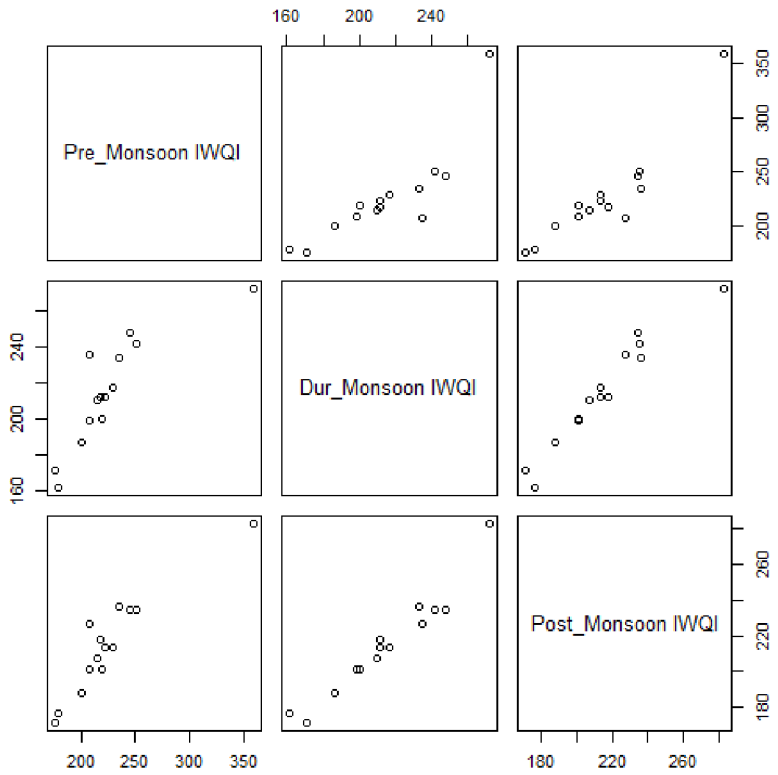


Table 4.8: KR, SSP and IWQI content of groundwater of Jalalabad (West) block

Village /Quality Parameteres	KR			SSP %			IWQI		
	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon	Pre_Mon	Dur_ Mon	Post_Mon
Chak Kabarwala	3.48	9.99	8.51	77.67	90.90	89.48	207.249	234.99	227.07
Chak Panjkohi	3.29	2.70	2.74	76.69	72.96	73.28	208.388	198.82	201.52
Chak Tarewala	2.10	1.45	1.33	67.71	59.26	57.03	178.5618	161.54	176.79
Chak Tambuwala	1.32	1.92	1.87	56.82	65.75	65.12	175.6653	171.25	171.06
Chak Rohiwala	4.44	3.07	3.23	81.62	75.44	76.39	219.6044	199.93	201.16
Kathgarh	3.22	2.77	2.97	76.29	73.45	74.79	200.2247	186.56	187.69
Chak Gulam Rasool	2.80	2.27	2.37	73.68	69.38	70.34	222.8262	211.86	213.43
Dhab Khushal Joyea	9.26	9.31	10.33	90.25	90.30	91.17	235.2768	233.52	236.60
Chak Jand Wala	8.70	6.16	6.10	89.69	86.02	85.92	229.7012	217.01	213.58
Ratakhera	4.21	3.51	3.86	80.81	77.83	79.44	217.9093	211.88	217.91
Bahmni wala	3.70	3.15	2.80	78.70	75.89	73.67	251.0621	241.87	234.97
Chak Lamochar	1.16	0.66	0.72	53.69	39.83	42.02	359.5173	271.97	283.03
Laduka	2.10	1.96	1.49	67.73	66.27	59.91	245.9033	247.69	234.78
Hojkhas	6.62	5.98	5.67	86.88	85.67	85.01	214.8337	210.24	207.52
Mean	4.03	3.92	3.89	75.59	73.50	71.70	226.19	214.24	214.99
Range	1.2-9.3	0.66-9.99	0.72-10.33	53.7-90.3	39.83-90.9	42.02-91.17	175.7-359.5	161.5-272	171.06-283.03
SD (±)	2.52	2.87	2.85	11.02	13.54	13.35	44.12	30.23	28.52
Permissible limit		KR <1.0			SSP = 20-40%			IWQI = 50-300	

Fig. 4.17: Correlation matrix of IWQI content of groundwater of Jalalabad west block



4.6: Correlation coefficient

The data of chemical properties are available in the table 4.9 significantly highly correlated among themselves by Pearson correlation coefficient between pre, during and post monsoon. The data cationic properties available in the table 4.10 is also significantly highly correlated among themselves by Pearson correlation coefficient between pre, during and post monsoon. The data anionic properties available in the table 4.11 is also significantly correlated among themselves by Pearson correlation coefficient between pre, during and post monsoon. The data groundwater quality parameters available in the table 4.12 is also significantly correlated among themselves by Pearson correlation coefficient between pre, during and post monsoon.

Table 4.9: Pearson correlation coefficient between pre, during and post monsoon (pH, EC and TDS)

Parameters / Season		pH			EC			TDS		
		Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon
Pre_ Mon	pH	1.00								
Dur_Mon		0.927**	1.00							
Post_ Mon		0.835**	0.961**	1.00						
Pre_ Mon	EC				1.00					
Dur_Mon					0.984**	1.00				
Post_ Mon					0.916**	0.966**	1.00			
Pre_ Mon	TDS							1.00		
Dur_Mon								0.978**	1.00	
Pre_ Mon								0.827**	0.871**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.10: Pearson correlation coefficient between pre, during and post monsoon (cations)

Parameters / Season		Na			K			Ca			Mg			Ca+Mg		
		Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon	Pre_ Mon	Dur_Mon	Post_ Mon
Pre_ Mon	Na	1.00														
Dur_Mon		0.995**	1.00													
Post_ Mon		0.890**	0.904**	1.00												
Pre_ Mon	K				1.00											
Dur_Mon					0.862**	1.00										
Post_ Mon					0.774**	0.539*	1.00									
Pre_ Mon	Ca							1.00								
Dur_Mon								0.989**	1.00							
Post_ Mon								0.969**	0.984**	1.00						
Pre_ Mon	Mg										1.00					
Dur_Mon											0.993**	1.00				
Post_ Mon											0.805**	0.849**	1.00			
Pre_ Mon	Ca+Mg													1.00		
Dur_Mon														0.797**	1.00	
Post_ Mon														0.487	0.830**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.11: Pearson correlation coefficient between pre, during and post monsoon (anions)

Parameters / Season		CO_3^-			HCO_3^-			Cl^-		
		Pre_ Mon	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**
Pre_ Mon	CO_3^-	1.00								
Dur_Mon		0.967**	1.00							
Post_ Mon		0.629*	0.737**	1.00						
Pre_ Mon	HCO_3^-				1					
Dur_Mon					0.965**	1.00				
Post_ Mon					0.913**	0.984**	1.00			
Pre_ Mon	Cl^-							1.00		
Dur_Mon								0.939**	1.00	
Post_ Mon								0.721**	0.785**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.12: Pearson correlation coefficient between pre, during and post monsoon (quality parameters)

		SAR			RSC			PI			KR			SSP			IWQI		
		Pre_ Mon	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**	**Pre_ Mon**	**Dur_Mon**	**Post_ Mon**
Pre_ Mon	SAR	1.00																	
Dur_Mon		0.81**	1.00																
Post_ Mon		0.75**	0.94**	1.0															
Pre_ Mon	RSC				1.00														
Dur_Mon					0.94**	1.00													
Post_ Mon					0.84**	0.91**	1.0												
Pre_ Mon	PI							1.0											
Dur_Mon								0.96**	1.0										
Post_ Mon								0.963**	0.973**	1.0									
Pre_ Mon	KR										1.0								
Dur_Mon											0.72**	1.00							
Post_ Mon											0.76**	0.96**	1.0						
Pre_ Mon	SSP													1.0					
Dur_Mon														0.87**	1.00				
Post_ Mon														0.84**	0.95**	1.0			
Pre_ Mon	IWQI																1.0		
Dur_Mon																	0.85**	1.0	
Post_ Mon																	0.92**	0.97**	1.0

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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Chapter :5

SUMMARY AND CONCLUSION

The present investigation entitled **'Seasonal variation of groundwater quality of Jalalabad (West) block of the district Fazilka, Punjab, India'** conducted during the year 2017-18 for the awards of the Master of Science (Agriculture) in Soil Science-Soil and Water Conservation. The study was done at the Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur. The observation recorded in the investigation, were analysed statistical, result obtained and discussed critically. On the basis of facts, results are summarized below and have been presented under separate heads and thereafter concluded.

5.1: Chemical parameters of groundwater

5.1.1: Groundwater pH of the Jalalabad west block varied significantly between different monsoon seasons. The pH values was ranged between 8.2 to 9.0, 8.0 to 8.90 and 7.9 to 8.8 and average value was obtained is 8.54 (±0.24), 8.5 (±0.25) and 8.44 (±0.25) during pre, within and post monsoon periods which was indicated during monsoon season, pH of ground water is reduced.

5.1.2: Groundwater EC of the Jalalabad west block varied significantly between different monsoon seasons. The EC values was ranged between 0.45 to 0.78 dS m^{-1}, 0.44 to 0.77 dS m^{-1} and 0.44 to 0.76 dS m^{-1} and average value was obtained is 0.690 dS m^{-1} (± 0.09 dS m^{-1}), 0.67 dS m^{-1} (±0.09 dS m^{-1}) and 0.66 dS m^{-1} (±0.0.09 dS m^{-1}) during pre, within and post monsoon periods. The WHO permissible limit for EC in groundwater for irrigation is 0.600 dS m^{-1} and when this exceeds 3.000 dS m^{-1} it is harmful for all crops.

5.1.3: Groundwater TDS of the Jalalabad west block varied significantly between different monsoon seasons. The TDS values was ranged between 518 to 3320 meq L^{-1}, 460 to 3150 meq L^{-1} and 350 to 2980 meq L^{-1} and average value was obtained is 2088.1 meq L^{-1} (±800.00 meq L^{-1}), 1899.29 meq L^{-1},

(±752.07 meq L^{-1}) and 1628.07 meq L^{-1} (±666.53 meq L^{-1}) during pre, within and post monsoon periods.

5.2: Cationic parameters of groundwater

5.2.1: Groundwater Na of the Jalalabad west block varied significantly between different monsoon seasons. The Na values was ranged between 0.52 to 25 meq L^{-1}, 0.47 to 22.8 meq L^{-1} and 0.43 to 20.65 meq L^{-1} and average value was obtained is 10.51 meq L^{-1} (±7.98 meq L^{-1}), 9.53 meq L^{-1} (±7.51 meq L^{-1}) and 8.03 meq L^{-1} (±6.78 meq L^{-1}) during pre, within and post monsoon periods. The permissible limit of Na in the groundwater is <3 meq L^{-1} but several data founded more than this limit and this was also clearly verified by correlation matrix. Thus, it can say that the groundwater quality was not safe for irrigation purpose.

5.2.2: Groundwater K of the Jalalabad west block varied values was ranged between 0.31 to 0.92 meq L^{-1}, 0.42 to 0.81 meq L^{-1} and 0.26 to 0.66 meq L^{-1} and average value was obtained is 0.69 meq L^{-1} (±0.17 meq L^{-1}), 0.62 meq L^{-1} (±0.11 meq L^{-1}) and 0.52 meq L^{-1} (± 0.11 meq L^{-1}) during pre, within and post monsoon periods, respectively and all the sample was below the permissible limit (potassium < 2.0 meq L^{-1}).

5.2.3: Groundwater Ca of the Jalalabad west block varied values was ranged between 0.40 to 2.05 meq L^{-1}, 0.3 to 1.7 meq L^{-1} and 0.25 to 1.55 meq L^{-1} and average value was obtained is 1.19 meq L^{-1} (± 0.54 meq L^{-1}), 1.04 meq L^{-1} (± 0.47 meq L^{-1}) and 0.89 meq L^{-1} (± 0.44 meq L^{-1}) during pre, within and post monsoon periods, respectively and most of the sample was below the permissible limit (Calcium < 20 meq L^{-1}).

5.2.4: Groundwater Mg of the Jalalabad west block varied values was ranged between 0.4 to 2.5 meq L^{-1}, 0.35 to 2.20 meq L^{-1} and 0.30 to 2.05 meq L^{-1} and average value was obtained is 1.40 meq L^{-1} (± 0.53 meq L^{-1}), 1.29 meq L^{-1} (± 0.51 meq L^{-1}) and 1.12 meq L^{-1} (± 0.45 meq L^{-1}) during pre, within

and post monsoon periods, respectively and most of the sample was below the permissible limit (Magnesium < 5 meq L^{-1}).

5.2.5: Groundwater Ca + Mg of the Jalalabad west block varied values was ranged between 0.45 to 3.40 meq L^{-1}, 0.71 to 3.75 meq L^{-1} and 0.60 to 3.40 meq L^{-1} and average value was obtained is 2.03 meq L^{-1} (± 0.81 meq L^{-1}), 2.33 meq L^{-1} (± 0.90 meq L^{-1}) and 2.03 meq L^{-1} (± 0.70 meq L^{-1}) during pre, within and post monsoon periods, respectively.

5.3: Anionic parameters of groundwater

5.3.1: Carbonate

5.3.1: Groundwater carbonate of the Jalalabad west block varied values was ranged between 1.2 to 5.6 meq L^{-1}, 1.1 to 3.80 meq L^{-1} and 1.20 to 4 meq L^{-1} and average value was obtained is 2.92 meq L^{-1} (± 1.44 meq L^{-1}), 2.41 meq L^{-1} (± 1.07 meq L^{-1} and 1.97 meq L^{-1} (± 0.93 meq L^{-1}) during pre, within and post monsoon periods, respectively. All the sample was below the permissible limit, except some groundwater sample (carbonate < 3 meq L^{-1}).

5.3.2: Groundwater bicarbonate of the Jalalabad west block varied values was ranged between 5.60 to 16 meq L^{-1}, 4.80 to 15.4 meq L^{-1} and 4 to 14.80 meq L^{-1} and average value was obtained is 9.86 meq L^{-1} (± 2.35 meq L^{-1}), 9.01 meq L^{-1} (± 2.45 meq L^{-1}) and 8.46 meq L^{-1} (± 2.65 meq L^{-1}) during pre, within and post monsoon periods, respectively. most of the samples was below the permissible limit, except some groundwater sample (bicarbonate < 10 meq L^{-1}).

5.3.3: Groundwater chloride of the Jalalabad west block varied values was ranged between 2.4 to 46 meq L^{-1}, 2.25 to 25.40 meq L^{-1} and 1.60 to 19.20 meq L^{-1} and average value was obtained is 20 meq L^{-1} (± 12.95 meq L^{-1}), 15.82 meq L^{-1} (± 8.79 meq L^{-1}) and 11.05 meq L^{-1} (± 6.63 meq L^{-1}) during pre, within and post monsoon periods, respectively and most of the samples was above the permissible limit, except some groundwater sample (chloride < 4 meq L^{-}.

5.4: Irrigation water quality parameters

5.4.1: Groundwater SAR of the Jalalabad west block varied values was ranged between 1.10 to 21.5, 0.79 to 20.6 and 0.79 to 20.65 and average value was obtained is 8.41 (± 6.19), 8.55 (± 6.46) and 7.66 (± 6.21) during pre, within and post monsoon periods, respectively and Most of the samples was below the permissible limit, except some groundwater sample (SAR < 10).

5.4.2: Groundwater RSC of the Jalalabad west block varied values was ranged between 4.95 to 15.8 meq L^{-1}, 5.19 to 12.28 meq L^{-1} and 4.20 to 14.40 meq L^{-1} and average value was obtained is 10.23 meq L^{-1} (± 3.13 meq L^{-1}), 9.09 meq L^{-1} (± 3.02 meq L^{-1}) and 8.41 meq L^{-1} (± 2.97 meq L^{-1}) during pre, within and post monsoon periods, respectively, Almost all the samples was above the permissible limit, except some groundwater sample (RSC <1.25 meq L^{-1}).

5.4.3: Groundwater PI of the Jalalabad west block varied values was ranged between 95.9 to 297.2, 91.7 to 225.5 and 93.40 to 235.29 and average value was obtained is 127.94 (± 52.08), 119.18, (± 36.73) 123.97 (± 38.30) during pre, within and post monsoon periods, respectively, All the samples was above the permissible limit (PI = 25-75).

5.4.6: Groundwater IWQI of the Jalalabad west block varied values was ranged between 175.67 to 359.52, 161.54 to 271.97 and 171.06 to 283.03 and average value was obtained is 226.19 (± 44.12), 214.24 (± 30.23) and 215.35 (± 29.65) during pre, within and post monsoon periods, respectively. Groundwater quality parameter for irrigation purpose, if the IWQI within the limit, it can categorized as fallowing:

1. <50 Excellent for Irrigation
2. 50 to 99.99 Good for Irrigation
3. 100 to 199.99 Poor for Irrigation
4. 200 to 299.99 Very Poor for Irrigation
5. > 300.0 Not Suitable for Irrigation

Conclusion

On the basis of results summarized above, in this study, it was found that the groundwater of the Jalalabad west block of the district Fazilka, Punjab comes under very deprived or not suitable for irrigation purpose.

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