

**“CHARACTERIZATION OF GROUND
WATER QUALITY OF SAFIDON BLOCK IN
DISTRICT JIND, HARYANA”**

BY

**MUKESH KUMAR
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in
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**COLLEGE OF AGRICULTURE
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2003

Dedicated

To My

Grand Parents

CERTIFICATE - I

This is to certify that this dissertation entitled "Characterization of ground water quality of block Safidon in district Jind, Haryana" submitted for the degree of Master of Science in the subject of Soil Science of the CCS Haryana Agricultural University, Hisar, is a bonafide research work carried out by Mukesh Kumar under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.


[S.S. DAHIYA]

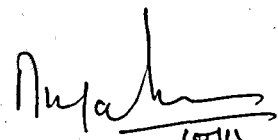
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CERTIFICATE - II

This is to certify that this dissertation entitled "Characterization of ground water quality of block Safidon in district Jind, Haryana" submitted by Mukesh Kumar to the CCS Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of Master of Science in the subject of Soil Science, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.


MAJOR ADVISOR 24/11/03


HEAD OF THE DEPARTMENT 24/11/03


DEAN, POST-GRADUATE STUDIES

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Hisar

24 September, 2003

Mukesh Kumar
Mukesh Kumar

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CHAPTER - I

Introduction

Ground water is the most important source of supplemental irrigation in arid and semi-arid regions in India. Unfortunately, the water in 32-83% of the aquifers surveyed in different states of the country has been observed to be of poor quality (Minhas & Gupta, 1992).

Suitability of waters for crop production is judged from their long-term effects on soil health. Indiscriminate use of poor quality water for irrigating agricultural crops deteriorates the productivity because of development of salinity, sodicity and toxic effects on crop plants. Degree of deterioration of soil, however, is governed by the interplay of number of factors such as nature and contents of soluble salts in the applied water, soil type, water table depth, nature of crop grown and the water management practices followed in an agroclimatic zone.

Manchanda (1976) classified the underground waters of Haryana and found 37% to be good, 8% marginal and 55% poor quality waters. Amongst the poor quality waters 18% sodic, 11% saline and 26% as saline sodic.

In Haryana, out of the total cultivated area of 3.4 million ha, only 66% is irrigated by canal whereas the rest of the area is dependent either on rainfall or on wells/tubewells which oftenly contains water of doubtful quality.

The ground water exploitation in the state is 69.3 per cent of the annual utilizable potential of 0.88 million ha year⁻¹ with an additional potential of 0.27 million ha year⁻¹ for future development (Ministry of water resources, 1987). In the past attempts have been made to establish water quality zones of Haryana state (Manchanda, 1976). However, due to less exploitation of under ground waters for irrigation and consequent rise in water table @ 9.28 cm year⁻¹ Manchanda, (1998) inferred that decline in water table in western (Hisar, Fatehabad and Sirsa) and North East of Haryana led to change in water quality. In recent years a large number of shallow wells/tubewells have been installed in this area to provide supplemental irrigation to rice and wheat crops. Therefore, a reappraisal on the nature, properties and quality of irrigation water is essential for sound irrigation planning and to assess any possibility of development of secondary salinization/sodification in this region. Keeping in view the above facts, it was proposed to carry out a location specific study with the following objectives.

1. To study and map the distribution of under ground water quality in Safidon block of district Jind, Haryana.
2. To examine the feasibility of different classification criteria of water.
3. To assess the effect of various quality water on soil properties.

CHAPTER - II

Review of Literature

The available literature related to the present investigation is briefly reviewed in this chapter under the following main heads:

- 2.1) Irrigation water quality classifications/ guidelines.
- 2.2) Water quality appraisal.
- 2.3) Effect of water quality on soil properties.

2.1 Irrigation water quality classifications/guidelines

Water quality guidelines have undergone considerable refinement since the scientists first came up with some rules of the game in the last decades of the nineteenth century. Hilgard (1907) wrote about these waters "Unfortunately it is not easy to give absolute rules in regards to the exact figures that constitute an excess of salts, but also the nature of the land to be irrigated, and the frequency of irrigation required, must be taken into consideration. Broadly speaking, the extreme limits of mineral content usually assigned for potable waters viz. 40 grains per gallon (684 ppm), also applies to irrigation waters. Yet it sometimes happens that all or most of the solid content is gypsum and Epsom salt, when only a large excess of the latter would constitute a bar to irrigation use. When, on the contrary, a large proportion of the solids consists of carbonate of sodium or common salt, even a smaller proportion of salt than 40 grains might preclude its regular use depending upon the nature of soil to be

irrigated". This above statement fairly well sums up the substance of future empirical work on preparation of guidelines for saline irrigation. The first guideline for saline irrigation in India seems to have originated from Leather, who characterized the quality of well water used in excess to permit adequate leaching (Leather, 1902). Higher limits could be permitted if the dissolved salts consisted of nitrates of calcium, magnesium or even potassium. The use of excess water contained in his recommendation, later took the form of leaching requirement, as used by workers of the United States Department of Agriculture (Richards, 1954).

The U.S. Salinity Laboratory, Riverside, derived a formula for characterizing irrigation waters with respect to their tendency to bring about deterioration in soil physical conditions. It was called sodium-adsorption ratio (SAR) and was defined as "the milliequivalent of dissolved sodium per litre divided by the square root of half the sum of the milliequivalents of dissolved calcium plus magnesium per litre". A relationship between SAR and exchangeable sodium percentage was developed (Richards, 1954) out of field observations to use SAR as a measure of sodicity hazard of irrigation waters (Richards, 1954). The U.S. Salinity Laboratory then developed a diagram with electrical conductivity on the horizontal axis and SAR on the vertical axis. The salinity hazard was divided into 4 classes (C_1 to C_4) i.e. low 100-250, medium, 250-750, high 750-2250 and very high, above 2,250 $\mu\text{mhos cm}^{-1}$. The SAR axis was divided between 0 and 30 with three lines crossing the axis, creating 4 classes (S_1 to S_4); the divisions had been based on long years of research experience. The 16 classes of water represent different degrees of salinity, sodicity or combined hazard. But Thorne and Thorne (1951) felt that the upper limit may be extended to 5000 $\mu\text{mhos cm}^{-1}$. Thorne and Peterson (1954) added

additional conductivity classes to U.S. Salinity Laboratory Scale to C₄ 2250-4000, C₅ 4000-6000 and C₆ above 6000 $\mu\text{mhos cm}^{-1}$ and modified the U.S. Salinity Laboratory, diagram using the same S.A.R. lines. Similarly, the definition of SAR has been sought to be modified both on the basis of role of magnesium and activities of divalents in waters of ionic strengths. Effects of silicate weathering, presence of low solubility salts in soils and leaching conditions have also been introduced.

Eaton (1950) considered the role of carbonates in irrigation water in precipitating calcium and magnesium. The concept termed as Residual Sodium Carbonate (RSC). The waters with same salinity levels but having Residual sodium carbonate being more harmful. Honda (1964) proposed a modification in the U.S. Salinity Laboratory classification to include bicarbonate waters and gypsum requirements for using such waters.

Kanwar (1961) agreed with Durand (1950) regarding the condition of fifth class (5000-20000 $\mu\text{mhos cm}^{-1}$) to the electrical classes of U.S. salinity laboratory workers and proposed a triangular diagram determining the suitability of irrigation water for different soils and crops based on sodium adsorption ratio (SAR).

Wilcox *et al.* (1954) proposed that waters with RSC more than 2.5 me L^{-1} are unsuitable. But Thorne and Thorne (1951), Aggarwal *et al.* (1956) and Kanwar (1961) found that most of the waters which are considered as unfit by Wilcox *et al.* (1954) standard are being successfully used.

Bhumbla *et al.* (1971) proved that water with electrical conductivity of about 4000 $\mu\text{mhos cm}^{-1}$ can safely be recommended for light textured soil where salt tolerant crops are grown.

Shaligram (1961) classified irrigation water in six classes depending upon total salt content. The maximum salt content according to him, which can be used under normal conditions is 300 ppm.

Bajwa *et al.* (1983) have reported that irrigation with water having EC upto 3 dS m^{-1} and RSC up to 8.0 me L^{-1} did not affect the growth of wheat crop.

Ayers and Westcot (1989) have given new guidelines for interpretation of water quality for irrigation, adopted from university of California Committee of consultants (1974). Accordingly, irrigation water having SAR <3 , 3-6, 6-12, 12-20 and 20-40 should have EC greater than 0.7, 1.2, 1.9, 2.9 and 5.0 dS m^{-1} respectively otherwise infiltration rate of water into the soil would be affected.

Asghar *et al.* (1936) considered all water and with salt content of less than 10 me L^{-1} salt ($\text{EC} < 1000 \mu \text{ mhos cm}^{-1}$) as suitable for irrigation and all water with more than 20 me L^{-1} ($\text{EC} > 2000 \mu \text{ mhos cm}^{-1}$) salt as unsuitable. The water having EC between these limits was considered suitable or unsuitable depending upon the negative amounts of sodium and calcium.

Ravikovitch and Murensky (1958) concluded that water which have an electrical conductivity $2835 \mu \text{ mhos cm}^{-1}$ and 1980 PPM salts is suitable for full and prolonged irrigation. They classified water with an EC $2231 \mu \text{ mhos cm}^{-1}$ and total salts 127 ppm as of faulty quality.

Kanwar and Manchanda (1964) observed that in Gurgaon, water with EC as high as $15050 \mu \text{ mhos cm}^{-1}$ had no deleterious effect on soil. Probably the heavy rains in the rainy season nullify the bad effect of these irrigation water.

Manchanda (1976) classified irrigation water into three categories of good, marginal and poor quality water based on EC, SAR and RSC parameters.

Good water quality has low value of EC ($< 2 \text{ dS m}^{-1}$) SAR (< 10) and RSC (absent). Poor quality water is further subdivided into saline (EC $> 4 \text{ dS m}^{-1}$) SAR < 10 RSC.nil). Sodic (EC $< 4 \text{ dS m}^{-1}$) SAR > 10 , RSC $> 2.5 \text{ me L}^{-1}$) and saline-sodic (EC $> 4 \text{ dS m}^{-1}$), SAR > 10 , RSC usually absent.

Handa (1983) classified water on the basis of anion dominance as chloride type, sulphate type, bicarbonate type and their combinations such as chloride sulphate, chloride bicarbonate etc.

The Water and Power Development Authority in Pakistan, who is working for land reclamation project is pumping saline ground water for lowering water table and subsequent reclamation of soils using the following guidelines to dispose off tubewell waters through irrigation (Sheikh, 1989) i.e.

Useable (EC = $< 1.5 \text{ dS m}^{-1}$, SAR = < 10 , RSC = $< 2.5 \text{ me L}^{-1}$)

Marginal (EC = $1.5 - 3.0 \text{ dS m}^{-1}$, SAR = $10-18$, RSC = $2.5-5.0 \text{ me L}^{-1}$)

Hazardous (EC = $> 3.0 \text{ dS m}^{-1}$, SAR = > 18 , RSC = $> 5.0 \text{ me L}^{-1}$)

The guidelines for saline irrigation cannot be very rigid, as the suitability of irrigation water is determined by the specific condition under which it will be used. Climate and soils are the most important variants. Local conditions like depth of water table, nature of crop to be grown and level of management influence decision making while assessing water quality under local conditions in practice. Bhumbla and Abrol (1972) published some guidelines that had emerged out of discussion with scientists in different parts of the country and taking into consideration experience of saline water use under field conditions. These guidelines were meant for advisory purpose and for

making recommendations on the use of irrigation water of a particular quality. The limits were fixed only for total salt concentrations.

Based on the study of characteristics features of majority of ground waters in use with the farmers in different ecological region of the country and the indices that describe the nature of hazards on soils and crops, Central Soil Salinity Research Institute, Karnal under its all India Coordinated Research Project on Management of Salt Affected Soils and Saline water Use in Agriculture has recommended the grouping of irrigation water into good, saline and alkali waters (AICRP, 1989). Depending upon the degree of restrictions, the two poor quality water classes have been further grouped each into three homogeneous subgroups. Since each subgroup needs specific management practices, this classification also serves the purpose of planning their development and management at block/mandal/Tehsil level.

The above guidelines were further improved by Experts on water quality from HAU Hisar, PAU Ludhiana, CSSRI Karnal and AICRP in 1990 (Minhas and Gupta, 1992). These guidelines were based on soil type, rainfall and climate i.e. amount of rainfall and sensitivity of crop to salinity or alkalinity. These guidelines were meant for site specific use of brackish water.

2.2 Water quality appraisal

Waters of varying salinity levels are distributed in different regions depending upon climatic condition particularly rainfall as well as chemical composition of parent rocks and soils. By and large, the river water are of good quality with pH ranging between 7 and 8 and EC ranging between 100 and 600 $\text{dS m}^{-1} \times 10^{-3}$ (Minhas and Gupta, 1992). Upper salinity limits of river water are observed during lean flows. The primary source of water in rivers is monsoon precipitation. As canal systems emanate from the rivers, the canal water is

generally of good quality. The quality of the ground water is highly variable. Intensive ground water surveys have been carried out and observations have been compiled by several researchers (Bhumbla *et al.*, 1971, Paliwal, 1972, Bajwa *et al.*, 1975, Manchanda, 1976, Dhir, 1977, Handa, 1983) covering different agro-climatic, soil and hydro-geological zones of the country. In general, ground waters in the arid and semi-arid regions are of marginal to poor quality while those in the high rainfall areas of the eastern regions are of good quality. Ground water quality in the coastal areas are of poor quality largely due to intrusion of sea water.

Dara *et al.* (1964) analysed water sample collected from wells of eight broad soil region in Rajasthan and some irrigation projects. The well waters were found moderately saline, and alkaline. The pH ranged from 7.5 to 9.1 and EC from 200 to 22800 μ mhos cm^{-1} sulphate and chlorides were the dominant anions. These constituted 25.4 per cent of the total anions. The CO_3^{-2} were present almost in all waters of eastern Rajasthan. Na^+ was the dominant cation followed by Ca^{+2} and Mg^{+2} in all soil groups. The data on canal waters generally showed that they happened to be of good quality.

The first approximation of under ground water quality map of the Punjab state based on the analysis of 12,234 samples of irrigation water from open wells and tubewells all over the state was presented by Bajwa *et al.* (1974). The composition of water was considered along with the soil texture, cropping pattern, availability of canal supplier and other local factors in placing underground waters in fit, unfit and marginal categories. The state was divided into five zones on the basis of the frequency distribution of water samples in a particular categories. Almost 40 per cent of the area of the state carried under ground water of marginal to unfit categories.

Tek Chand *et al.* (1993) conducted the quality survey of under ground water in five villages like Tihara, Aslwas, Shahpur, Kasanwas and Bawal in Rewari district and analysed that 52% water belonged to sodic categories in village Aslwas followed by Shahpur (43%) and Bawal (27%). The proportion of saline and sodic waters was maximum in village Kasanawas (100%) followed by Bawal (19.4%) and Aslwas (9.5%). In Tihara and Shahpur villages the marginal saline and saline-sodic waters were absent.

Gupta *et al.* (1994) prepared the map of "Ground water quality" of irrigation in India based on quality survey of ground water conducted under AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Poor quality water was observed to be used in the range of 32 to 84 per cent with an average of about 45 per cent of the total ground water development. Estimates suggested that out of the ground water development of 13.5 million ha m yr⁻¹, poor quality ground waters accounted for about 3.2 million ha m yr⁻¹.

Manchanda (1976) found that 37 per cent of ground water in Haryana are of good quality, 8 per cent marginal and 55 per cent are of poor quality. The survey of Safidon block indicated that 15% water samples were good, 11% marginal, saline 25% saline, 13% sodic and 36% saline sodic in nature.

Tanwar (1998) reported that irrigation with tube well is more or less spread over to entire state of Haryana and exclusively supporting 34% of the total area. Ground water in deep aquifers is fresh in 37%, marginal in 16% and saline in 47% area, whereas in shallow aquifers in fresh in 42% area, marginal in 43% area and saline in 15% area. There is a large variation in ground water quantity in horizontal and vertical direction.

Lal *et al.* (1998) reported that the Bikaner district under groundwater were mostly sodium, magnesium, calcium ions with dominance of chlorides followed by carbonate and bicarbonates. Electrical conductivity of the soil was significantly and positively correlated with electrical conductivity of irrigation water.

Sood *et al.* (1998) observed that electrical conductivity of water samples collected from 88 villages of Talwandi-Sabotehsil (Bathinda district) varied from 0.55 to 13.74 dS m⁻¹. Soluble carbonates, bicarbonates and residual sodium carbonates (RSC) of these waters varied from nil to 3.2, 2.0 to 17.7 and nil to 14.6 me L⁻¹ respectively. Soluble sodium (3.0 to 90.0 me L⁻¹) was the dominant cation and sodium adsorption ratio (SAR) ranged from 2.3 to 31.3. Based on the EC and RSC of the waters 15,38,12 and 35 per cent samples were good (Low EC and RSC), marginal-saline, marginal-sodic and poor (high EC and RSC) respectively for irrigation purpose. Salinity is more prevalent than sodicity in the area.

Phogat *et al.* (1999) carried out the survey of the underground irrigation waters of Hansi-I and Hansi-II blocks of Hisar district of Haryana and classified it. The result showed that a lion's share of samples in both the blocks were classified in good (32.1 and 31.8%) and marginally saline (32.2 and 36.4%) quality class. The samples in other classes were 21.4 and 13.6% in saline 12.5 and 18.2% in high SAR saline and 1.8 and nil in alkali class, in Hisar-I and Hisar-II blocks respectively. The analysis of water samples of both the blocks showed that 64.2% of the samples recorded EC less than 4 dS m⁻¹ in Hisar-I block, where as the respective figure in Hisar-II was 35.2%. The SAR ranged from 0.3 to 26.8 (m mol⁻¹)^½ in Hisar-I and the corresponding range for Hisar-II block was from 0.3 to 27.2 (m mol⁻¹)^½. The tubewell waters showing SAR>10

were 12.5% in Hisar-I block and 18.2% in Hisar-II block. Most of the problematic water samples in both the blocks were of saline in nature. However, the samples of Badon Barhaman village in Hisar-I block were found to be dominated by RSC (5.5 me l^{-1}) and classified into alkali waters.

Yadav (2000) reported that the electrical conductivity of the underground water samples from Hansi block (Hisar) ranged between ($0.45 - 3.35 \text{ dS m}^{-1}$) and SAR ranged from ($0.15 - 22.4 (\text{m mol L}^{-1})^{1/2}$). The classification revealed that a major portion of the samples were found in good (25.7%) and normal (36.0%) water quality classes. The percent samples in other classes were 24.3% and 14.0% marginally saline and saline sodic respectively.

Yadav (2002) found that the majority ground waters in the Bawal region were sodic (62%) in nature and the sodic waters upto RSC of 12.0 me L^{-1} could be successfully used for crop production in combination with gypsum without much adverse effect on physical and chemical characteristics in light textured soils.

2.3 Effect of water quality on soil properties

The long term effect of irrigation water on soils depends upon the composition of water, soil type, water table conditions, annual rainfall, annual evaporation, the nature of crop to be grown and the water management practices followed in an agro-climatic condition. The impact of water quality on soil properties is reviewed as under:

2.3.1 Effect on Soil Physical Properties

Lal and Singh (1974) reported that hydraulic conductivity increased with increasing electrolyte concentration and decreased with SAR, the effect of the later being more pronounced.

Saha *et al.* (1978) reported that increasing electrolyte concentration of the irrigation water increased diffusibility, more so with increasing water content and Exchange Sodium Percentage (ESP) of the soil.

Kanwar and Kanwar (1971) reported that continuous irrigation with waters containing no RSC increased the electrical conductive more than the continuous irrigation with waters containing RSC but the pH of the soil increased as the RSC increased They also reported that RSC in the form of CO_3^{-2} was more harmful than in the form of HCO_3^- .

Singh and Bhumbla (1968) also reported the structure destroying nature of cations in the order of $\text{Na}^+ > \text{K}^+ > \text{Mg}^{+2} > \text{Ca}^{+2}$. According to them monovalent and divalent cations had structure destroying and structure building nature, respectively.

Lal and Singh (1973) found a reduction of about 40 per cent in the hydraulic conductivity of a loamy sand soil on irrigation of 102.5 cm of water with SAR of 36.0 (m molL^{-1})^{1/2}. The hydraulic conductivity further reduced after fallow phase which was attributed to reduction in salt concentration after rainy season.

Paliwal and Gandhi (1976) found that the infiltration rates of a soil with irrigation waters of same salinity and SAR varied a great deal depending upon the kind of divalent cations. The composition of the exchangeable cations of the soils also affected infiltration rates definitely on a $\text{Na}^+ + \text{Mg}^{+2}$ soils where $\text{Na}^+ + \text{Ca}^{+2}$ waters increased infiltration from 19.0 to 29.1 cm hr^{-1} only, showing thereby that $\text{Na}^+ + \text{Ca}^{+2}$ water could be considered of better quality as compared to $\text{Na}^+ + \text{Mg}^{+2}$ waters (Shah and Palkhiwala, 1979).

Shainberg *et al.* (1981) stated that hydraulic conductivity of soil containing salt concentrations less than 10 me L^{-1} decreased drastically even at low (10) ESP when leached with distilled water.

Zartman and Gichuru (1984) reported that hydraulic conductivity (K) were significantly reduced in Ap horizons of plots irrigated with high and medium levels of blow-down waters ($\text{EC}_{\text{iw}}=12 \text{ dS m}^{-1}$, $\text{SAR}=11$) K values ranged from 2 mm min^{-1} in the AP Horizon of high irrigation, blow-down water plots to $37 \text{ mm per 30 min.}$ in the control plots. K values for the B horizon were less significantly affected by irrigation treatments. Bulk density and water retention were not significantly affected by irrigation treatments.

Manchanda *et al.* (1985) observed that the addition of FYM @ 50 t/ha/yr in a fine loamy soil under prolonged irrigation (7 yrs) with sodic water ($\text{EC} = 4 \text{ dS m}^{-1}$, $\text{SAR} = 26$, $\text{RSC} = 15 \text{ me L}^{-1}$) decreased the steady state infiltration of soil, which was 0.11 mm hr^{-1} relative to 0.18 mm hr^{-1} for gypsum control and 2.25 mm hr^{-1} for the canal treatment. They suggested that decreased infiltration rate of FYM added treatment was possibly caused by the clogging of soil micropores due to the increased dispersion of farm yard manure and the colloidal particles owing to irrigation with bicarbonate rich sodic water.

Minhas *et al.* (1998) stated on the basis of review of 25 years of research work on under the aegis of AICRP on management of salt affected soils and use of saline water in agriculture, the infiltration problem increased swelling and dispersion with increasing ESP (SAR) and decreasing salinity. The CCC (Critical Coagulation Concentrations) of smectitic and illitic soil clays showed that dispersability of clay decreased exponentially with increasing salt concentration. The CCC values of illitic soil clays were nearly three times than those of smectitic soil clays of each SAR value. Differences in CCC increased

further in magnitude with SAR. The CCC values ranges from 10.7 to 22.0 and 29.3 to 64.3 in SAR range of 10-40 and pH 7-9 for smectite and illitic soil clay respectively. Where as CCC ranged sharply for mont morillonitic soil clays as a results of a change in SAR from 10 to 20, there was little effect on illitic clays.

With increase in SAR beyond 20 (m mol L^{-1})^{1/2} dispersible clay increase sharply. This suggests that illitic clay particles domains begins to be broken at SAR>20. Often stability lines involving EC, SAR of waters based upon laboratory determinations are used to characterize waters, those induce permeability problems. In a sandy loam soil when electrolyte was raised from 0 to 40 me L^{-1} amount of water infiltrated in 40 hrs. was nearly 14, 6.5, 5.4, 1.7 and 1.6 times in soils having ESP of 70, 30, 22, 14 and 5 respectively. Increase in Mg : Ca ratio and SAR and decrease of EC of leaching water increased degree of dispersion and decreased hydraulic conductivity. The adverse effect of increasing Mg^{2+} : Ca^{2+} ratio were more pronounced at higher SAR and illitic soils.

Quirk and Schofield (1955) observed that the hydraulic conductivity of soils saturated with varying levels of sodium decreased when the electrolyte concentrations of the flowing water decreased below a threshold level. Decrease in soil permeability with increasing SAR and decreasing. Electrolyte concentration in the percolating solution has been reported by Mcneal and Coleman (1966). They also noted that such changes were more pronounced in soils containing most electrolyte clay than in soils containing Kaolinite type clay or sesquioxides.

2.3.2 Effect on soil Chemical Properties

Manchanda (1960) observed significant positive correlation between the carbonates and bicarbonates content of irrigation waters and pH of soil.

Kelly (1962) found that HCO_3^- containing irrigation water tended to increase the Na^+ content of soil solution under impeded drainage.

Kanwar and Kanwar (1971) observed that continuous irrigation with waters containing no RSC, increased the Electrical Conductivity more than the continuous irrigation with waters containing RSC but the pH of the soil increased as RSC increased. They also reported that RSC in the form of CO_3^{2-} was more harmful than in the form of HCO_3^- .

Gupta and Abichandani (1970) reported that saline water irrigated soils in the semi arid zone of western Rajasthan became completely non saline up to 40cm with annual the rainfall of 350 to 450mm.

Dhir (1977) observed that low annual rainfall (300mm) completely leached the salts in a loamy sand soil that accumulated during the previous wheat season. This much of rainfall was sufficient to leach 80% of the salts from surface 40cm of sandy loam to loam textured salts. Salts leaching in the finer-textured soil, however, ranged from 50 to 80%. In a year with 59.6 cm rainfall complete leaching of salts took place in all soils except the silty clay loam, where the leaching from 0-60cm was only 70%.

Manchanda and Chawla (1981) reported that 500 mm rainfall during monsoon removed, the salts accumulated during the winter season (EC_e 14, 14-33.6 dS m^{-1}) due to the irrigation water of EC_{iw} 15-19 dS m^{-1} in a coarse loamy sand to sandy soils.

Singh and Bhumbla (1968) reported that in general, EC_e was about half of the EC of irrigation waters in soils with clay less than 10 per cent, three-fourth in soils with clay 10-20 per cent but it was 1.5 times that of waters in soils where clay was 20-30 per cent EC of irrigation water and EC_e for various types of soils were significantly co-related with ESP of soil. They further observed

that the effect of RSC became pronounced only when the EC of water was also high i.e. more than 1500 dS m^{-1} .

Tripathi *et al.* (1971), Chawla (1972), Lal and Singh (1974), Paliwal and Gandhi (1976) and Dhankhar *et al.* (1980) reported that waters with high sodium and low salt concentration could successfully be used in light textured soil. They also observed that the quality of irrigation waters is not conditioned merely by its chemical composition, but also depends upon factors such as the type of soil, nature of crop grown, climate of area and the management practices.

Manchanda and Bhandari (1976) reported that the irrigation with high saline waters ($\text{EC } 15 - 19 \text{ dS m}^{-1}$), SAR (12-16) on well drained coarse loamy soils in Haryana developed an EC of $15-35 \text{ dS m}^{-1}$ in the top 30 cm soil depth. The initial ECE was, however, reduced to 2.5 dS m^{-1} after a rainfall event of about 500 mm. However, Jain *et al.* (1976) based on three years field experiment observed the irrigation waters having an EC of 4.8 dS m^{-1} has no appreciable accumulation of salts in 0-60 cm depth owing to higher permeability of experimental soil.

Manchanda *et al.* (1982) observed that application of tubewell water (SAR 15, RSC 7.5 me L^{-1}) for seven years on clay loam and sandy loam type of soils resulted in lighter ESP build up in the clay loam soils than in the sandy loam soils.

Bajwa *et al.* (1983) reported that irrigation with 8 RSC and 25 SAR waters for five years on sandy loam and Nagar loam soil resulted in an ESP build up of 27.6 and 27, respectively in soil layer of 75 cm depth. They further reported that rise in RSC of irrigation water from 2.0 to 8.0 me L^{-1} , the surface

pH rose from 8.9 to 9.3 in the tubewell sandy loam and 8.8 to 9.2 in Nagar loam soil.

Sharma and Manchanda 1989 observed that even highly sodic waters as at site II $SAR=53$ ($m\ mol\ L^{-1}$)^{1/2} $RSC =10\ me\ L^{-1}$ could be utilized successfully as a supplemental irrigation in wheat-fallow rotation whereas sodic waters at Site I= $SAR_{iw}=22$ ($m\ mol\ L^{-1}$) $RSC =3.4\ me\ L^{-1}$ in bajra-wheat and guar-wheat rotation on sandy loam to loam soil types in areas, receiving more than 400 mm rainfall annually.

Bajwa *et al.* (1992) conducted an experiment on the use of sodic waters for duration of five years and observed that the soil pH and ESP increased with an increase in RSC and SAR of the irrigation water. The build up of salts and ESP was considerably higher under saline sodic irrigation treatment.

Parsad *et al.* (1996) stated that the pH, EC and SAR increased with increase in RSC of irrigation water. The SAR was relatively higher with $CO_3^{2-} + HCO_3^-$ source of RSC than CO_3^{2-} or HCO_3^- alone. A decrease in E_{ce} and increase in SAR with the increase in RSC of irrigation water was due to reduced concentration of calcium and magnesium and increased proportion of sodium in the soil solution.

Minhas *et al.* (1998) reported that periodic changes in salinity and SAR down to 0.9 m soil showed that at similar SAR_{iw} with higher salinity waters ($EC_{iw}\ 12dS\ m^{-1}$) as expected resulted in higher accumulation of salts but also the sodicity (SAR_e) leaching of salts with monsoon rains simultaneously reduced SAR_e in soil but higher SAR_e values persisted in soils irrigated with higher SAR_{iw} and EC_{iw} waters. It seems that due to higher initial value of SAR_e, *the dispersive and swelling ability of the soil is enhanced which reduced water intake.*

Yadav *et al.* (1998) reported that the pH, EC and ESP was increased when the soil was irrigated with water of RSC 12 meL^{-1} as compared to 2.8 meL^{-1} RSC waters. Similar results were obtained by Minhas *et al.* (1996).

Sharma and Minhas (1998) conducted a long term experiment on the effect of sodic waters (having RSC, SAR and EC of the order of 5 and 10 me L^{-1} , 20 and $30 (\text{m mol}^{-1})^{1/2}$ and EC 2 and 4 dS m^{-1} , respectively) and observed that the soil pH increased initially and stabilized after 3 years of irrigation where as sodicity and salinity continued to increase during the experimental period. The mean SAR_e and EC_e (0-0.6 m soil) after five years of irrigation were 1.05 adj. RNA and 1.45 EC_{iw} respectively.

CHAPTER - III

Materials and Methods

To achieve the objectives of the study entitled, "Characterization of ground water quality of Safidon block in district Jind, Haryana", the Materials and Methods followed are described as under:

3.1 GENERAL DESCRIPTION OF SAFIDON BLOCK

3.1.1 Location

Safidon block is a part of Jind district which constitute the part of central Haryana. Safidon lies between latitude $29^{\circ}3'25''$ to $29^{\circ}50'35''$ and longitude $75^{\circ}54'5''$ to $76^{\circ}45'18''$ with a total area of 56200 hacters, which has forty villages. The location of the block is shown in Fig. 1.

3.1.2 Geology

Geologically Safidon block forms a part of the large alluvial track between peninsula and extra peninsula covered by thick alluvial deposits. Entire area has been viewed as an alluvial basin that was formed as a result of synclinal depressions. Based on the period of deposition, alluvium mostly consists older alluvium or Bhangar, mineralogically the alluvium is reported to comprise quartz, feldspar, calcite, biotite and muscovite in the light fraction and high ores i.e. garnets in the heavy sand fraction.

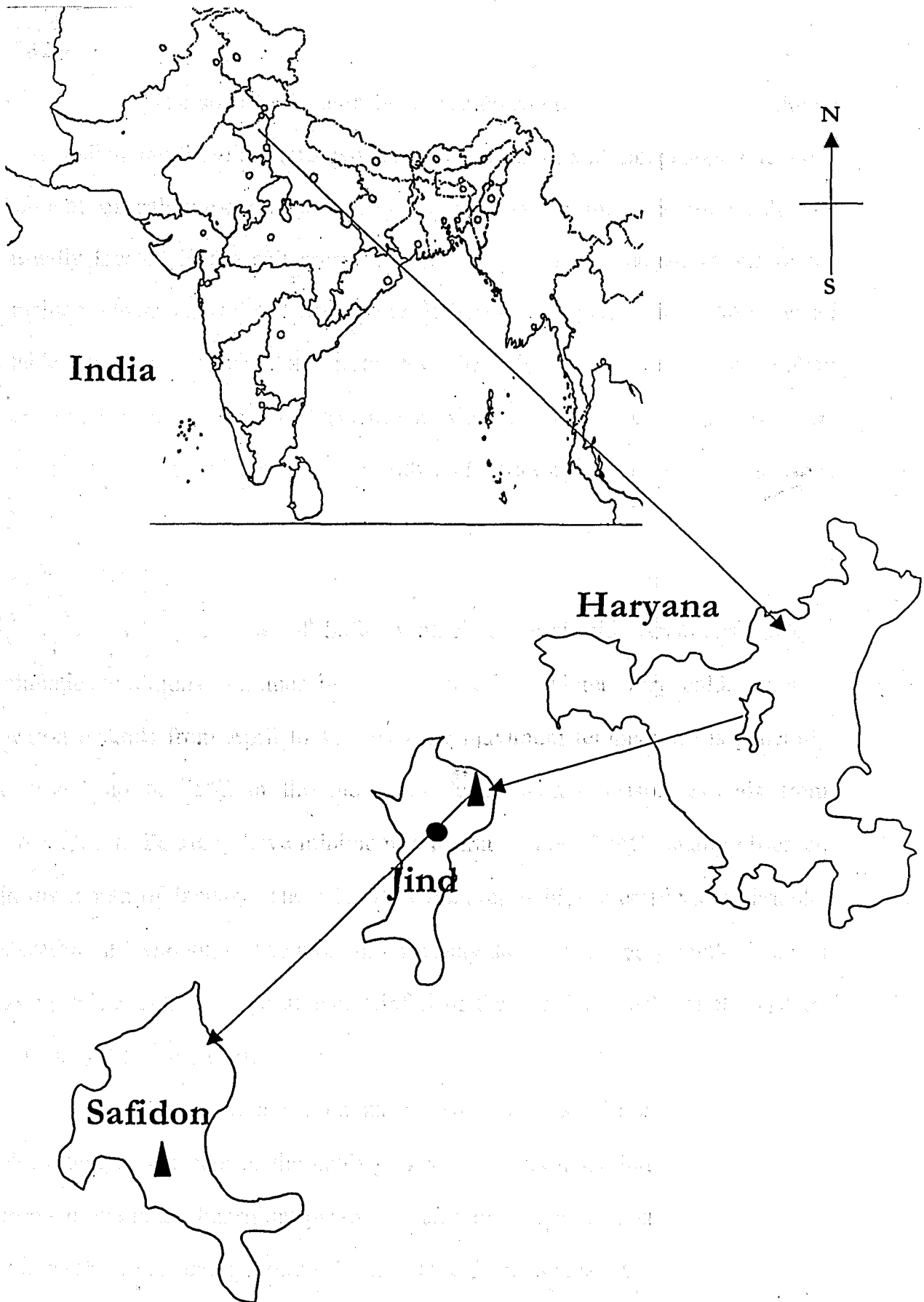


Fig. 1: Location map of Safidon Block of Jind District

3.1.3 Soils

The soils of Safidon block are conventionally referred as alluvial and aeolian and these fall into two orders viz. entisols and inceptisols. Excessive amount of calcium-carbonate is present in nodular form. Sodium salts are usually located in the soil crust and control of their movement is one of the major problem in irrigated agriculture. It has leveled plain with shallow water table, sandy loam to clay loam in texture with yellowish brown to brown colour calcium carbonate present in surface as well as sub-surface soils, which are negligibly eroded. Composition of sub soil water is saline, sodic and saline sodic.

3.1.4 Climate

The climate of Safidon block is semi-arid. Area has extreme climatic conditions, summer being very hot and winter very cold. Summer season extends from April to June and the maximum temperature is generally recorded up to 45°C in the month of June. Winter season extends from November to February have minimum temperature upto 3.5°C usually observed in the month of January. The rainfall of the area is highly erratic and variable, therefore, its amount, distribution and intensity during the crop growth season is highly important. Average annual rainfall of the Safidon block for the last 10 years is 433.5 mm. (Table 1).

Cultivated area accounts for 86.1 per cent of the total area of the block, and 98 per cent of the cultivated area has the irrigation facilities. Major crops grown in the kharif are paddy, Jowar, bajra, sugarcane and vegetables etc. and in rabi wheat, barley, mustard, berseem and vegetables etc.

Table 1: Annual rainfall of Safidon block

Year	Rainfall (mm)
1993-94	183.5
1994-95	484.5
1995-96	788.0
1996-97	378.5
1997-98	590.0
1998-99	655.0
1999-2000	141.0
2000-01	288.0
2001-02	524.0
2002-03	301.0
Average	433.5

3.1.5 Agriculture and land use

Main occupation of the people of this block is agriculture.

Table 2: Important land use statistics of Safidon- block (2001-2002)

Total area	=	52,600 ha
Cultivated area	=	45,300 ha
Total cropped area	=	89,400 ha
Irrigated area	=	44,800 ha
Unirrigated area	=	500 ha
Irrigated area by tube-wells	=	21,400 ha
Irrigated area by canals	=	23,400 ha

3.2 Collection of water samples

For assessing irrigation water quality of safidon Block in Jind District, during 2002-2003 (339) water samples were collected from 40 villages from running tubewells during the months of November to March. Location of the Safidon Block is presented in Fig 2. Water samples collected represented the different directions of each village. It was also ensured that the tubewell had been running at least for an hour before taking a representative water sample. Prior to water sampling, the bottles were thoroughly rinsed with the water to be sampled. These bottles were carefully corked, properly labelled and brought to the laboratory for chemical analysis. Information collected, comprised of name of owner of the tubewell, depth of tubewell, years for which tubewell had been in operation, crops grown, date of sampling and the general opinion of the farmer about the quality of water and problems faced by him which are given in Appendix I.

3.2.1 Processing of water samples

Samples were filtered in the laboratory and stored in polyethylene bottles. One or two drops of toluene were added in the water samples to check the microbial growth.

3.2.2 Analysis of water samples

The water samples were analysed for pH, Electrical conductivity (EC), soluble cations, (Ca^{+2} , Mg^{+2} , Na^+ , K^+) and anions (CO_3^{-2} , HCO_3^- , Cl^- and SO_4^{-2}) by the methods given below:

Electrical conductivity (EC)

EC of water samples were measured with the help of a conductivity bridge having a predetermined cell constant.

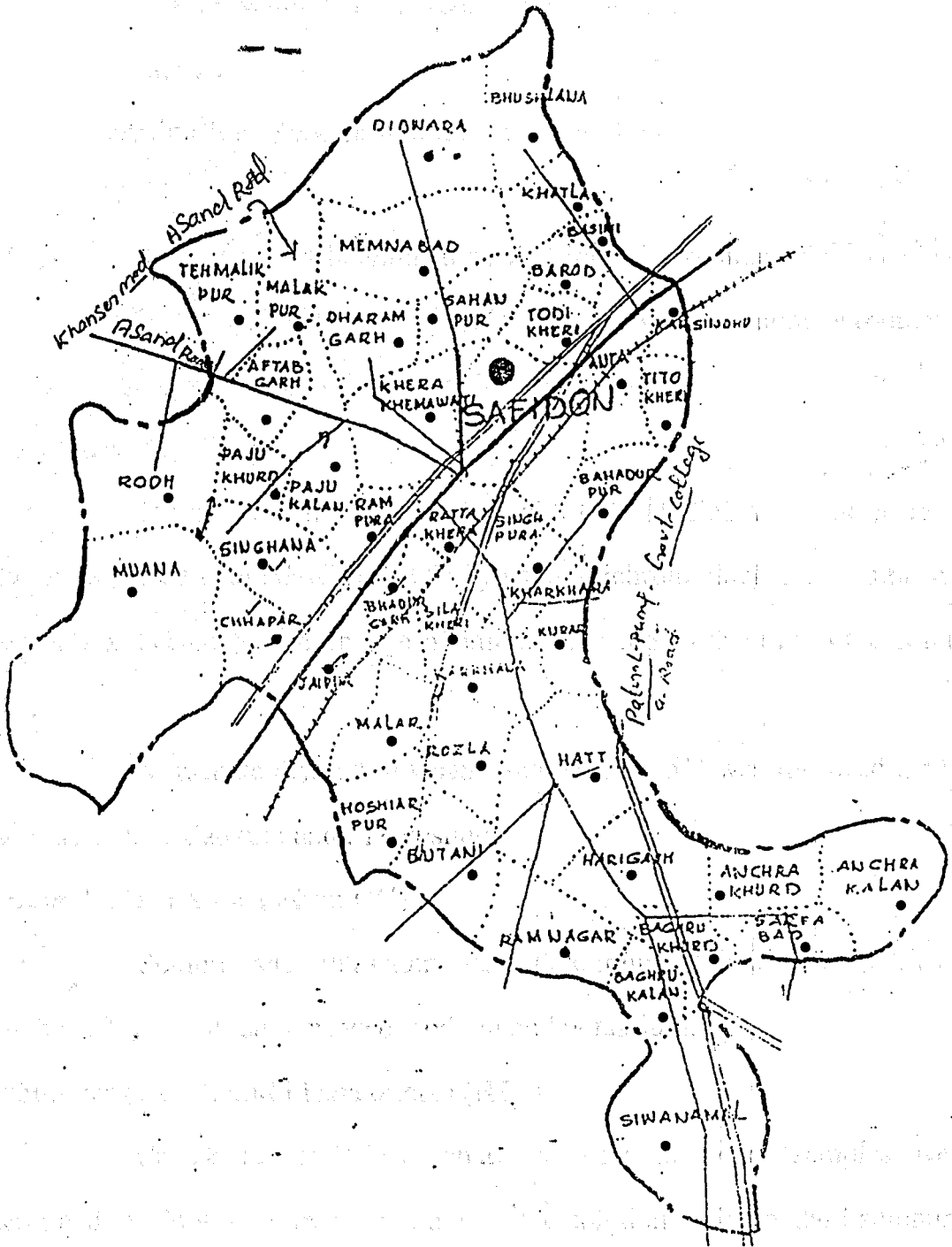


Fig. 2: Map of Safidon Block indicating water sampling sites

pH

pH of water was measured with the help of Backman's glass electrode, pH meter.

3.2.3 Determination of water soluble cations and anions in water samples

Calcium (Ca^{+2})

Calcium was determined by titration with standard 0.01 N EDTA at pH 12 obtained with the help of NaOH by using ammonium purpurate as indicator, when pink colour of solution changed to purple.

Magnesium (Mg^{+2})

It was estimated by titration with 0.01 N EDTA by buffering the solution to pH 10 with $\text{NH}_4\text{Cl-NH}_4\text{OH}$ by using erichrom black T indicator. End point was indicated by the change of initial wine red to the final blue colour.

Versenate method of Chang and Bray (1951) was followed for the determination of Calcium and Magnesium.

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

Sodium and potassium were determined flame photometrically with the help of a standard curve of sodium and potassium.

Carbonates (CO_3^{-2}) and bicarbonates (HCO_3^-)

Carbonates and bicarbonates present in water samples were determined by titrating a known volume of the solution with standard sulphuric acid, first in the presence of phenolphthelin and then in methyl red as indicators.

Chloride (Cl^-)

It was determined by titration with standard (0.02 N) silver nitrate solution by using potassium chromate as indicator. End point was obtained when

white precipitate of AgCl changed to brick red colour suggesting complete precipitation of Cl^- with Ag^+ .

Sulphates (SO_4^{-2})

SO_4^{-2} was determined colorimetrically by measuring the turbidity produced by barium chloride at 420 nm wave length as described by Chesnin and Yien (1950).

3.2.4 Classification of irrigation water

To characterize the quality of irrigation water sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were worked out by using the following equation:

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

$$\text{RSC} = (\text{CO}_3^{-2} + \text{HCO}_3^-) - (\text{Ca}^{+2} + \text{Mg}^{+2})$$

Here concentration of Na^+ , Ca^{+2} , Mg^{+2} , CO_3^{-2} and HCO_3^- represent in me L^{-1} . The SAR (m mol L^{-1})^{1/2} and RSC (me L^{-1}) are the indices for the determination of sodicity hazard. In addition to SAR and RSC, the EC of irrigation water was considered to assess the quality of irrigation water.

3.2.4.1 Characterization of water

After quality analysis of 339 water samples, these waters were characterized and classified as per Manchanda (1976) and (AICRP on Management of Salt Affected Soil and Saline Water Use in Agriculture 1989). Based on the EC, SAR and RSC, Manchanda (1976) gave a criteria for classification of irrigation waters. Ground water quality map of Haryana was

prepared on the basis of this classification. The limits suggested in this criteria are given in Table 3.

Table 3: Water quality classification criteria (Manchanda, 1976)

Quality	Class	EC (dS m ⁻¹)	SAR (m molL ⁻¹) ^{1/2}	RSC (me L ⁻¹)
Good*	A	<2	<10	Usually <2.5
Marginal	B	2-4	<10	Absent
Poor	C			
1.Saline	C ₁	>4	<10	Absent
2.Sodic	C ₂	<4	>10	Usually >2.5
3.Saline sodic	C ₃	>4	>10	Usually absent

* Good category waters with RSC > 2.5 (me L⁻¹) when used copiously during kharif season also tends to behave like sodic waters.

Central Soil Salinity Research Institute, Karnal under its All India Coordinated Research Project on Management of Salt Affected Soils and Saline Water use in Agricultural, has recommended the grouping of irrigation water into good, saline and alkali waters (AICRP, 1989). Depending upon the degree of restrictions, the two poor quality water classes have been further grouped each into three homogenous subgroups. The limits suggested by AICRP (1989) Management of Salt Affected Soil and Saline Water Use in Agriculture are given in Table 4.

Table 4: Criteria for water quality classification (AICRP, 1989)

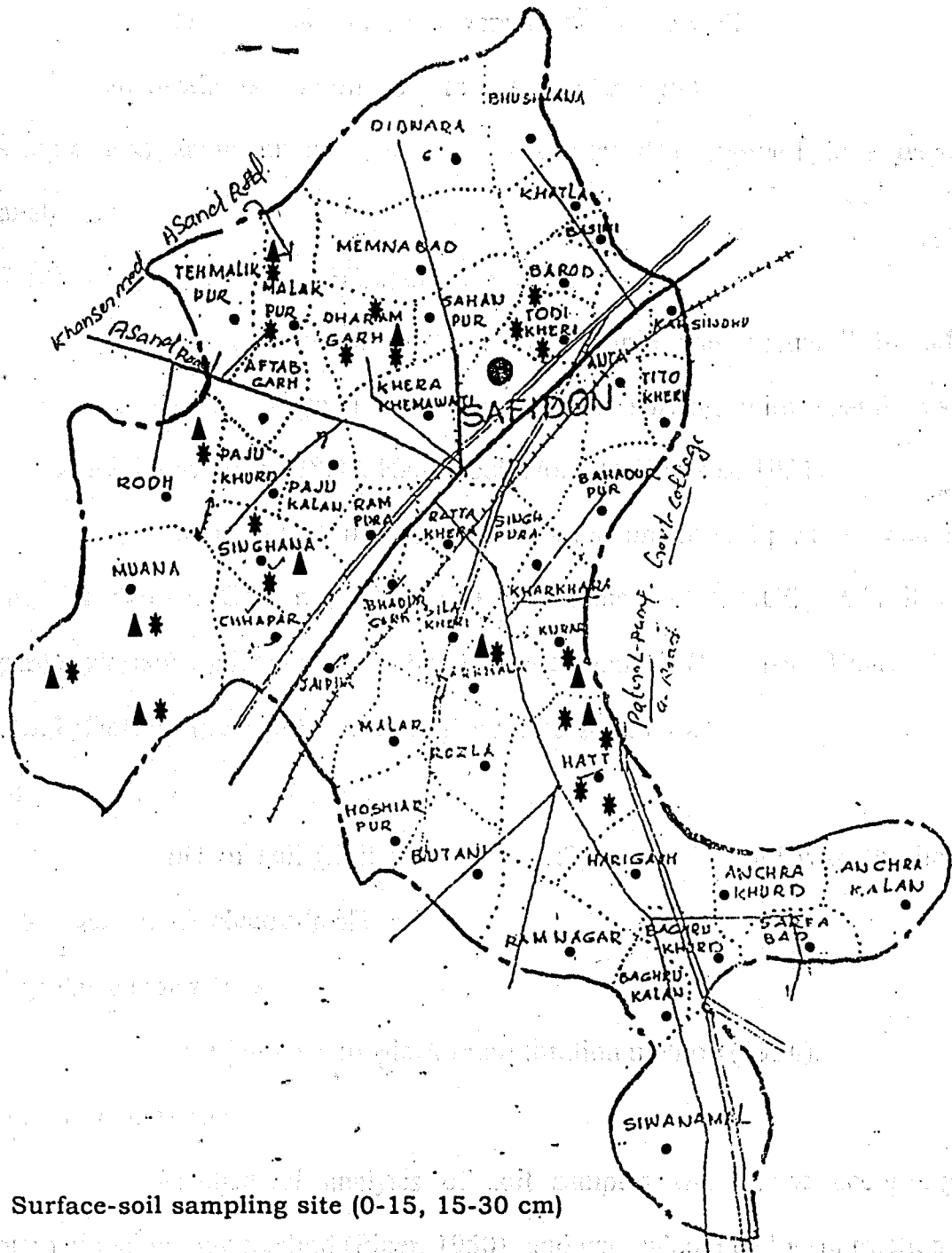
Quality	Class	EC (dS m ⁻¹)	SAR (m mo L ⁻¹) ^{1/2}	RSC (me L ⁻¹)
Good	A	<2	<10	<2.5
Saline waters	B			
Marginally saline	B ₁	2-4	<10	<2.5
Saline	B ₂	>4	<10	<2.5
High SAR saline	B ₃	>4	>10	<2.5
Alkali waters	C			
Marginally alkali	C ₁	<2	<10	2.5-4.0
Alkali	C ₂	<2	<10	>4.0
Highly alkali	C ₃	Variable	>10	>4.0

3.3 SOIL CHARACTERISTICS

3.3.1 Collection of soil samples

Based on the results of under ground irrigation water, the soil samples were collected during the month of June 2003. Ten sites were selected for soil sampling from (0-75cm) soil depth at an interval of 15cm. Out of ten sites eight sites belong to irrigation with saline sodic water, one marginally saline, and one sodic.

In addition to the above sampling ten surface (0-15) and subsurface (15-30cm) soil samples were also collected from the field of same farmer where these waters were in use in conjunction with canal water irrigation.



* Surface-soil sampling site (0-15, 15-30 cm)

▲ Soil samples (0-75 cm) depth

Fig. 3: Map of Safidon Block indicating soil sampling sites

3.3.2 Processing of soil samples

The collected samples were air dried and well ground with the help of wooden pestle and mortar and then sieved through 2 mm sieve. Each soil sample was again mixed thoroughly and placed in polyethylene bags for analysis.

3.3.3 Preparation of soil saturation paste

Saturated paste of each soil sample was prepared by adding distilled water to weighted soil samples and stirring with spatula as per procedure described in USDA Hand book No. 60 (Richards, 1954).

Saturation extract collected from saturated soil paste was analysed for E_{Ce}, cations (Ca^{+2} , mg^{+2} , Na^+ , K^+) and anions (CO_3^{-2} , HCO_3^- , Cl^- , SO_4^{-2}) as per standard procedures as described for water analysis (Richards, 1954).

3.3.4 Determination of chemical properties of soil

pH

pH of soil (Soil water ratio 1:2) was measured with the help of Backman's glass electrode pH meter.

Organic carbon (%)

By Walkley and Black rapid titration method (1934).

Mechanical analysis

Mechanical analysis of soil samples were done according to international pipette method (Piper, 1950) sand was calculated by subtraction.

Cation exchange capacity

It was determined by leaching the soil first with neutral 1 N sodium acetate, followed by washing with alcohol. The adsorbed sodium was displaced by neutral 1N ammonium acetate and the displaced sodium in solution, was estimated flame photometrically.

Results and Discussion

This chapter deals with the results and discussion of present study, carried out in safidon block for characterization of under ground water and their effects on soil properties under the following heads:

4.1 Chemical composition of water samples

All the collected water samples (339) were analysed for various chemical parameters viz. pH, EC, cations (Ca^{+2} , Mg^{+2} , Na^+ , K^+) and anions (Cl^- , SO_4^{-2} , CO_3^{-2} , HCO_3^-). The range of different water quality parameters (EC, SAR, RSC) of safidon block are presented in Table 5.

The lowest EC (0.5 dSm^{-1})/salt content in water sample (0.5 dS m^{-1}) was observed in Village Todikheri and the highest EC (10.9 dS m^{-1}) in village Muana was recorded. The highest SAR [$21.7 (\text{m mol L}^{-1})^{1/2}$] of under ground water was observed in village Muana and the lowest [$0.4 (\text{m mol L}^{-1})^{1/2}$] in village Baisini. The RSC varied from ($0.1-10 \text{ me L}^{-1}$). The minimum RSC (0.1 me L^{-1}) was found in water sample of village Bhadurgarh and maximum (10.0 me L^{-1}) observed in village Malikpur. It means that in Muana village the water were having high EC and high SAR,

Table 5: Range of different water quality parameters of the water samples

Parameter	Range
pH	7.1-9.4
EC (dS m ⁻¹)	0.5-10.9
RSC (me L ⁻¹)	0.1-10.0
SAR (m mol L ⁻¹) ^½	0.4-21.7
Ca ⁺² (me L ⁻¹)	1.8-24.8
Mg ⁺² (me L ⁻¹)	0.8-18.2
Na ⁺ (me L ⁻¹)	0.4-71.0
K ⁺ (me L ⁻¹)	0.1-0.7
Cl ⁻ (me L ⁻¹)	1.0-57.2
SO ₄ ⁻² (me L ⁻¹)	0.3-39.8
CO ₃ ⁻² (me L ⁻¹)	0.1-5.6
HCO ₃ ⁻ (me L ⁻¹)	1.6-22.2

indicating thereby saline sodic waters. Similar results have also been reported by Manchanda (1976).

The analysis of water samples, indicated that sodium content was maximum (71.0 me L⁻¹) followed by calcium (24.8 me L⁻¹), magnesium (18.2 me L⁻¹) and potassium (0.7 me L⁻¹). The Na⁺ concentration in the samples had a wider range (0.4-71.0 me L⁻¹) followed by Ca⁺² (1.8-24.8 me L⁻¹) and Mg⁺² (0.8-18.2 me L⁻¹).

Among anions chloride was the dominant ion with a maximum value (57.2 me L⁻¹) found in village Muana and minimum value (1.0 me L⁻¹) was observed in village Todikheri. The highest value of sulphate (39.8 me L⁻¹) was recorded in village Muana and minimum was found in village Sarfabad. The bicarbonate ranged (1.6-22.2 me L⁻¹) with a maximum (22.2 me L⁻¹) value in the water sample of village Bagrhu Kalan and minimum (1.6 me L⁻¹) was observed in village Rattakhera. The carbonates varied from (0.1-5.6 me L⁻¹) with maximum value (5.6 me L⁻¹) in water samples of village Anchrakurd and minimum 0.1 me L⁻¹ in village Rattakhera.

It is concluded that under ground water of sodifon block are Na⁺-Ca⁺²-Mg⁺²-K⁺ type dominated by chlorides.

The high potassium concentration 0.7 me L⁻¹ in the water samples of Bagrhu Khurd indicated that 20 kg of potassium is supplied per hectare per 7.5cm of irrigation.

The salt distribution in under ground water presented in Fig. 4 showed that percent samples in various EC classes increased with increase in the EC of irrigation upto 2 dS m⁻¹ and thereafter decreased gradually with further increase in EC of the irrigation waters. The highest

(28%) samples remained concentrated in EC class 1-2 dS m⁻¹. It is observed that 73 percent water samples had EC <4 dS m⁻¹ and 27 percent sample had EC 4-10 dS m⁻¹ (Fig. 4). Only four samples were having EC >10 dS m⁻¹.

The village wise chemical analysis of the 339 samples is presented in Appendix-I. The concentration of sodium, calcium, magnesium, potassium, chloride, sulphate, bicarbonate and carbonate ions increased with increase in EC of the water samples (Table 6 and Fig. 5 & 6).

Cationic concentration showed the dominance of Na⁺ followed by Ca⁺², Mg⁺² and then K⁺. As shown in Fig. 6, the anionic concentration was found in order HCO₃⁻ > Cl⁻ > SO₄⁻² upto EC 3 dS m⁻¹ and EC between 3-6 dS m⁻¹ the trend was (Cl⁻ > HCO₃⁻ > SO₄⁻²). Above EC 6 dS m⁻¹ chlorides dominated over sulphate followed by bicarbonate and carbonate.

The similar results of chemical composition of under ground water of Safidon block was observed by Manchanda (1976).

4.2 CLASSIFICATION OF IRRIGATION WATERS

4.2.1 Manchanda's classification

Based on the EC, SAR and RSC, the water samples were classified as per criteria given by Manchanda, 1976 for water quality classification.

The data presented in Table 7 and Fig. 7 revealed that 27% water samples were found in good quality class where as 25% samples were marginally saline. Amongst the poor quality water, 9% saline, 19% sodic and 20% were saline-sodic in nature. The highest number of water samples 92 followed by 85 samples in good and marginally categories

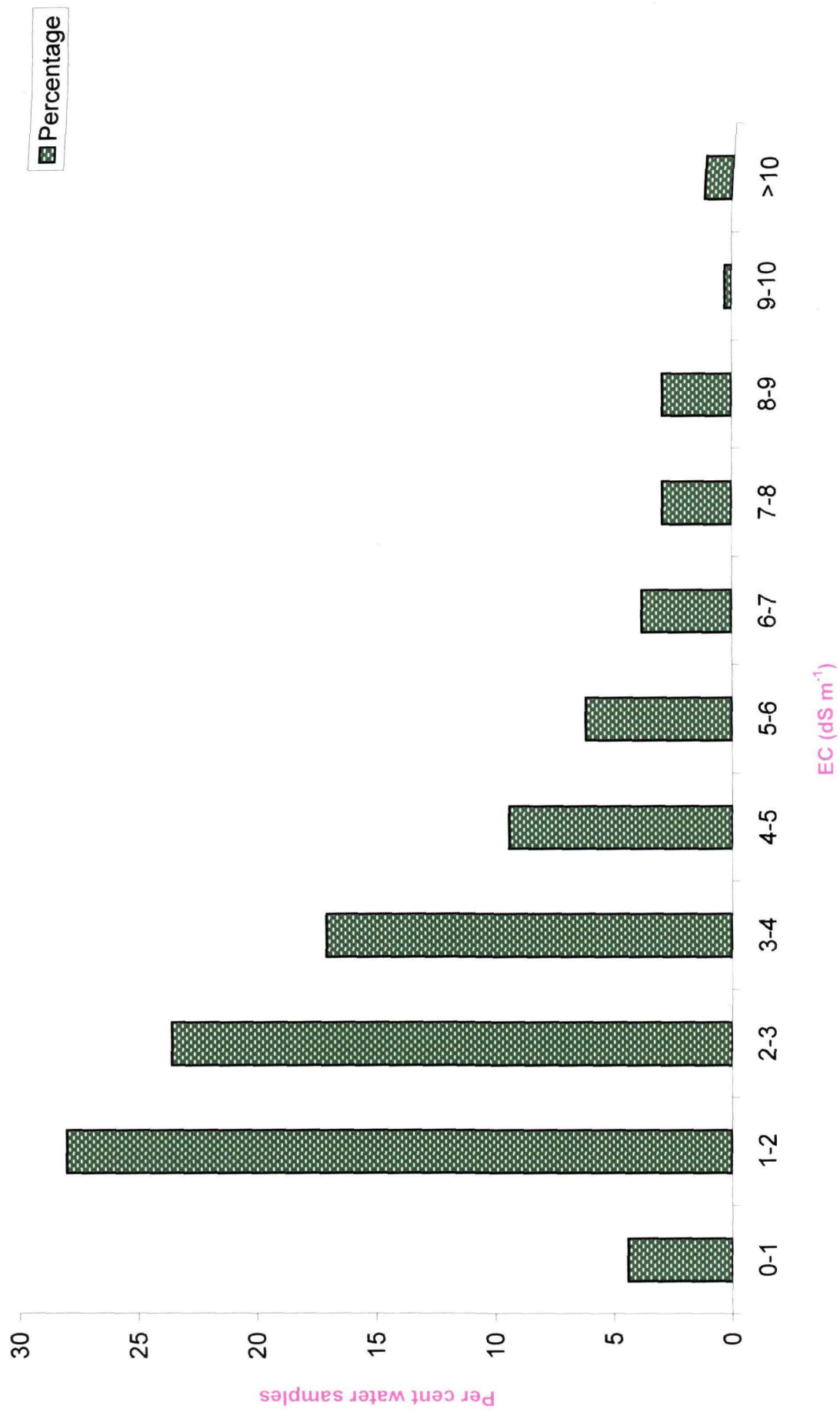


Fig. 4: Per cent water samples in different EC classes

Table 6: Chemical composition of Tube well water samples of Safidon block in different EC classes (meL^{-1})

EC (iw) Classes (dS m^{-1})	No. of Samples	Na^+	Ca^{+2}	Mg^{+2}	K^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}
0-1	15	2.7	3.4	2.1	0.7	0.6	3.9	1.9	1.3
1-2	95	6.7	4.1	2.8	0.2	0.8	5.7	4.1	2.7
2-3	80	14.0	5.6	3.7	0.2	1.1	8.5	6.5	5.2
3-4	58	22.4	6.9	4.6	0.3	1.7	10.9	13.8	7.1
4-5	32	25.0	10.4	6.6	0.3	1.5	11.9	19.0	9.8
5-6	21	32.9	12.6	7.9	0.3	1.1	11.8	28.1	10.7
6-7	13	37.3	16.3	9.9	0.5	1.7	12.7	37.9	13.5
7-8	10	49.3	13.6	8.2	0.5	1.8	10.2	36.6	18.7
8-9	10	56.4	16.4	9.6	0.6	2.0	9.4	43.4	25.4
9-10	1	64.0	17.6	11.2	0.3	0.6	10.8	45.0	30.0
>10	4	67.3	21.3	12.4	0.6	0.7	7.9	51.2	33.9

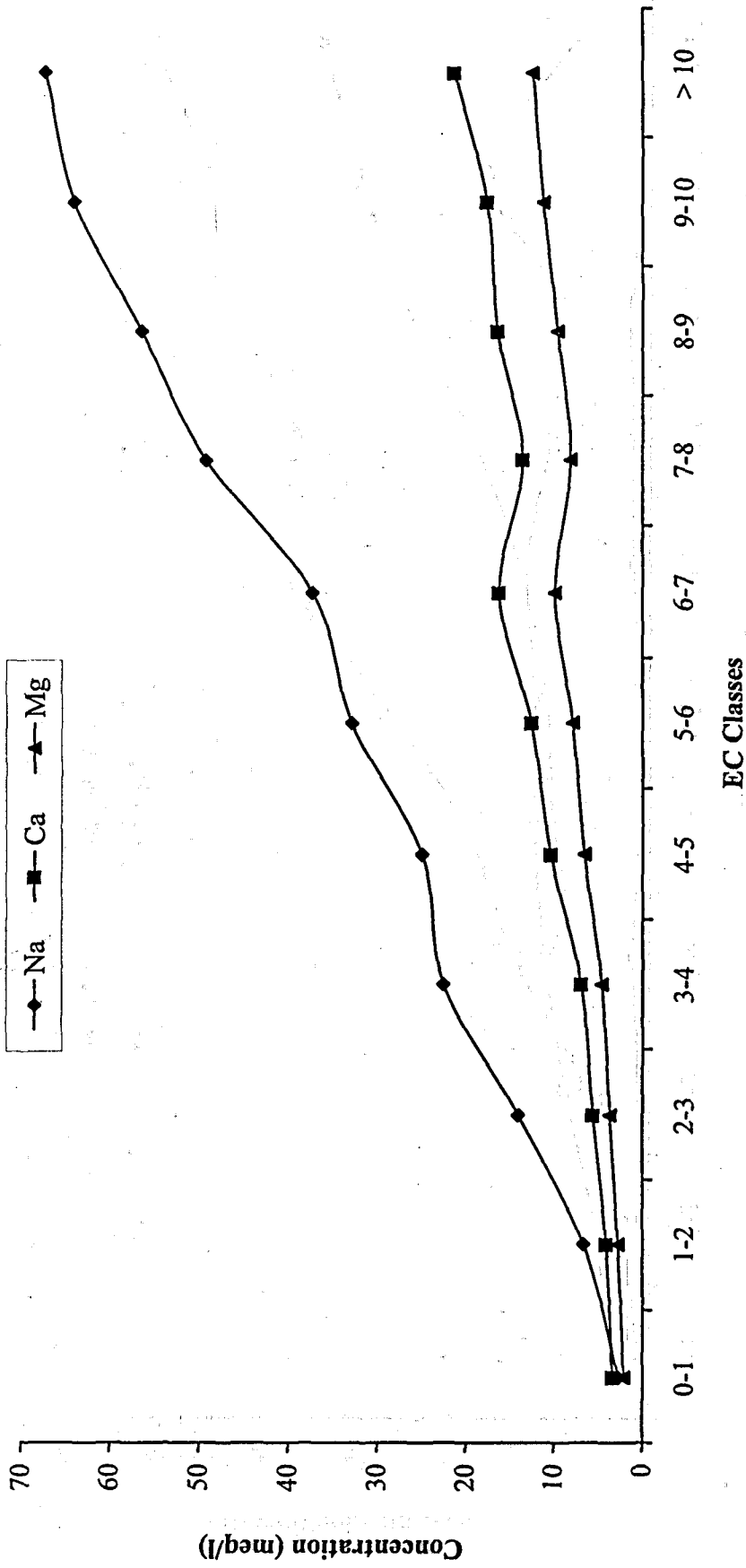


Fig. 5: Average cationic composition (Na^+ , Ca^{+2} and Mg^{+2}) of water samples in different EC classes in Safidon block.

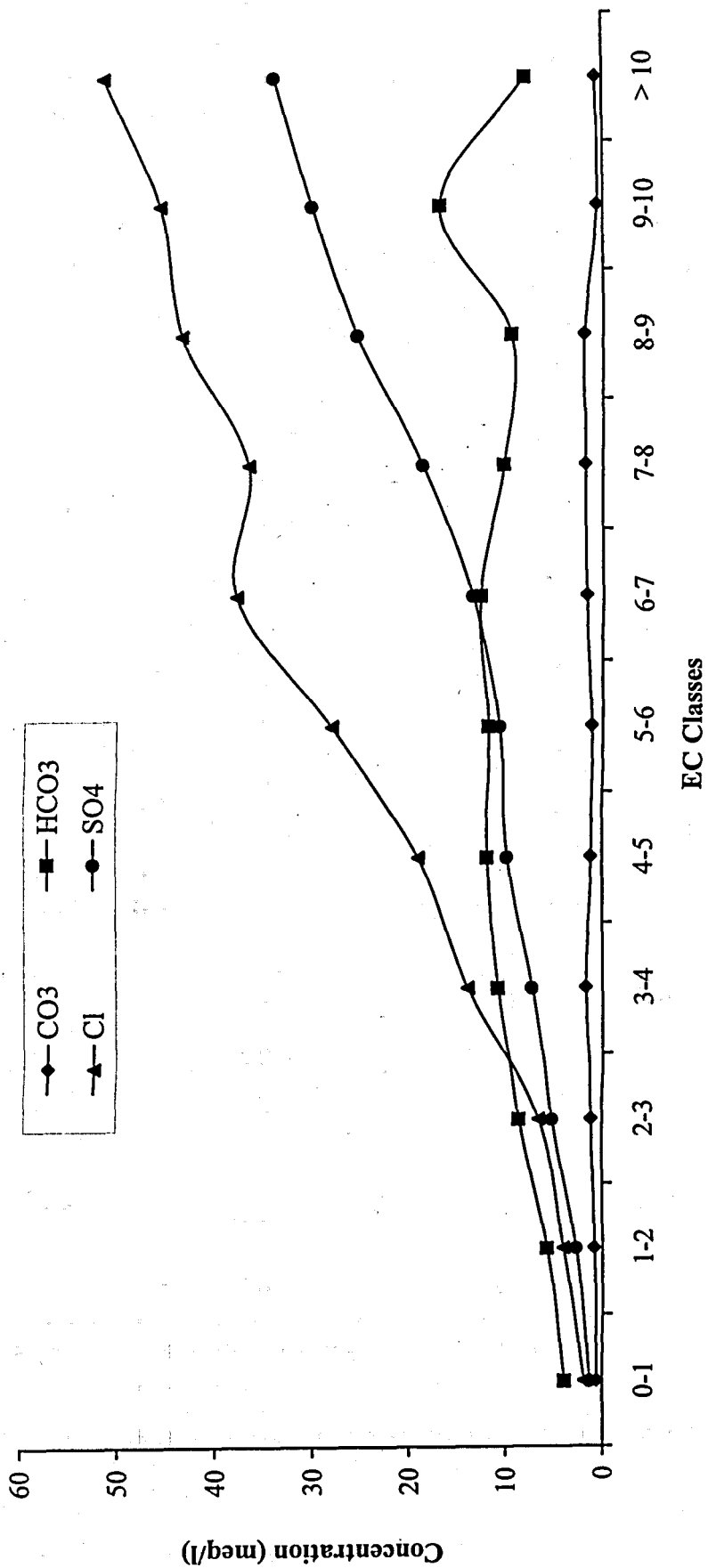


Fig. 6: Average anionic composition (CO₃⁻², HCO₃⁻, Cl⁻ and SO₄⁻²) of water samples in different EC classes in Safidon block.

Table 7: Ground water quality classification (Manchanda, 1976)

Quality	Class	No. of Samples	Percentage
Good Water	A	92	27
Marginal Water	B	85	25
Poor Water			
i) Saline	C ₁	29	9
ii) Sodic	C ₂	66	19
iii) Saline sodic	C ₃	67	20

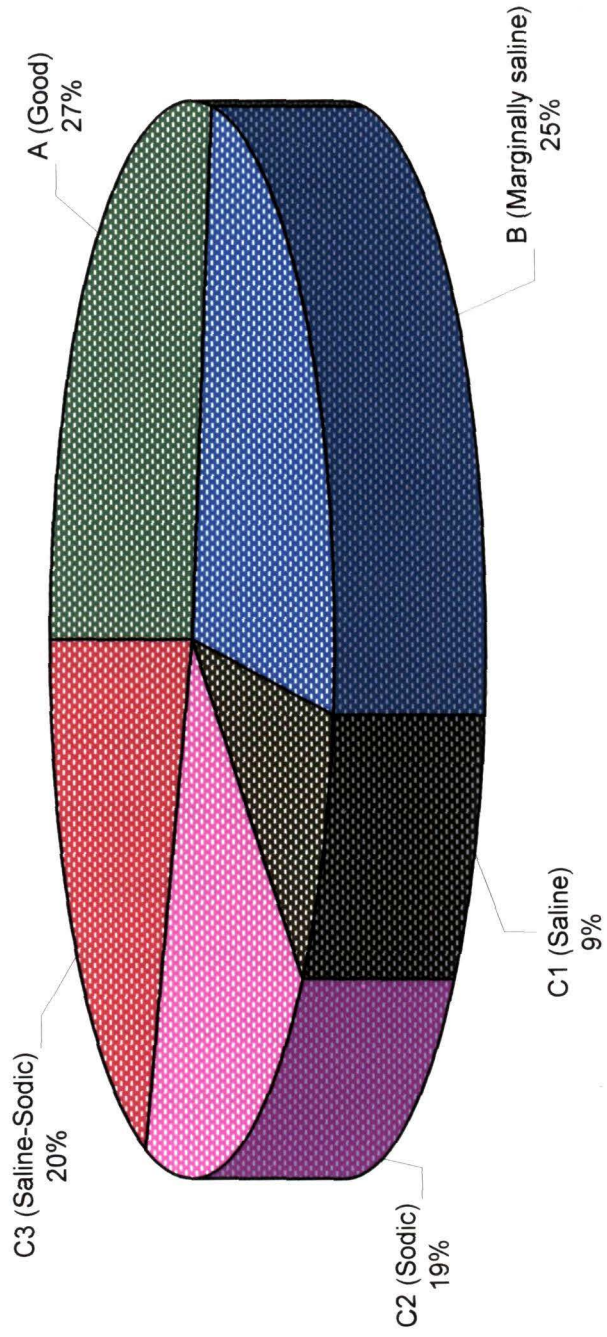


Fig. 7: Per cent frequency distribution of water quality in Safidon Block of Jind district (2002-2003)

respectively. The village wise quality of under ground water is presented in Appendix-II.

Earlier Manchanda (1976) found that in Safidon Block 15% water samples were good, 11% marginally saline. Among the poor quality waters 25%, 13% and 36% were saline, sodic and saline-sodic respectively as shown in Fig. 8.

It is observed that the quality of water has changed over the 26 years. Fig (8 & 7) showed that good quality water changed from past 15% to 27%, marginally saline 11% to 25%, saline 25% to 9% and sodic 13% to 19% and saline sodic 36% to 20%. The water quality change during the period may be ascribed to the introduction of a large number of canals and development of irrigation facilities, large volumes of water due to seepage from canals and water courses and excess irrigations percolated down to aquifer, thereby, diluting the under ground water. Manchanda (1998) also speculated the similar reasons that due to non exploitation of under ground water for irrigation and consequent rise in water table @ 9.28 cm years-1 in this area has led to change in water quality.

4.2.2 AICRP classification

AICRP (1989) classification is based on the characteristics features of majority of ground water in use with the farmers in different agro ecological regions of the country and indices that describe the nature of hazards on soils and crop i.e. EC, SAR and RSC.

According to this criteria 27% water samples were good, 23% marginal, 9% saline, 16% high SAR saline, 8%, 20% and 15% were marginally alkali, alkali and highly alkali respectively (Table 8 and Fig. 9).

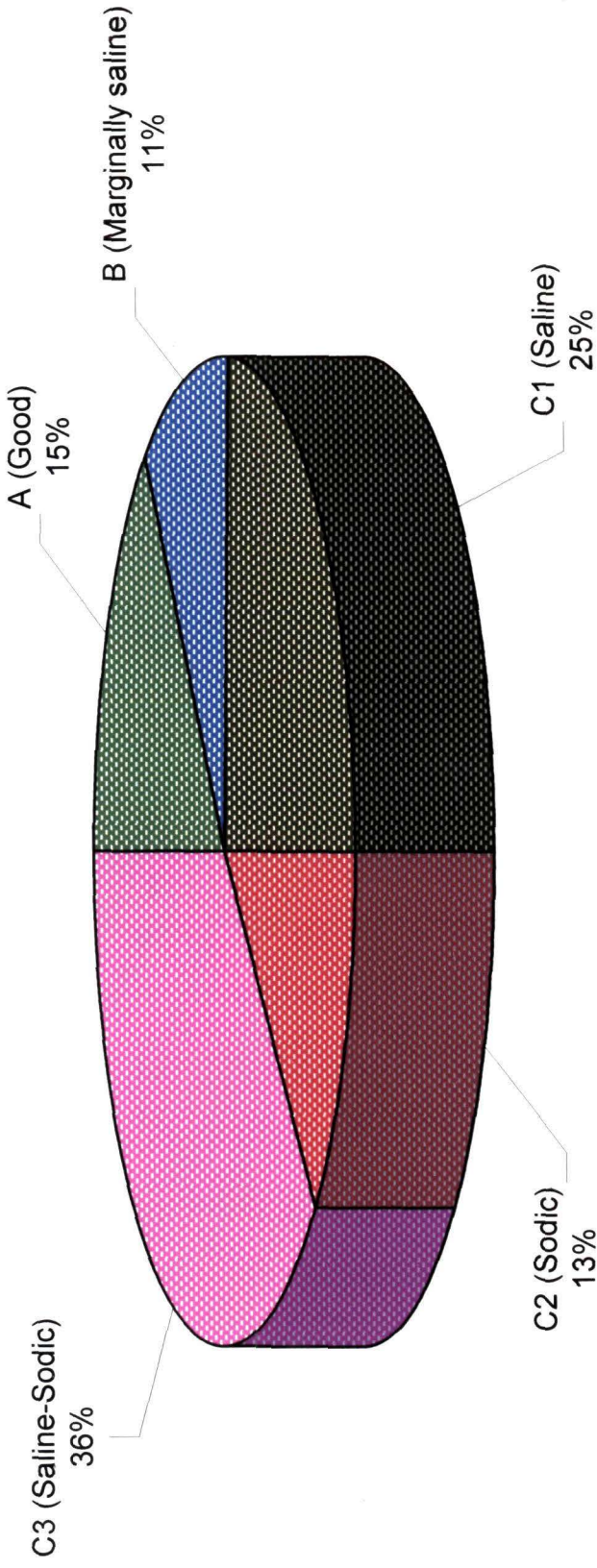


Fig. 8: Per cent frequency distribution of water quality in Safidon Block of Jind district (Manchanda, 1976)

Table 8: Ground Water quality classification

Quality	Class	No. of Samples	Percentage
Good	A	92	27
Saline waters	B		
i) Marginally saline	B ₁	79	23
ii) Saline			
iii) High SAR saline	B ₂	31	9
	B ₃	53	16
Alkali waters	C		
i) Marginally alkali	C ₁	26	8
ii) Alkali	C ₂	8	2
iii) Highly Alkali	C ₃	50	15

The highest number of samples 92 were found in good category 79, 31 and 53 samples in marginally saline, saline and high SAR categories, respectively. The number of samples in alkali waters were 26, 8 and 50 marginally alkali, alkali and highly alkali class, respectively.

The fig. 7 & 9 depict that water quality was at par with both the criteria for classification. Although limits of classifying parameters are same but the only discernible difference is in the name of classes. The marginal water of Manchanda's classification were designated marginally saline in AICRP and similarly saline-sodic and marginally saline waters were described as high SAR saline and saline waters, respectively. The difference is in case of alkali water classification. Sodic waters were categorized into 3 classes in AICRP classification as compared to one class in Manchanda (1976) classification.

The water samples (73%) having $EC < 4 \text{ dS m}^{-1}$ may be used with no appreciable harmful effect on crop and soil. But its long term use depends on type of soil, rainfall and crops to be grown and another 27% water required specific management practices depending upon the soil type, crop and climatic factors.

4.3 Effect of different quality waters on soil properties

4.3.1 Site-I-Village Muana

The chemical composition of the tubewell water is shown in Table 9. The EC of this tubewell water sample was 10.0 dS m^{-1} , SAR 16.0 (m mol L^{-1})^{1/2} and RSC nil. Sodium (66.8 me L^{-1}) was the dominant cation followed by calcium (24.2 me L^{-1}) and magnesium (10.8 me L^{-1}). The anionic concentration was in the order ($\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{CO}_3^{2-}$). The

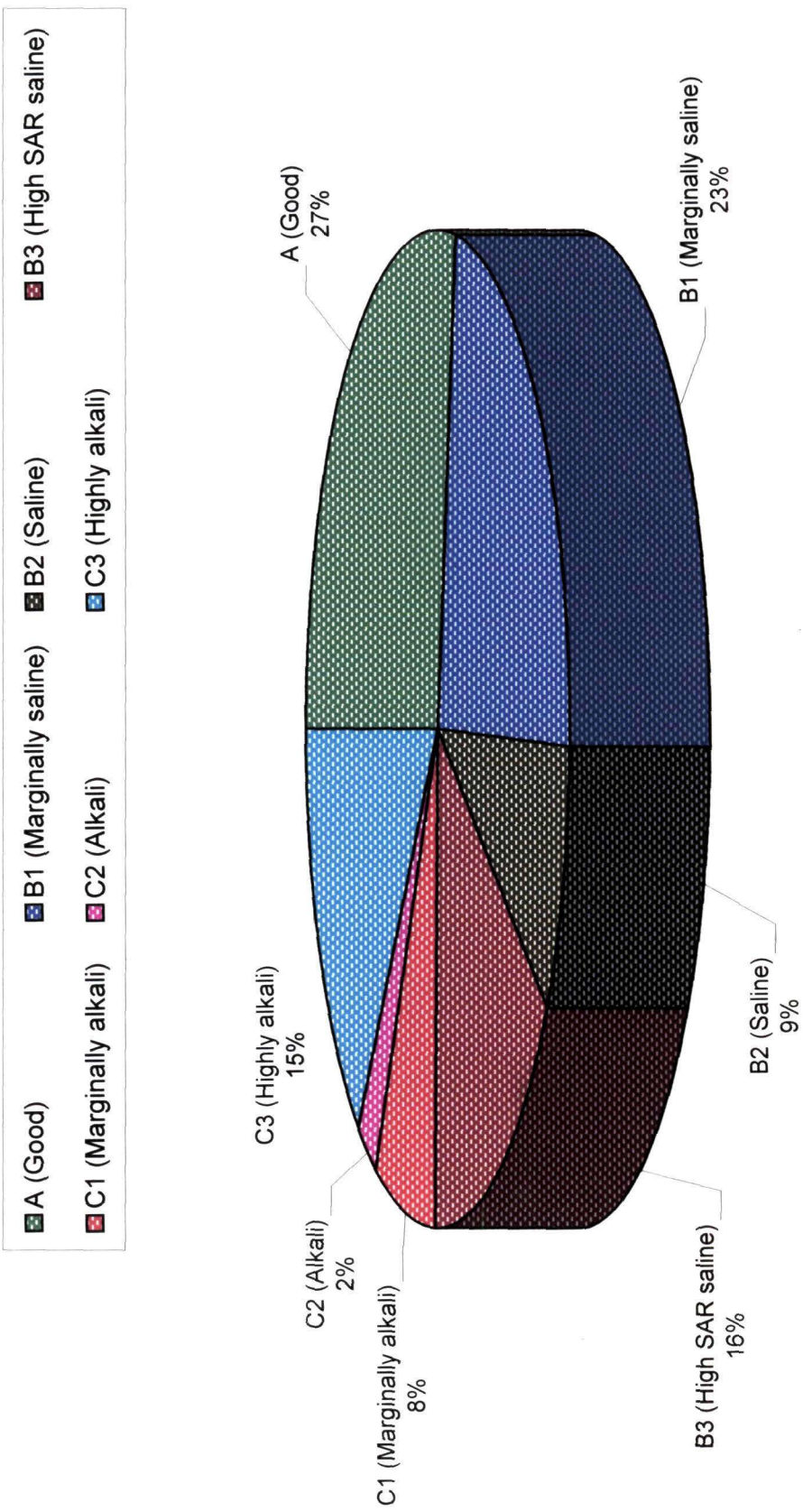


Fig. 9: Per cent frequency distribution of water quality in Safidon Block of Jind district

SITE-I (MUANA)

Table 9: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	me L ⁻¹				RSC	SAR (m mol L ⁻¹) ^{1/2}
						Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺		
7.3	10.0	1.2	6.0	50.4	36.0	24.2	10.8	66.8	0.5	nil	16.0

Name of farmer=Mangat Ram S/O Shish Ram
 Number of years the tube well is in operation =15 years
 Depth of tube well =50 ft.

Table 10: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
0-15	32.3	8.9	11.1	11.8	77.1	Loam	0.4
15-30	35.2	9.9	15.0	14.8	70.3	Sandy loam	0.4
30-45	45.6	14.5	24.4	22.0	53.6	Silty loam	0.3
45-60	40.3	12.2	19.6	18.3	62.0	Silty loam	0.2
60-75	42.2	13.0	21.4	19.7	58.9	Silty loam	0.1

general information about installation of tubewell, depth, cropping pattern and farmer's comments are presented in appendix III.

The data on Physico-chemical properties of soil is presented in Table 10 showed that the texture of soil was loam in upper (0-15cm) surface, sandy loam in sub surface (15-30cm) and silty loam in the lower depths (30-45, 45-60, 60-75cm). Clay content ranged from 11.2 –24.4 percent. The cation exchange capacity (CEC) varied from 8.9 to 14.5 C mol (P⁺) Kg⁻¹. The organic carbon varied from 0.1-0.4 percent. The soil pH at surface and subsurface was 8.9 and 8.8 respectively. The pH had no trend with depth.

The chemical composition of saturation extract of soil in table 11 revealed that the maximum E_{Ce} (32.3 dS m⁻¹) was observed in surface layer. The E_{Ce} and SARE decreased with increasing depth. The mean value of E_{Ce} and SARE (0-75cm) layer were 23.2 dS m⁻¹ and 27.8 (m molL⁻¹)^{1/2} respectively. Kanwar and Kanwar (1971) reported that continuous irrigation with water having no RSC increased the electrical conductivity more than the continuous irrigation with water containing RSC but pH of the soil was increased as the RSC increased. They also reported that RSC in the form of CO₃⁻² was more harmful than in the form of HCO₃⁻.

The mean cationic composition of saturation extract in the soil profile (0-75 cm) was in order (Na⁺>Ca⁺²>Mg⁺²>K⁺), likewise mean anionic composition of saturation extract was of the order (Cl⁻>SO₄⁻²>HCO₃⁻>CO₃⁻²). Appreciable amount of K⁺ (3.3, me L⁻¹) was observed in upper layers of soil (0-15, 15-30cm). The highest accumulation of salts in the upper surface may be due to low annual rainfall (301.3mm) during

Table 11: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	Ece (dS m ⁻¹)	me L ⁻¹										SARe (m mol L ⁻¹) ^{1/2}
			CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺			
0-15	8.9	32.3	11.1	38.4	201.8	73.0	64.4	34.7	227.8	3.3	32.4		
15-30	8.9	27.3	6.7	32.5	170.2	58.2	53.8	26.9	187.6	2.7	29.5		
30-45	8.1	19.8	2.63	22.8	125.7	42.0	40.3	19.3	138.4	1.6	25.4		
45-60	8.6	19.8	Nil	18.8	132.9	37.7	33.7	17.9	140.9	1.4	27.7		
60-75	8.5	16.5	Nil	9.5	112.1	30.3	34.1	13.2	114.5	0.8	23.5		
Mean	8.9	23.2	4.1	24.4	148.5	48.3	45.2	22.4	161.8	1.9	27.8		

2001-2002. The higher concentration of Na^+ led to hardening of soil when dry and resulted the problem of water stagnation. Gupta and Abi Chandani (1970) reported that saline water irrigated soils in the semi arid zone of western Rajasthan became completely non-saline upto 40cm after the rainfall of 350 to 450 mm.

4.3.2 Site – II (Village: Muana)

The chemical composition of the sample of tube well water is shown in Table 12. The EC of the water sample was 7.4 dS m^{-1} , SAR 20.8 (m mol^{-1})^{1/2} and RSC nil. The dominant cation was Sodium (57.0 me L^{-1}) followed by calcium (9.8 me L^{-1}) and magnesium (5.4 me L^{-1}). Whereas among the anions, chloride (28.4 me L^{-1}) was dominant followed by sulphate (25.0 me L^{-1}) and bicarbonate (8.8 me L^{-1}). This water was in operation for the last eight years. In initial 2-3 years bumper paddy-wheat crops were obtained and after that the yields declined. Now the farmer is following fallow-wheat crop rotation and obtained poor yield of wheat. The data presented in Table (13) indicated that the texture of soil was loam through out the profile upto 0-75 cm. Clay content varied from 17.1 to 20.5 per cent. The CEC ranged from 11.4 to 12.6 C mol (P^+) kg^{-1} and low organic carbon content ranged from 0.2 to 0.4 per cent. The pH had no specific trend with depth. The chemical composition of saturation extract of soil (Table 14) revealed that maximum, E_{Ce} (27.1 dS m^{-1}) and SARE [$32.5 (\text{m mol L}^{-1})^{1/2}$] was on the upper surface (0-15 cm) of soil. The E_{Ce} and SARE decreased from 27.1 to 16.4 dS m^{-1} and 32.5 to $27.7 (\text{m mol L}^{-1})^{1/2}$ respectively with increasing soil depth from 0-15cm to 60-75cm.

SITE-II (MUANA)

Table 12: Chemical composition of Tube-well water

pH	Eciw (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC	SAR (m mol L ⁻¹) ^{1/2}
		me L ⁻¹									
7.6	7.4	1.0	8.8	28.4	25.0	9.8	5.4	57.0	0.5	Nil	20.9

Name of farmer=Vikram S/O Tarif Singh
 Number of years the tube well is in operation =8years
 Depth of tube well =50 ft.

Table 13: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
0-15	40.4	12.2	19.7	18.4	61.9	Loam	0.4
15-30	38.6	11.5	18.0	17.1	65.0	Loam	0.3
30-45	41.2	12.6	20.5	19.0	60.5	Loam	0.2
45-60	38.5	11.3	17.9	17.0	65.1	Loam	0.2
60-75	38.7	11.4	18.1	17.1	64.8	Loam	0.2

Table 14: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m^{-1})	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+	SARE ($\text{m mol L}^{-1/2}$)
0-15	9.1	27.1	6.9	53.5	116.8	90.1	50.5	22.8	196.5	2.8	32.5
15-30	9.1	26.7	3.1	52.8	116.0	90.1	50.8	21.8	193.7	2.3	32.2
30-45	8.9	23.5	0.9	45.6	100.9	81.5	41.7	18.4	171.2	1.8	31.2
45-60	9.1	19.6	Nil	35.3	86.1	75.8	29.1	14.5	148.4	1.3	31.8
60-75	9.2	16.4	Nil	21.7	68.6	63.9	26.8	12.4	122.8	0.7	27.7
Mean	9.1	22.6	2.18	41.8	97.7	80.3	39.8	17.8	166.5	1.8	30.9

The mean cationic composition of saturation extract of soil profile (0-75cm) was in the order of $\text{Na}^+ > \text{Ca}^{+2} > \text{mg}^{+2} > \text{K}^+$. Similarly, mean anionic composition was in the order ($\text{Cl}^- > \text{SO}_4^{-2} > \text{HCO}_3^- > \text{CO}_3^{-2}$).

4.3.3 Site – III (Village: Muana)

The chemical composition of tubewell water in western direction of village is given in table 15. The water contained high amounts of sodium (62.0 me L^{-1}), calcium (14.8 me L^{-1}) and magnesium (5.8 me L^{-1}). The EC of the water was (8.4 dS m^{-1} and SAR was $19.3 (\text{m mol L}^{-1})^{1/2}$. This water was in use for the last seven years and the depth of tubewell was 50 feet.

The soil physico-chemical data reported in (Table 16) revealed that the texture of soil was loam up to depth 0-60 cm and at lower layer (60-75cm) it was sandy loam. The clay content varied from 17.6 to 19.2 per cent in (0-75cm) soil depth. The CEC and organic carbon ranged from 11.2 to 12.0 C mol (P^+) Kg^{-1} and organic carbon varied from 0.1 to 0.4 per cent respectively. The chemical composition of saturation extract as indicated in (Table 17) revealed that the salt build up decreased with increase in depth of soil and the maximum ECe (17.5 dS m^{-1}) was found on the surface layer (0-15cm) and minimum ECe 11.4 dS m^{-1} in 60-75cm soil depth. The SARe did not show any trend with depth but the highest value ($21.6 \text{ m mol L}^{-1})^{1/2}$ was observed in 15-30 cm soil layer because sodium concentration in this layer was more than others. The mean value of ECe (14.3 dS m^{-1}) and SARe $20.67 (\text{m mol L}^{-1})^{1/2}$ were observed in the profile. The mean cationic composition of the saturation extract of soil profile down to 75 cm was in the orders $\text{Na}^+ > \text{Ca}^{+2} > \text{Mg}^{+2} > \text{K}^+$.

SITE-III (MUANA)

Table 15: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	me L ⁻¹							SAR (m mol L ⁻¹) ^{1/2}		
		CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	Ca ⁺²	Mg ⁺²	Na ⁺		K ⁺	RSC
7.5	8.4	1.4	9.2	35.2	33.0	14.8	5.8	62.0	0.5	Nil	19.3

Name of farmer=Pitamber Singh S/O Kali Ram
 Number of years the tube well is in operation =7 years
 Depth of tube well =50 ft.

Table 16: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	39.8	12.0	19.5	18.0	62.9	Loam	0.2
30-45	38.9	11.5	10.3	17.3	64.4	Loam	0.3
45-60	69.2	11.7	18.3	17.5	63.9	Loam	0.1
60-75	38.2	11.3	17.6	16.8	65.7	Sandy loam	0.1

Table 17: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	E _{Ce} (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	SARE (m mol L ⁻¹) ^{1/2}
0-15	9.4	17.5	14.1	63.6	48.5	38.4	33.3	19.2	108.1	3.2	21.1
15-30	9.3	15.6	9.0	57.2	43.2	33.1	28.1	16.1	101.4	2.2	21.6
30-45	9.4	14.2	6.2	52.4	32.9	27.8	24.7	15.4	94.6	1.9	21.1
45-60	9.3	12.9	3.1	48.9	31.1	21.4	21.4	13.0	82.6	0.9	19.8
60-75	9.2	11.4	Nil	38.7	27.7	11.5	19.9	9.4	76.4	0.6	19.9
Mean	9.4	14.3	6.5	52.2	36.7	26.4	25.5	14.7	92.6	1.8	20.7

The mean anionic composition followed the trend $\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-} > \text{CO}_3^{2-}$.

Generally, salt build up in all the soils irrigated with saline water showed higher deposition of salts on the surface layer which gradually decreased with depth. This phenomenon of accumulation of higher salts in surface layers was due to up-ward movement of salts during summers because sampling was done in the month of June, 2003 well before the onset of monsoon.

Rainfall is also one of the important factor which regulate the salt build up in soil depending on soil depth. Manchanda and Chawala (1981) also reported that 500mm rainfall during monsoon removed, the salts accumulated during the winter season ($\text{ECe}-14-33.6 \text{ dS m}^{-1}$) due to the irrigation water of $\text{EC}_{\text{iw}} 15-19 \text{ dS m}^{-1}$ in a coarse loamy sand to sandy soils but the results in present investigation also showed the salt accumulation on surface layer. This development is attributed to very scanty and erratic rainfall during the last four years (Table 1). Therefore, the salts added in soil with tubewell waters could not be leached down from the root zone.

4.3.4 Site - IV (Village: Singhana)

The chemical composition of the tubewell water under study is given in Table 18. The EC of this water was 4.7 dS m^{-1} , SAR 18.6 (mmol L^{-1})^{1/2} and RSC 2.0 me L^{-1} . Among the cations sodium (38.0 me L^{-1}) was the dominant followed by calcium (4.6 me L^{-1}) and magnesium (3.8 me L^{-1}) the anionic concentration showed that chloride (28.0 me L^{-1}) was dominate over SO_4^{2-} (11.0 me L^{-1}) and HCO_3^- (10.0 me L^{-1}). This water was in use for the last six years. The farmer explained that during initial

Site-IV (SINGHANA)

Table 18: Chemical composition of Tube-well water

pH	EC _{iw} (dS m ⁻¹)	me L ⁻¹										SAR (m mol L ⁻¹) ^{1/2}
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC		
8.0	4.7	0.4	10.0	28.0	11.0	4.6	3.8	38.0	0.2	2.0	18.6	

Name of farmer: Hukum Singhs S/O Punjaba Singh
 Number of years the tube well is in operation =6years
 Depth of tube well =120ft.

Table 19: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
0-15	36.0	10.1	13.3	15.0	69.7	Loam	0.5
15-30	33.7	8.8	12.8	13.0	74.2	Sandy loam	0.3
30-45	45.6	14.5	24.4	22.0	53.6	Clay loam	0.2
45-60	37.3	10.7	16.7	16.0	67.3	Loam	0.2
60-75	34.2	9.1	13.3	13.5	73.2	Loam	0.1

years paddy-wheat crop rotation was followed, continuous use of this water decreased yield of both the crops, to deterioration of physical conditions of the soil.

The analysis of soil samples down to 75 cm revealed that the texture of soil was loam and sandy loam in the upper layer (0-15cm and 15-30cm), clay loam to loam in the lower depth (30-45, 45-60, 60-75). The CEC ranged from 8.8-14.5 C mol (P⁺) kg⁻¹, the organic carbon varied from 0.1-0.5 per cent (Table 19).

The chemical composition of the saturation extract of the soil profile (Table 20) revealed maximum accumulation of salts in the upper layer of soil (0-15 cm). Salt accumulation (ECe) in the soil decreased with increasing depth. The maximum value of ECe (19.0 dS m⁻¹) was found on the surface with mean value of ECe (14.3 dS m⁻¹) in the subsequent layers of profile. SARE of the soil profile also decreased with depth, highest SARE was 19.5 (m mol L⁻¹)^{1/2} in surface soil with a mean value of SARE 17.1 (m mol L⁻¹)^{1/2} in the subsequent layers profile.

The mean cationic composition of saturation extract of soil profile down to 0-75 cm depth was in the order Na⁺ > Ca⁺² > Mg⁺² > K⁺. Similarly mean anionic composition was in the order Cl⁻ > HCO₃⁻ > SO₄⁻² > CO₃⁻².

Manchanda and Bhandari (1976) observed that the irrigation of wheat with highly saline waters EC (15-19 dS m⁻¹) SAR (12-16) on coarse loamy well drained soils in Haryana developed an ECe of 15-35 dS m⁻¹ in the 0-30 cm soil depth. The initial ECe was, reduced to 2.5 dS m⁻¹ after a rainfall of event about 500 mm. However, Jain *et al.* (1976) reported from Rajasthan that irrigation with brackish water EC 4.8 dS m⁻¹,

Table 20: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	me L ⁻¹										SARe (m mol L ⁻¹) ^{1/2}
			CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺			
0-15	9.2	19.0	6.7	53.3	91.0	36.6	45.5	24.4	115.4	1.6	19.5		
15-30	9.2	17.1	5.9	49.8	80.6	32.0	39.1	22.5	107.9	1.3	19.4		
30-45	9.4	11.7	4.4	35.0	54.3	20.1	23.6	14.1	72.7	0.7	16.7		
45-60	9.4	13.4	4.3	38.6	57.9	18.2	27.9	15.0	77.2	0.7	16.7		
60-75	9.7	10.1	2.4	32.9	43.6	16.5	34.2	12.9	62.4	0.7	12.9		
Mean	9.3	14.3	4.7	41.9	65.5	24.7	34.1	17.8	87.1	1.0	17.1		

SAR 32 (m mol L^{-1})^{1/2} and RSC 7.4 me L^{-1} for three year did not cause appreciable accumulation of salts in 0-60cm depth of sandy loam permeable soil.

4.3.5 Site – V (Village: Dharmgarh)

The chemical composition of tubewell water is presented in Table 21. Electrical conductivity of the water was 2.9 dS m^{-1} , SAR 9.9 (m mol L^{-1})^{1/2} and RSC 5.8 me L^{-1} . Sodium (20.7 me L^{-1}) was the dominant cation followed by calcium (4.8 me L^{-1}) and magnesium (3.8 me L^{-1}). The anionic constituents showed that the water sample was dominated by HCO_3^- ions (13.2 me L^{-1}) followed by Cl^- (10.1 me L^{-1}), SO_4^{-2} 3.6 (me L^{-1}) and small amount of CO_3^{-2} (1.2 me L^{-1}).

This tubewell has been running for the last 15 years. The farmer opined that his water was sweet in taste, hastens the cooking of vegetables and pulses. Initially paddy wheat crop rotation was followed after some time the farmer observed decline in yield of both the crops and water stagnation problems.

The physico-chemical analysis from 0-75cm given in (Table 22) revealed that texture of soil was sandy loam in surface (0-15cm) and sub surface (15-30cm), layers loam in the (30-45 and 45-60cm) and sandy loam in the lower layer (60-75cm). Clay content varied from 11.7 to 17.2 percent. The CEC ranged from 8.3 to 11.4 $\text{C mol (P}^+) \text{ kg}^{-1}$ and organic carbon varied from 0.1 to 0.5 percent.

The chemical composition of saturation extract of soil (Table 23) revealed that maximum salt build up ($\text{ECe } 8.4 \text{ dS m}^{-1}$) was in the upper surface layer. It decreased with increase in soil depth. The maximum SARe 8.2 (m mol L^{-1})^{1/2} was observed on the upper layer and it

SITE-V (DHARMGARH)

Table 21: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	me L ⁻¹						RSC	SAR (m mol L ⁻¹) ^{1/2}		
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²			Na ⁺	K ⁺
8.8	2.9	1.2	13.2	10.1	3.6	4.8	3.8	20.7	0.2	5.8	9.9

Name of farmer=Puran Singh S/O Kartar Singh
 Number of years the tube well is in operation =15 years
 Depth of tube well =150 ft.

Table 22: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	34.6	9.3	13.8	13.8	72.4	Sandy loam	0.4
30-45	35.7	9.9	15.0	14.7	70.3	Loam	0.3
45-60	37.8	11.0	17.2	16.4	66.4	Loam	0.2
60-75	38.4	11.4	17.3	16.9	65.3	Sandy loam	0.1

Table 23: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	E _{Ce} (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	SAR _e (m mol L ⁻¹) ^{1/2}
0-15	9.7	8.4	6.9	26.6	27.7	19.1	26.6	13.9	36.9	3.1	8.2
15-30	9.5	7.1	4.4	19.0	20.2	16.8	21.3	12.3	33.0	2.6	8.1
30-45	9.7	5.7	Nil	16.9	13.7	14.8	17.9	10.0	25.9	2.3	6.9
45-60	9.8	4.3	Nil	14.6	10.9	10.4	14.6	7.3	21.8	1.9	6.6
60-75	9.7	4.1	Nil	14.2	11.2	8.9	13.6	7.7	23.1	0.9	7.1
Mean	9.7	5.9	2.3	18.3	16.8	13.9	18.8	10.2	28.2	2.2	7.4

showed no trend with depth. The mean value of E_{Ce} SARE was 5.9 dS m⁻¹ and 7.4 (m mol L⁻¹)^{1/2} respectively.

The cationic composition of soil saturation extract was in the same order as that of irrigation water i.e. sodium (28.2 me L⁻¹), calcium 18.8 (me L⁻¹), magnesium (10.2 me L⁻¹) and potassium (2.2 me L⁻¹). The anionic composition of saturation extract showed the trend bicarbonate (18.3 meL⁻¹) > Chloride (16.8>me L⁻¹) > Sulphate (13.9 meL⁻¹) > Carbonate (5.9 me L⁻¹).

Tripathi *et al.* (1971), Chawla (1972), Lal and Singh (1974), Paliwal and Gandhi (1976) and Dhankar *et al.* (1986) reported that waters with high sodium and low salt concentration could successfully be used in light textured soil. Sharma and Minhas (1998) conducted a long term experiment on the effect of sodic waters having RSC, 5 & 10, SAR 20 and 30 (m mol L⁻¹)^{1/2} and EC 2 and 4 dS m⁻¹ and found that pH increased initially and stabilized after 3 years of irrigation where as sodicity and salinity continued to increase during the experimental period. The mean SARE and E_{Ce} (0-0.6 m soil) after 5 years of irrigation were 1.05 Adj RNA and 1.45 EC_{iw}, respectively.

4.3.6. Site-VI (Village: Malikpur)

The chemical composition of tubewell water in North direction of the village Malikpur is shown in Table 24. The EC of the water was 4.2 dS m⁻¹, SAR was 15.8 (m mol L⁻¹)^{1/2}. The maximum RSC (10.0 me L⁻¹) was observed in Village Malikpur. Sodium (33.2 me L⁻¹) was the dominant cation followed by calcium (4.8 me L⁻¹) Magnesium (4.0 me L⁻¹) and potassium (0.4me L⁻¹).

SITE-VI (MALIKPUR)

Table 24: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC	SAR (m mol L ⁻¹) ^{1/2}
9.3	4.2	2.6	16.2	14.1	8.4	4.8	4.0	33.2	0.4	10.0	15.8

Name of farmer = Jagtar Singh S/O Shrain Singh
 Number of years the tube well is in operation =13 years
 Depth of tube well =150 ft.

Table 25: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
0-15	33.7	8.8	12.8	13.0	74.2	Sandy loam	0.6
15-30	33.4	8.8	12.4	12.8	74.8	Sandy loam	0.4
30-45	35.9	10.0	15.2	14.9	69.9	Sandy loam	0.3
45-60	34.8	9.4	14.0	14.0	72.0	Sandy loam	0.2
60-75	35.6	9.9	14.9	14.9	70.5	Sandy loam	0.1

The study of soil profile (Table 25) 0-75cm revealed that the texture was sandy loam through out the profile, the clay content ranged from 12.4 to 15.2 percent. The CEC varied from 8.8 to 10.0 C mol (p+) kg⁻¹ and organic mater ranged from 0.1 to 0.6 percent.

The chemical composition of soil saturation extract (Table 26) showed that maximum build up of salts was on in the upper soil surface layer. The highest ECe 11.3 dS m⁻¹ was in the top layer and it decreased with increase in the soil depth. The maximum SARE 12.4 (m mol L⁻¹)^{1/2} was also found in the surface layer and decreased with increasing soil depth. The cationic composition followed the same trend as water sample i.e. sodium (29.9me L⁻¹) > calcium (19.3 me L⁻¹) > magnesium (10.4 me L⁻¹) > potassium (1.7 me L⁻¹). In anionic composition bicarbonate (31.4 me L⁻¹) dominated over chloride (21.9 me L⁻¹) followed by sulphate (8.4 me L⁻¹) and then carbonate (7.2 me L⁻¹). pH showed no specific trend with depth. The mean value of ECe and SARE was 6.8 dS m⁻¹ and 7.8 (m mol L⁻¹)^{1/2} respectively.

Parsad *et al.* (1996) reported that the pH, EC and SAR increased with increase in the RSC of irrigation water. The SAR was relatively higher with CO₃⁻²+HCO₃⁻ source of RSC then CO₃⁻² or HCO₃⁻ alone. A decrease in ECe and increase in SAR with the increase in RSC of irrigation water was due to reduced concentration of calcium and magnesium and increased proportion of sodium in the soil solution.

Chauhan and Kumar (1993) also reported that increase in RSC of irrigation water resulted in progressively increased pH (from 8.2 to 8.9) and SAR [7.8 to 19.2 (m mol L⁻¹)^{1/2}].

Table 26: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	me L ⁻¹							SARe (m mol L ⁻¹) ^{1/2}	
			CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺		K ⁺
0-15	9.5	11.3	11.9	52.2	37.9	13.6	28.5	15.4	58.1	2.9	12.4
15-30	9.5	8.5	9.6	38.3	26.3	10.8	22.7	13.2	40.1	2.3	9.5
30-45	9.4	6.1	6.7	28.9	21.2	6.7	17.8	10.0	26.2	1.4	7.0
45-60	9.7	4.5	4.6	19.5	13.8	5.7	14.9	6.9	14.3	1.0	4.3
60-75	9.6	3.4	3.4	17.9	10.1	5.0	12.3	5.0	10.7	0.6	3.6
Mean	9.5	6.8	7.2	31.4	21.9	8.4	19.3	10.1	29.8	1.7	7.8

4.3.7 Site-VII (Village: Rodh)

The Chemical composition of the tubewell water in South direction of the village Rodh is shown in Table 27.

The EC of the water was 7.4 dS m^{-1} , SAR $17.2 (\text{m mol L}^{-1})^{1/2}$ and RSC nil. The dominant cation was sodium (53.0 me L^{-1}) followed by calcium (11.8 me L^{-1}), magnesium (7.2 me L^{-1}) and potassium (0.5 me L^{-1}). In anions chloride (38.2 me L^{-1}) dominated over bicarbonate (14.6 me L^{-1}) followed by sulphate (14.3 me L^{-1}) and carbonate (1.8 me L^{-1}). This water had been used for last 12 years. The taste of water was saline.

The important properties of soil up to 75cm depth are presented in Table 28. The texture of the soil was sandy loam in the upper (0-15cm) surface layer, loam in the subsurface (15-30cm), sandy loam at lower depth (30-45, 45-60cm) and (60-75cm). The maximum and minimum clay content, CEC and organic carbon were (12.4-15.2%), (8.7-10.0 C mol (P⁺) kg⁻¹) and (0.2-0.6%), respectively.

Chemical composition of soil saturation extract presented in Table 29 revealed that maximum E_{Ce} (15.4 dS m^{-1}) was in the surface layer and decreased with soil depth. The maximum SARE [$9.8 (\text{m mol L}^{-1})^{1/2}$] was also observed on surface soil layer. The cationic composition of saturation extract of soil contained dominant cation sodium (45.1 me L^{-1}) followed by calcium (34.4 me L^{-1}) and magnesium (17.4 me L^{-1}). Potassium content was found in appreciable amounts (1.3 me L^{-1}). The anionic composition followed the same trend as that of water sample.

4.3.8 Site-VIII (Village: Karkhana)

Chemical composition of the water collected from village Karkhana is given in Table 30. The EC of the irrigation water was 5.4 dS

SITE-VII (RODH)

Table 27: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	me L ⁻¹										SAR (m mol L ⁻¹) ^{1/2}
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC		
8.3	7.4	1.8	14.6	38.2	14.3	11.8	7.2	53.0	0.5	Nil	17.2	

Name of farmer= Mukhtyar Singh S/O Suba Singh
 Number of years the tube well is in operation =12 years
 Depth of tube well =80 ft.

Table 28: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	34.6	9.3	13.8	13.8	72.4	loam	0.5
30-45	35.8	10.0	15.2	14.8	70.1	Sandy loam	0.4
45-60	35.4	9.8	14.7	14.5	70.9	Sandy loam	0.2
60-75	34.4	9.3	13.7	13.7	72.6	Sandy loam	0.2

Table 29: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	me L ⁻¹							SARe (m mol L ⁻¹) ^{1/2}	
			CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺		K ⁺
0-15	9.3	15.4	11.9	38.3	74.1	32.3	50.2	27.5	61.0	1.1	9.8
15-30	9.2	13.3	9.2	30.1	67.0	27.7	43.9	21.9	54.3	2.1	9.5
30-45	9.0	10.9	6.7	25.7	52.4	17.9	31.2	14.5	41.3	1.6	8.6
45-60	9.1	9.7	4.5	19.2	46.2	15.8	24.8	12.4	34.9	1.02	8.1
60-75	9.3	8.7	Nil	18.5	42.8	9.3	22.0	10.5	33.6	0.6	8.3
Mean	9.2	11.6	6.5	26.3	56.5	20.6	34.4	17.4	45.0	1.3	8.8

m^{-1} , SAR 15.7 (m mol L^{-1}) $^{1/2}$ and RSC 1.2 me L^{-1} . Sodium concentration (39.8 me L^{-1}) dominated over calcium (6.8 me L^{-1}) followed by magnesium (6.0 me L^{-1}). The concentration of different cations in the irrigation water followed the trend $\text{Na}^+ > \text{Ca}^{+2} > \text{Mg}^{+2} > \text{K}^+$. The anionic composition of this water was in the order $\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{-2}$. This water had been applied for the last 12 years for growing paddy, wheat, sorghum, bajra etc.

The analysis of soil for physico-chemical properties presented in Table 31 revealed that the soil texture in soil depth 0-75cm was loamy sand. Clay content ranged from 10.8 to 12.5 percent, CEC ranged from 7.9 to 8.7 $\text{C mol (P}^+) \text{ kg}^{-1}$ and organic carbon valued from 0.1 to 0.6 percent, respectively.

It is seen from the Table 32 that pH had no trend with depth. The ECe ranged from 14.6 dS m^{-1} to 7.9 dS m^{-1} , thus higher salts concentration was deposited in the upper layer which gradually decreased with depth. The average sodium concentration in the saturation extract was (59.9 me L^{-1}), calcium (32.1 me L^{-1}) and magnesium (16.4 me L^{-1}). Water soluble K^+ was present in appreciable amount (2.3 me L^{-1}). The highest value of SARe ($14.4 \text{ m mol L}^{-1}$) $^{1/2}$ was found in the upper (0-15cm) layer. The anionic concentration of saturation extract was in the order $\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{-2}$. The mean concentration of CO_3^{-2} was 4.9 me L^{-1} .

4.3.9 Site – IX (Village: HATT)

The chemical composition of the tubewell water collected from the above site is given in Table 33. The EC of the water sample was 3.8 dS m^{-1} , SAR 19.2 (m mol L^{-1}) $^{1/2}$ and RSC 5.0 me L^{-1} . The sodium

SITE-VIII (KARKHANA)

Table 30: Chemical composition of Tube-well water

pH	EC _{iw} (dS m ⁻¹)	me L ⁻¹							SAR (m mol L ⁻¹) ^{1/2}		
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺		K ⁺	RSC
8.1	5.4	1.2	12.8	26.8	9.4	6.8	6.0	39.8	0.3	1.2	15.7

Name of farmer= Randhir Singh S/O Moti Ram
 Number of years the tube well is in operation =12 years
 Depth of tube well =70

Table 31: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	32.6	0.2	11.5	12.0	76.5	Loamy sand	0.5
30-45	32.4	8.1	11.3	11.9	78.9	Loamy sand	0.4
45-60	33.5	8.7	12.5	12.9	74.6	Loamy sand	0.3
60-75	32.8	8.3	11.7	12.2	76.0	Sandy loam	0.1



Table 32: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	me L ⁻¹							SARE (m mol L ⁻¹) ^{1/2}	
			CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺		K ⁺
0-15	9.3	14.6	12.5	51.2	63.7	23.7	38.7	21.2	78.7	3.4	14.4
15-30	9.0	12.1	7.4	45.3	52.7	19.6	35.5	19.6	63.7	2.9	12.1
30-45	9.4	10.9	4.9	41.9	48.1	17.3	32.1	17.3	59.2	2.2	11.9
45-60	8.7	8.9	Nil	32.2	38.2	13.1	28.7	13.1	50.1	1.3	10.9
60-75	8.5	7.9	Nil	29.3	31.7	10.9	25.6	10.9	47.6	1.1	11.2
Mean	8.9	10.9	4.9	40.1	46.9	16.9	32.1	16.4	59.9	2.2	12.1

content (32.8 me L^{-1}) dominated over calcium (3.2 me L^{-1}) followed by magnesium (2.6 me L^{-1}) in water sample.

The water was dominated by chloride (15.0 me L^{-1}) ions followed by sulphate (9.4 me L^{-1}) and then bicarbonate (8.2 me L^{-1}). The carbonates (2.6 me L^{-1}) were also present in this water sample. The tubewell was in operation for the last two years and this water was used for growing wheat, Jowar, bajra etc.

The data presented in Table 34 revealed that the texture of the soil was sandy loam in soil layers (0-15 and 15-30 cm). Whereas the texture varied from loam to sandy loam in 30-60cm and 60-75cm soil depth respectively. Clay content varied from 12.3 to 13.6 per cent, CEC from 8.6 to 9.2 C mol (P^+) kg^{-1} and organic carbon varied from 0.1 to 0.5 per cent, respectively.

Chemical composition of soil saturation extract presented in Table 35 showed that average ECe and SARE were 10.6 dS m^{-1} and $(11.8 \text{ m mol L}^{-1})^{1/2}$ respectively. The highest and lowest ECe were 13.8 dS m^{-1} and 7.2 dS m^{-1} and SARE $14.1 \text{ (m mol L}^{-1})$ and $7.4 \text{ (m mol L}^{-1})^{1/2}$ respectively in 0-15cm and 60-75cm soil depth. The dominant cation was sodium (54.0 me L^{-1}) followed by Ca^{+2} (28.1 me L^{-1}), Mg^{+2} (13.6 me L^{-1}) and K^+ was found in appreciable amounts. Farmers emphasised about the sweet taste of water however, in a short span of two years the normal soil turned to sodic in nature as the soil was very hard when dry and water stagnated during rainy season. Yadav *et al.* (1998) reported that the pH, EC and ESP was increased when the soil was irrigated with water of RSC 12 meL^{-1} as compared to 2.8 me L^{-1} . Similar results were obtained by Minhas *et al.* (1996).

SITE-IX (HATT)

Table 33: Chemical composition of Tube-well water

pH	EC _w (dS m ⁻¹)	me L ⁻¹										SAR (m mol L ⁻¹) ^{1/2}
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC		
8.8	3.8	2.6	8.2	15.0	9.4	3.2	2.6	32.7	0.3	5.0	19.2	

Name of farmer=Shamsher Singh S/O Dhan Singh
 Number of years the tube well is in operation =2 years
 Depth of tube well = 140 ft.

Table 34: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	33.9	9.0	13.0	13.2	73.8	Sandy loam	0.4
30-45	33.3	8.6	12.3	12.9	75.0	Loam	0.2
45-60	34.1	9.1	13.2	13.4	73.4	Loam	0.2
60-75	34.4	9.2	13.6	13.6	72.8	Sandy loam	0.1

Table 35: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	SARe (m mol L ⁻¹) ^{1/2}	me L ⁻¹	
0-15	8.5	13.8	10.5	38.5	66.6	18.7	37.4	18.7	74.7	2.2	14.1		
15-30	8.6	12.0	7.1	34.2	62.4	16.5	30.6	16.5	61.3	1.6	12.6		
30-45	8.7	10.9	4.8	27.6	56.4	13.2	25.8	13.2	58.8	1.3	13.3		
45-60	8.7	8.9	Nil	24.6	42.2	10.5	21.1	10.5	44.5	1.1	11.2		
60-75	8.7	7.2	Nil	22.1	32.5	8.1	25.7	9.3	30.8	0.9	7.4		
Mean	8.6	10.6	4.5	29.4	52.1	13.4	28.1	13.6	54.0	1.4	11.8		

4.3.10 Site-X (Village: Korda)

The chemical composition of tubewell water collected from village Korda is presented in Table 36. The water was saline having $EC > 4$ $dS\ m^{-1}$, SAR 11.8 ($m\ mol\ L^{-1})^{1/2}$ and RSC nil. Sodium ($30.0\ me\ L^{-1}$) was dominant cation followed by calcium ($7.4\ me\ L^{-1}$) and then magnesium ($5.4\ me\ L^{-1}$). Potassium content was very less in this water. The anionic composition of this water followed the order chloride ($24.0\ me\ L^{-1}$) > bicarbonates ($10.0\ me\ L^{-1}$) > sulphate ($6.7\ me\ L^{-1}$) and then carbonate ($1.8\ me\ L^{-1}$). This water was used for the last 25 years and the depth of the tubewell was 140 ft. The potato yield was reduced and shifted for growing wheat, jowar and bajra crops.

The important soil properties of the soil up to 75 cm are presented in Table 37. The texture of the soil was loamy sand in the upper layer (0-15 cm) and loam in the other layer (15-30, 30-45, 45-60 and 60-75cm). Clay content and CEC varied from 11.0 to 13.2 per cent and 7.9 to 9.1 $C\ mol\ (P^+)\ kg^{-1}$, respectively. The organic carbon decreased with depth varied from 0.2 to 0.5 per cent.

The data presented in table 38 showed that accumulation of salts was maximum $21.5\ dS\ m^{-1}$ in 0-15 cm soil depth. The EC_e decreased with increasing depth and still higher than threshold value of $EC\ 4\ dS\ m^{-1}$. Higher EC_e of surface layer indicated higher salinization of soil surface than at deeper layer. The SAR_e also decreased with soil depth.

The ionic composition of saturation extract showed that sodium ($109.7\ me\ L^{-1}$) was the dominant cation followed by calcium ($30.2\ me\ L^{-1}$) and magnesium ($17.4\ me\ L^{-1}$). The K^+ content was low but it was also noted as be as high as the mean value. In anions chloride ($43.6\ me\ L^{-1}$) dominated

SITE-X (KORDA)

Table 36: Chemical composition of Tube-well water

pH	ECiw (dS m ⁻¹)	me L ⁻¹										SAR (m mol L ⁻¹) ^{1/2}
		CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC		
8.6	4.4	1.8	10.0	24.0	6.7	7.4	5.4	30.0	0.2	Nil	11.8	

Name of farmer= Inder Singh S/O Lal Singh

Number of years the tube well is in operation =25 years

Depth of tube well = 140 ft.

Table 37: Physico-chemical properties of soil

Soil depth (cm)	S.P. (%)	CEC C mol (P ⁺) kg ⁻¹	Clay (%)	Silt (%)	Sand (%)	Texture	O.C. (%)
15-30	32.4	8.1	11.3	11.9	76.9	Loam	0.5
30-45	33.5	8.7	12.5	13.0	74.6	Loam	0.3
45-60	34.1	9.1	13.2	13.4	73.4	Loam	0.2
60-75	33.9	9.0	13.0	13.2	73.8	Loam	0.2

Table 38: Chemical composition of saturation extract of soil profile (0-75 cm).

Soil depth (cm)	pH (1:2)	ECe (dS m ⁻¹)	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	SARe (m mol L ⁻¹) ^{1/2}
0-15	8.7	21.5	17.4	78.2	59.6	47.2	41.0	23.6	132.9	4.0	23.4
15-30	8.7	19.1	11.1	70.3	53.1	40.7	34.6	19.7	124.6	2.7	23.9
30-45	8.7	16.5	7.2	60.9	38.2	32.2	28.7	17.9	109.8	2.3	22.8
45-60	8.9	14.9	3.5	56.3	35.7	24.6	24.6	15.2	94.9	1.1	21.3
60-75	8.9	12.8	Nil	43.6	31.2	13.0	22.4	10.6	86.0	0.6	21.2
Mean	8.8	17.0	9.8	61.9	43.6	31.5	30.2	17.4	109.7	2.1	22.5

over bicarbonates (61.9 me L^{-1}) followed by sulphates (31.5 me L^{-1}) and carbonates.

Dhir (1977) observed that low annual rainfall (300mm) completely leached the salts in a loamy sand soil that accumulated during the previous wheat season. This much of rainfall was sufficient to leach 80% of the salts from surface 40cm of sandy loam to loam textured soils. Salts leaching in the finer-textured soil, however, ranged from 50 to 80%. In a year with 59.6 cm rainfall complete leaching of salts took place in all soils except the silty clay loam, where the leaching from 0-60cm was only 70%.

Thus accumulation of salts is attributed to very scanty rainfall during the last year. Therefore, the salts added in soil with tubewell waters could not be leached out of rootzone.

4.4 Salt accumulation behaviour in soils irrigated with poor quality water and in conjunction with canal water

Salt accumulation in the soil as a result of irrigation with tube well waters alone and in conjunction with canal water is presented in Table 39. Highest ECe 32.3 dS m^{-1} and 27.3 dS m^{-1} was observed at Site-I (Village: Muana), irrigated with poor quality water as compared to ECe 13.7 dS m^{-1} and 11.9 dS m^{-1} where poor quality water was used with canal water at surface (0-15 cm) and sub-surface 15-30 cm soil depth respectively. At Site II irrigation with saline water alone resulted an build up of an ECe 27.1 and 26.7 dS m^{-1} compared to ECe value 11.2 and 10.6 dS m^{-1} irrigated with saline water in conjunction with canal water at surface and sub-surface layers, respectively.

Table 39: ^{on} Effect of Salt accumulation with poor quality water and in conjunction with canal water

Villages	Soil depth (cm)			
	0-15		15-30	
	Poor quality water	Conjunctive use	Poor quality water	Conjunctive use
Muana-1	32.3	13.7	27.3	11.9
Muana-2	27.1	11.2	26.7	10.6
Muana-3	17.5	13.3	15.6	12.8
Singhana	19.1	9.9	17.1	9.5
Dharmgarh	8.4	3.5	7.1	3.2
Malikpur	11.3	5.2	8.5	4.7
Rodh	15.4	9.7	13.3	8.6
Karkhana	14.6	6.4	12.1	6.3
Hatt	13.8	5.8	12.6	5.9
Korda	8.5	5.3	8.4	5.2

Similarly at Site III (Village: Muana) and Site IV (Village: Singhana) showed that use of canal water with tube-well water resulted lesser amount of salt accumulation in surface and sub surface layers as compared to irrigation with poor quality water alone. In Village Dharamgarh at Site-V, lowest salt build up (EC_e 8.4 dS m^{-1}) was observed at 0-15 cm and 7.1 dS m^{-1} and at 15-30cm soil depth when irrigated with tube-well water having EC_{iw} 2.9 dSm^{-1} as compared to 3.5 dS m^{-1} and 3.1 dS m^{-1} when irrigated with canal water in mixing mode at respective depth.

Data of site VI (Malikpur) revealed that use of saline-sodic water having EC_{iw} 4.2 dS m^{-1} and RSC 10 me L^{-1} had created the problem of salt accumulation. This water alone resulted development of EC_e 11.3 and 8.5 dS m^{-1} at surface and sub-surface. However, conjunctive use of tube-well water with canal water reduced the EC_e from 11.3 to 5.2 dS m^{-1} and 8.5 to 4.7 dS m^{-1} respectively in surface and sub-surface layers.

Electrical conductivity of the saturation extract of soil at site VII (Rodh) and VIII (Karkhana) were 15.4 and 14.6 dS m^{-1} at surface and 13.3 , 12.2 dS m^{-1} sub surface layers respectively when irrigated with saline water. Whereas salt content reduced to an EC_e of 9.9 and 6.4 dS m^{-1} at surface and 8.6 and 6.3 dS m^{-1} in surface respective sites when irrigated with saline water in conjunction with canal waters.

Similarly in village Hatt (Site IX) and Korda (Site X) irrigated with tubewell waters having EC 3.8 dS m^{-1} and EC_{iw} 4.4 dS m^{-1} and RSC 5.0 me L^{-1} and Nil. The EC_e observed was 13.8 and 12.6 and 8.5 and 8.4 dS m^{-1} in surface (0-15cm) and subsurface (15-30cm) layer at respective site IX and site X. Conjunctive use of canal water reduced the salt content and observed EC_e was 5.8 and 5.9 and 5.3 , 5.2 dS m^{-1} in respective soil layers.

This data revealed that poor quality waters when used with good quality water in mixing modes may be harnessed safely for growing different crops.

These results are in agreement with Kanwar and Kanwar (1971). Dhankhar *et al.* (1986) also reported that water with high sodium and low salt concentration could successfully be used in light textured soil. They also observed that quality of irrigation waters is not conditioned merely by its chemical composition, but also depends upon factors such as the type of soil, nature of crop grown, climate of area and the management practices.

CHAPTER - V

Summary and Conclusion

The investigation on survey and characterization of underground irrigation waters of Safidon block of Jind district and their effect on soil properties was carried out. From forty villages of the block total 339 water samples were collected from running tube wells representing different directions in each village. The water samples were analysed for pH, EC, soluble cations (Ca^{+2} , Mg^{+2} , Na^+ , K^+) and anions (CO_3^{-2} , HCO_3^- , Cl^- and SO_4^{-2}) following the standard procedures. Based on electrical conductivity (EC) sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) of the waters, the samples were classified into various classes according to classification given by Manchanda (1976) and AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture (1989). Depth wise soil samples from (0-15, 15-30, 30-45, 45-60 and 60-75cm) soil layers from 10 different sites were collected representing various qualities of water usage i.e. eight sites were saline-sodic water, one from marginally saline and one from sodic waters irrigated conditions.

Soil samples were analysed for important physico-chemical properties, water soluble cations (Na^+ , Ca^{+2} , Mg^{+2} , K^+), anions (Cl^- , SO_4^{-2} , HCO_3^- , CO_3^{-2}), ECe and SARE from saturation extract.

The result of water samples showed that EC, SAR and RSC ranged from 0.5 to 10.9 dS m⁻¹), 0.4-21.7 (m mol L⁻¹)^{1/2} and 0.1-10.0 me L⁻¹ respectively. Cationic concentration showed the dominance of Na⁺ followed by Ca⁺², Mg⁺² and then K⁺. The Na⁺ concentration ranged from 6.4-71.0 me L⁻¹.

Anionic concentration of waters were found in order (HCO₃⁻ > Cl⁻ > SO₄⁻²) upto EC 3 dS m⁻¹ and EC between 3-6 dS m⁻¹ trend was Cl⁻ > HCO₃⁻ > SO₄⁻². However, above EC 6 dS m⁻¹ chlorides were dominant followed by SO₄⁻² and HCO₃⁻ ions. The concentration of CO₃⁻² varied in a narrow range (0.1-5.6 me L⁻¹).

The classification of water samples according to (Manchanda, 1976) showed that 27% water samples were found in good quality where as 25% samples marginally saline. Among poor quality water (9%) saline, 19% sodic and 20% were saline-sodic.

According to classification of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture (1989) classification of water samples showed that 27 % samples were found in good quality, 23, 9 and 16 per cent marginally saline, saline and high SAR saline respectively. Among the sodic classes highly sodic class recorded the maximum per cent samples 15% followed by marginally alkali 8% and alkali 2%. Out of 339 water samples collected, 73 per cent waters indicated EC < 4 dS m⁻¹, whereas only 27% samples showed EC > 4 dSm⁻¹ only 4 samples were having EC > 10 dS m⁻¹. The water samples classified by both the criteria were at par.

The marginal water (73%) may be used with no appreciable harmful effect on crop and soil. But its long term use depends on type of soil, rainfall and crops to be grown and another 27% water required special management practices depending upon the soil type, crop and climatic factors.

The use of poor quality water resulted salt accumulation throughout the soil profiles. Highest E_c and SAR_e were observed in the upper layer (0-15cm) of soil which gradually decreased with increasing soil depth irrespective of texture and quality of irrigation water. The E_c of the soil also decreased where tube-well of the soil also decreased where tube-well water were used in conjunction with canal water.

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Village wise chemical composition of ground water samples of Safidon Block

Village	Name of farmer	pH	EC (dSm ⁻¹)	CO ₃	HCO ₃	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	RSC	SAR (m mol ⁻¹) ^{1/2}
								me L ⁻¹					
Jaipur	Sukhvinder Singh	8.5	3.3	0.0	12.4	13.8	4.0	6.2	3.8	20.2	0.1	2.4	9.0
"	Dhup Singh	8.7	3.2	0.0	12.2	13.2	4.5	8.6	6.9	15.9	0.2	NIL	5.7
"	Ria Singh	8.8	3.0	0.0	16.0	12.4	4.0	8.4	6.6	13.4	0.1	1.0	4.9
"	Nafe Singh	8.4	5.4	0.0	15.2	30.4	6.4	20.8	9.4	20.7	0.5	NIL	5.3
"	Jai Bhagwan	8.7	5.2	0.0	16.2	27.6	7.2	15.8	12.9	20.2	0.3	NIL	5.3
"	Jaswant Singh	8.6	4.0	0.0	16.8	20.8	1.3	14.6	10.5	14.5	0.2	NIL	4.1
"	Kali Ram Lat	9.1	2.2	0.0	10.6	6.4	1.5	8.8	3.4	9.3	0.1	NIL	3.8
"	Sukhwinder	9.0	2.4	0.0	10.8	5.2	6.2	9.2	6.2	7.9	0.1	NIL	2.9
Chapper	Darshan Singh	8.9	2.3	0.0	9.6	7.4	2.2	9.6	6.6	4.8	0.0	NIL	1.7
"	Bakha Singh	8.9	2.8	0.0	12.8	10.2	4.2	8.2	6.8	11.6	0.1	NIL	4.2
"	Amrik Singh	8.8	4.2	0.0	14.2	17.6	8.2	10.4	6.9	20.5	0.1	NIL	7.0
"	Mohinder Singh	8.8	4.4	0.0	13.8	20.0	9.6	13.6	6.4	21.2	0.2	NIL	6.7
"	Mohinder Singh	8.7	4.3	0.0	13.6	18.5	9.2	10.6	8.1	20.2	0.2	NIL	6.6
"	Sinder Singh	8.8	4.1	0.0	12.8	18.4	8.4	11.8	7.7	21.2	0.2	NIL	6.8
"	Tehl Singh	9.0	4.4	0.1	11.6	19.2	7.5	12.8	7.4	20.8	0.2	NIL	6.5
"	Chain Singh	8.7	4.0	0.0	12.4	15.2	6.9	9.6	7.1	21.1	0.1	NIL	7.3
"	Ram Kumar	9.3	2.9	1.4	11.2	8.4	8.2	3.2	2.0	21.0	0.1	7.4	13.0
"	Swarn Singh	9.1	3.0	0.0	13.2	7.2	4.5	4.2	2.7	20.8	0.1	6.3	11.2

"	Hardeep Singh	9.3	2.1	0.0	12.2	6.8	3.3	2.2	1.4	16.3	0.1	8.6	12.2
"	Preetam Singh	8.8	2.5	2.8	9.8	8.0	2.3	5.4	3.8	14.4	0.1	4.4	6.7
"	Harbhan Singh	8.8	2.4	0.0	12.2	6.4	3.2	5.6	3.4	13.0	0.0	3.2	6.1
"	Amarjeet Singh	8.9	2.4	3.8	6.2	7.4	4.1	6.8	3.3	12.2	0.1	NIL	5.4
Bahadurgharh	Kuldeep Singh	8.5	2.2	0.0	10.2	7.0	0.5	6.2	3.9	9.2	0.2	0.1	4.1
"	Ladwa Pt.	8.9	2.1	0.8	9.0	8.2	2.9	5.4	3.7	9.0	0.2	0.7	4.2
"	Ram Kumar	8.8	2.2	0.0	10.0	6.4	3.1	5.8	3.0	12.6	0.1	1.2	6.0
"	Shish ram	8.9	1.7	1.0	4.6	7.4	4.4	4.6	4.5	6.4	0.1	NIL	3.0
"	Phool Singh	8.7	2.7	0.0	10.6	16.2	5.9	8.8	5.3	10.2	0.1	NIL	3.9
"	Mange Ram	9.0	4.1	3.4	6.6	18.0	8.4	11.6	6.9	21.7	0.1	NIL	7.1
Mallar	Rattan Singh	9.0	3.0	1.6	11.2	9.2	5.9	5.2	2.8	21.2	0.2	4.8	10.6
"	Hawa Singh	9.0	3.4	4.0	13.4	11.4	6.2	9.8	6.7	17.4	0.2	0.9	6.1
"	Harikrishan	8.9	3.4	2.4	12.4	12.6	5.8	6.4	6.1	20.9	0.1	2.3	8.4
"	Raghubir Singh	8.8	5.1	0.0	13.0	25.0	9.8	15.6	10.5	21.0	0.2	NIL	5.8
"	Takdir Singh	8.4	6.1	0.0	13.8	29.0	15.0	22.4	17.4	21.1	0.2	NIL	4.7
"	Basau Ram	8.7	4.3	0.0	8.6	27.0	7.1	12.6	7.4	21.2	0.1	NIL	6.7
"	Kuldeep Singh	8.6	5.6	0.0	8.6	32.4	11.4	20.8	12.4	30.9	0.2	NIL	7.6
"	Rangopal	8.8	3.7	0.0	11.8	14.0	8.9	12.4	5.4	17.0	0.2	NIL	5.7
"	Barada Kundu	8.8	3.7	0.0	10.4	16.8	8.6	8.4	6.5	19.2	0.1	NIL	7.0
"	Naseeb Singh	8.9	2.9	0.0	13.2	10.4	5.6	9.2	6.1	12.4	0.2	NIL	4.5
"	Raghubir Singh	8.6	4.1	0.0	14.4	16.6	6.6	14.2	10.1	15.2	0.2	NIL	4.4
"	Sant Ram	8.4	5.1	0.0	14.0	25.0	11.3	18.6	11.4	18.9	0.1	NIL	4.9
"	Pt. Nathu Ram	9.0	4.3	0.0	17.4	15.0	8.3	6.2	3.0	20.3	0.2	8.2	9.5
"	Vivek	9.1	2.3	2.6	8.7	8.2	4.9	2.8	1.6	17.1	0.2	6.9	11.5

"	Master Rai Singh	9.0	2.6	0.0	12.2	9.8	3.1	8.4	4.6	12.8	0.2	NIL	5.0
"	Om Prakash	8.6	2.3	0.0	8.4	9.4	4.6	12.4	6.6	3.5	0.1	NIL	1.2
"	Lal Singh	8.8	3.5	1.2	10.4	17.2	5.3	9.4	5.8	18.7	0.2	NIL	6.8
Rozla	Bichha Ram	9.1	1.8	0.0	11.6	4.2	3.8	4.0	2.8	10.8	0.2	4.8	5.9
"	Karn Singh	8.8	1.5	1.8	7.6	3.2	4.4	2.4	1.8	10.0	0.1	5.2	6.9
"	Sat Pal	8.9	1.7	0.0	7.6	8.2	0.9	4.8	3.9	6.4	0.2	NIL	3.1
"	Karn Singh	8.9	4.0	0.0	13.2	15.8	3.9	12.8	7.2	18.2	0.1	NIL	5.8
"	Om Singh	9.0	4.2	0.0	16.2	15.2	5.6	12.6	6.7	20.8	0.2	NIL	6.7
"	Sher Singh	8.2	4.5	0.0	15.2	19.2	10.0	18.4	9.2	17.1	0.2	NIL	4.6
"	Ved Pal	8.6	6.1	3.0	10.8	35.4	10.8	22.8	14.9	20.8	0.2	NIL	4.8
"	Nafe Singh	8.7	2.5	0.0	7.5	9.2	6.4	8.4	6.2	9.8	0.1	NIL	3.6
"	Rohtash	8.7	5.1	2.2	15.4	18.2	12.3	17.6	11.1	20.4	0.2	NIL	5.4
"	Om Singh	8.8	3.6	2.8	7.4	14.2	9.0	11.6	6.6	17.0	0.2	NIL	5.6
"	Rambhaj	9.1	3.3	3.8	10.3	12.0	6.1	6.4	5.0	18.0	0.1	2.7	7.6
"	Chander Singh	9.1	3.1	4.2	9.2	10.8	5.9	4.8	3.2	20.6	0.2	5.4	10.3
"	Sat Pal	9.0	3.5	4.4	7.4	19.0	5.9	12.6	6.8	13.8	0.1	NIL	4.4
"	Gopi Chand	9.0	2.9	3.4	6.0	10.2	9.3	4.8	3.4	20.6	0.3	1.2	10.2
"	Khyali Ram	8.8	3.4	5.0	5.8	17.8	6.9	12.6	6.0	14.9	0.2	NIL	4.9
"	Punit Kumar	9.0	2.9	4.8	4.0	12.8	7.9	8.8	6.0	12.6	0.1	NIL	4.6
"	Dalip Singh	9.4	2.0	2.4	7.2	7.0	3.8	4.6	4.0	10.2	0.2	1.0	4.9
"	Vajeer Singh	9.0	1.9	0.0	9.2	4.4	4.4	3.4	2.7	9.9	0.1	3.1	5.7
Butani	Anand Singh	9.1	1.8	4.2	3.8	4.8	3.1	4.8	3.3	7.3	0.2	NIL	3.6
"	Prem Singh	9.0	2.0	0.0	10.0	7.6	2.1	4.2	2.9	13.4	0.2	2.9	7.1
"	Bichha Ram	9.1	2.4	2.8	9.0	7.4	2.7	6.6	3.4	15.5	0.2	1.8	6.9

"	Sher Singh	9.1	1.5	0.2	7.0	6.2	2.3	3.8	1.3	9.0	0.1	2.1	5.6
"	Balbir Singh	9.0	2.8	3.0	6.4	8.6	7.2	8.4	5.5	13.1	0.3	NIL	5.0
"	Atar Singh Malik	9.0	1.5	3.4	4.0	4.8	2.2	6.2	3.8	3.9	0.1	NIL	1.8
"	Sandeep Malik	8.9	4.5	4.8	15.2	8.0	12.6	12.8	9.3	21.0	0.3	NIL	6.3
"	Karan Singh	9.0	1.8	4.2	3.6	6.6	3.0	6.4	3.6	7.1	0.2	NIL	3.2
"	Charan Singh	8.9	1.8	0.0	5.4	5.6	3.1	4.4	2.7	8.2	0.2	NIL	4.3
Shahnpur	Raj Kumar	8.6	2.2	0.0	7.6	5.8	8.9	6.8	3.6	10.0	0.2	NIL	4.4
"	Pala Ram	8.7	2.4	1.8	3.4	8.3	6.4	6.6	3.8	10.8	0.2	NIL	4.7
"	Nafe Singh	9.1	1.3	0.0	7.4	2.7	1.5	4.4	2.8	4.1	0.1	NIL	2.2
"	Raja Singh	9.2	1.3	0.0	5.0	4.9	1.3	3.8	3.0	5.7	0.1	NIL	3.1
"	Seva Singh	8.9	1.6	0.0	10.0	3.5	2.2	5.4	4.4	5.0	0.1	NIL	2.3
"	Trilok Singh	9.1	2.1	0.0	8.0	5.5	4.1	5.6	3.8	9.6	0.2	NIL	4.4
"	Hari Singh	8.8	1.6	2.8	2.6	4.9	3.3	5.2	3.8	7.0	0.2	NIL	3.3
"	Janpal Singh	8.7	1.7	1.0	6.0	4.4	2.6	5.4	3.4	6.4	0.2	NIL	3.1
Nimnabad	Jaswant Singh	8.6	1.8	0.0	7.8	4.6	3.5	4.6	3.4	7.5	0.2	NIL	3.8
"	Gurdev Singh	8.9	1.7	0.0	7.6	4.6	3.3	6.4	3.8	5.7	0.1	NIL	2.5
"	Pyara Singh	9.0	1.3	1.4	5.8	2.8	1.0	3.2	2.6	5.5	0.1	1.4	3.3
"	Gurdeep Singh	8.9	1.3	1.6	6.6	2.4	1.3	5.2	3.6	4.1	0.1	NIL	2.0
"	Balkar Singh	8.9	1.1	1.2	7.2	2.1	0.8	4.4	2.8	2.8	0.1	1.2	1.5
"	Sucha Singh	8.8	1.1	0.0	7.4	3.0	1.0	4.8	3.6	2.7	0.2	NIL	1.3
"	Sukha Singh	9.0	2.5	0.0	11.2	6.1	6.6	5.2	3.6	14.5	0.2	2.4	6.9
"	Sukhvinder Singh	8.9	1.9	0.0	11.0	5.0	3.3	7.2	5.4	5.7	0.1	NIL	2.3
Anta	Surat Singh	8.8	1.7	0.0	5.0	5.7	2.3	4.8	3.0	8.8	0.1	NIL	4.5
"	Asha Ram	8.3	3.4	0.0	6.8	13.7	11.2	7.4	5.3	19.3	0.3	NIL	7.7

"	Somnath	8.9	1.7	0.8	6.4	4.8	4.1	4.8	3.8	6.8	0.2	NIL	3.3
"	Ramswarup	9.1	1.9	1.4	8.0	5.1	3.1	5.2	3.4	11.4	0.2	0.8	5.5
"	Mukhtyar Singh	9.0	1.7	0.4	5.8	4.6	3.4	4.2	2.8	7.0	0.2	NIL	3.7
"	Harbhajan Singh	9.0	1.3	0.0	7.2	2.5	1.7	5.4	3.4	3.7	0.1	NIL	1.8
"	Gurdeep Singh	8.6	1.7	1.0	6.0	5.0	4.6	5.6	3.6	7.1	0.1	NIL	3.3
Barod	Sukhvinder Singh	8.9	1.4	0.8	6.8	2.5	2.3	5.8	3.0	3.5	0.1	NIL	1.7
"	Gurdeep Singh	9.0	1.4	0.0	9.4	2.9	1.2	4.2	2.8	8.1	0.1	2.4	4.3
"	Sukhvinder Singh	9.0	1.7	0.6	7.6	4.2	2.6	3.8	3.6	5.7	0.2	0.8	3.0
"	Gurdeep Singh	8.7	1.1	0.0	6.0	2.9	1.9	5.6	3.0	2.8	0.1	NIL	1.4
Baisini	Balvinder Singh	8.8	1.6	0.0	10.2	2.1	1.6	5.8	3.4	6.2	0.1	1.0	2.9
"	Mahinder Singh	8.9	2.3	0.0	11.8	6.2	3.4	4.6	3.6	14.5	0.2	3.6	7.1
"	Ram Singh	8.8	1.1	0.0	8.2	2.0	0.9	4.2	3.6	3.5	0.1	0.4	1.8
"	Ajay Krishan	8.9	1.0	0.0	5.8	2.4	0.9	3.8	2.8	3.4	0.1	NIL	1.9
"	Ravi Sharma	8.6	0.8	0.0	5.6	2.2	0.9	5.4	3.6	0.9	0.1	NIL	0.4
"	Ram Phal	8.7	0.8	0.0	4.2	1.5	0.8	3.8	2.4	1.5	0.6	NIL	0.8
Khatla	Nihal Singh	9.0	1.3	0.0	6.2	2.1	2.3	4.2	3.8	4.8	0.1	NIL	2.4
"	Nirmaljit Singh	8.9	1.8	0.0	4.9	6.3	5.6	4.8	3.8	7.2	0.1	NIL	3.5
"	Rishpal Singh	8.9	1.4	0.0	8.8	3.5	2.5	5.4	2.8	5.1	0.1	0.6	2.5
Bhuslana	Pt. Goverdhan	8.8	2.0	0.0	11.4	3.8	2.7	3.4	2.8	13.8	0.2	5.2	7.9
"	Daya Nand	8.9	0.8	0.4	5.0	1.7	0.9	4.2	3.2	1.5	0.5	NIL	0.8
"	Karan Singh	8.9	0.9	0.0	5.2	1.6	0.9	3.6	2.2	1.5	0.6	NIL	0.9
"	Rameshwar	9.1	0.8	0.0	5.8	1.2	0.8	3.2	2.4	1.4	0.6	NIL	0.9
"	Abhay Ram	8.4	1.3	0.0	5.0	2.4	2.3	2.8	2.4	6.5	0.1	NIL	4.1
Karsandu	Sukhvinder Singh	8.7	1.2	0.0	4.2	3.8	4.6	5.2	3.4	3.5	0.1	NIL	1.7

"	Rajbir Singh	8.9	0.9	0.0	3.0	1.7	2.4	4.8	2.4	1.5	0.1	NIL	0.8
"	Ishwar Singh	8.5	1.1	0.0	2.2	2.4	2.3	3.8	2.6	2.1	0.1	NIL	1.2
"	Ram Mehar	8.6	1.1	0.0	4.4	2.9	2.5	4.2	3.4	1.3	0.1	NIL	0.7
"	Jagbir	8.8	0.9	0.0	3.2	2.0	2.3	3.8	2.0	1.7	0.6	NIL	1.0
"	Vajir Singh	8.9	1.3	0.0	6.4	1.5	2.2	3.4	2.6	3.5	0.1	0.4	2.0
Titokheri													
"	Naresh	8.9	1.2	0.0	3.6	1.4	2.2	3.2	2.4	3.0	0.2	NIL	1.8
"	Ashok Singh	9.0	1.4	1.0	7.4	3.3	2.7	2.4	2.4	7.4	0.2	3.6	4.8
"	Zile Singh	8.8	0.9	0.8	3.0	1.6	1.0	3.2	2.0	3.2	0.6	NIL	2.0
"	Jai Bhagwan	8.9	1.1	0.0	5.2	3.0	2.0	3.6	2.1	4.7	0.6	NIL	2.8
"	Lila Chaudhary	8.9	1.1	0.4	5.8	2.1	0.9	2.8	2.4	5.9	0.1	1.0	3.7
"	Maha Singh	9.0	1.2	0.8	7.2	1.7	2.2	2.6	2.2	6.3	0.1	3.2	4.1
"	Vijay Singh	8.3	1.3	0.6	7.6	2.8	1.8	4.4	3.4	5.0	0.1	0.4	2.5
Bahadurpur													
"	Jaswant Singh	8.6	1.1	0.0	6.6	2.6	0.5	3.8	2.6	4.1	0.2	0.2	2.3
"	Balwant Singh	8.8	1.1	0.0	5.2	2.5	0.4	2.2	1.6	7.2	0.1	1.4	5.2
"	Kuldeep Singh	8.7	1.2	0.8	6.8	3.0	1.2	3.2	2.4	5.3	0.2	2.0	3.2
"	Karnail Singh	9.0	1.8	1.2	9.6	3.9	2.3	4.6	2.6	10.3	0.2	3.6	5.4
"	Sohan Singh	9.0	1.8	2.0	3.8	6.4	4.3	4.4	3.4	10.1	0.2	NIL	5.1
"	Ch. Molad Ram	8.9	1.6	1.2	9.0	4.0	1.7	4.2	2.4	8.0	0.2	3.6	4.4
"	Jaspal Singh	8.6	1.0	1.2	2.2	2.9	0.7	2.6	1.2	4.9	0.6	NIL	3.6
Singhpura													
"	Meva Singh	8.8	1.0	0.4	5.0	3.1	0.9	2.6	1.2	5.3	0.1	1.6	3.9
"	Hukam Singh	8.9	0.9	2.4	3.4	2.4	3.0	2.2	0.8	6.7	0.6	2.8	5.5
"	Hari Singh	8.8	0.7	1.2	3.0	1.8	1.2	1.8	1.0	8.5	0.6	1.4	7.2
"	Meha Singh	8.8	1.3	0.6	7.2	3.9	2.5	3.4	1.8	5.6	0.1	2.6	3.5
"	kartar Singh	8.4	1.6	2.0	3.6	2.2	4.0	4.6	2.6	8.1	0.1	NIL	4.3

"	Sattish singh	8.8	1.4	0.6	7.0	4.0	2.3	4.4	3.4	6.0	0.2	NIL	3.0
"	Piyara singh Jat	8.9	1.1	1.2	5.6	3.1	0.9	2.4	1.4	5.0	0.1	3.0	3.7
Shilakheri	Mai Ram Jat	8.7	5.7	1.4	19.0	24.0	9.5	9.4	6.2	40.9	0.3	4.8	14.6
"	Dharm pal	8.8	3.9	3.0	12.6	13.0	8.0	6.2	5.2	26.8	0.3	4.2	11.2
"	Balbir Singh	8.7	3.0	2.8	9.2	12.2	4.1	7.4	5.2	19.8	0.3	NIL	7.9
"	Dilawar Singh	8.8	3.5	2.2	12.6	15.3	5.9	4.8	4.0	24.2	0.3	6.0	11.5
"	Rohtash	8.8	4.0	2.6	12.4	12.0	9.2	6.6	4.8	26.5	0.3	3.6	11.1
"	Trilok Singh	8.5	3.7	2.6	15.6	13.8	5.3	6.8	5.0	26.1	0.4	6.4	10.8
"	Pt.Hari kishan	8.6	3.1	2.0	12.4	11.6	4.3	4.2	2.0	25.1	0.3	8.2	14.3
"	Amarpal	8.9	1.0	1.0	2.8	1.9	4.4	2.8	1.8	5.9	0.1	NIL	3.9
Karkhnana	Satbir Singh	8.9	1.9	1.6	5.6	3.1	5.9	4.6	3.4	10.3	0.2	NIL	5.2
"	Randhir Singh	8.1	5.4	1.2	12.8	26.8	9.5	6.8	6.0	39.8	0.3	1.2	15.7
"	Bir Singh	8.0	3.2	1.2	13.8	12.7	2.6	6.4	3.8	22.7	0.3	4.8	10.1
"	Jile Singh	8.6	2.8	1.8	4.8	14.0	4.3	4.2	3.6	18.5	0.3	NIL	9.4
"	Mansa Ram	8.9	3.4	0.8	9.4	15.0	8.4	6.4	4.8	20.2	0.4	NIL	8.5
"	Satbir Singh	9.0	2.3	1.2	7.2	10.2	4.6	5.2	3.8	12.2	0.3	NIL	5.8
"	Partap Singh	9.0	2.6	0.0	8.4	9.9	5.3	4.8	3.8	14.8	0.2	NIL	7.1
"	Balwan Singh	8.7	5.3	1.0	7.8	34.4	9.1	7.4	5.4	38.1	0.4	NIL	15.1
Korda	Inder-Singh	8.6	4.4	1.8	10.0	24.0	6.8	7.4	5.4	30.0	0.3	NIL	11.9
"	Parmanand	8.7	4.4	0.4	14.6	20.4	9.0	6.2	5.6	33.8	0.3	3.2	13.9
"	Jai Bhagwan	8.9	1.6	1.6	5.0	3.6	2.1	4.8	3.4	7.8	0.2	NIL	3.9
"	Ragh bir Singh	8.3	1.9	1.8	7.2	6.1	2.3	4.6	2.6	9.9	0.2	1.8	5.2
"	Kanwar Pal	8.7	3.1	2.4	10.0	10.0	7.7	5.2	2.8	20.5	0.3	4.4	10.3
"	Balwinder Singh	8.9	2.8	2.4	9.6	10.7	7.4	4.8	3.2	20.7	0.4	4.0	10.4

"	Balkh rajjinh	9.0	3.0	1.4	14.4	8.2	4.2	7.8	4.6	16.8	0.3	3.4	6.8.
"	Randhir Singh	8.9	2.0	2.4	5.4	6.2	2.3	6.4	3.6	9.1	0.2	NIL	4.1
Ratta khera	Inder Singh	8.9	2.0	2.0	7.2	7.9	3.3	5.8	3.2	10.3	0.2	0.2	4.9
"	Miya Singh	8.9	2.2	1.2	6.2	9.2	4.3	3.8	3.2	13.1	0.2	0.4	7.0
"	Jai bhagwan	8.6	1.1	1.6	1.6	5.8	2.5	2.4	1.4	7.4	0.1	NIL	5.4
Khera Khemavati	Somdudd	8.8	1.8	1.0	7.0	5.2	2.6	3.4	2.8	9.6	0.2	1.8	5.4
"	Ram sawroop	9.0	1.8	2.0	5.4	6.3	3.3	4.2	2.8	10.5	0.2	0.4	5.6
"	Ram niwas	8.9	1.8	1.4	5.4	7.5	2.5	4.6	3.2	10.3	0.2	NIL	5.2
"	Rameshwar	8.9	1.8	1.2	6.2	4.9	3.4	3.4	1.8	11.5	0.2	2.2	7.1
"	Gyasu Ram	9.0	2.0	1.4	6.2	5.3	2.1	3.6	1.6	15.2	0.2	2.4	9.4
"	Birsa	8.9	2.7	2.0	9.2	9.4	3.3	3.8	2.8	17.8	0.3	4.6	9.8
"	Ved parkash	8.9	2.5	2.6	6.2	8.1	4.3	3.6	3.0	15.7	0.2	2.2	8.6
Pajukalan	Kapoor Singh	8.8	2.6	1.8	7.8	8.2	5.0	4.2	1.8	17.5	0.3	3.6	10.1
"	Badlu Ram	8.8	2.4	0.0	12.0	10.0	2.3	3.8	2.4	15.9	0.2	5.8	9.0
"	Prem Singh	8.9	2.0	0.0	10.8	4.5	2.3	3.2	2.4	13.7	0.2	5.2	8.2
"	Jag mohinder	9.0	2.4	1.6	9.4	7.1	4.3	4.6	3.4	14.2	0.2	3.0	7.1
"	Ramdiya Fauji	8.8	2.6	0.0	10.2	7.8	3.2	4.4	3.4	16.1	0.2	2.4	8.2
"	Satyawan	8.9	4.9	2.4	11.8	22.8	11.2	6.4	5.0	33.7	0.4	2.8	14.1
Pajukhurd	Subhash	9.0	3.6	2.6	8.4	15.9	5.8	4.8	4.0	34.2	0.4	2.2	16.3
"	Hawa Singh	8.6	7.0	2.4	10.4	36.3	17.4	12.8	8.6	45.2	0.4	NIL	13.8
"	Jaswant Singh	8.6	7.0	2.6	10.4	36.3	18.6	12.6	9.0	46.2	0.4	NIL	14.1
"	Raj Singh	8.6	8.5	3.6	9.2	50.8	18.0	13.8	9.8	58.3	0.5	NIL	17.0
"	Ram Jowari	8.8	8.6	3.1	9.6	51.5	17.4	11.8	7.8	64.0	0.5	NIL	20.4
Aftabgarh	Madu Ram	9.0	2.4	2.4	9.4	8.5	2.3	3.2	2.2	16.8	0.2	6.4	10.2

"	Gurpreet Singh	8.6	3.1	0.8	11.7	11.3	4.7	5.4	3.8	18.3	0.3	3.3	8.5
"	Pala Singh	8.8	2.3	1.2	6.6	9.1	6.3	3.8	4.0	13.4	0.2	NIL	6.8
"	Sukhan Singh	8.9	3.4	0.0	10.6	10.8	7.1	4.4	2.8	27.7	0.3	3.4	14.6
"	Mohinder Singh	8.5	4.9	0.4	16.0	21.2	4.1	7.4	5.3	34.5	0.4	3.7	13.7
"	Master Chud Singh	8.6	2.3	0.0	10.8	9.4	2.3	6.8	4.8	11.2	0.3	NIL	4.6
"	Ram phal	8.9	3.6	2.0	11.2	12.8	7.0	4.2	2.8	27.8	0.4	6.2	14.9
Dharmgarh	Gurbachan Singh	8.9	2.5	0.8	9.0	9.8	3.8	5.2	4.2	14.3	0.2	0.4	6.6
"	Puran Singh	9.0	2.3	2.2	7.6	8.5	2.4	4.8	4.2	12.1	0.3	0.8	5.7
"	Gurbachan Singh	8.8	2.0	0.4	9.8	7.5	3.2	5.2	3.6	10.0	0.2	1.4	4.8
"	Karnail Singh	8.8	2.0	0.8	6.0	7.1	6.1	3.8	3.0	10.3	0.2	0.0	5.6
"	Gernail Singh	8.7	2.4	0.0	10.4	6.2	3.8	5.6	3.8	12.3	0.2	1.0	5.7
"	Purn Singh	8.9	2.9	1.2	13.2	10.1	3.6	4.8	3.8	20.7	0.3	5.8	10.0
"	Sisha Singh	9.0	2.4	1.4	9.2	9.7	2.3	4.6	4.2	14.2	0.3	1.8	6.8
"	Gurbachan Singh	8.9	4.1	2.2	5.4	16.0	4.9	6.4	3.8	28.3	0.4	NIL	12.5
"	Harbhan Singh	8.8	2.3	0.6	8.8	7.6	4.8	2.2	2.0	17.8	0.2	5.2	12.3
"	SarbjeeetSingh	8.9	2.9	1.8	8.4	11.3	5.8	3.8	2.2	22.9	0.2	4.2	13.2
Malikpur	Jagtar singh	9.3	4.3	2.6	16.2	14.1	8.5	4.8	4.0	33.2	0.4	10.0	15.8
"	Trilok Singh	9.0	3.8	2.1	10.8	11.1	5.3	3.8	3.2	30.4	0.4	5.9	16.3
"	Nirmal Singh	8.9	3.1	2.1	10.8	10.7	5.0	4.8	4.2	20.2	0.3	3.9	9.5
"	Tahal Singh	8.9	3.7	2.0	12.4	13.4	7.3	6.2	4.4	24.1	0.4	3.8	10.5
"	Sewa Singh	8.7	3.9	0.0	15.2	18.4	4.9	6.4	4.0	26.8	0.4	4.8	11.8
"	Balihar Singh	8.8	3.7	1.4	13.4	13.9	6.2	6.8	3.6	25.2	0.4	4.4	11.1
"	Nishan Singh	9.0	3.9	2.0	13.5	13.1	9.8	5.6	6.2	26.2	0.4	3.7	10.8
"	Mulkha Singh	8.7	4.0	1.8	13.8	15.0	9.9	7.4	5.4	28.5	0.2	2.8	11.3

"	Hazoor Singh	8.6	3.3	1.6	12.8	10.9	9.0	5.4	4.2	21.8	0.3	4.8	10.0
"	Shera Singh	8.8	3.8	2.6	11.2	14.0	7.9	6.8	3.2	25.4	0.4	3.8	11.4
"	Joga Singh	8.9	4.0	1.4	12.4	13.6	9.1	5.8	3.8	28.4	0.3	4.2	13.0
"	Angrej Singh	8.8	3.4	1.8	12.5	11.8	8.3	6.4	3.6	22.6	0.4	4.3	10.1
"	Nidan Singh	8.7	3.8	1.4	13.2	14.7	8.2	5.4	4.4	26.8	0.3	4.8	12.1
Rodh	Jagbir Singh	8.5	6.7	2.8	17.6	28.7	12.4	11.6	8.2	44.5	0.5	0.6	14.1
"	Shekher Singh	8.6	6.3	2.4	13.6	35.9	10.4	10.8	7.8	43.5	0.5	NIL	14.3
"	Mohinder Singh	8.7	1.9	0.4	6.6	6.3	4.6	2.2	2.2	14.3	0.1	2.6	9.6
"	Sewa Singh	8.9	3.3	0.6	9.8	9.5	9.6	4.2	3.4	22.2	0.3	2.8	11.4
"	Satnam Singh	8.8	2.8	0.4	9.0	9.7	8.5	5.4	3.9	15.7	0.3	0.1	7.3
"	Mukhtiyar Singh	8.3	7.4	1.8	14.6	38.2	14.4	11.8	7.2	53.0	0.5	NIL	17.2
"	Subha Singh	8.5	8.1	2.2	17.4	45.5	12.4	12.6	8.6	59.3	0.6	NIL	18.2
"	Nishan Sing	8.9	3.6	2.6	8.0	12.4	11.4	4.4	2.8	28.8	0.4	3.4	15.2
Hatt	Shamsher Singh	8.8	3.9	2.6	8.2	15.0	9.4	3.2	2.6	32.7	0.4	5.0	19.2
"	Sant Ram	8.8	3.1	2.8	8.2	11.9	5.1	4.2	2.8	20.0	0.3	4.0	10.7
"	Bhoop Singh	8.7	2.4	2.0	8.4	9.8	2.7	4.8	4.0	14.2	0.3	1.6	6.8
"	Chander Singh	8.6	2.3	1.6	6.2	10.6	5.4	3.6	2.8	23.7	0.2	1.4	13.2
"	Satbeer Singh	8.8	4.2	2.4	11.6	17.0	8.4	6.4	5.2	29.0	0.4	2.4	12.1
"	Krishan Cand	8.8	2.5	1.4	10.1	8.2	2.1	4.6	4.2	13.2	0.3	2.7	6.3
"	Telu Ram	8.7	3.1	1.6	9.8	10.7	7.9	4.8	3.8	20.5	0.2	2.8	9.9
"	Deepak	8.6	2.1	1.4	6.6	7.8	3.5	4.2	4.2	9.9	0.2	NIL	4.8
"	Jagbeer Singh	8.7	2.2	2.8	5.6	8.2	4.0	6.8	3.4	10.3	0.3	NIL	4.6
"	Jagjit Singh	8.8	4.4	1.2	12.2	15.0	13.3	5.6	2.8	33.2	0.3	5.0	16.2
Baghru Kalan	Rajinder Singh	8.6	2.3	1.4	6.8	8.4	4.2	5.8	3.4	13.6	0.2	NIL	6.3

"	Satyavan	8.6	2.5	1.2	7.4	7.6	4.9	6.4	2.8	13.6	0.3	NIL	6.3
"	Dharm Singh	8.5	2.5	1.8	7.8	7.1	5.6	6.6	2.8	13.3	0.2	0.2	6.1
"	Surjeet Master	7.8	6.7	2.0	24.0	30.6	7.2	18.5	12.0	34.3	0.5	NIL	8.8
"	Ravinder Singh	7.8	6.9	1.8	22.2	37.1	6.6	20.4	14.2	31.3	0.4	NIL	7.5
Baghru Khurd	Rajesh Kumar	8.8	2.1	1.4	6.0	7.0	2.7	6.6	3.6	9.8	0.2	NIL	4.3
"	Mahaveer Singh	8.5	1.1	2.0	0.8	2.5	2.0	3.2	1.8	4.6	0.2	NIL	2.9
"	Daya Singh	8.0	8.1	3.8	8.8	52.5	12.4	22.4	13.6	43.3	0.5	NIL	10.2
"	Balbeer Singh	8.2	4.1	1.0	11.2	20.5	6.5	8.6	5.4	25.1	0.7	NIL	9.5
Anchra Khurd	Karm chand	8.4	1.2	2.2	3.6	3.8	3.0	5.4	3.2	2.7	0.2	NIL	1.3
"	Satbir Singh	8.0	7.0	2.1	9.4	41.5	10.0	14.6	8.6	44.2	0.5	NIL	13.0
"	Chanda Singh	8.2	7.0	2.8	10.4	46.8	10.6	15.4	7.6	44.4	0.6	NIL	13.1
"	Bhaga Ram	8.1	6.2	1.6	11.2	36.1	10.2	16.6	8.2	35.3	0.7	NIL	10.0
"	Pawan Singh	8.1	5.0	4.0	7.6	27.4	10.3	12.8	7.2	31.5	0.5	NIL	10.0
"	Shadhu Ram	7.2	7.6	1.2	14.8	41.5	6.2	18.8	12.2	43.2	0.6	NIL	11.0
"	Tara Chand	7.9	4.9	5.6	10.2	25.6	8.9	12.4	8.2	28.3	0.4	NIL	8.8
"	Ram Karan	7.9	7.0	2.8	6.8	46.8	9.2	17.8	11.4	39.5	0.5	NIL	10.3
Sarfabad	Hukum Chand	7.9	5.7	2.0	6.3	37.741.6	9.2	12.4	7.6	34.8	0.3	NIL	11.0
"	Ram kumar	8.3	6.6	2.2	12.8	34.7	9.6	14.6	7.6	41.5	0.5	NIL	12.5
"	Satbeer Singh	8.6	5.5	1.6	11.8	37.9	7.1	11.8	6.2	35.6	0.6	NIL	11.9
"	Surinder Singh	8.0	5.2	2.6	8.2	27.9	4.2	16.6	9.6	39.8	0.4	NIL	11.0
"	Telu Ram	8.2	4.8	1.2	9.4	27.5	8.3	17.8	13.2	13.4	0.5	NIL	3.4
"	Jile Singh	8.7	2.7	1.6	4.6	10.0	5.9	9.4	-5.4	0.3	0.3	2.2	0.2
Todi Kheri	Chander bhan	8.3	1.0	1.2	3.2	1.9	2.8	3.8	3.2	1.5	0.6	NIL	0.8
"	Satpal	8.5	0.7	1.4	2.2	1.8	0.3	2.2	0.8	2.4	0.6	0.6	2.0

"	Rajinder Singh	8.3	0.5	0.0	3.4	1.0	0.4	2.6	1.8	0.5	0.1	NIL	0.3
"	Om Singh	8.7	2.4	1.2	6.2	6.3	8.3	4.4	3.0	1.4	0.2	NIL	0.7
Didwada	Jai bhagwar	8.2	1.4	1.0	5.0	4.1	3.3	4.2	3.6	6.2	0.1	NIL	3.1
"	Ram Kishan	8.2	1.2	0.9	3.2	3.0	3.9	3.8	2.8	4.0	0.2	NIL	2.2
"	Singh Ram	8.3	1.3	0.9	6.8	3.2	2.3	3.6	3.0	6.0	0.2	1.1	3.3
"	Narsi Singh	7.7	1.3	0.7	6.4	4.2	2.1	4.8	3.4	2.6	0.1	NIL	1.3
"	Parsa Ram	8.0	1.5	0.0	8.6	3.5	1.8	5.2	3.2	4.2	0.2	0.2	2.1
"	Shyama	8.4	1.3	1.0	6.4	3.8	2.1	3.8	2.4	5.2	0.1	1.2	3.1
"	Hukum Singh	8.2	1.2	0.6	6.6	3.7	1.8	3.6	3.2	5.0	0.1	0.4	2.7
"	Ranbir Singh	7.9	1.0	0.4	4.2	3.0	2.7	3.8	2.6	3.2	0.1	NIL	1.8
Singhana	Jagdish	8.8	5.0	1.0	19.6	27.0	3.1	8.4	7.2	42.6	0.3	5.0	15.4
"	Jai Narayan	8.2	3.8	0.6	16.0	15.0	5.9	7.6	6.2	24.2	0.3	2.8	9.2
"	Ram Phal	8.2	2.0	0.6	4.4	10.0	4.4	5.2	4.4	9.6	0.2	NIL	4.4
"	Chanda Singh	7.8	4.1	0.8	15.4	16.2	6.6	6.8	5.0	26.6	0.2	4.4	11.2
"	Punjaba Singh	8.0	4.8	0.4	10.0	28.0	10.5	4.6	3.8	38.2	0.2	2.0	18.6
"	Chaman Singh	8.7	5.8	0.8	15.6	31.0	10.5	6.8	4.0	45.3	0.4	5.6	19.4
"	Dhuan Singh	7.8	4.6	0.8	17.6	20.0	13.5	12.6	7.4	24.0	0.3	NIL	10.8
Muana	Dham Singh	7.9	9.6	0.6	16.8	45.0	30.0	17.6	11.2	64.2	0.3	NIL	16.9
"	Ram Kishan	8.0	8.9	0.6	12.4	44.0	35.0	16.8	11.7	58.2	0.1	NIL	15.4
"	Mangat Ram	7.5	10.9	0.8	7.0	52.0	39.8	24.8	18.2	60.5	0.5	NIL	13.2
"	Karam Singh	8.1	1.3	0.4	6.2	4.0	4.8	4.2	2.0	5.0	0.1	0.4	2.8
Malsiwana	Ram Kishan	8.4	1.4	0.6	4.4	4.2	8.6	3.2	1.8	8.2	0.1	NIL	5.2
"	Ram Phal	8.1	1.8	0.4	6.4	7.0	4.1	3.4	1.9	10.3	0.2	1.5	6.2
"	Hawa Singh	7.8	1.9	0.6	7.0	6.0	4.8	4.2	3.4	9.8	0.2	NIL	5.1

"	Bittu Sarpanch	7.9	2.7	1.0	9.8	8.1	8.2	5.2	3.6	19.2	0.3	2.0	9.1
"	Harbhan Singh	8.1	3.7	0.0	16.2	17.0	4.2	7.6	5.2	23.2	0.4	3.4	9.1
"	Kirpal Singh	7.7	3.7	0.0	15.2	14.2	6.0	6.8	5.4	23.1	0.3	3.0	9.4
"	Kam Singh	7.2	5.7	0.6	18.8	22.0	12.8	14.4	10.2	30.2	0.5	NIL	8.6
"	Pt. Rama	7.6	3.3	0.6	10.9	18.2	7.3	7.4	5.0	90.2	0.3	NIL	8.1
"	Rattan Singh	7.6	5.1	1.2	6.4	29.0	10.1	9.4	7.2	32.8	0.5	NIL	11.5
"	Baru Ram	7.8	6.1	0.6	5.0	37.0	14.3	17.4	8.4	34.3	0.5	NIL	9.5
"	Om Parkash	9.1	1.5	1.0	7.0	4.0	2.5	2.2	1.8	9.7	0.2	4.0	6.9
"	Balbeer Singh	8.1	5.3	0.6	9.1	30.0	8.6	8.8	6.4	35.2	0.5	NIL	12.7
"	Ravinder Singh	7.7	4.1	1.0	6.0	23.7	7.9	8.5	5.9	24.3	0.4	NIL	8.9
"	Mahaveer Singh	7.9	3.7	0.6	4.4	22.2	6.3	7.6	4.9	22.3	0.3	NIL	8.8
"	Yesh Dev	8.0	3.0	0.6	4.0	16.1	7.3	5.4	3.4	20.1	0.3	NIL	9.6
"	Bhim Singh	8.1	2.5	0.6	5.0	15.2	4.8	5.6	3.0	14.2	0.3	NIL	6.8
"	Lal Chand	8.0	3.8	0.6	5.2	24.7	8.3	8.4	4.8	23.3	0.3	NIL	9.0
"	Satbeer Singh	8.0	2.8	1.3	8.2	7.3	9.3	5.6	1.2	21.1	0.3	2.7	10.0
"	Rajbeer Singh	7.8	2.8	1.2	8.0	6.2	10.3	3.2	2.2	20.7	0.2	3.8	12.8
"	Vijay Singh	7.8	2.9	1.0	5.0	10.1	10.8	7.2	5.6	14.4	0.2	NIL	5.6
"	Lakhmi Namberdar	7.7	2.7	1.2	6.8	8.6	10.6	4.8	2.6	17.7	0.2	0.6	9.4
"	Om Parkash	8.3	1.6	1.0	6.2	4.3	5.5	2.8	41.2	10.2	0.1	NIL	6.8
"	Bijender	7.9	2.2	1.4	7.6	7.2	4.8	3.2	2.6	14.1	0.1	3.2	8.2
"	Vijay Singh	7.7	2.6	1.0	4.8	10.4	10.5	6.4	4.4	4.9	0.2	NIL	2.1
"	D harmSingh	8.3	1.6	1.6	9.6	2.5	4.8	3.2	2.0	10.6	0.2	6.0	6.8
"	Karan Singh	7.4	2.9	2.0	11.2	7.0	7.3	4.2	2.8	20.2	0.2	6.2	10.7
"	Suraj Singh	7.1	1.2	1.0	4.6	5.0	1.7	4.6	2.6	4.4	0.1	NIL	2.3

"	Mangat Ram	7.3	10.5	1.2	6.0	50.4	36.0	24.2	10.8	66.8	0.5	NIL	16.0
Rampura	Virender Singh	7.2	8.1	1.4	7.0	38.1	33.0	17.4	10.1	52.3	0.5	NIL	14.1
"	Manpal Singh	7.7	8.2	1.2	5.0	40.2	32.0	18.6	9.6	51.8	0.5	NIL	13.9
"	Fateh Singh	8.0	3.9	1.2	8.0	20.2	14.9	6.4	4.2	26.7	0.3	NIL	11.7
"	Amarpal Singh	7.4	7.8	1.4	11.2	33.1	26.3	12.8	6.6	54.4	0.5	NIL	17.4
Muana	Karan Singh	8.2	5.5	0.6	6.4	30.2	14.6	12.6	6.2	35.8	0.4	NIL	11.8
"	Kirpal Singh	7.8	7.2	1.0	9.6	28.1	28.0	10.6	7.0	53.4	0.5	NIL	17.9
"	Rohtash	7.3	6.9	1.2	8.0	29.1	25.0	9.8	6.7	50.7	0.5	NIL	17.8
"	Yesh Pal Singh	7.2	3.0	1.0	6.6	12.1	10.5	8.4	4.8	15.3	0.3	NIL	5.9
"	Vijay Singh	7.7	3.1	1.2	6.0	7.5	7.5	7.2	4.2	17.4	0.3	NIL	7.1
"	Abhan Singh	7.6	8.4	1.6	10.7	37.1	30.8	17.6	9.6	55.7	0.2	NIL	15.2
"	Prem Singh	7.4	3.4	1.2	6.6	14.8	10.8	12.4	2.8	17.5	0.3	NIL	6.5
"	Raj Singh	7.9	7.9	1.0	5.0	30.1	30.8	13.8	6.8	56.9	0.6	NIL	17.8
"	Vinod Kumar	7.1	4.2	1.0	4.8	14.1	20.5	13.6	5.8	21.2	0.3	NIL	6.8
"	Subhash	7.1	6.8	1.4	6.0	30.2	27.1	17.6	8.8	39.3	0.5	NIL	10.7
"	Nakel Singh	7.1	5.1	1.0	6.4	22.2	17.1	12.8	5.4	31.1	0.3	NIL	10.3
"	Babu Ram	7.1	3.8	1.0	6.6	15.2	13.3	9.6	6.6	19.4	0.3	NIL	6.7
"	Man Singh	6.9	8.8	0.6	5.0	40.1	30.0	18.4	9.6	58.3	0.2	NIL	15.5
"	Bajrang Singh	7.6	4.2	1.6	7.0	13.8	18.4	6.4	3.8	28.4	0.4	NIL	12.4
"	Ishwer Singh	7.8	1.1	0.4	4.8	4.2	1.1	3.2	2.0	4.2	0.1	NIL	2.6
"	Leelu Ram	7.6	4.2	1.6	5.4	15.2	16.9	9.8	5.4	23.4	0.4	NIL	8.4
"	Dhoom Singh	6.3	10.2	0.4	7.3	57.2	31.5	18.6	10.0	70.9	0.2	NIL	18.8
"	Vikram Singh	7.6	7.5	1.0	8.8	28.4	25.0	9.8	5.4	57.4	0.5	NIL	20.8
"	Sompal Singh	7.7	2.2	1.2	6.4	7.4	6.8	5.2	4.6	10.3	0.2	NIL	4.7

"	Ram Kumar	8.5	1.8	1.6	9.0	4.2	3.5	2.0	1.2	12.6	0.2	7.4	10.3
"	Jogi Ram	8.0	5.6	1.8	10.4	19.2	18.0	5.4	3.4	45.3	0.5	3.4	21.7
"	Mehar Singh	7.9	4.6	0.4	8.0	19.9	15.4	12.4	6.1	35.8	0.4	NIL	11.8
"	Pitamber Singh	7.5	8.5	1.4	9.2	35.2	33.0	14.8	5.8	62.4	0.5	NIL	19.4
"	Kanwar Pal	7.3	10.1	0.4	11.4	45.2	40.0	17.6	10.6	70.3	0.2	NIL	18.7
"	Ram Phal	7.9	6.7	1.2	10.4	34.3	17.8	14.8	6.2	44.8	0.6	NIL	13.9
"	Deep Singh	7.7	1.3	1.4	5.4	3.4	3.9	4.2	3.2	4.9	0.1	NIL	2.6
"	Sukhwinder Singh	7.5	1.5	1.2	5.7	4.0	2.2	5.1	3.1	4.7	0.1	NIL	2.3
"	Brij Pal Singh	7.4	3.1	1.4	7.8	9.4	12.3	4.8	4.0	20.9	0.2	0.4	10.0

APPENDIX - II**Table 1: Village wise distribution of water samples in various classes**

Village	No. of samples	Good	Marginal	Saline	Sodic	Saline sodic
		A	B	C ₁	C ₂	C ₃
Jaipur	8	-	5	3	-	-
Chapper	14	-	4	5	5	-
Bahadurgarh	6	1	5	-	-	-
Mallar	17	1	7	6	2	-
Rozla	18	1	7	4	6	-
Butani	9	5	2	1	1	-
Shanpur	8	5	3	-	-	-
Nimna Bad	8	7	1	-	-	-
Anta	7	6	1	-	-	-
Barod	4	4	-	-	-	-
Baisini	6	5	1	-	-	-
Khatla	3	3	-	-	-	-
Bhuslana	5	4	1	-	-	-
Karsandu	6	6	-	-	-	-
Titokheri	7	6	-	-	1	-
Bahadurpur	7	5	-	-	2	-
Singhpura	7	4	1	-	2	-
Shilakhari	8	1	1	-	3	3
Karkhana	8	1	4	-	1	3
Korda	8	3	-	-	3	2
Rattakhera	3	1	2	-	-	-

Contd...

Village	No. of samples	Good	Marginal	Saline	Sodic	Saline sodic
		A	B	C ₁	C ₂	C ₃
Khera khemavati	7	3	3	-	-	1
Paju kalan	6	-	2	-	3	1
Paju kurd	5	-	-	-	-	5
Aftabgarh	7	-	2	-	4	1
Dharmgarh	10	-	6	-	3	1
Malikpur	13	-	-	-	12	1
Rodh	8	-	1	-	3	4
Hatt	10	-	4	-	4	2
Bagrhu kalan	5	-	3	2	-	-
Bagrhu khurd	4	1	1	1	-	1
Anchra khurd	8	1	-	-	-	7
Sarfabad	6	-	1	1	-	4
Todikhari	4	4	-	-	-	-
Didwada	8	7	1	-	-	-
Singhana	7	-	2	-	-	5
Malsiwana	14	3	3	1	4	3
Anchra kalan	14	2	7	-	4	1
Rampura	4	1	1	-	2	-
Muana	32	4	4	3	2	19

APPENDIX - IIIGeneral information about tubewell water samples of Safidon block

Sample No.	Name of farmer	Depth of tubewell (ft.)	Crops grown	Years the water in use	Farmers comments
Village: Jaipur					
1	Sukhvinder Singh	120	Paddy, wheat, Jowar	10	Marginal water reduction in yield
2	Dhup Singh	130	-do-	12	Marginal water reduction in yield
3	Ria Singh	115	-do-	10	Brackish water, problem of water stagnation
4	Nafe Singh	120	-do-	13	Brackish water, problem of water stagnation
5	Jai Bhagwan	140	-do-	4	Brackish water, problem of water stagnation
6	Jaswant Singh	140	Paddy, wheat, Jowar, Bajra	4	Marginal water
7	Kali Ram Lat	120	-do-	8	Sweet in taste, but problematic
8	Sukhwinder	130	-do-	10	Marginal water
Village: Chapper					
9	Darshan Singh	130	Paddy, wheat	22	Marginal water reduction in paddy and wheat yield
10	Bakha Singh	120	-do-	8	Marginal water reduction in paddy and wheat yield
11	Amrik Singh	200	-do-	22	Marginal water, reduction in paddy and wheat yield
12a	Mohinder Singh	200	-do-	3	Sweet in taste, problem of water stagnation
12b	Mohinder Singh	180	-do-	7	Sweet in taste, problem of water stagnation

Contd...

13	Sinder Singh	120	-do-	12	Brackish water, made soil harder
14	Tehl Singh	140	Paddy, wheat, Jowar, Bajra	14	Marginal water, continuously reduction in paddy & wheat
15	Chain Singh	200	-do-	10	Sweet in taste, problem of water stagnation
16	Ram Kumar	120	-do-	7	Marginal water
17	Swarn Singh	200	-do-	5	Brackish water
18	Hardeep Singh	200	-do-	23	Marginal water, reduction in wheat and paddy yield
19	Preetam Singh	200	-do-	10	Marginal water
20	Harbhan Singh	150	-do-	33	Marginal water
21	Amarjeet Singh	170	-do-	12	Problem of water stagnation
Village: Bahadurgarh					
22	Kuldeep Singh	140	Paddy, Wheat	8	Problem of water stagnation
23	Ladwa Pt.	140	-do-	23	Marginal water
24	Ram Kumar	140	-do-	20	Sweet in taste, made soil harder
25	Shish ram	70	Paddy, wheat, Barseem, Jowar	12	Good quality water
26	Phool Singh	60	Paddy, wheat, Jowar	8	Marginal water
27	Mange Ram	70	-do-	4	Marginal water
Village: Mallar					
28	Rattan Singh	70	Paddy, wheat, Bajra	1	Sweet in taste, made soil harder
29	Hawa Singh	60	-do-	5	Marginal quality water
30	Harikrishan	70	-do-	15	Marginal quality water
31	Kaghubir Singh	55	-do-	8	Saline water
32	Takdir Singh	55	-do-	6	Saline water
33	Basau Ram	55	-do-	5	Namkeen water

Contd...

34	Kuldeep Singh	100	-do-	8	Marginal water
35	Ramgopal	80	-do-	3	Marginal water
36	Barada Kundu	60	-do-	10	Marginal water
37	Naseeb Singh	90	Banana, Mustard, Vegetables	7	Fairly good, water used mixing with canal
38	Raghubir Singh	30	Wheat, mustard, Paddy	5	Marginal water
39	Sant Ram	100	Paddy, wheat	5	Marginal water
40	Pt. Nathu Ram	140	-do-	6	Marginal water
41	Vivek	130	-do-	2	Marginal water
42	Master Rai Singh	100	-do-	5	Marginal water
43	Om Prakash	70	-do-	11	Marginal water
44	Lal Singh	60	-do-	3	Marginal water
Village: Rozla					
45	Bichha Ram	140	Wheat, gram, rice	10	Marginal water
46	Karn Singh	120	Wheat, mustard, paddy	7	Brackish water, problem of water stagnation
47	Sat Pal	40	Paddy, wheat, Jowar, barseem	2	Good quality water
48	Karn Singh	32	-do-	5	Marginal water
49	Om Singh	74	-do-	5	Marginal water
50	Sher Singh	42	-do-	6	Brackish water
51	Ved Pal	20	-do-	3	Brackish water
52	Nafe Singh	20	-do-	2	Brackish water
53	Rohtash	130	-do-	2	Marginal water
54	Om Singh	42	-do-	2	Namkeen water
55	Rambhaj	150	-do-	7	Marginal water, made soil harder
56	Chander Singh	60	-do-	23	Brackish water, made soil harder
57	Sat Pal	130	Wheat, Paddy	23	Marginal water
58	Gopi Chand	100	-do-	15	Marginal water
59	Khyali Ram	90	Wheat, Mustard	23	Marginal water

Contd...

60	Punit Kumar	37	-do-	25	Marginal water
61	Dalip Singh	165	-do-	1	Marginal water
62	Vajeer Singh	90	-do-	18	Marginal water
Village: Butani					
63	Anand Singh	60	-do-	18	Brackish water, problem of water stagnation
64	Prem Singh	60	Paddy, wheat, Barseem, Jowar	4	Fairly good
65	Bichha Ram	140	Paddy, wheat	23	Brackish water, made soil harder
66	Sher Singh	150	-do-	3	Sweet in taste, problem of water stagnation
67	Balbir Singh	57	-do-	14	Marginal water
68	Atar Singh Malik	58	Paddy, wheat, Barseem	21	Good water
69	Sandeep Malik	58	Paddy, wheat, Jowar	3	Brackish water
70	Karan Singh	55	-do-	6	Fairly good
71	Charan Singh	60	-do-	8	Fairly good
Village: Shahnpur					
72	Raj Kumar	40	Wheat, paddy, Barseem, Vegetable	18	Good quality water
75	Pala Ram	100	Paddy, wheat, Jowar	10	Marginal quality
76	Nafe Singh	135	Paddy, wheat, vegetables	3	Good quality water
77	Raja Singh	100	-do-	8	Good quality water
78	Seva Singh	130	-do-	3	Good quality water
79	Trilok Singh	150	Paddy, wheat, Jowar	4	Marginal quality water
80	Hari Singh	150	Paddy, wheat, Barseem, vegetables	18	Good quality water
81	Janpal Singh	140	-do-	18	Good quality water

82	Kulvinder Singh	150	-do-	2	Good quality water
Village: Nimnabad					
83	Jaswant Singh	150	-do-	15	Good quality water
84	Gurdev Singh	150	-do-	18	Good quality water
85	Pyara Singh	160	-do-	19	Good quality water
86	Gurdeep Singh	150	-do-	23	Good quality water
87	Balkar Singh	100	-do-	3	Good quality water
88	Sucha Singh	70	Paddy, wheat, Jowar	33	Marginal water, made soil harder
89	Sukha Singh	150	Paddy, wheat, Vegetables	33	Good quality water
90	Sukhvinder Singh	175	-do-	5	Good quality water
Village: ANTA					
91	Surat Singh	175	Paddy, wheat, Jowar	23	Marginal quality water
92	Asha Ram	130	Paddy, wheat, vegetables, Barseem	18	Good quality water
93	Somnath	150	-do-	33	Good quality water
94	Ramswarup	220	-do-	1	Good quality water
95	Mukhtyar Singh	130	-do-	8	Good quality water
96	Harbhajan Singh	160	-do-	5	Good quality water
97	Gurdeep Singh	160	-do-	28	Good quality water
Village: Barod					
98	Sukhvinder Singh	140	-do-	28	Good quality water
99	Gurdeep Singh	140	-do-	18	Good quality water
100	Sukhvinder Singh	150	-do-	3	Good quality

					water
101	Gurdeep Singh	155	-do-	7	Good quality water
Village: Baisini					
102	Balvinder Singh	150	Paddy, wheat, Jowar	23	Marginal water
103	Mahinder Singh	100	Paddy, wheat, Barseem	33	Good quality water
104	Ram Singh	140	-do-	23	Good quality water
105	Ajay Krishan	140	-do-	8	Good quality water
106	Ravi Sharma	140	-do-	1	Good quality water
107	Ram Phal	100	-do-	33	Good quality water
Village: Khatla					
108	Nihal Singh	150	-do-	13	Good quality water
109	Nirmaljit Singh	150	-do-	11	Good quality water
110	Rishpal Singh	150	Wheat, Paddy, Jowar, Bajra	10	Brackish water, problem of water stagnation in rainy season
Village: Bhuslana					
111	Pt. Goverdhan	140	Barseem, Vegetables, Paddy and wheat	3	Good quality water
112	Daya Nand	180	-do-	8	Good quality water
113	Karan Singh	140	-do-	7	Good quality water
114	Rameshwar	80	-do-	1	Good quality water
115	Abhay Ram	180	-do-	13	Good quality water
Village: Karsandu					
116	Sukhvinder Singh	160	-do-	11	Good quality water
117	Rajoir Singh	140	-do-	8	Good quality

Contd...

					water
101	Gurdeep Singh	155	-do-	7	Good quality water
Village: Baisini					
102	Balvinder Singh	150	Paddy, wheat, Jowar	23	Marginal water
103	Mahinder Singh	100	Paddy, wheat, Barseem	33	Good quality water
104	Ram Singh	140	-do-	23	Good quality water
105	Ajay Krishan	140	-do-	8	Good quality water
106	Ravi Sharma	140	-do-	1	Good quality water
107	Ram Phal	100	-do-	33	Good quality water
Village: Khatla					
108	Nihai Singh	150	-do-	13	Good quality water
109	Nirmaljit Singh	150	-do-	11	Good quality water
110	Rishpal Singh	150	Wheat, Paddy, Jowar, Bajra	10	Brackish water, problem of water stagnation in rainy season
Village: Bhuslana					
111	Pt. Goverdhan	140	Barseem, Vegetables, Paddy and wheat	3	Good quality water
112	Daya Nand	180	-do-	8	Good quality water
113	Karan Singh	140	-do-	7	Good quality water
114	Rameshwar	80	-do-	1	Good quality water
115	Abhay Ram	180	-do-	13	Good quality water
Village: Karsandu					
116	Sukhvinder Singh	160	-do-	11	Good quality water
117	Rajbir Singh	140	-do-	8	Good quality

Contd...

					water
118	Ishwar Singh	150	-do-	8	Good quality water
119	Ram Mehar	200	-do-	9	Good quality water
120	Jagbir	160	-do-	7	Good quality water
121	Vajir Singh	80	-do-	23	Good quality water
Village: Titokheri					
122	Naresh	80	Wheat, Paddy and Jowar	28	Brackish water
123	Ashok Singh	130	Paddy, wheat, vegetables, Barseem, Jowar	10	Good quality water
124	Ziic Singh	90	-do-	23	Fairly good
125	Jai Bhagwan	100	-do-	11	Good quality water
126	Lila Chaudhary	140	Paddy, wheat	18	Brackish water
127	Maha Singh	160	Paddy, wheat, vegetables, Barseem, Jowar	8	Good quality water
128	Vijay Singh	150	-do-	23	Good quality water
Village: Bahadurpur					
129	Jaswant Singh	130	-do-	33	Good quality water
130	Balwant Singh	150	-do-	13	Good quality water
131	Kuldeep Singh	130	Paddy, wheat, Jowar	10	Brackish water, made soil hard
132	Karnail Singh	150	Paddy, wheat, barseem	18	Good quality water
133	Sohan Singh	150	Paddy, wheat, Jowar	18	Brackish water, problem of water stagnation
134	Ch. Molad Ram	150	Paddy, wheat, vegetables, barseem, Jowar	6	Good quality water
135	Jaspal Singh	150	Paddy, wheat, vegetables, barseem, Jowar	1	Good quality water

Village: Singhana

136	Meva Singh	150	Paddy, wheat, Jowar	11	Sweet in taste, but problematic
137	Hukam Singh	140	Paddy, wheat, Jowar	11	Good quality water
138	Hari Singh	150	Paddy, wheat, Barseem	33	Sweet in taste, but problematic
139	Meha Singh	150	-do-	6	Good quality water
140	kartar Singh	90	Paddy, Wheat, Jowar	38	Good quality water
141	Satish singh	140	-do-	38	Marginal water
142	Piyara singh Jat	130	-do-	28	Brackish water

Village: Shilakheri

143	Mai Ram Jat	150	-do-	11	Brackish water
144	Dharm pal	140	-do-	20	Marginal quality water
145	Balbir Singh	140	-do-	17	Brackish water
146	Dilawar Singh	160	-do-	6	Brackish water
147	Rohtash	140	-do-	7	Brackish water
148	Trilok Singh	150	-do-	11	Brackish water
149	Pt.Hari kishan	80	Paddy, wheat, vegetables	7	Good quality water
150	Amarpal	85	-do-	5	Good quality water

Village: Karkhana

151	Satbir Singh	85	Paddy, wheat, Jowar	10	Brackish water, made soil harder
152	Randhir Singh	70	-do-	4	Brackish water, made soil harder
153	Bir Singh	120	-do-	10	Marginal quality water
154	Jile Singh	110	-do-	12	Marginal quality water
155	Mansa Ram	100	-do-	5	Marginal quality water
156	Satbir Singh	130	-do-	3	Marginal quality water

157	Partap Singh	130	-do-	6	Marginal quality water
158	Balwan Singh	120	-do-	38	Marginal quality water
Village: Korda					
159	Inder Singh	140	-do-	10	Marginal quality water
160	Parmanand	140	Sugarcane, Paddy, wheat, Jowar, vegetable		Good quality water
161	Jai Bhagwan	140	-do-	25	Good quality water
162	Ragh bir Singh	120	-do-	19	Good quality water
163	Kanwar Pal	150	Paddy, Jowar	7	Brackish water
164	Balwinder Singh	170	-do-	10	Brackish water
165	Balkh rajingh	200	-do-	28	Brackish water
166	Randhir Singh	150	-do-	28	Fairly good
Village: Ratta Khera					
167	Inder Singh	150	-do-	28	Marginal quality water
168	Miya Singh	150	-do-	11	Marginal quality water
169	Jai bhagwan	150	Wheat, Vegetables, paddy, barseem, mustard	38	Good quality water
Village: Khera Khemavati					
170	Somdutt	150	-do-	13	Good quality water
171	Ram sawroop	150	-do-	18	Good quality water
172	Ram niwas	220	-do-	7	Good quality water
173	Rameshwar	150	Paddy, wheat, Jowar	38	Marginal quality water
174	Gyasu Ram	150	-do-	7	Marginal quality water
175	Birsa	150	-do-	6	Sweet in taste, but harmful for crops

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176	Ved parkash	160150	-do-	18	Marginal quality water
Village: Pajukalan					
177	Kapoor Singh	220	-do-	9	Marginal quality water
178	Badlu Ram	220	-do-	18	Brackish water
179	Prem Singh	220	-do-	1	Brackish water
180	Jag mohinder	220	-do-	13	Brackish water
181	Ramdiya Fauji	230	-do-	18	Brackish water
182	Satyawan	220	-do-	5	Marginal water
Village: PajuKhurd					
183	Subhash	200	-do-	23	Marginal water
184	Hawa Singh	140	-do-	2	Marginal water
185	Jaswant Singh	120	-do-	10	Marginal water
186	Raj Singh	130	-do-	20	Marginal water
187	Ram Jowari	80	-do-	23	Marginal water
Village: Aftabgarh					
188	Madu Ram	150	Paddy, wheat, Jowar	5	Sweet in taste, but made soil harder
189	Gurpreet Singh	150	-do-	23	Brackish water
190	Pala Singh	250	-do-	36	Marginal water
191	Sukhan Singh	140	-do-	30	Marginal water
192	Mohinder Singh	260	-do-	4	Marginal water
193	Master Chud Singh	260	-do-	3	Marginal water
194	Ram phal	150	-do-	19	Marginal water
Village: Dharmgarh					
195	Gurbachan Singh	140	Paddy, wheat, Jowar	18	Marginal water
196	Puran Singh	140	-do-	38	Marginal water
197	Gurbachan Singh	150	-do-	8	Marginal water
198	Karnail Singh	150	-do-	28	Marginal water
199	Gernail Singh	150	-do-	23	Marginal water
200	Purn Singh	150	-do-	15	Brackish water

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201	Sisha Singh	150	Paddy, wheat, Jowar	23	Marginal water
202	Gurbachan Singh	150	Paddy, wheat, Jowar	23	Oily water, Brackish
203	Harbhan Singh	150	Paddy, wheat, Jowar	10	Oily water, Brackish
204	Sarbjeet Singh	150	Paddy, wheat, Jowar	19	Oily water, Brackish
Village: Malikpur					
205	Jagtar Singh	150	Paddy, wheat, Jowar	13	Water Brackish
206	Trilok Singh	150	Paddy, wheat, Jowar	28	Water, Brackish
207	Nirmal Singh	150	Paddy, wheat, Jowar	13	Water, Brackish
208	Tahal Singh	150	Paddy, wheat, Jowar	18	Water, Brackish
209	Sewa Singh	150	Paddy, wheat, Jowar	38	Water, Brackish
210	Balihar Singh	150	Paddy, wheat, Jowar	33	Water, Brackish
211	Nishan Singh	150	Paddy, wheat, Jowar	28	Water, Brackish
212	Mulkha Singh	150	Paddy, wheat, Jowar	33	Water, Brackish
213	Hazoor Singh	150	Paddy, wheat, Jowar	19	Water, Brackish
214	Shera Singh	150	Paddy, wheat, Jowar	23	Water, Brackish
215	Joga Singh	150	Paddy, wheat, Jowar	33	Oily water, Brackish
216	Angrej Singh	150	Paddy, wheat, Jowar	43	Oily water, Brackish
217	Nidan Singh	235	Paddy, wheat, Jowar	3	Marginal water
Village: Rodh					
218	Jagbir Singh	120	Paddy, wheat, Jowar	16	Marginal water, reduction in paddy and wheat yield
219	Shekher Singh	80	-do-	8	Marginal water, reduction in

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					paddy and wheat yield
220	Mohinder Singh	50	-do-	2	Marginal water, reduction in paddy and wheat yield
221	Sewa Singh	70	-do-	18	Marginal water, reduction in paddy and wheat yield
222	Satnam Singh	60	-do-	18	Marginal water, reduction in paddy and wheat yield
223	Mukhtiyar Singh	80	-do-	4	Marginal water, reduction in paddy and wheat yield
224	Subha Singh	80	-do-	13	Marginal water, reduction in paddy and wheat yield
225	Nishan Sing	100	-do-	18	Marginal quality water, reduction in wheat yield
Page: Hatt					
226	Shamsher Singh	140	Paddy, wheat, Jowar	1	Sweet in taste, made soil hard
227	Sant Ram	150	-do-	23	Sweet in taste, made soil hard
228	Bhoop Singh	130	-do-	3	Marginal quality water
229	Chander Singh	140	-do-	23	Marginal quality water
230	Satbeer Singh	140	-do-	23	Marginal quality water
231	Krishan Cand	120	-do-	22	Marginal quality water
232	Telu Ram	120	-do-	11	Marginal quality water
233	Deepak	80	-do-	33	Marginal quality water
234	Jagbeer Singh	80	-do-	1	Marginal quality water
262	Jagjit Singh			4	Marginal quality

					water
Block: BaghruKalan					
235	Rajinder Singh	30	Paddy, wheat, Jowar	11	Marginal quality water
236	Satyavan	80	-do-	9	Marginal quality water
237	Dharm Singh	80	-do-	2	Marginal quality water
238	Surjeet Master	100	-do-	21	Marginal quality water
239	Ravinder Singh	70	-do-	38	Marginal quality water
Block: BaghruKhurd					
240	Rajesh Kumar	100	Paddy, wheat, Jowar	5	Marginal quality water
241	Mahaveer Singh	60	-do-	23	Marginal quality water
242	Daya Singh	100	-do-		Marginal quality water
243	Balbeer Singh	70	-do-	13	Marginal quality water
Block: Anchra Khurd					
244	Karm chand	90	Paddy, wheat, vegetables, Barseem	23	Good quality water
245	Satbir Singh	90	Paddy, wheat, Jowar	38	Brackish water
246	Chanda Singh	90	-do-	23	Brackish water
247	Bhaga Ram	90	-do-	23	Brackish water
248	Pawan Singh	90	-do-	23	Brackish water
249	Shadhu Ram	70	-do-	1	Brackish water
250	Tara Chand	80	-do-	33	Brackish water
251	Ram Karan	80	-do-	6	Brackish water
Block: Sarfabad					
252	Hukum Chand	70	Paddy, wheat, Jowar	6	Brackish water
253	Ram kumar	70	-do-	10	Marginal water, made soil hard
254	Satbeer Singh	80	-do-	11	Marginal water, made soil hard

Contd...

					made soil hard
255	Surinder Singh	90	-do-	28	Marginal water, made soil hard
256	Telu Ram	80	-do-	11	Marginal water, made soil hard
257	Jile Singh	45	-do-	2	Marginal water, made soil hard
Village: Todi kheri					
258	Chander bhan	120	Paddy, wheat, vegetables, Barseem, Jowar, Bajra	15	Good quality water
259	Satpal	130	-do-	17	Good quality water
260	Rajinder Singh	120	-do-	12	Good quality water
261	Om Singh	80	-do-	10	Good quality water
Village: Didwada					
1	Jai bhagwan	140	Paddy, wheat, Barseem, Vegetables	16	Good quality water
2	Ram Kishan	140	-do-	10	Good quality water
3	Singh Ram	140	-do-	12	Good quality water
4	Narsi Singh	140	-do-	15	Good quality water
5	Parsa Ram	140	-do-	33	Good quality water
6	Shyama	140	Paddy, wheat, Jowar	10	Fairly good
7	Hukum Singh	140	-do-	11	Fairly good
8	Ranbir Singh	140	-do-	14	Good quality water
Village: Singhana					
10	Jagdish	210	Fellow-wheat, Jowar	3	Brackish water
11	Jai Narayan	140	-do-	20	Marginal water
12	Ram Phal	160	-do-	23	Brackish water
13	Chanda Singh	120	-do-	15	Brackish water

14	Punjaba Singh	120	-do-	6	Brackish water reduction in wheat yield
15	Chaman Singh	90	-do-	10	Brackish water reduction in wheat yield
16	Dhuman Singh	120	-do-	28	Brackish water, made soil hard
Village: Muana					
17	Dham Singh	120	-do-	7	Brackish water, made soil hard
18	Ram Kishan	120	-do-	12	Brackish water, made soil hard
19	Mangat Ram	120	-do-	14	Brackish water, made soil hard
20	Karam Singh	120	Paddy, wheat, Barseem, Vegetables	10	Brackish water, made soil hard
Village: Mal Siwana					
21	Ram Kishan	60	Paddy, wheat, Barseem, Vegetables	1	Good quality water
22	Ram Phal	170	-do-	8	Good quality water
23	Hawa Singh	170	-do-	10	Good quality water
24	Bittu Sarpanch	170	Fellow-wheat	3	Marginal quality water
25	Harbhan Singh	35	-do-	1	Brackish water, made soil hard
26	Kirpal Singh	30	-do-	5	Brackish water, made soil hard problem of water stagnation in rainy season
27	Kam Singh	35	-do-	5	Brackish water
28	Pt. Rama	60	-do-	10	Good quality water
30	Rattan Singh	60	-do-	12	Good quality water
31	Baru Ram	31	-do-	10	Good quality water
32	Om Farkash	60	-do-	15	Marginal quality

					water, made soil hard
33	Balbeer Singh	60	-do-	16	Marginal quality water, made soil hard
34	Ravinder Singh	30	-do-	20	Marginal quality water, made soil hard
35	Mahaveer Singh	65	-do-	7	Marginal quality water, made soil hard
village: Anchra Kalan					
36	Yesh Dev	105	Paddy, wheat, Jowar	23	Marginal quality water, made soil hard
37	Bhim Singh	100	-do-	13	Marginal quality water, made soil hard
38	Lal Chand	100	-do-	8	Marginal quality water, made soil hard
40	Satbeer Singh	100	-do-	3	Marginal quality water, made soil hard
41	Rajbeer Singh	100	-do-	5	Marginal quality water, made soil hard
42	Vijay Singh	100	-do-	10	Marginal quality water, made soil hard
43	Lakhmi Namberdar	60	-do-	9	Marginal quality water, made soil hard
44	Om Parkash	60	Wheat, paddy, Jowar, Barseem	8	Fairly good
45	Bijender	60	Fellow-wheat	12	Brackish quality water
46	Vijay Singh	70	-do-	8	Brackish quality water
47	D harmSingh	150	-do-	10	Brackish water
48	Karan Singh	180	-do-	15	Brackish water
49	Suraj Singh	69	-do-	23	Brackish water
50	Mangat Ram	130	-do-	11	Brackish water

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Village: RamPura

51	Virender Singh	140	Fellow wheat	10	Brackish water
52	Manpal Singh	140	-do-	12	Brackish water
53	Fateh Singh	130	-do-	8	Brackish water
54	Amarpal Singh	140	-do-	7	Brackish water, problem of water stagnation in rainy season

Village: Muana

55	Karar Singh	70	Fellow wheat	6	Sweet in taste, made soil hard
56	Kirpal Singh	70	-do-	10	Brackish water poor yield of wheat
57	Rohtash	40	-do-	28	Brackish water poor yield of wheat
58	Yesh Pal Singh	90	-do-	3	Brackish water poor yield of wheat
62	Vijay Singh	90	-do-	18	Marginal quality water
63	Abhan Singh	70	-do-	18	Marginal quality water
64	Prem Singh	30	-do-	8	Marginal quality water
65	Raj Singh	60	-do-	4	Marginal quality water
66	Vinod Kumar	60	-do-	8	Marginal quality water
67	Subhash	70	-do-	17	Brackish water
68	Nake! Singh	60	-do-	1	Brackish water
69	Babu Ram	60	-do-	10	Brackish water
70	Man Singh	45	-do-	7	Brackish water
71	Bajrang Singh	47	-do-	12	Brackish water
72	Ishwer Singh	50	Paddy, wheat, vegetables, barseem	8	Good quality water
73	Leelu Ram	50	Fellow-wheat	6	Brackish water
74	Dhoom Singh	50	Fellow-wheat	12	Brackish water

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75	Vikram Singh	50	-do-	4	Brackish water, made soil hard, problem of water stagnation in rainy season
76	Sompal Singh	47	-do-	6	Brackish water, made soil hard, problem of water stagnation in rainy season
77	Ram Kumar	70	-do-	5	Brackish water, made soil hard, problem of water stagnation in rainy season
78	Jogi Ram	70	-do-	6	Brackish water, made soil hard, problem of water stagnation in rainy season
79	Mehar Singh	70	-do-	7	Brackish water, made soil hard, problem of water stagnation in rainy season
80	Pitamber Singh	70	-do-	10	Brackish water, made soil hard, problem of water stagnation in rainy season
81	Kanwar Pal	75	-do-	12	Brackish water, made soil hard, problem of water stagnation in rainy season
82	Ram Phal	80	-do-	8	Brackish water, made soil hard, problem of water stagnation in rainy season
83	Deep Singh	80	Paddy, wheat, vegetables, Barseem	15	Good quality water
84	Sukhwinder Singh	70	Paddy, wheat, vegetables, Barseem	15	Good quality water
87	Brij Pal Singh	120	Fellow-wheat	8	Brackish water

Chemical composition of saturation extract of soil samples (0-15, 15-30 cm)

Sample no.	Villages (Site)	Name of Farmer	Soil depth	pH (1:2)	ECe	CO ₃ ⁻²	HCO ₃ ⁻	CL	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	SARe
1	Site 1 - Muana	Mangat Ram	0-15	8.76	13.69	7.50	47.50	65.00	17.50	35.00	20.00	71.25	2.75	13.59
2	"	"	15-30	8.83	11.89	Nil	39.23	56.40	13.49	31.88	17.16	64.98	1.59	13.12
3	Site 2 - Muana	Vikram Singh2	0-15	9.48	11.24	5.94	31.68	56.43	17.82	30.69	16.83	60.39	2.38	12.39
4	"	"	15-30	9.35	10.67	Nil	30.04	54.91	14.50	27.97	14.50	60.09	1.86	13.04
5	Site 3 - Muana	Pitamber Singh	0-15	9.77	13.28	11.96	39.47	58.60	19.44	44.25	22.72	55.37	2.63	9.57
6	"	"	15-30	9.68	12.08	6.94	33.52	47.97	15.90	35.84	18.50	48.67	1.50	9.34
7	Site 4 - Singhana	Hukum Singh	0-15	9.55	10.05	6.66	29.97	47.73	23.31	29.97	18.87	59.94	1.33	12.13
8	"	"	15-30	9.45	9.49	4.74	28.46	40.32	22.53	28.46	18.98	51.00	0.95	10.47
9	Site 5 - Dharmgah	Puran Singh2	0-15	9.83	5.43	5.78	31.21	16.42	1.45	19.65	9.25	24.51	1.39	6.45
10	"	"	15-30	9.7	4.07	Nil	25.21	9.40	1.15	13.75	6.88	18.79	0.92	5.85
11	Site 6 - Malikpur	Jagtar Singh	0-15	9.7	7.50	8.96	40.32	29.12	4.82	31.36	12.32	35.95	1.23	7.69
12	"	"	15-30	9.48	6.59	5.78	39.30	26.59	1.45	27.74	11.56	31.67	0.92	7.15
13	Site 7 - Rodh	Mukhtiar Singh	0-15	9.49	9.99	8.27	43.73	39.01	7.09	42.55	20.09	27.72	1.77	4.95
14	"	"	15-30	9.36	7.35	Nil	32.31	32.31	4.68	36.76	15.60	19.38	1.00	3.79
15	Site 8 - Karkhana	Randhir Singh	0-15	9.61	6.89	8.34	21.76	38.33	8.29	19.68	11.40	39.37	1.14	9.99
16	"	"	15-30	9.5	4.95	4.95	18.43	30.07	5.82	15.52	13.58	21.34	0.68	5.59
17	Site 9 - Hatt	Shamsher Singh2	0-15	9.09	5.78	7.01	24.53	21.02	4.32	22.19	10.51	24.53	1.28	6.07
18	"	"	15-30	9.03	4.65	2.36	22.38	14.14	3.42	15.31	7.07	20.03	0.82	5.99
19	Site 10 - Korda	Inder Singh2	0-15	8.84	7.70	7.45	21.11	47.20	4.22	22.36	11.18	38.50	1.93	9.40
20	"	"	15-30	8.88	6.91	2.47	17.28	39.49	2.84	19.74	8.64	35.79	1.11	9.50
21	Todikheri	Rameshwar Das	0-15	9.12	3.37	8.29	18.65	7.25	3.32	17.61	8.29	5.23	1.19	1.45
22	"	"	15-30	9.23	2.13	5.82	10.67	4.07	2.13	12.61	6.79	3.78	0.87	1.21

23	"	Chander Bhan	0-15	9	3.93	8.09	19.65	9.25	4.51	18.50	10.40	4.97	1.27	1.31
24	"	"	15-30	9.19	2.24	Nil	15.68	4.82	2.91	14.56	7.84	2.46	0.90	0.74
25	"	Satpal	0-15	9.67	3.41	5.98	16.74	14.35	1.91	16.74	9.57	7.53	1.55	2.08
26	"	"	15-30	9.77	2.28	3.34	15.60	8.91	1.34	10.58	7.24	4.29	0.61	1.44
27	"	Dhman Singh	0-15	8.92	15.98	13.32	36.63	79.92	31.54	32.19	14.43	114.33	1.00	23.68
28	"	"	15-30	8.3	10.61	9.49	20.16	51.00	18.98	16.60	8.30	60.49	0.83	17.14
29	Dharmgarh	Gurbachan Singh2	0-15	9.23	10.34	4.54	48.85	48.85	21.58	27.26	14.77	59.07	1.59	12.89
30	"	"	15-30	9.16	9.71	2.23	43.52	43.52	20.09	23.44	13.39	54.68	0.89	12.74
31	"	Jagtar Singh2	0-15	9.77	10.52	9.57	51.43	33.49	12.56	27.51	16.74	52.50	1.44	11.16
32	"	"	15-30	9.66	9.43	3.56	48.63	28.46	11.03	20.16	13.05	45.31	0.71	11.12
33	Hatt	Master Krishan	0-15	8.82	7.95	12.96	34.16	24.74	8.25	20.03	15.31	42.41	3.30	10.09
34	"	"	15-30	8.88	6.66	7.20	32.40	21.60	7.20	13.20	8.40	38.40	2.28	11.68
35	"	Chander Singh	0-15	8.76	8.56	9.38	36.33	28.13	9.38	22.27	14.06	44.54	2.70	10.45
36	"	"	15-30	8.83	7.20	4.65	31.37	24.40	4.65	18.59	10.46	37.18	1.39	9.76
37	"	Satbeer Singh	0-15	9.02	8.24	6.68	26.74	35.76	13.37	20.05	15.60	43.45	1.45	10.29
38	"	"	15-30	8.96	7.42	4.64	20.88	33.76	12.18	16.24	12.76	35.96	0.93	9.44
39	Singhana	Mahender Singh	0-15	9.6	6.9	2.5	17.3	39.5	2.8	19.4	8.6	35.8	1.1	9.5
40	"	"	15-30	9.5	4.6	2.3	22.4	14.1	3.4	15.3	7.1	20.3	0.8	5.6

