GROUND WATER QUALITY AS INFLUENCED BY CANAL IRRIGATION IN PURNA COMMAND AREA

BY

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DEDICATED TO MY PARENTS

AND BROTHER NAGA MUNI REDDY

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CHAPTER-1

INTRODUCTION

1 INTRODUCTION

It is generally recognised that the quality of the groundwater is just as important as its quantity. Groundwater is one of the main sources of irrigation, quality of which changes due to climate, hydrological conditions, soil type and irrigation status. All groundwaters contain salts in solution, the type and concentration of salts depend on the environment. Higher concentration of dissolved constituents are found in groundwater, than in surface water because of the greater exposure to the soluble materials in geologic strata. Paliwal (1972) classified the quality of groundwater resources of India in to three groups :

1. Water quality of arid and semiarid region having rainfall less than 4.5 cm per annum consisting major parts of Rajastan, Gujrat, Agra and Mathura districts of Uttarpradesh, Ferojpur, Bhatinda and Sangrur districts of Punjab, Rothak, Gurgaon, Hissar districts of Haryana.

2. Water quality as influenced by hydrological conditions as high water table consisting some of the areas of Punjab, Haryana, Delhi, Uttarpradesh and Rajastan.

3. Water quality of wells in some area of coastal regions of country as influenced by backward flow of sea water.

The quality of irrigation water has been determined conventionally on the basis of electrical conductivity, sodium adsorption ratio, residual sodium carbonate etc. Suitability of water for irrigation will be determined by the kind and amount of salts present . Irrigation with poor quality water creates soil and cropping problems. Quality of water is an important appraisal of salinity or alkalinity conditions in an irrigated area. There are many places in India particularly in the desert area of Rajastan, Gujrat, Haryana and Punjab, and also in the adjoining areas such as Delhi, Uttar-pradesh, where groundwater is available but the quality is questionable or unsatisfactory. However, it has been observed that though the quality of the waterís generally good the canal irrigation lead to salinity, alkalinity problems. The problems are mainly due to the over irrigation, seepage from canals resulting in rising in water table, nearly 20 per cent of irrigation water is percolating to groundwater.

Patil et al.(1982) reported the effect of Mula canal seepage on water table fluctations and quality upto distance of 250 metres from the canal. Electrical conductivity of groundwater near the canal increased from 1.0 to 2.06 dsm^{-1} indicating the salt accumulation at the surface. The quality of ground water has deteriorated badly as evidenced by high electrical conductivity and sodium adsorption ratio values. Excess irrigation also leads to deteriorate the quality of groundwater by increasing the electrical conductivity values, Carbonates, bicarbonates and sodium etc. (Singh et al., 1984).

The problem of salinity and alkalinity is developed due to improper use of irrigation water. This problem is higher in case of vertisols due to high clay content resulting in poor drainage. Development of salinity and alkalinity is attributed to seepage of water from uplands or unlined canals and consequent water logging (Katti and Rao, 1979). The subsurface layers from unlined canals, irrigated fields and the natural nalas, thereby raising the groundwater level. In canal irrigated area soils have developed salinity problem due to high water table (Sharma et al., 1968).

The irrigation in Purna project commenced in 1964, the project has been fully developed during

last 25 years. Purna project is an irrigation and hydel project across river Purna. It is major project having culturable command area of 67,800 hectares. The extent of shallow, medium and deep soils in the command is 7.67, 48.7 and 43.55 per cent respectively. The soils under Purna command are dominated by a montmorillonite clay with high coefficient of expansion and shrinkage (Malewar, 1976) Due to existence of non drainable soils and excess use of irrigation water by farmers, the water table has raised to extent of 3 meters or less from the groundlevel posing the problem of water logging and salinity (Abhange et al., 1986). The damages were noticed for the first time in 1969-70, since then it continued to about, 7,000 hectares salt affected area i.e. 10.23 per cent of total C C A in 1978. [CCA - culturable command Area].

The farmers in Purna command area are using percolation water from canals for irrigation purposes. The wells are dug by the farmers either near the bank of canal or in the rivers where the most of percolated canal water is collected. The farmers are also lifting the nala or river water for irrigation which is received as seepage from the catchment (More et al., 1988). The chemical

composition of such irrigation water is of prime importance in determining its suitability for irrigation. However, the suitability of such water for irrigation has not given much attention. Therefore the present investigation was undertaken with the following objectives :

1. To determine the groundwater quality in command area.
2. To determine the groundwater quality in uncommand area.
3. To compare the groundwater quality in command and uncommand area.
4. To study the suitability of groundwater for irrigation in command area.
5. To determine the characteristics of soils of command area.
6. To determine the characteristics of soils of uncommand area.
7. To compare the soil characteristics in command and uncommand areas under Purna project.

CHAPTER-2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The past research work carried out on the various aspects of present investigation is revealed in this chapter.

2.1 Groundwater quality in command area

Mehta et al. (1959) reported that the Chambal river water has been found to be good for irrigation. The quality of waters varied with depth and drainage of soils. Most of the waters fall in medium to high salinity class.

Gupta and Abichandani (1967) examined saline groundwaters from seven sites in Jodhpur and Pali districts of Western Rajastan for seasonal variation in salt composition. Salinity varied from 2316 to 10,160 micromhos electrical conductivity per cm during rabi season.

Mehta et al. (1968) reported that the change in quality was not influenced by rising trend of groundwaters, nearness to canal and soil characteristics. Excessive seepage and flooding seems to be the main reasons responsible for water logging and change in quality in the area commanded by Chambal project.

Kulkarni and Saranganath (1970) reported that in general there is increase in cations, anions, electrical conductivity and SAR from monsoon to summer in all the waters. There is no significant variations in pH values due to season.

Abrol et al.(1972) reported that the underground waters which are markedly saline lead to secondary salinization whenever they are used for irrigation or whenever the water table raises to critical levels as a result of excessive seepage in the canal irrigation system.

The mean electrical conductivity values varied from 0.6 to 2.25 mmhos/cm. The mean pH of these well waters ranged from 7.51 to 8.15 with the highest value during summer. Sodium adsorption ratio ranged from 2.04 to 15.91. All the wells in Krishnagiri reservoir project area excepting one well had low sodium hazard of less than 10.0 $me.L^{-1}$ Residual sodium carbonate ranged from 0.99 to 10.59 with the mean Residual sodium carbonate of 3.57 me/l (Krishnamoorthy et al., 1978).

Ashry (1980) reported that the groundwater system in many of the irrigated areas of Colorado river basin is derived almost entirly from deep

percolation of irrigation water and seepage from irrigation convence and tail water collection system, slit pick up rates form irrigated soils in the basin vary in different areas.

Janardhan et al.(1980) collected water samples for one year at monthly intervals around Dharwad indicated that quality of irrigation water changes in different seasons of the year. The salinity and sodium adsorption ratio values of waters decreased after monsoon season and increased during summer.

Joginder Singh (1982) recorded that the groundwater fluctuation and quality trend over an area of 1,46,875 hectares in rising water table area (Part of Hissar district) have been analysed from June 1980 which includes drought year. Nearly 70 per cent of underground water had electrical conductivity more than 3000 micromhos/cm and hence very low utilization for irrigation.

A three year project was launched to study the effect of Mula canal seepage on water table fluctuations up to distance of 250 meteres from the canal. Electrical conductivity of groundwater near the canal increased from 4.0 to 2.06 mmhos/cm indicating

the salt accumulation at the surface. The quality of groundwater has deteriorated badly as evidenced by high electrical conductigity and SAR values (Patil et al., 1982).

Patil and Patil (1982) collected twenty four water samples from wells of central campus MPAU, Rahuri to determine the effect of season on quality and suitability of well waters for irrigation. The concentration of cations and anions in well waters increased as the season advanced from kharif, rabi to summer. All the well waters are alkaline and pH values did not change much according to season. Average pH value was 8.05, electrical conductivity increased during summer and the values ranged between 0.11 to 1.96 mmhos/cm.

Joginder Singh and Ranvir Kumar (1983) recorded the water table fluctuations and quality variation trends from 250 observation wells spread in an area of 11,000 km^2 in lower Chaggar basin of Haryana from 1974-1979. About 45 per cent of the area was overlain by saline groundwater of 6,000 - 10,000 micromhos/cm, electrical conductivity.

Singh et al.(1984) conducted studies on critical evaluation of quality of groundwater and

its suitability for irrigation purposes in Saryu command area of block Ikauna and Balrampur which indicated that the waters of both the blocks has electrical conductivity less than 1000 micromhos/cm except in village Katra. Sodium is dominant cation and most of the water contain residual soidium carbonate but their amount is generally less than 2.5 me/l except in the water of villages Lemvia and Maheshbhari.

Hooda et al.(1986) recorded fifty four observations on groundwater salinity from observation wells in the month of January and June 1982 from a watershed of 2565 hectares covering the farm of Haryana Agricultural University and its adjoining areas. Groundwater salinity observations in the watershed were spatially independent of one another and therefore randomly distributed.

The salinity of surface soil (0-15 cm) and underground waters from different soil series increased after introduction of canal irrigation in the area. Location of the canal at higher topography, basin type, shape of the irrigated area and seepage are main causes of salinization. Large periodical variations in the composition and

depth of water table in fine textured soils belonging to Sawargaon, Nimone and Umbraj series were observed as against little fluctuation in the coarse textured soils of Torkewadi and Pargaon series. (Somawanshi and Patil, 1986).

More et al.(1988) collected fifteen samples from wells of Purna command for water quality. The order of different anions in irrigation water was $HCO_3^- > Cl^- > SO_4^= > CO_3^=$. It was observed that all well waters were of good quality based on SAR values of waters. The waters were also observed to be in safe limit based on soluble sodium percentage except the water from Pawdewadi.

Singh et al.(1989) conducted a study on the position of water table and the quality of barrages, surface and groundwaters in the Basti branch command area of Saryu canal project of Uttarpradesh. It indicated that the water table rises above the critical depth in rainy season and reaches as high as 0.70 metres in September. This rise in water table did not affect the quality of ground water so the groundwaters are good hence safly used for irrigation.

Maliwal and Timbadia (1990) reported that well waters of Inland Area of Amreli district in Gujrat had electrical conductivity range as 1 to 13 dsm^{-1}.

Chauhan et al.(1990) reported that the underground irrigation waters of Mathura district had the problem of severe salinity, the problem of RSC was associated with low salinity (EC_w below 3 dsm^{-1}). Multiple correlations between water quality parameters and soil characteristics showed that salinity build up in soil was positively correlated with salinity of water.

Mehta (1991) observed that groundwater quality was to be highly saline throughout the year in coastal salt affected soils of Maharashtra. The salinity varied from as high as 9 dsm^{-1} to as low as 5 dsm^{-1}. The distance from creek also had a remarkable influence on the groundwater salinity.

2.2 Groundwater quality in uncommand area

Shankar Narayana et al.(1965) conducted a experiment on quality of groundwaters of Arid tract of Western Rajastan. The data indicated the highly saline nature of the waters with high amounts of Na, Ca and comparatively higher amounts of Mg than Ca. In case of anions Cl and SO_4 predominate to an extent harmful to plant growth. SAR values were also high in the waters showing toxicity of Na.

Krishnamoorthy (1970) reported that electrical conductivity of water samples from Kavilpatti taluka ranged from 2.6 to 12 mmhos/cm. Sodium adsorption ratio ranged between 13.68 to 108.3.

Deshpande and Venkata Rao (1972) found that well waters of some parts of Mysore were slightly acidic to neurtal in reaction and well waters located in granite and grainite-gneissic area have high flouride concentration.

Paliwal et al. (1975) reported that the waters of 14 districts of Rajastan are Na - Mg - Ca type and Mg content was maximum (31.1 per cent of the total salinity) up to 1 mmhos/cm and remains constant (+ 16.0 per cent) at higher salinity levels.

Ramaswami et al.(1975) analysed twenty four water samples from Salem district. Most of the samples from Salem district are neutral to mildly alkaline in reaction.

Pal et al.(1978) analysed 30 representative irrigation waters from open wells and tube wells of Agra district which revealed that majority of waters contained excessive residual sodium carbonate. These waters were largely Na - Mg - Ca cation type and HCO_3 - SO_4 - Cl anion type.

Ram Deo (1978) recorded the chemical composition of underground well waters from Bhilwara district of Rajastan revealed that waters high in bicarbonate are associated with low total salt concentration and HCO_3^- consistutes as high as 60 per cent of total anions. The elctrical conductivity of waters having RSC more than 2.5 me/l mostly ranged between 1000 to 2 500 micromhos/cm.

Joginder Singh and Ranvir Kumar (1982) studied the groundnwater quality in the viscinity of flood plains of Sahibi river from December 1976 to December 1979. The overall electrical conductivity of underground water was observed to be within 5 mmhos/cm.

The results of exploratory drilling have indicated that groundwater quality in Rohtak district deteriorates with depth (Gupta, 1984).

Mahale et al.(1985) collected 16 water samples from Agricultural College farm Dhule and analysed. The waters in general are of fairly good quality, the values of electrical conductivity, SAR and RSC of all the waters are in safe limit and can be used for irrigation with proper soil management practices.

Gupta (1986) analysed six hundred and two groundwater samples from Chittorgarh district in South Rajastan. The waters were of low to medium salinity having electrical conductivity mostly less than 3.0 dsm^{-1} , SAR values were generally less than 10 but RSC was more than 2.5 me/l . Ground waters have medium salinity.

Channal et al.(1988) reported that the waters from Agricultural College farm Dharwad were neutral to alkaline, on the basis of electrical conductivity. All samples come under C_3 class establishing their high salinity.

Singh et al.(1989) studied the salinity and sodicity problems in soil and groundwater of semi arid tract in the central peninsular India. About 34 and 26 per cent samples of groundwaters have residual sodium carbonate values between 2.5 to 5.00 and over 5.0 me/l respectively.

Chauhan et al.(1990) reported that the under ground irrigation waters of Mathura district had the problems of severe salinity. The problem of RSC was associated with low salinity (EC_w below 3 dsm^{-1}).

Maliwal and Timbadia (1990) reported that the well waters of Inland area of Amreli district had electrical conductivity ranged from 1 to 13 dsm^{-1}.

2.3 Soil characteristics of command area

Sharma et al.(1968),reported that in canal irrigated area soils have developed salinity problems due to high water table and in well irrigated areas the salinity problem have developed due to use of saline undergrsund water.

The soils in Chambal command area of Madhya pradesh were adequate in potassium, but deficit in Ca, Mg and Fe as compared to nbrmal soils (Gupta et al., 1970).

Singh et al. (1970) reported that the $CaCO_3$ pH and ESP, SAR and SSP of saturation extracts were found to be higher in case of irrigated soils as compared to unirrigated ones while the reverse trend was observed with pore space.

Murthy and Landey (1976) reported that the causes of salinization in Tungabhadra watershed were rise in water table, drainage and water containing soluble salts from adjoining high lands and impedance of drainage.

An estimation of the nature and extent of salinization in the coastal tract of Tamluk sub division Mindapare in West Bengal revealed that the soils of which, the salinity ranged between 1.8 and 52.4 mmhos/cm were, in general degraded saline-alkali. Differences in water table from 0.3 to 0.6 m over a distance of 3.22 km possibly contributed to the seepage of saline river water causing salinity to increase in land (Subramanyam et al., 1976).

Bhadrapur and Seshagiri Rao (1979) reported that the lowland soils of Tungabhadra project were affected by salinity and alkalinity due to seepage from uplands. All the soil bodies were saline-sodic however the ESP values and the ionic concentration decreased from the surface layer to downwards. The concentration of sodium exceeded the combined concentration of calcium and magnesium throughout the soil body.

A detailed soil survey of command area of Abichenmetong canal in Ladhak area was conducted. Soils were alkaline, to about 90 cm depth, organic carbon content was very low, CEC of the soil was about 0.76 me/100 g and ESP 27.8 (Gawande et al., 1979).

Jadhav et al.(1979) reported the physico chemical properties of Jayakwadi command area and $CaCO_3$ ranged from 2.0 to 18.5 per cent. Soils were slightly alkaline to distinctly alkaline. pH of soils varied from 7.5 to 8.9, while electrical conductivity varied in a narrow range of 0.107 to 0.356 mmhos/cm.

Katti and Rao (1979) concluded that the development of salinity and alkalinity in the soils of Challa Prabha left bank canal area was attributed to seepage of water from uplands or unlined irrigation canals and consequent water logging .

Pathak and Patel (1980) collected twelve soil profiles from Mahi canal right bank area in Kaira district which indicated that salt accumulation was more in surface layers and salinity hazard was more in low lying coastal area. The values of ESP and pH were comparatively higher in low layers of salt affected areas. Simiarly $CaCO_3$ and soluble boron were also noted to be more in salt affected area.

Tyagi et al.(1981) collected soil samples from Chambal command area and analysed. pH values

ranged between 7.4 and 9.0, the electrical conductivity varied between 0.1o to 11.0 mmhos/cm. It was also observed that salts were more concentrated on surface than subsurface and sub stratum. The organic carbon in the surface soil ranged from 0.29 and 0.64 per cent while in sub surface and substratum ranged between 0.11 to 0.36 per cent, the $CaCO_3$ in surface and sub surface was from 2.5 to 28.1 per cent and 2.6 to 39.5 per cent respectively.

Tiwari et al.(1983) observed that the accumulation of salts through runoff water from an adjoining area, impeded drainage due to poor hydraulic conductivity and very high sodium content, fluctuating water table caused by canal flow near these fields and consequently capillary rise of water resulting in accumulation of alkali salts on the surface during summer were some of the contributory factors to the development of salt affected soils.

Bharambe et al.(1984) presented the fertility status in Jayakwadi command. The soils of Pathri and Partur showed normal soil reaction. While it was tending towards alkaline range in soils of Paithan, Ambad, Georai and Majalgaon locations. Electrical conductivity of all soils was normal.

Bharambe and Ghonsikar (1985) reported that all the soil types of Jayakwadi command showed nbrmal range of pH, EC and calcareous nature of soil. The soils were found to have medium nitrogen, phosphorus and high potassium.

Mediratta et al.(1985) recorded the characteristics of Harsi command soils of Madhya pradesh. The soils of Kethoda series showed strongly alkaline reaction with pH ranging between 8.7 to 9.5, ESP was found to vary from 8 to 24, electrical conductivity ranged from 1.2 to 13.9 mmhos/cm as a result of excess accumulation of salts.

Baskaran et al.(1986) reported the soil characteristics of Krishnagiri reservoir project area. The electrical conductivity ranged from 0.29 to 4.3 mmhos/cm and pH from 8.3 to 10.2. ESP varied from 18.9 to 41.1, the organic carbon content in all the locations were found to be low, the available nitrogen status was low while available P was low to medium and potassium medium to high.

The soils of Bargi command were neutral to alkaline in pH, saturated with calcium dominating the exchange complex (Kaushal et al., 1986).

The salinity of surface soil was increased after introduction of canal, location of the canal at higher topography, basin type, shape of the irrigated area and seepage of irrigation water from high lying area were the main causes of salinization of the soil (Somawanshi and Patil, 1986).

Abha Lakshmi Singh and Najmul Islam Hasmi (1987) reported that the soil salinity and alkalinity are becoming problems after introduction of canal irrigation in India mainly in Uttarpradesh.

More et al.(1987) reported that out of the suspected area the extent of saline soils in Purna command was 65 per cent, the percenateg of saline, saline-sodic, sodic and normal soils in the suspected command area were 22.92, 14.58, 33.33 and 29.17 respectively. The pH of the soils ranged from 8.0 to 10.74, the EC of soils ranged from 0.84 to 39.20 mmhos/cm, exchangeable calcium was dominant cation in all soils, CEC ranged from 33.60 to 48.00 me/100 g.

Canal irrigation had brought down the pH of the surface soil and rise in the pH of subsurface soil in Malaprabha command area. Among the exchangeable cations Ca, Mg were dominant over Na. The ESP of soils increased with depth. Irrigated block soils recorded lower ESP values than unirrigated soils (Shadaksharappa, 1987).

More et al.(1988) reported the soil characteristics of Purna command and The pH of soils ranged from 8.1 to 10.7 and CEC from 8.0 to 45 cm C mol (P^+) kg^{-1}. Calcium was the dominant cation in the saline soils, ECe of the soils ranged from 0.8 to 18.0 dsm^{-1}.

More et al. (1988) studied the seasonal changes of salt distribution in Purna command area. The salt status of soil profile was very low at the end of monsoon season. Soil salinization continued from winter season to June, highest salt content was recorded at surface layer during June.

Soils from higher physiographic positions contained lower percentage of available water as compared to lowland soils in Kangsabati command area (Das et al., 1989)

Bharambe et al.(1990) reported about the soil characteristics of Jayakwadi command . The soils were highly clayey and neutral to alkaline in reaction and possess the usual characteristics of vertisols.

Srivastav and Srivastav (1991) reported that the CEC was positively and significantly correlated with soil pH and CEC increased at the rate of 3.7 C mol (P^+) kg^{-1} per unit increase in soil pH.

2.4 Soil characteristics in uncommand area

Gajbe et al.(1976) stated that the soils of Marathwada were normal and alkaline in reaction. Soils of Ambajogai of Bhir district had the pH range of 7.0 to 8.1 whereas soils of Nanded, Latur, Tuljapur and Parbhani were alkaline in reaction with pH range of 8.0 to 8.5. Vaijapur, Badnapur, Parbhani soils had the electrical conductivity with average of 0.3 dsm^{-1} . The soils of Parbhani, Ambejogai, Nanded, Latur were medium in organic carbon content.

Malewar (1976) analysed the soils of MAU campus. The soils had the pH range of 7.8 to 9.2, free $CaCO_3$ 5.5 to 13.0 per cent and organic matter 0.36 to 1.81 per cent.

More et al.(1976) stated that the pH organic carbon and $CaCO_3$ of Basmat soils were 8.20 to 8.70, 0.58 to 1.2 per cent and 2.5 to 14.0 per cent respectively. The pH, organic carbon and $CaCO_3$ of Parbhani soils were 7.85 to 8.85, 0.44 to 0.92 per cent and 3.5 to 10.0 per cent respectively.

Siddiqui et al (1976) concluded that the Marathwada soils had the pH range of 7.7 to 9.2.

Basmat soils had the electrical conductivity, organic carbon and $CaCO_3$ as 1.97 dsm^{-1} , 0.43 per cent, 20.1 per cent respectively. Parbhani soils had electrical conductivity, organic carbon and $CaCO_3$ as 0.53 dsm^{-1}, 0.69 per cent and 8.5 per cent respectively.

Lande et al (1977) analysed thirty one soil samples from Marathwada. Parbhani district soils had the pH range of 7.1 to 8.9 and EC from 0.140 to 8.4 dsm^{-1} organic carbon was 0.66 to 1.08 per cent and $CaCO_3$ 3.5 to 18.5 per cent.

Malewar and Randhawa (1978) analysed 54 surface soil samples of Marathwada. Soils had pH, EC, organic carbon and $CaCO_3$ in the range of 7.2 to 8.9, 0.17 to 0.90 dsm^{-1}, 0.18 to 1.36 % and 0.00 to 22.0 % respectively.

Malewar and Jadhav (1979) reported that the fertility status of orchards of Marathwada as almost all soils were clayey in texture, highly calcareous in nature and slightly alkaline in reaction and contained 0.66 to 1.08 per cent organic carbon. Available phosphorus ranged from 0.0030 to 0.0330 per cent.

Kachave and More (1982) analysed fifty soil samples from Marathwada region. The available potassium in these soils ranged from 190 to 780 kg K_2O/ha with an average value of 481.44 kg K_2O per hectare. Soil pH and organic carbon did not bear any correlation with available potassium.

CHAPTER-3

MATERIALS AND METHODS

3 MATERIALS AND METHODS

The present investigation was carried out to study the groundwater quality and soil chemical characteristics of Purna Command Area. The water samples were collected from wells and soil samples (0-30 cm depth) from cultivators field.

3.1 Materials

3.1.1 Physiography

The Marathwada lies in the south eastern part of Indian union and extends from 17° 35' to 20° 40' North latitudes and 74° 40' to 78° 15' East longitude. Purna project is a major irrigation project. Purna command area forms the parts of Parbhani and Nanded districts. The storage reservoir on river Purna is located near Yeldari village in Jintur Taluka of Parbhani district and the diversion dam is located down stream of Yeldari at a distance of sixty four kilometeres along the river near Sidheswar village in Hingoli taluka of Parbhani district. The diversion dam at Sidheswar was constructed to supply water to the Purna command with a gross capacity of 250.7 Mm^3.

3.1.2 Topography

In general, topography of the culturable command area is gently undulating type and there are numeral natural drainage courses by which the disposal of rainwater by surface drainage is fairly quick. Forty seven per cent of area is having less than 1 per cent slope and nearly 40 per cent area with 2 per cent slope.

3.1.3 Climate

The western part of command area comprising one village in Jintur taluka, four in Hingoli, eight in Parbhani and 50 villages in Basmat taluka lie in the "Assured Rainfall Zone" receiving annual rainfall between 813 mm and 889 mm. The eastern part comprising the remaining villages of Parbhani, Kalamnuri, Basmat and Nanded talukas lie in the "Moderately high rainfall zone". The average annual rainfall being 889 mm to 1143 mm. Though the rainfall in both the above climatic zones is enough to grow kharif and rabi crops, many a times, the prolonged storm durations create water logged conditions and the crops die due to submergence. The annual maximum temperature ranges from 29.8°C to 35.6 in summer and minimum from 10.9 to 24.5°C in June and December respectively. The mean minimum and maxium relative humidity varies between 10 to 63 per cent and 41 to 87 per cent respectively.

3.1.4 Geology

The black soils of command region are formed from weathering of trap rocks, rich in iron, lime and magnesium on which cotton and other rainfed crops thrive well. Black soils are formed as weathered products of Basalts and also of metamorphic rocks transported down by stream as alluvium. The soils of Parbhani district are also formed from trap rocks but it vary widely in texture and depth. The soils are low to medium in Organic carbon, high in $CaCO_3$, medium in total nitrogen and available P, high in available K content (More et al., 1986). The salt affected area in Purna command was found to the extent of 3,500 ha (Abhange et al., 1986). The gross area of 92,740 hectares covered by this command was classified in to different soil depth classes (Fig 1).

a) Shallow soil = 7,097 ha (8 %)
   (Soil cover 0-40 cm)

b) Medium soil = 45, 105 ha (49 %)
   (Soil cover 40-240 cm)

c) Deep soil = 40,272 ha (43%)
   (Soil cover more than 250 cm)

The clay content in command Soils is high i.e. 32-72 per cent (Bharambe et al., 1986).

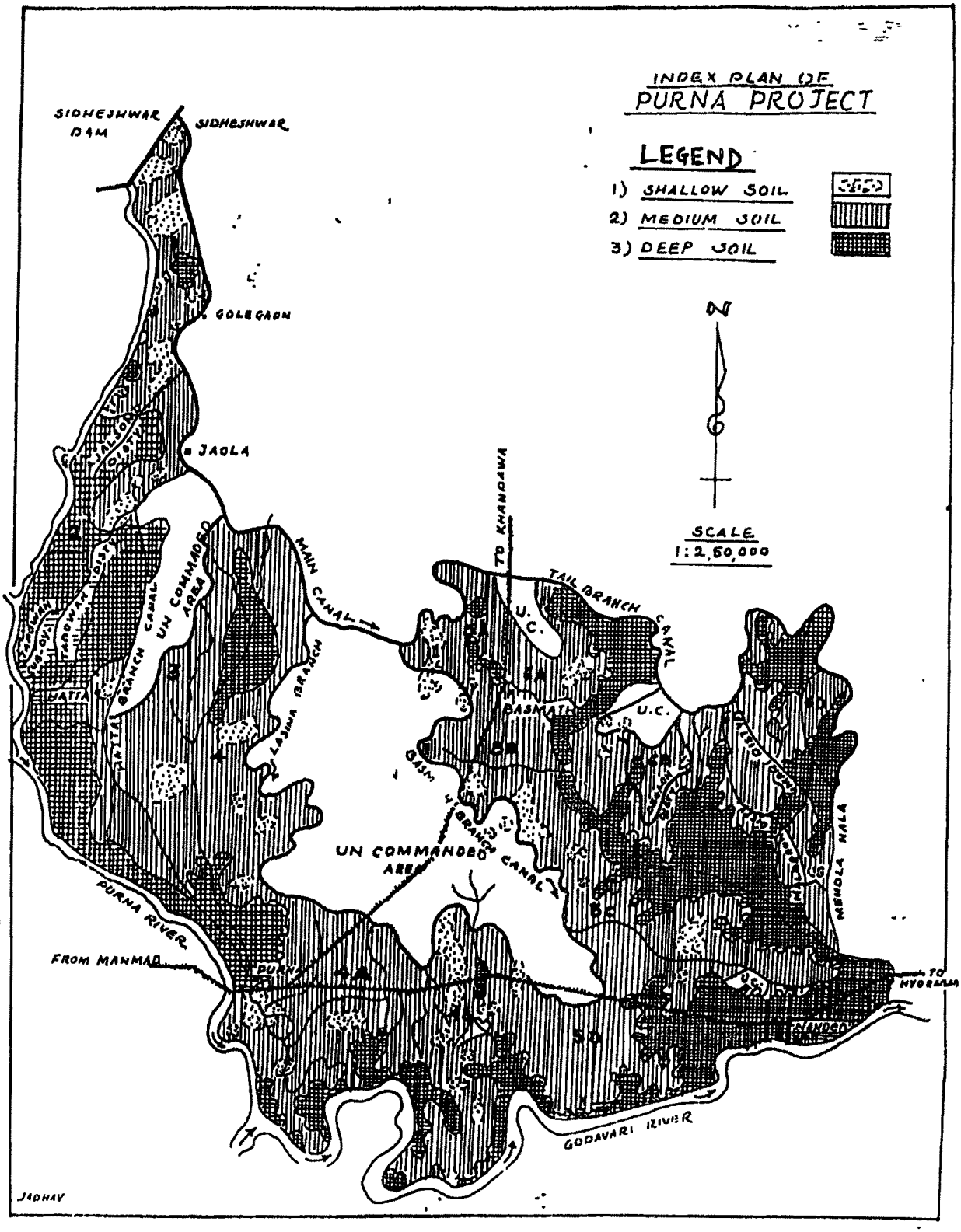

FIG1 Map showing different soil types of Purna Command area.

3.1.5 Collection of water and soil samples

Twenty five water samples and same number of soil samples were collected from various villages of command and uncommand area (Fig 2). The samples were collected in the month of December, 1991. The soil samples were collected from surface layers (0-30 cm depth). The details of water and soil samples collected from Purna command area are given below :

Table 1. Details of water and soil samples collected from Purna command and uncommand area

Sr. No.	Name of the village	Command / Uncommand
1.	Kathneshwar	Command
2.	Yerandeshwar	Command
3.	Hatta	Command
4.	Chikhali	Command
5.	Tuljapurwadi	Command
6.	Aral	Command
7.	Balegaon	Command
8.	Telgaon	Command
9.	Aherwadi	Command
10.	Mategaon	Command
11.	Ridhora	Command
12.	Chudawa	Command
13.	Pimpla	Command
14.	Pokharni	Command
15.	Ganeshpur	Command
16.	Basmat	Command
17.	Kanhergaon	Command
18.	Kamtha	Command
19.	Malegaon	Command
20.	Kasarkheda	Command

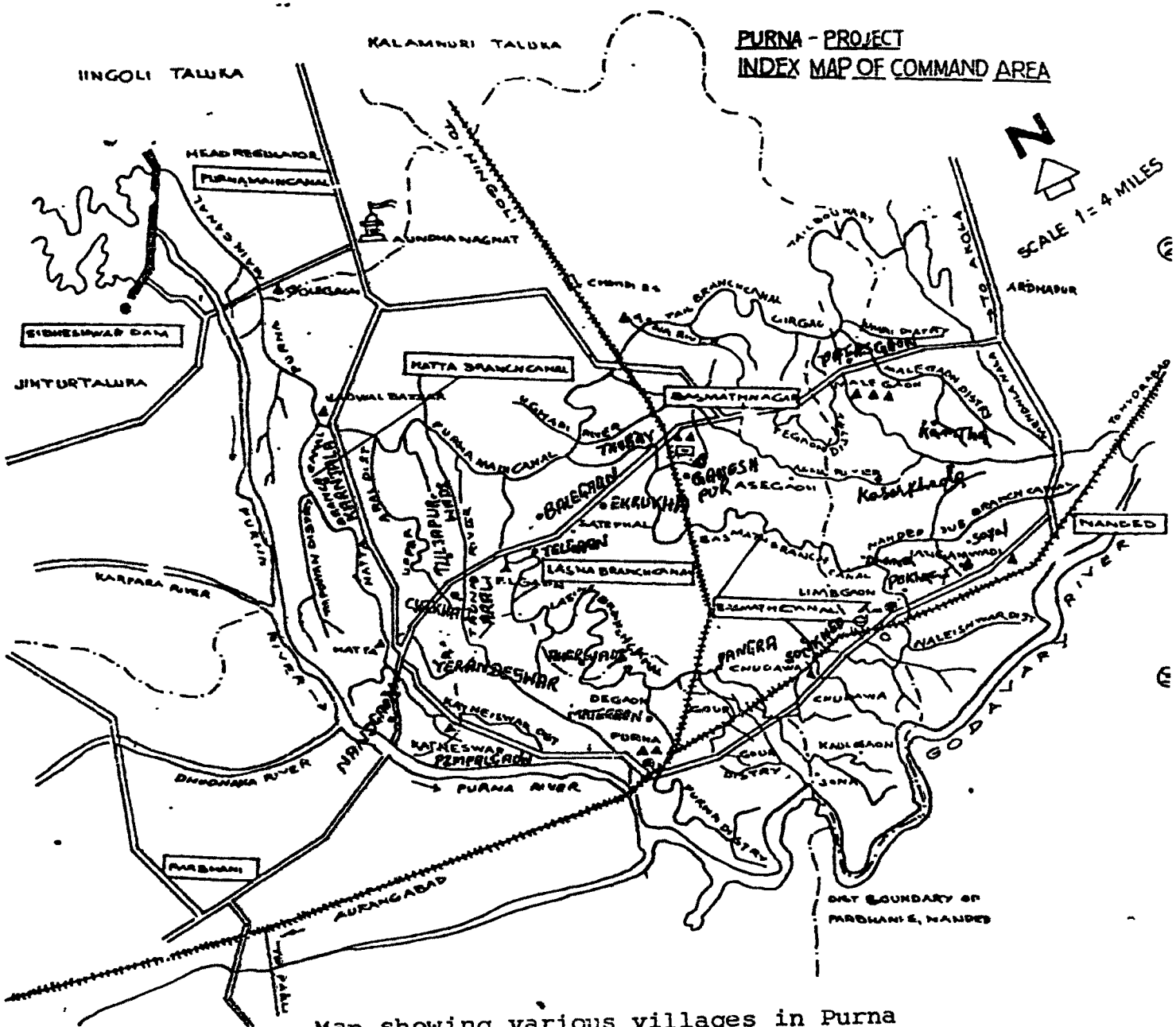

FIG 2. Map showing various villages in Purna Command and uncommand area.

Sr.No.	Name of the village	Command/Uncommand
21.	Nandgaon	Command
22.	Pimpalgaon	Command
23.	Ajarsonda	Command
24.	Purna	Command
25.	Alegaon	Command
26.	Ekrukha	Uncommand
27.	Satephal	Uncommand
28.	Lingi	Uncommand
29.	Hayatnagar	Uncommand
30.	Gour	Uncommand
31.	Limbgaon	Uncommand
32.	Thorav	Uncommand
33.	Pangra	Uncommand
34.	Palasgaon	Uncommand
35.	Girgaon	Uncommand
36.	Degaon	Uncommand
37.	Dhanora	Uncommand
38.	Adgaon	Uncommand
39.	Bori	Uncommand
40.	Gunda	Uncommand
41.	Karanjala	Uncommand
42.	Jawala bazar	Uncommand
43.	Revalgaon	Uncommand
44.	Sonkhed	Uncommand
45.	Hivara	Uncommand
46.	Dhotra	Uncommand
47.	Regaon	Uncommand
48,	Wakhari	Uncommand
49.	Sayal	Uncommand
50.	Warkhed	Uncommand

3.2 Methods

3.2.1 Preparation of soil samples and water samples

The water samples were collected in plastic bottles from various villages and preserved with toluene to avoid microbial growth.

The soil samples collected from various villages were dried in shade by spreading on white glazed sheets of paper. Another sheet of white paper was put on the samples as a cover sheet to avoid contamination with extraneous matter. After air drying for about five days, gravels and primary soil particles were discarded. The grinding of soil samples was done with wooden morter and pest le. The samples were passed through 2 mm sieve, placed in paper bags and labelled properly. Subsequently both water and soil samples were used for analysis.

3.2.2 Water analysis

The water samples were analysed by following standard methods as mentioned below.

1. pH : pH of the water samples was directly determined by using Beckman pH meter with glass electrode (Piper, 1966).
2. Electrical conductivity : It was determined by conductivitymeter (Jackson, 1967).

3. Calcium and Magnesium were analysed by Versanate method by using EDTA as titrating agent (Chopra and Kanwar, 1980).

4. Sodium and potassium were determined flame photometrically (Chopra and Kanwar, 1980).

5. Carbonates and bicarbonates were determined by titrating with sulphuric acid (Chopra and Kanwar, 1980).

6. Sulphates were determined by gravimetric method (Richards, 1954).

7. Chlorides were determined using silver nitrate as a titrating agent (Richards, 1954).

8. Sodium adsorption ratio was calculated by using the following formula

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

9. The adjusted SAR was calculated as proposed by Ayers and Westcot (1976) as follow

$$\text{Adjusted SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \; 1 + (8.4 - pHC)$$

Where,

$$pHC = (pk_2 - pk_c) + P(Ca + Mg) + P(Alk)$$

$(pk_2 - pk_c)$ is obtained from using the sum of Ca + Mg + Na in mel^{-1}

P (Ca + Mg) is obtained from using the sum of Ca + Mg in mel^{-1}.

P (Alk) is obtained from using the sum of $CO_3 + HCO_3$ in mel^{-1}.

10. Soluble sodium percentage was calculated as

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

(Richards, 1954)

11. Residual sodium carbonate was calculated by using the following formula

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

(Richards, 1954)

12. Boron was determined using procedure proposed by Richards (1954)

Soil samples were analysed by following the standard methods as mentioned below :

1. Available nitrogen was determined using Alkaline permanganate method (Subbaiah and Asija, 1956).

2. Available phosphorus determination was done by following the Olsen's method (Sankaram, 1966).

3. Available potassium was determined flame photometrically using normal neutral ammonium acetate as an extractant (Black, 1965).

4. pH and EC of the soil samples were determined by preparing 1 : 2.5 (Soil : Water) suspension, with help of Beckman pH meter with glass electrode and conductivity meter respectively (Piper, 1966).

5. Free calcium carbonate was determined by rapid titration method (Piper, 1966).

6. Organic carbon was determined using Wakley & Black's method as described by Piper (1966).

4. RESULTS

4. RESULTS

An experiment was conducted to study the effect of canal irrigation on ground water quality and soil characteristics. It was also aimed to see the ground water quality and soil characteristics in uncommand area under Purna project. The results obtained in the study are presented appropriately in tabulated forms. The chapter is organised in the following heads.

4.1 Groundwater quality of Purna command area

The water samples collected from Purna command area were analysed for pH, EC, anions, cations and boron. The quality parameters were calculated on the basis of chemical composition of irrigation water. Waters were classified in to different suitability classes based on the water characteristics.

4.1.1 pH

The data in Table 2 revealed that pH of groundwater ranged from 7.45 to 8.95 in water samples from Basmat and Kanhergaon respectively. In general pH of water samples was little higher exceeding 8.0. The average pH of groundwater in Purna command area for 25 locations was 8.36.

4.1.2 Electrical conductivity

The electrical conductivity values of ground water in command area ranged from 0.568 to 3.195 dsm^{-1}. The highest EC value was recorded with Kanhergaon (3.195) water sample followed by Kasarkheda (2.91) and Mategaon (2.414), whereas Aherwadi water sample showed lowest EC value 0.568 dsm^{-1} followed by Pimpla (0.603 dsm^{-1}). The average EC value for the waters in command area was 1.165 dsm^{-1}.

4.1.3 Anions

Carbonates

The carbonates contents of groundwater was in the range of 1.60 to 7.20 mel^{-1}. The waters from Chudawa (7.20 mel^{-1}) and Kamtha (6.80 mel^{-1}) have shown little higher concentration of carbonates in water. Whereas the samples from Ajarsonda, Telgaon and Yerandeswar showed lowest and same amount of CO_3 (1.60 mel^{-1}). The average value of water samples from 25 villages with respect to carbonates was 3.20 mel^{-1}.

Bicarbonates

The bicarbonate content in water samples from Purna command (Table 2) was little higher than carbonate content. Village Balegaon recorded lowest bicarbonate content i.e. 1.20 mel^{-1} in water, whereas the villages

Table 2. Chemical composition of groundwaters from Purna command area

Name of the village	pH	EC dsm^{-1}	Anions mel^{-1}				Cations mel^{-1}			
			CO_3	HCO_3	Cl	So_4	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
Kathneswar	8.25	0.781	4.00	2.40	3.20	0.67	3.60	2.50	6.00	0.68
Yerandeswar	8.46	0.994	1.60	2.40	3.00	0.59	2.60	5.60	5.40	0.65
Hatta	8.40	0.852	3.60	6.00	3.00	1.30	2.00	5.00	4.80	0.57
Chikhali	8.50	0.994	1.80	5.20	9.40	0.75	3.20	4.00	4.00	0.55
Tuljapurwadi	8.51	1.065	2.00	3.20	3.60	1.75	2.70	4.20	8.56	0.45
Aral	8.45	0.994	2.00	2.40	4.00	5.15	2.20	4.10	2.20	0.50
Balegaon	8.40	0.781	2.00	1.20	2.80	1.58	2.40	3.00	4.20	0.58
Telgaon	8.50	0.642	1.60	2.00	3.80	1.78	2.30	3.40	1.50	0.35
Aherwadi	8.51	0.568	2.00	5.60	3.00	5.50	4.50	2.50	1.40	0.57
Mategaon	8.80	2.414	2.80	5.20	9.60	4.80	4.00	6.80	14.00	1.00
Ridhora	8.01	0.923	4.80	2.80	3.20	2.15	4.80	4.40	2.40	0.48
Chudawa	8.04	0.904	7.20	5.00	2.40	2.74	6.00	4.00	3.65	0.88
Pimpla	8.64	0.603	4.00	4.80	2.00	1.75	4.80	4.90	4.50	0.41
Pokharni	8.49	0.994	2.00	6.00	1.80	2.84	2.70	2.30	3.60	0.32
Ganeshpur	7.67	1.136	4.40	2.80	2.80	3.25	5.20	6.40	8.40	0.65
Basmat	7.45	0.710	3.60	1.60	2.40	1.10	5.00	5.30	2.50	0.82
Kanhergaon	8.95	3.195	3.80	1.40	2.80	6.40	4.80	8.60	15.00	0.68
Kamtha	8.58	0.710	6.80	2.80	3.20	1.85	5.20	4.30	2.40	0.75
Malegaon	8.31	1.562	2.00	3.00	5.20	2.48	6.30	5.10	3.00	0.30
Kasarkheda	8.75	2.911	4.00	4.00	6.21	1.50	5.80	14.40	13.50	0.85
Nandgaon	8.08	1.562	2.80	4.80	4.60	2.48	4.90	2.00	8.00	0.35
Pimpalgaon	8.11	1.136	2.00	4.00	3.20	2.52	5.50	3.00	7.50	0.27
Ajarsonda	8.54	0.710	1.60	4.00	2.00	3.50	5.70	8.80	4.70	0.82
Purna	8.45	0.850	3.60	1.60	2.60	2.20	4.70	8.50	4.50	0.84
Alegaon	8.10	1.136	4.00	4.20	6.80	2.92	5.50	14.00	7.68	0.75
Averages	8.4	1.165	3.20	3.53	3.86	2.54	4.25	5.48	5.73	0.60

Pokharni and Hatta have groundwater with bicarbonates 6.0 mel^{-1}. The average bicarbonate content in water samples was 3.53 mel^{-1}.

Chlorides

Chloride content in irrigation waters from 25 locations in Purna command ranged from 1.30 to 9.60 mel^{-1} in Pokharni and Mategaon samples respectively. The water from Chikhali also showed high chloride content (9.40 mel^{-1}). The average value of chlorides in water samples from command area was 3.86 mel^{-1}.

Sulphates

The water samples from Kanhergaon showed highest value of sulphates (6.40 mel^{-1}) followed by the sample from Aherwadi (5.50 mel^{-1}) and Aral (5.15 mel^{-1}). The villages Katneswar, Yerandeshwar and Chikhali recorded sulphates less than 1.0 mel^{-1} (Table 2). The water sample from Yerandeswar was found to have lowest sulphate content (0.59 mel^{-1}). The average value for sulphates in groundwater of Purna command was 2.54 mel^{-1}.

4.1.4 Cations

The cationic composition in groundwater from Purna command area is presented in Table 2.

Calcium

The village Malegaon was found to have highest calcium content in water (6.30 mel^{-1}) followed by Chudawa (6.00 mel^{-1}). The lowest content of calcium was in water samples from Hatta (2.0 mel^{-1}). The average calcium content in water samples from command area was 4.25 mel^{-1}.

Magnesium

The magnesium content in water from different locations in command area ranged from 2.30 to 14.00 mel^{-1} in Pokharni and Alegaon samples respectively. Most of the samples were found to have high magnesium than calcium content. The average content of Magnesium in water was 5.48 mel^{-1}.

Sodium

In general sodium content in water was higher than potassium in almost all the samples of Purna command area. Water samples from Kanhergaon showed highest sodium (15.00 mel^{-1}) followed by Kasarkheda (13.50 mel^{-1}), Tuljapurwadi (8.56 mel^{-1}), Ganeshpur (8.40 mel^{-1}) and Nandgaon (8.0 mel^{-1}). The water sample from Aherwadi village recorded lowest sodium content (1.40 mel^{-1}) followed by Telgaon (1.50 mel^{-1}).

Average value of sodium content for 25 villages in command area was 5.73 mel^{-1}.

Potassium

Most of the water samples from command area showed less than 1 mel^{-1} potassium content except Mategaon. The K content in water was in the range of 0.27 to 1.00 mel^{-1}. The village Pimpalgaon was lowest in K content in groundwater. The average K content in waters from command area was 0.60 mel^{-1}.

4.2 Water quality parameters of Purna command area

The different quality parameters were calculated from the chemical composition of waters from Purna command area. The values are reported in Table 3.

4.2.1 Sodium adsorption ratio SAR

SAR values from waters in command area ranged from 0.74 to 6.03 in Aherwadi and Mategaon samples respectively. Most of the water samples have shown SAR values less than 5 except the village Kanhergaon and Mategaon. The samples from Telgaon and Aherwadi recorded SAR value less than

Table 3. Quality parameters of groundwaters from Purna command area

Name of the village	SAR	Adj. SAR	RSC me/l-1	SSP	Boron (ppm)
Kathneshwar	3.44	8.25	0.30	49.58	0.95
Yerandwswar	2.67	6.14	-0.20	39.70	1.10
Hatta	2.56	6.40	2.60	40.67	1.00
Chikhali	2.11	5.06	-0.20	35.71	0.88
Tuljapurwadi	4.62	10.62	-1.70	55.36	1.20
Aral	1.24	2.72	-1.90	25.88	0.84
Balegaon	2.56	5.12	-2.20	43.75	0.92
Telgaon	0.89	1.86	-2.10	20.83	0.85
Aherwadi	0.74	1.77	0.60	16.66	0.74
Metegaon	6.03	15.67	-2.80	56.45	1.45
Ridhora	1.12	2.80	-1.60	20.68	0.60
Chudawa	1.163	4.56	2.20	26.73	0.95
Pimpla	2.04	5.30	-0.90	31.60	0.75
Pokharni	2.27	5.44	3.00	41.86	1.00
Ganeshpur	3.50	5.25	-4.40	42.00	1.15
Basmat	1.10	2.75	-5.10	19.53	0.85
Kanhergaon	5.81	14.52	-8.20	52.81	1.70
Kamtha	1.10	2.86	1.00	20.16	0.94
Malegaon	1.26	3.15	-6.40	20.83	0.96
Kasarkheda	4.25	12.32	-12.20	40.05	1.42
Nandgaon	4.32	10.36	0.70	53.69	0.90
Pimpalgaon	3.64	9.10	-2.50	46.87	0.82
Ajarsonda	1.74	4.52	-8.90	24.47	0.92
Purna	1.75	4.55	-8.00	25.42	0.80
Alegaon	2.46	6.88	-11.30	28.25	0.75
Averages	2.59	6.31	-2.97	35.18	0.93

1.00. The average value of SAR in water samples from Purna command area was 2.5.

4.2.2 Adjusted SAR

The adjusted SAR values were calculated for each sample. The samples from Tuljapurwadi, Kanhergaon, Kasarkheda and Nandgaon have recorded adjusted SAR value more than 10.0 whereas the villages Telgaon and Aherwadi were with less than 2.00 adjusted SAR values. The average adjusted SAR in waters of 25 locations of Purna command was 6.31.

4.2.3 Residual sodium carbonate

Most of the waters in command area were with negative RSC value (Table 3). The water samples from Katneswar, Hatta, Aherwadi, Chudawa, Pokharni, Kamtha and Nandgaon reforded positive RSC values. Water samples from the village Hatta and Pokharni was with RSC value greater than 2.5. Range of RSC value was from -12.20 mel^{-1} in Kasarkheda to 3.00 mel^{-1} in Pokharni water samples. The average value of RSC in command area waters was -2.968 mel^{-1}.

4.2.4 Soluble sodium percentage

The SSP was calculated on the basis of chemical composition of water (Table 3). All the

water samples contained less than 60 SSP. The SSP values for different waters ranged from 16.66 to 36.45 in the water samples from Aherwadi and Mategaon respectively. The average value of SSP for all the samples in the command area was 35.18.

4.2.5 Boron

The Boron content in irrigation waters from Purna command area was determined and the data is presented in Table 3. The results revealed that the Boron was ranging from 0.60 to 1.95 ppm in waters from different villages. Water sample from Kanhergaon recorded highest Boron followed by Mategaon and Kasarkheda. The average Boron content in water from command area was 0.939 ppm.

4.3 Classifications of groundwater from Purna command area

The water samples from different villages were classified on the basis of different quality parameters. The villages were grouped into different categories. The suitability of groundwater for irrigation was decided with different criteria.

4.3.1 U.S.D.A. classification

Based on salinity and sodicity values, all the samples were classified into different salinity-sodicity classes (Table 4). Only three salinity sodicity classes were found with the different water samples in the command. Water samples from Telgaon, Aherwadi, Pimpla, Basmat, Kamtha, Pimpalgaon and Ajarsonda were rated as C_2S_1 class. Katneswar, Yerandeshwar, Hatta, Chikhali, Tuljapurwadi, Aral, Balegaon, Ridhora, Chudwa, Pokharni, Ganeshpur, Mategaon, Nandgaon, Purna and Alegaon were grouped in C_3S_1. Whereas Mategaon, Kanhergaon and Kaserkheda were in C_4S_1 class. The percentage of samples in C_2S_1, C_3S_1 and C_4S_1 was 28.0, 60.0 and 12 respectively.

4.3.2 Classification based on RSC value

The water samples were also grouped into different RSC classes (Table 5). Most of the villages in command area come under good quality with RSC value < 1.25 mel^{-1}. Only one sample from Chudawa was marginal in RSC value whereas the samples from Hatta and Pokharni were grouped under unsuitability class with RSC value greater than 2.5 mel^{-1}.

Table 4 USDA classification of groundwaters from Purna command area

Sr. No.	Salinity-Sodicity class	Name of the villages
1.	C_2S_1	Telgaon, Aherwadi, Pimpla, Basmat, Kamtha .. and Ajarsonda
2.	C_3S_1	Kathneswar, Yerandeswarr, Hatta, Chikhali, Aral, Tuljapurwadi, Balegaon, Pimpalgaon Ridhora, Chudawa, Pokharni Ganeshpur, Mategaon, Malegaon. Nandgaon, Purna and Alegaon
3.	C_4S_1	Kasarkheda, & Kanhergaon.

Table 5. Classification of groundwaters of Purna command on the basis of RSC value

Sr. No.	RSC value	Class	Name of the villages
1.	< 1.25	Good quality	Kathneswar, Yerandeswar, Chikhali, Tuljapurwadi, Aral, Balegaon, Telgaon, Aherwadi, Mategaon, Ridhora, Pimpla, Kamtha, Ganeshpur, Malegaon, Kasarkheda,, Nandgaon, Pimpalgaon, Ajarsonda, Basmat, Purna, Alegaon, Kanhargaon
2.	1.25 - 2.5	Marginal quality	Chudawa
3.	> 2.5	Not suitable for irrigation	Hatta, Pokharni

4.3.3 ABC classification

The water samples were further classified as suggested by Gupta (1979). The results are presented in Table 6. All waters from Purna command area were classified each on the basis of alkalinity hazard (Adjusted SAR), Boron and salinity hazard (EC). Most of the water samples were rated as normal sodium water i.e. A_1 class (Adjusted SAR $<$ 10). However, the samples from Mategaon, Kasarkheda, Kanhergaon and Nandgaon were rated as A_2 class i.e. low sodium waters (Adjusted SAR 10-20).

All the water samples from command area were normal with respect to Boron content ($<$ 3 ppm). They were rated as B_1 class.

Large number of samples from command area respect. to salinity and were grouped in C_1 class (EC $<$ 1.5 dsm^{-1}).

The samples from Mategaon, Malegaon, Kasarkheda and Nandaon were grouped in C_2 class i.e. low salinity water (EC 1.5 - 3.0 dsm^{-1}), only one sample from Kanhergaon village was rated as C_3 class i.e. medium salinity water (EC 3.0 - 5.0 dsm^{-1}).

Table 6. ABC classification of groundwater from Purna command area

Name of the village	A	B	C
Kathneswar	A_1	B_1	C_1
Yerandeswar	A_1	B_1	C_1
Hatta	A_1	B_1	C_1
Chikhali	A_1	B_1	C_1
Tuljapurwadi	A_1	B_1	C_1
Aral	A_1	B_1	C_1
Balegaon	A_1	B_1	C_1
Telgaon	A_1	B_1	C_1
Aherwadi	A_1	B_1	C_1
Mategaon	A_2	B_1	C_2
Ridhora	A_1	B_1	C_1
Chudawa	A_1	B_1	C_1
Pimpla	A_1	B_1	C_1
Pokharni	A_1	B_1	C_1
Ganeshpur	A_1	B_1	C_1
Basmat	A_1	B_1	C_1
Kanhergaon	A_2	B_1	C_3
Kamtha	A_1	B_1	C_1
Malegaon	A_1	B_1	C_2
Kasarkheda	A_2	B_1	C_2
Nandgaon	A_2	B_1	C_2
Pimpalgaon	A_1	B_1	C_1
Ajarsonda	A_1	B_1	C_1
Purna	A_1	B_1	C_1
Alegaon	A_1	B_1	C_1

A_1=Adjusted SAR $<$ 10
A_2=Adjusted SAR 10-20

B_1=Boron less than 3 ppm

C_1=EC in dsm^{-1} $<$ 1.5
C_2=EC in dsm^{-1} 1.5-3.0
C_3= 3.0-5.0

4.4 Groundwater quality of Purna uncommand

The water samples were also collected from uncommand area under Purna project, the samples were analysed for pH, EC, anions and cations (Table 7). The data on chemical composition of water was further used to ascertain the quality parameters as SAR, adjusted SAR, RSC and SSP. The water samples were also analysed for Boron content (Table 8).

4.4.1 pH

pH of the water samples in uncommand area was found to vary from 7.75 to 8.50 in Sayal and Gunda villages respectively. Most of the samples had pH around 8.00, the average pH value for all samples was 8.08.

4.4.2 Electrical conductivity

The electrical conductivity of waters varied from 0.49 to 1.633 dsm^{-1} in different samples with as average value of 0.669 dsm^{-1}.

4.4.3 Anions

Carbonates

The carbonate content in water samples ranged between 1.6 to 4.8 mel^{-1} with an average

Table 7. Chemical composition of groundwaters from Purna uncommand area

Name of the village	pH	EC dsm^{-1}	Anions mel^{-1}				Cations mel^{-1}			
			$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+
Ekruka	8.30	0.694	2.0	2.6	3.2	1.84	1.0	4.7	5.10	0.38
Sathephal	7.95	0.665	2.4	1.8	2.8	0.89	4.3	4.2	4.20	0.60
Lingi	8.28	1.633	3.6	5.2	3.8	2.25	8.0	4.6	7.80	0.56
Hayatnagar	8.30	0.578	1.6	3.2	4.8	1.92	5.5	3.4	6.48	0.58
Gour	8.07	0.587	2.4	2.8	4.0	1.50	5.6	1.1	3.50	0.42
Limbagaon	8.00	0.678	1.6	5.2	4.0	1.52	5.2	5.8	5.00	0.78
Thorav	8.16	0.578	2.0	2.0	2.0	1.86	2.2	3.6	4.50	0.74
Pangra	8.16	0.745	3.6	3.0	3.0	2.72	5.1	3.2	4.00	0.23
Palasgaon	8.10	0.649	4.2	0.8	5.0	2.08	5.8	7.3	3.55	0.28
Girgaon	7.99	0.731	2.0	3.6	2.8	1.80	3.6	3.3	4.95	0.45
Degaon	7.80	0.659	2.8	5.0	5.2	3.00	8.7	6.4	4.63	0.82
Dhonora	8.28	0.694	4.0	4.8	5.2	1.55	4.9	5.4	2.50	0.38
Adgaon	8.12	0.710	4.8	2.2	2.6	0.68	4.4	4.6	3.25	0.51
Bori	8.00	0.692	3.2	4.8	2.0	2.20	4.5	5.0	3.52	0.32
Gunda	8.50	0.507	3.2	2.8	3.6	1.50	3.7	5.6	3.12	0.20
Karanjala	8.10	0.662	2.0	1.8	4.0	2.10	1.8	1.6	3.00	0.35
Jawalabazar	7.81	0.497	2.0	3.2	2.4	1.42	4.0	6.6	1.60	0.48
Revalgaon	8.20	0.720	3.0	3.0	4.6	1.92	2.2	4.0	3.00	0.20
Sonkhed	7.95	0.660	1.98	3.2	4.0	2.00	5.1	3.4	4.92	0.64
Hivara	8.30	0.678	2.0	2.4	2.6	1.90	5.4	3.5	5.60	0.70
Dhotra	7.90	0.714	2.0	2.6	3.2	2.25	4.3	4.0	5.10	0.82
Kegaon	8.10	0.600	4.6	5.2	3.8	1.80	4.4	5.0	3.60	1.43
Wakhari	7.85	0.660	2.5	3.2	4.8	1.00	3.5	3.4	4.80	0.54
Sayal	7.75	0.750	1.9	2.6	3.0	1.50	4.3	4.5	4.90	0.84
Warkhed	7.90	0.740	2.8	5.0	2.2	1.85	1.0	4.7	3.95	0.68
Average values	8.07	0.699	2.72	3.28	3.54	1.80	4.14	4.39	4.30	0.59

value of 2.72 mel^{-1} in Purna uncommand area. The water from Hayatnagar and Limbagaon showed lowest carbonate content (1.60 mel^{-1}) and Adgaon sample showed highest carbonate content (4.8 mel^{-1}).

Bicarbonates

The water sample from village Palasgaon recorded lowest bicarbonate content (0.8 mel^{-1}) whereas the sample from Lingi and Regaon had highest bicarbonate (5.2 mel^{-1}). The average bicarbonate content of 25 villages in uncommand area was 3.28 mel^{-1}.

Chlorides

The chloride content in water samples varied from 2.0 to 5.2 mel^{-1}. The water from Thorav recorded lowest chloride content whereas Degaon and Dhanora villages contained highest and equal amount of chlorides in irrigation water. The mean value of chlorides for all the samples was 3.5 mel^{-1}.

Sulphates

The sulphate content in irrigation water was in the narrow range of 0.98 to 3.00 mel^{-1} in different samples. The village Degaon was highest in sulphate content of water followed by Pangra.

The mean value of sulphates for different water samples from uncommand area was 1.80 mel^{-1}.

4.4.4 Cations

The water samples were analysed for different cations as Ca, Mg, Na, K and the results are reported in Table 7.

Calcium

In general, calcium content in waters ranged from 1.00 to 8.00 mel^{-1} with an average value of 4.14 mel^{-1}. The sample from Ekruka and Warkhed had lowest calcium (1.00 mel^{-1}) followed by Karanjala (1.80 mel^{-1}). Water sample from Lingi village had highest calcium content.

Magnesium

The range of Magnesium in different water samples was from 1.11 to 7.30 mel^{-1} with a mean value of 4.39 mel^{-1}. Water from Gour village showed lowest magnesium whereas that from Palasgaon recorded highest value.

Sodium

Sodium content in groundwater of uncommand area varied from 1.60 (Jawalabazar) to 7.80 (Lingi) mel^{-1}. The mean value of sodium in 25 water samples from uncommand area was 4.30 mel^{-1}.

Potassium

Potassium content in irrigation water was in general low i.e. < 1.0 mel^{-1}. The water from Sayal recorded lowest K followed by Degaon and Dhotra (0.82 mel^{-1}). The sample from Gunda and Revalgaon villages showed lowest K content (0.20 mel^{-1}) followed by Pangra. The average value of K for different samples was 0.52 mel^{-1}.

4.5 Quality parameters of groundwaters from Purna uncommand area

The chemical components of irrigation water were used to determine the quality parameters of groundwaters from Purna uncommand area. SAR, adjusted SAR, RSC, SSP and Boron were determined and the data is presented in Table 8.

4.5.1 Sodium adsorption ration SAR

SAR was in general less than 4 in all the water samples from uncommand area, it ranged from 0.69 in Jawalabazar to 3.12 in Lingi sample with mean value of 2.14.

4.5.2 Adjusted SAR

The adjusted SAR values were calculated for different water samples as suggested by Ayers and Westcot (1976).

Table 8. Quality parameters of groundwaters from Purna uncommand area

Name of the village	SAR	Adj. SAR	RSC mel^{-1}	SSP	Boron ppm
Ekruka	3.03	6.36	-1.1	47.20	0.46
Sathephal	2.03	4.66	-4.3	33.00	0.93
Lingi	3.12	8.42	-3.8	38.23	0.63
Hayatnagar	3.08	7.08	-4.1	42.13	0.50
Gour	1.91	4.77	-1.5	34.31	0.86
Limbagaon	2.17	5.64	-4.2	31.25	0.80
Thorav	2.92	6.71	-1.8	43.68	0.94
Pangra	1.97	4.92	-1.7	32.52	0.85
Palasgaon	1.39	3.61	-8.1	21.32	1.00
Girgaon	2.67	6.14	-1.3	41.77	1.10
Degaon	2.06	5.35	-2.3	31.43	1.25
Dhanora	1.05	2.83	-2.5	18.11	0.52
Adgaon	1.53	3.82	-2.0	26.53	0.84
Bori	1.62	4.21	-1.5	27.03	0.98
Gunda	1.91	4.77	-3.3	30.70	1.20
Karanjala	2.30	5.06	-0.4	46.87	0.88
Jawalabazar	0.69	1.72	-5.4	13.11	0.75
Revalgaon	1.70	4.25	-0.2	32.60	0.68
Sonkhed	2.38	5.71	-3.3	36.66	0.90
Hivara	2.66	5.11	-4.5	38.62	0.85
Dhotra	2.51	5.77	-3.7	38.05	0.64
Regaon	1.66	4.31	0.4	27.69	0.59
Wakhari	2.59	5.69	-2.2	41.02	0.98
Sayal	2.34	5.38	-4.3	35.76	0.78
Warkhed	2.35	5.40	2.1	40.93	0.88
Average	2.14	5.15	-2.56	34.02	0.83

The values ranged between 1.7 to 8.42 with a mean value of 5.15. The sample from the village Lingi recorded highest adjusted SAR followed by Hayatnagar and Thorav whereas Jawalabazar recorded lowest adjusted SAR.

4.5.3 Residual sodium carbonate (RSC)

The values of RSC for different samples in uncommand area were negative. The water samples from Karanjala, Regaon and Warkhed had + ve RSC values. The waters from Warkhed had highest RSC i.e. 2.1.

4.5.4 Soluble sodium percentage (SSP)

SSP values for different water samples in uncommand area were found between 18.11 to 46.87 in Dhanora and Karanjala respectively. The mean value of SSP for twenty five samples was 34.02 in uncommand area.

4.5.5 Boron

In general boron content in water samples was below 1.00 ppm except the samples from Palasgaon, Girgaon, Degaon and Gunda. The boron content in waters varied from 0.46 to 1.25 ppm. The sample from Degaon recorded highest boron followed by Gunda and Girgaon. The average Boron content in water samples was 0.83 ppm in uncommand area.

4.6 Classifications of groundwater from uncommand area

Waters were classified into different classes on the salinity. Suitability of ground water from uncommand area was decided accordingly.

4.6.1 USDA classification

All the waters from the Purna uncommand area were grouped into different salinity, sodicity classes based on USDA classification (Table 9). Most of the samples were grouped under C_2S_1 class i.e. medium salinity, low sodium water. However, the water samples from Lingi and Sayal rated as C_3S_1 class i.e. high salinity, low sodium water.

4.6.2 Classification based on RSC

Water samples from uncommand area were grouped in to different RSC classes (Table 10). All the samples were rated as good quality (RSC $<$ 1.25 mel^{-1}) except the water sample from Warkhed which was marginal in RSC value (RSC 1.25 to 2.5 mel^{-1}).

4.6.3 ABC classification

Based on adjusted SAR, Boron and EC, the waters were grouped in different categories as

Table 9. USDA classification of irrigation water from Purna uncommand area

Sr. No.	Salinity-Sodicity class	Name of the villages
1.	C_2S_1	Ekruka, Sathephal, Hayatnagar, Gour, Thorav, Limbagaon, Pangra, Bori, Palasgaon, Girgaon, Degaon, Dhonora, Adgaon, Gunda, Karanjala, Hiwara, Jawalabazar, Dhotra, Revalgaon, Sonkhed, Wakhari, Warkhed , Regaon
2.	C_3S_1	Lingi, Sayal

Table 10. Classification of groundwater of Purna uncommand on the basis of RSC value

Sr. No.	RSC value	Water class	Name of the villages
1.	< 1.25 (good quality)	Good	Ekruka, Sathephal, Lingi, Hayatnagar, Gour, Lambagaon, Bori, Pangra, Palasgaon, Girgaon, Degaon, Dhonora, Adgaon, Gunda, Jawalbazar, Sonkhed, Hivara, Dhotra, Regaon, Wakhari and Sayal, Thorav, Karanjala, Revalgaon
2.	1.25 - 2.5	Marginal	Warkhed

Table 11 ABC classification of groundwater from Purna uncommand area

Name of the village	A	B	C
Ekruka	A_1	B_1	C_1
Sathephal	A_1	B_1	C_1
Lingi	A_1	B_1	C_2
Hayatnagar	A_1	B_1	C_1
Gour	A_1	B_1	C_1
Limbagaon	A_1	B_1	C_1
Thorav	A_1	B_1	C_1
Pangra	A_1	B_1	C_1
Palasgaon	A_1	B_1	C_1
Girgaon	A_1	B_1	C_1
Degaon	A_1	B_1	C_1
Dhónora	A_1	B_1	C_1
Adgaon	A_1	B_1	C_1
Bori	A_1	B_1	C_1
Gunda	A_1	B_1	C_1
Karanjala	A_1	B_1	C_1
Jawalabazar	A_1	B_1	C_1
Revalgaon	A_1	B_1	C_1
Sonkhed	A_1	B_1	C_1
Hivara	A_1	B_1	C_1
Dhotra	A_1	B_1	C_1
Regaon	A_1	B_1	C_1
Wakhari	A_1	B_1	C_1
Sayal	A_1	B_1	C_1
Warkhed	A_1	B_1	C_1

A_1=Adjusted SAR less than 10

B=Boron less than 3

C_1=EC dsm^{-1} less than 1.5

C_2= EC dsm^{-1} 1.5-3.0

suggested by Gupta (1979) and the resuls are computed in Table 11. All water samples in uncommand area were rated as A_1 class with respect to adjusted SAR. Similarly, all waters came under B_1 class i.e. normal water (< 3 ppm b). These waters also showed C_1 class of salinity (normal water) except the water from Lingi which was rated as low salinity water (EC 1.50 to 3.00 dsm^{-1}).

4.7 Soil properties and fertility in Purna command area

The surface soil samples collected from twenty five locations in Purna command area were subjected to analysis for pH, EC, free $CaCO_3$, organic carbon, available N, available P_2O_5 and available K_2O. The data on soil properties and fertility as influenced by long term canal irrigation in command area is presented in Table 12.

4.7.1 Soil pH

In general soil pH in command area was above 8.00 except the soils from Pokharni and Basmat. pH in command area ranged from 7.90 to 8.42 with an average value of 8.18. Highest soil pH was recorded in Aherwadi sample followed by Alegaon and Aral.

Table 12. Soil properties as influenced by long term canal irrigation in Purna command area

Name of the village	pH	EC dsm^{-1}	Free $CaCO_3$ %	Organic C %	Available $Kgha^{-1}$		
					N	P_2O_5	K_2O
Kathneswar	8.08	1.42	8.5	1.05	297	47.3	420
Yerandeswar	8.22	1.17	9.7	1.10	200	47.3	380
Hatta	8.16	1.85	7.5	1.32	191	47.6	480
Chikhali	8.12	1.56	7.5	1.66	225	44.4	394
Tuljapurwadi	8.26	0.99	10.0	1.28	220	42.5	483
Aral	8.29	1.31	8.4	0.98	222	50.2	450
Balegaon	8.05	0.99	11.5	1.32	219	65.9	437
Telgaon	8.20	0.88	6.0	1.68	220	44.5	445
Aherwadi	8.42	0.99	19.0	0.57	225	48.3	337
Mategaon	8.20	0.71	7.5	1.00	197	53.5	224
Ridhora	8.18	1.84	9.5	1.22	210	45.1	490
Chudawa	8.22	0.78	2.7	1.22	190	44.5	355
Pimpla	8.15	1.27	3.0	0.35	229	41.9	349
Pokharni	7.92	0.78	7.5	1.02	200	14.2	350
Ganeshpur	8.05	1.56	12.5	1.40	329	47.3	429
Basmat	7.90	1.34	2.5	1.31	190	59.8	380
Kanhargaon	8.19	1.34	6.0	1.00	215	44.0	358
Kamtha	8.20	0.95	12.5	1.24	203	45.8	360
Malegaon	8.11	1.34	9.0	1.20	220	45.3	400
Kasarkheda	8.20	0.88	7.5	1.31	222	48.3	387
Nandgaon	8.25	1.31	8.4	0.87	200	46.3	400
Pimpalgaon	8.30	1.27	9.0	0.95	225	47.3	350
Ajarsonda	8.25	0.78	1.5	0.94	232	43.4	394
Purna	8.28	0.78	10.2	0.63	210	50.6	350
Alegaon	8.31	0.94	9.2	0.97	230	53.8	450
Average values	8.18	1.15	8.2	1.10	220	46.7	394

4.7.2 Electrical conductivity

The electrical conductivity in soils of command area varied from 0.71 to 1.84 dsm^{-1} with an average value of 1.15 dsm^{-1}. The soils of Ridhora showed highest salinity followed by Chikhali and Ganeshpur where as the lowest salinity was recorded in the soils of Mategaon followed by the soil from Chudawa, Ajarsonda and Purna which were equal in salinity status.

4.7.3 Free calcium carbonate

Most of the soils in command area contained free $CaCO_3$ more than 5 per cent, only soils of Chudawa, Pimpla, Basmat and Ajarsonda were found to contain low calcium carbonate (< 5 per cent).

4.7.4 Organic carbon

Soils in general were high in organic carbon content (> 0.75 per cent). However, the soils from Aherwadi and Purna were medium in organic carbon and only one sample from Pimpla was rated as low in organic carbon (0.35 per cent).

4.7.5 Available nitrogen

The availability of nitrogen in the soils of Purna command varied from 190.0 to 329.2 $kgha^{-1}$

with a mean value of 220.9 kgha^{-1} . The soils of Kathneswar and Ganeshpur were medium in nitrogen.

4.7.6 Available P_2O_5

The range of available P_2O_5 in soils of command area was between 14.21 to 65.94 with a mean value of 46.79 kg P_2O_5 ha^{-1}. The soils value of Balegaon recorded highest available P_2O_5 followed by Basmat and Alegaon. Availability of P was lowest in the soils of Pokharni.

4.7.7 Available K_2O

Potassium availability in soils of command area varied from 224 to 490 kg K_2O ha^{-1} in the soils of Mategaon and Ridhora respectively. The average value of potassium availability in command area was 394 kg K_2O ha^{-1}.

4.7.8 Fertility classification of soils from Purna command

The soils from Purna command were classified in to different fertility classes based on availability of N, P, K (Table 13).

All the soils were rated as low in nitrogen except Kathneswar and Ganeshpur which were medium in

Table 13. Fertility classification of soils from Purna command area

Name of the village	Fertility class		
	Available N	Available P	Available K
Kathneswar	medium	medium	high
Yerandeswar	low	medium	high
Hatta	low	medium	high
Chikhali	low	medium	high
Tuljapurwadi	low	medium	high
Aral	low	high	high
Balegaon	low	high	high
Telgaon	low	medium	high
Aherwadi	low	medium	high
Mategaon	low	high	medium
Kidhora	low	medium	high
Chudawa	low	medium	high
Pimpla	low	medium	high
Pokharni	low	medium	high
Ganeshpur	medium	medium	high
Basmat	low	high	high
Kanhergaon	low	medium	high
Kamtha	low	medium	high
Malegaon	low	medium	high
Kasarkheda	low	medium	high
Nandgaon	low	medium	high
Pimpalgaon	low	medium	high
Ajarsonda	low	medium	high
Purna	low	high	high
Alegaon	low	high	high

available nitrogen. Availability of phosphorus was medium to high in soils of the command area. Almost all the soils were rated as high in available potassium except the soil from Mategaon which was medium in available potassium.

4.8 Soil properties and fertility in Purna uncommand area

The soils of uncommand area were analysed for pH, EC, free $CaCO_3$, organic carbon and available N, P, K and the results are predicted in Table 14.

4.8.1 Soil pH

The soils from Karanjala recorded highest pH value (8.32) followed by Thorav (8.25). The soil from Bori village had minimum pH (7.80).

4.8.2 Electrical conductivity

The electrical conductivity in soils varied from 0.56 to 1.50 dsm^{-1} with a mean value of 0.94 dsm^{-1} Lingi soil showed highest electrical conductivity followed by Gour.

Table 14. Soil properties of Purna uncommand area

Name of the village	pH	EC dsm^{-1}	Free $CaCO_3$ %	Organic C %	Available Kg ha^{-1}		
					N	P_2O_5	K_2O
Ekruka	8.25	0.92	12.5	0.62	220	47.6	383
Sathephal	8.15	0.92	12.0	0.60	200	33.4	320
Lingi	7.83	1.50	17.5	0.50	190	44.1	418
Hayatnagar	8.02	0.94	16.0	0.52	160	47.3	398
Gour	8.21	1.17	12.0	0.56	260	47.3	400
Limbagaon	8.00	1.02	10.0	0.51	203	35.0	350
Thorav	8.26	0.90	13.0	0.80	185	45.3	420
Pangra	8.02	1.02	5.0	0.51	210	51.9	350
Palasgaon	8.05	1.00	9.0	0.41	192	35.0	410
Gir gaon	8.21	0.90	6.5	0.57	198	55.2	286
Degaon	8.20	0.94	5.5	0.61	185	44.5	304
Dhonora	8.04	0.93	7.5	0.65	180	37.9	350
Adgaon	8.19	0.78	7.5	0.54	220	40.0	374
Bori	7.80	1.15	2.5	0.90	370	44.0	470
Gunda	8.10	1.00	10.0	0.47	175	41.2	207
Karanjala	8.32	0.71	2.3	0.45	166	32.9	455
Jawalabazar	7.90	1.06	5.0	0.40	190	56.4	372
Revalgaon	8.13	0.96	11.0	0.51	185	41.2	355
Sonkhed	7.90	0.84	12.5	0.50	165	42.3	420
Hivara	8.10	0.97	3.0	0.60	160	46.9	380
Dhotra	8.04	0.99	8.0	0.52	175	55.2	325
Regaon	8.16	0.78	13.0	0.42	200	35.0	345
Wakhari	8.05	0.94	12.0	0.48	210	50.6	370
Sayal	8.24	0.90	14.0	0.45	220	49.5	220
Warkhed	8.04	0.56	8.5	0.45	195	44.8	365
Average values	8.08	0.95	9.4	0.54	200	44.2	361

4.8.3 Free $CaCO_3$

The free $CaCO_3$ content in general was high (>5 per cent) in soils from uncommand area. However, soils from Bori, Karanjala and Hivara recorded $CaCO_3$ < 5 per cent. The average value of $CaCO_3$ for twenty five samples in uncommand area was 9.40.

4.8.4 Organic carbon

Most of the soil samples in uncommand area were medium in organic carbon content. It ranged from 0.41 to 0.90 per cent with a mean value of 0.54 per cent.

4.8.5 Available nitrogen

The soils of uncommand area ranged between 160 to 370 kg N ha^{-1} in Hayatnagar and Bori soils respectively. The average value of available N in uncommand area was 200 kg ha^{-1}.

4.8.6 Available P_2O_5

Most of the soils in uncommand area were grouped in medium category of available phosphorus. It varied from 33.41 to 56.46 kg P_2O_5 ha^{-1}. The average P_2O_5 content in uncommand area was 44.2 kg ha^{-1}.

4.8.7 Available K_2O

Potassium availability was in the range of 207 to 470 kg K_2O ha^{-1} with a mean value of 361 kg in Purna uncommand area. Most of the soils were medium in potassium availability.

4.8.8 Fertility classification of soils, from uncommand area

On the basis of available N, P, K, soils were grouped as low, medium and high with regard to nutrient availability (Table 15). The availability of N was low in all the soils except Gour and Bori which were medium in available N. The availability of phosphorus in uncommand area was medium to high. The soils from Pangra, Girgaon, Jawalabazar, Dhotra, Wakhari were high in available phosphorus and rest of the spils were medium in available phosphorus. Similarly, potassium availability in uncommand soils was medium to high with large number of sample in high category except Girgaon, Gunda and Sayal which were rated in medium category with respect to availabee potassium.

Table 15. Fertility classification of soils from Purna uncommand

Sr. No.	Name of the village	Fertility class		
		Available N	Available P	Available K
1.	Ekruka	low	medium	high
2.	Sathephal	low	medium	high
3.	Lingi	low	medium	high
4.	Hayatnagar	low	medium	high
5.	Gour	medium	medium	high
6.	Limbagaon	low	medium	high
7.	Thorav	low	medium	high
8.	Pangra	low	high	high
9.	Palasgaon	low	medium	high
10.	Gir gaon	low	high	medium
11.	Degaon	low	medium	high
12.	Dhanora	low	medium	high
13.	Adgaon	low	medium	high
14.	Bori	medium	medium	high
15.	Gunda	low	medium	medium
16.	Karanjala	low	medium	high
17.	Jawalbazar	low	high	high
18.	Revalgaon	low	medium	high
19.	Sonkhed	low	medium	high
20.	Hivara	low	medium	high
21.	Dhotra	low	high	high
22.	Regaon	low	medium	high
23.	Wakhari	low	high	high
24.	Sayal	low	medium	medium
25.	Warkhed	low	medium	high

5. DISCUSSION

5. DISCUSSION

5.1 Groundwater quality in Purna command and uncommand area

The water samples collected from twenty five locations each from command and uncommand under Purna project were analysed for different characteristics. The chemical composition of water from command and uncommand area was compared and depicted in Fig.3 and 4. The long term use of canal water for irrigation had influenced all the water characteristics. pH varied from 7.45 to 8.95 in command area and 7.75 to 8.50 in uncommand area. All the samples in command and uncommand were neutral to slightly alkaline in reaction. An average pH was higher (8.36) in command area as compared to uncommand area (8.07). These results corroborate with observations of Ramaswami et al.(1975) who found that most of water samples from Salem district have neutral to mildly alkaline reaction. Further, More et al (1988) also made similar observations on groundwaters from Purna command area. Similarly, there was wide

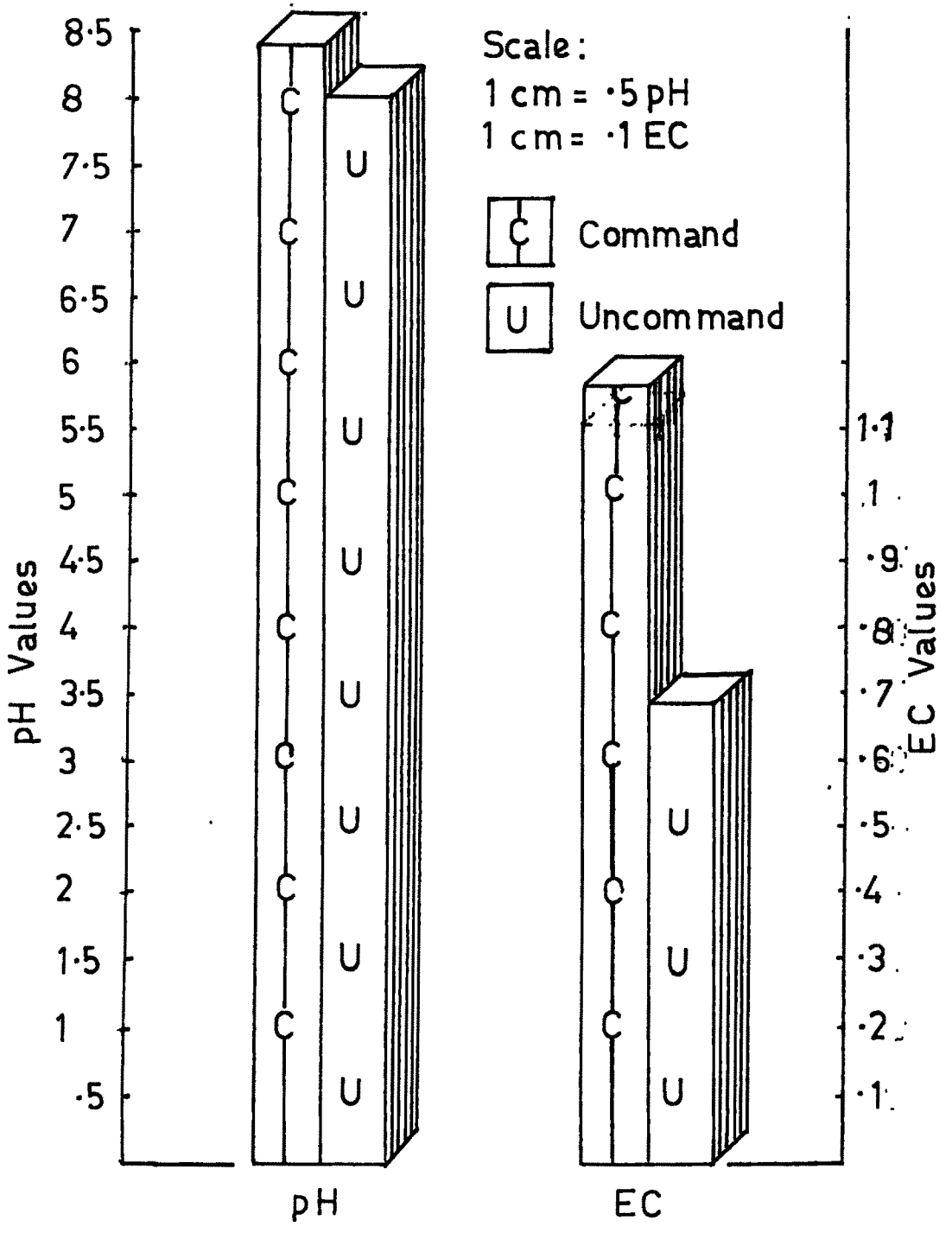

Fig. 3. pH AND EC VALUES OF GROUNDWATERS OF COMMAND AND UNCOMMAND AREA

variation in electrical conductivity of water (0.568 to 3.195 dsm^{-1}) in command area as compared to that in uncommand area (0.497 to 1.633 dsm^{-1}). Average values of electrical conductivity (1.165) were high in command area than uncommand area (0.669 dsm^{-1}).

Patil et al.(1992) on his three years project to study the effect of Mula canal seepage on groundwater quality recorded that EC of ground water near the canal increased from 1.0 to 2.06 dsm^{-1} indicating the salt accumulation at the surface.

Somawanshi and Patil (1986) also observed the increase in the salinity of groundwater after introduction of canal in the area. Location of canal at higher topography, basin type, shape of irrigated area and seepage are the main causes of salinization.

The critical observation on ionic composition of groundwaters from Purna command and uncommand area lead the conclusion that canal irrigation had positive influence on accumulation of ions in groundwater. All the anions as well as cations were reported to be high in groundwaters from command area. The average carbonate, bicarbonate

chlorides and sulphates in command and uncommand groundwaters were 3.20 and 2.72, 3.53 and 3.28 3.86 and 3.54, 2.54 and 1.80 mel^{-1} respectively. Similarly, cationic concentration was also relatively higher in groundwaters of command area. The average cationic composition of command and uncommand groundwaters with respect to Ca, Mg, Na, K were 4.25 and 4.15, 5.48 and 4.39, 5.23 and 4.30 and 0.60 and 0.52 mel^{-1} respectively. The sequence of anions in groundwaters of command was chlorides > bicarbonates > carbonates > sulphates, same sequence of anions was also observed in groundwaters of uncommand area. Sodium was dominant cation followed by Magnesium in command area water, whereas Magnesium was dominant cation followed by sodium and calcium in the groundwaters of uncommand area, Potassium concentration was low in both the types of water.

More et al.(1988) studied groundwater quality under Purna command area as influenced by long term canal irrigation and envisaged that ionic composition in groundwaters, they observed the order of different anions in irrigation water as $HCO_3 > Cl > So_4 > Co_3$. The reports of

Paliwal et al.(1975) on the quality of waters of fourteen districts of Rajastan were in agreement with these results. The waters were Na - Mg - Ca type. Gupta (1979) reported that sodium is the most predominant cation followed by magnesium in ground water. Magnesium is higher than calcium. Bicarbonate is dominant in low salinity waters and chloride become predominant anion.

5.2 Classification of groundwater in command and uncommand area

The quality parameters were determined on the basis of chemical composition from command and uncommand area. These parameters further used to decide the suitability classes of water for irrigation. The comparision of SAR, RSC and Boron content in groundwaters of command and uncommand area was made with the help of diagram (Fig 4).

In general the values of water quality parameters were high in command area. The average values of SAR, adjusted SAR, RSC, SSP and Boron in command and uncommand were 2.59 and 2.15, 6.31 and 5.15, -2.97 and -2.56 mel^{-1}, 35.18 and 34.02 and 0.93 and 0.83 ppm respectively.

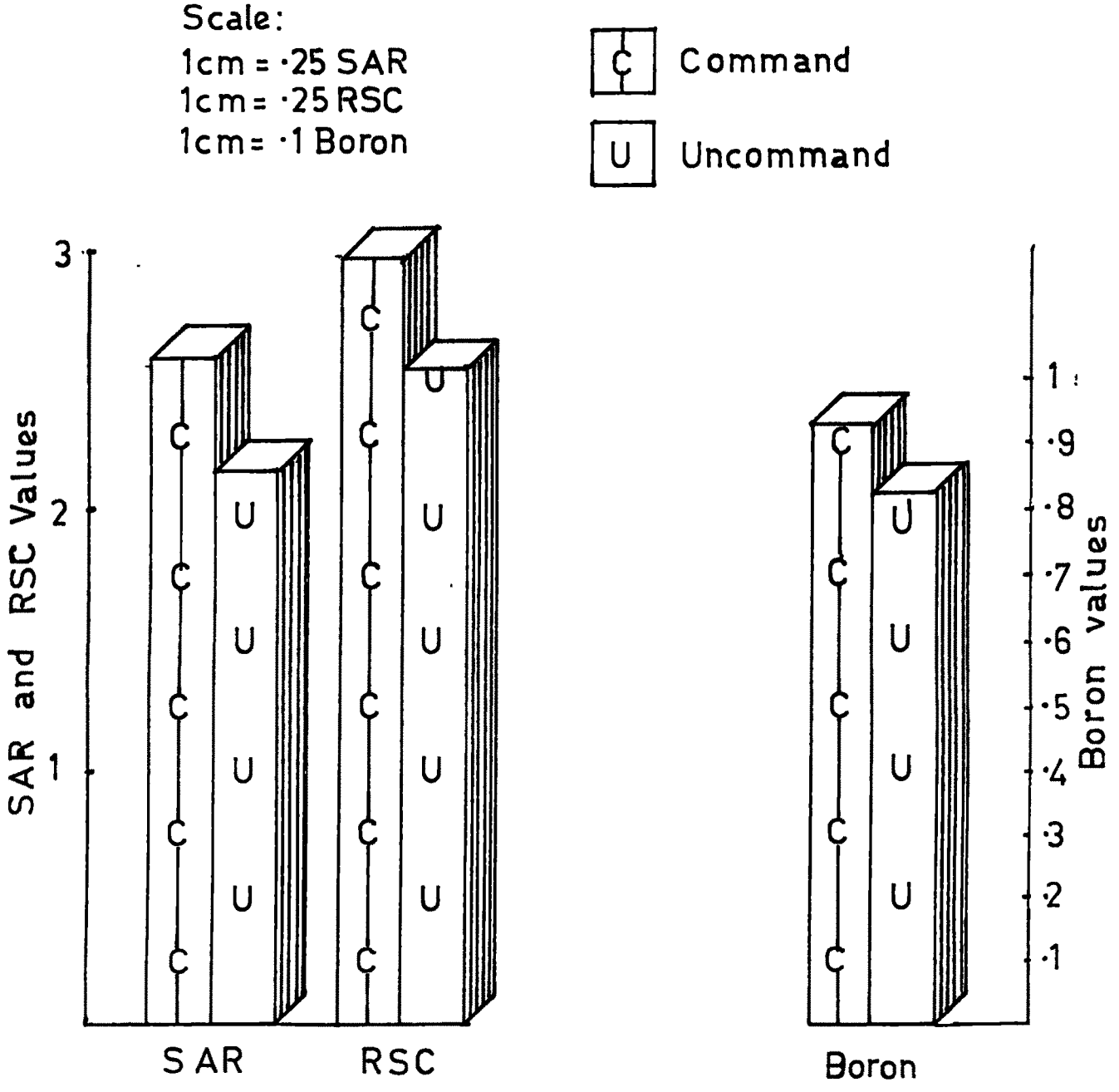

Fig.4. SAR, RSC AND BORON VALUES OF GROUNDWATERS FROM PURNA COMMAND AND UNCOMMAND AREAS.

These waters were further classified on the basis of salinity and sodicity (USDA classification). Large number of samples were found in C_2S_1 class (medium salinity low sodium) from uncommand area. Whereas, most of the waters from command area were grouped in C_3S_1 class (high salinity low sodium). It was obvious that irrigation waters from command area were slightly saline as per the classification proposed by USDA. As per this classification 60 per cent water samples in command area and 8 per cent in uncommand waters were high in salinity posing the problems of soil salinization. However, experiences proved much the contrary in India, it was recently realised that this system of classification served very little purpose, because in arid regions of Rajastan, Haryana, Gujrat, UttarpPradesh ground waters with high salinity (EC 5-10 dsm^{-1}) have been used since decade on light to medium textured soil (Gupta, 1979).

The residual sodium carbonate was used for appraising the quality of irrigation water in terms of bicarbonate, most of the waters both in uncommand as well as command were safe water with RSC value < 1.25 mel^{-1}. About 88 per cent water samples in command and 96 per cent samples in uncommand were rated

as good quality water with respect to RSC values. Only one sample was marginal in RSC from uncommand area. In command area 4 per cent samples were marginal and 8 per cent samples were unsuitable for irrigation.

These waters were further classified on the basis of alkalinity hazard, boron and electrical conductivity called as ABC classification. In command area 84 per cent of groundwaters were rated as normal waters and 16 per cent as low sodium waters, whereas in uncomand area almost all waters rated as normal waters. Normal waters can be used for irrigation on almost all soils with little possibility of the development harmful level of exchangeable sodium and harmful effect on semi tolerant or tolerant crop. Low sodium waters from command area could be used for irrigation on light and medium textured soils without any problem. On heavy textured soils if well drained but may present problem in deep black soils and alluvial soil with clay greater than 30 per cent.

There was no problem of boron hazard in any of waters from both command and uncommand area, all the waters were rated as normal water with respect

to boron content. These waters with normal boron could be used in all soils without any injurious effect. In command area 80 per cent water samples were rated as normal waters, 16 per cent as low salinity waters and 4 per cent as medium salinity waters. In uncommand area 96 per cent of the waters were normal and 4 per cent low salinity waters. Normal waters can be used for irrigation to all the crops on most soils with little possibility of any problem. The low salinity water can be used for irrigation for growing most of the crop on light and medium textured soils, but on heavy textured and deep black soils only semi tolerant crops could be grown well, if soils have moderately good drainage. These results are in agreement with the results of Krishnamoorthy et al. (1978) who reported that all the wells in Krishnagiri reservior project area excepting one well had low sodium hazard of 10. Residual sodium carbonate ranged from 0.99 to 10.59 with the mean RSC value of 3.57 mel^{-1}.

In contrast to this, Patil et al.(1982) reported deterioration of groundwater in command area as evidenced by high EC and SAR values. But the observations of More et al.(1988) further

confirmed the results in this study, who observed that all well waters in Purna command were of good quality based on SAR values of water. The waters were also found to be in safe limit based on soluble sodium percentage except the water from Pawde wadi.

5.3 Soil characteristics in command and Uncommand area

The characteristics of soils as influenced by canal irrigation in command area were compared with soil characteristics in uncommand area (Fig. 5 & 6)

The average values of pH, EC, free $CaCO_3$, organic carbon, available N, available P_2O_5 and available K_2O in command and uncommand area were 8.18 and 8.08, 1.15 and 0.95 dsm^{-1}, 8.2 and 9.4 per cent, 1.10 and 0.54 per cent, 220 and 200 kg ha^{-1}, 46.79 and 44.20 kg ha^{-1} and 394 and 361 kg ha^{-1} respectively. pH and EC were reported to be high in command area whereas $CaCO_3$ was found to be higher in uncommand area. The higher values of pH and EC in command area were due to long term use of irrigation water resulting in accumulation of salts. These results corroborate with the reports of Singh et al.(1970) who recorded that

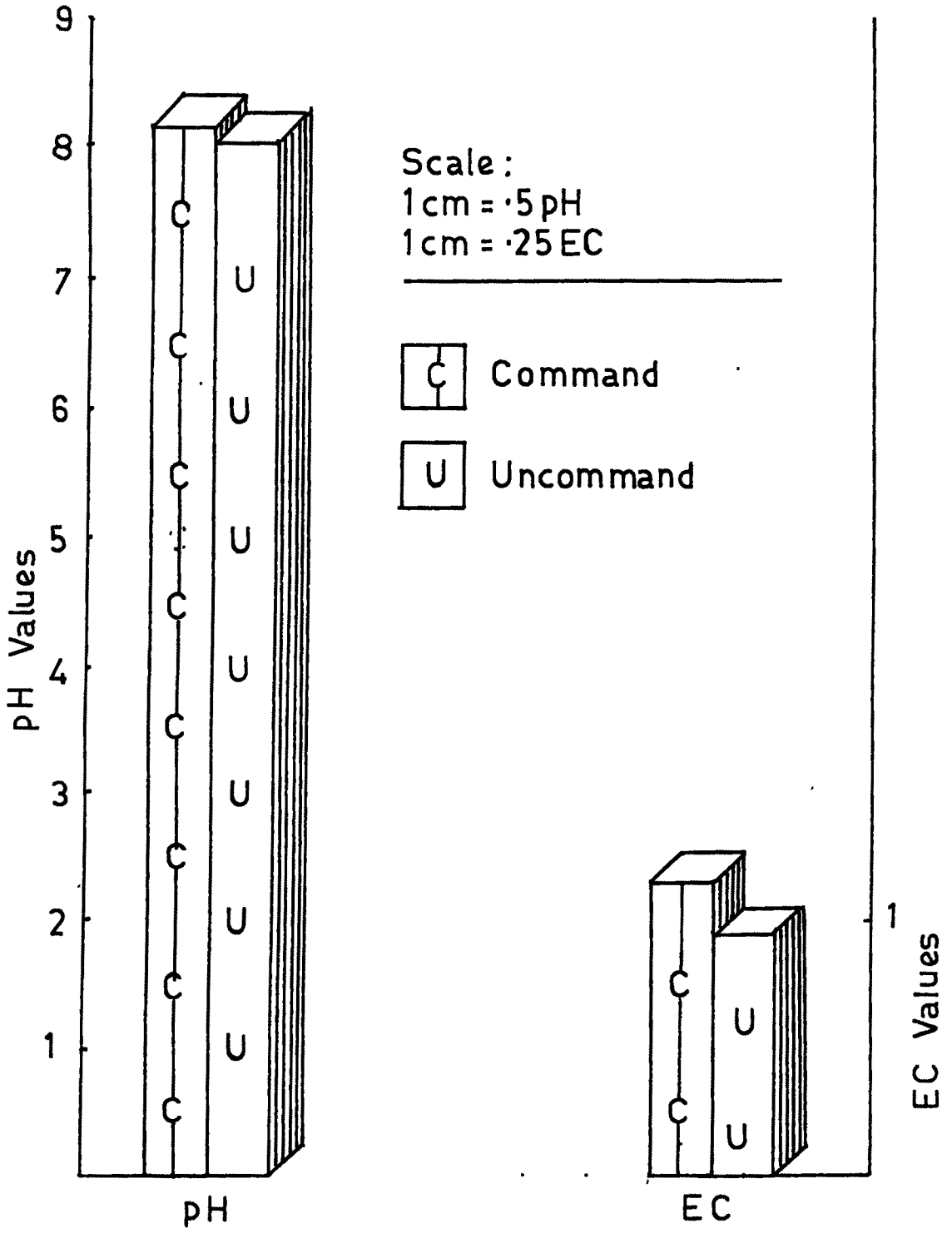

Fig.5. pH AND EC VALUES OF SOILS FROM PURNA COMMAND AND UNCOMMAND AREAS.

$CaCO_3$, pH , ESP, SAR and SSP of saturation extract were found to be higher in irrigated soils as compared to unirrigated ones.

Katti and Rao (1979) condluded that the development of salinity and alkalinity in the soils of Challaprabha left bank area was attributed to seepage of water from upland, unlined irrigation canal and consequent water logging.

Jadhav et al.(1979) studied physico-chemical properities of Jayakwadi command area and found soil pH alkaline ranging from 7.5 to 8.9 and $CaCO_3$ from 2.0 to 18.5 per cent.

Further Bharambe et al.(1984) pointed out that pH of soils from Paithan, Ambad, Georai, Majalgaon villages under Jayakwadi command were tending to alkaline condition. There are several reports of increasing soil salinity and alkalinity due to introduction of canal irrigation (Somawanshi and Patil, 1986; Abha Lakshami Singh and Hasmi, 1987; More et al.,1987 and Bharambe et al., 1990).

Further the soil fertility was little rich in command area as compared to uncommand soils. High

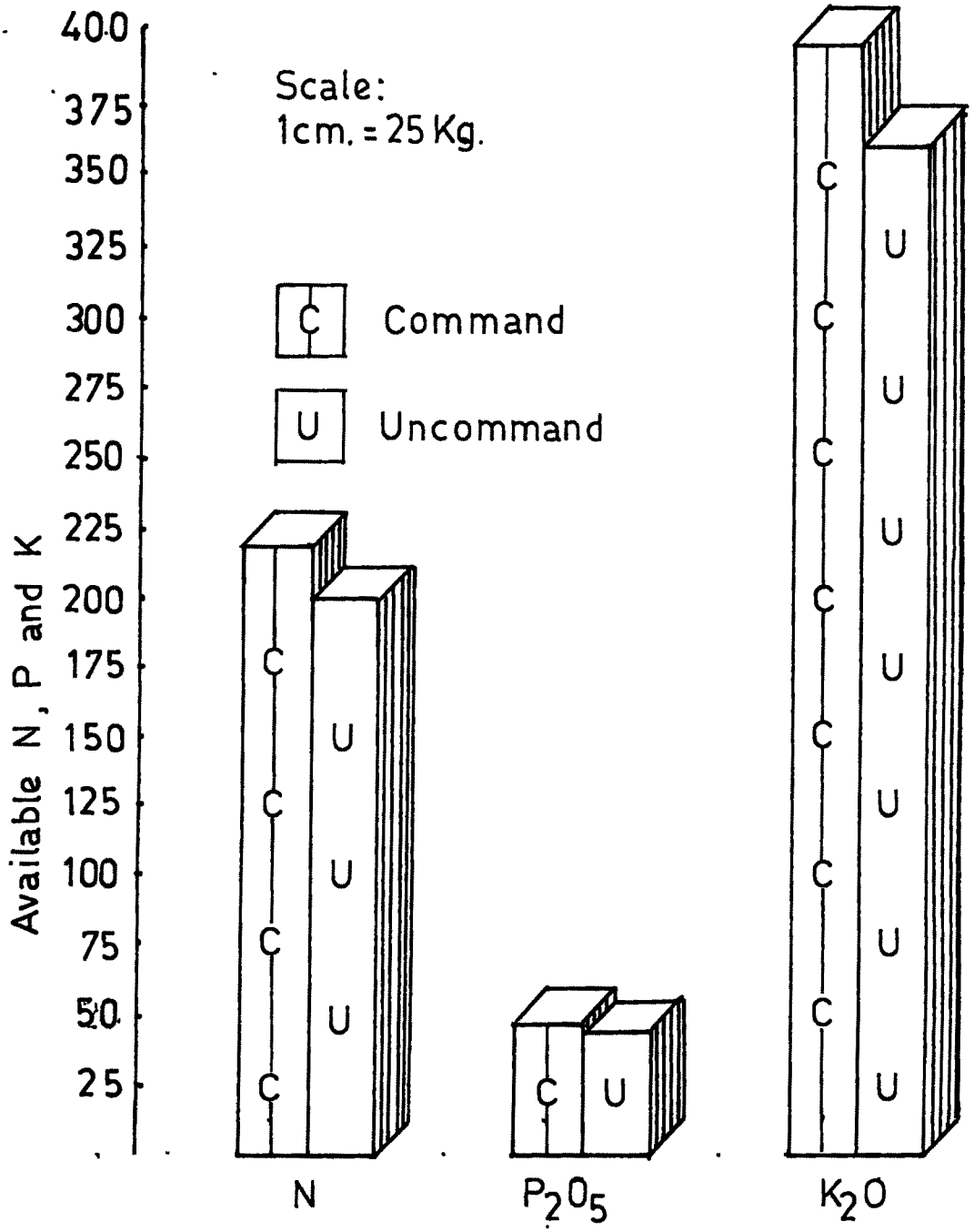

Fig.6. AVAILABLE N, P AND K VALUES OF SOILS FROM PURNA COMMAND AND UNCOMMAND AREAS.

organic carbon content in command area was found due to regular application of fertilizers along with irrigation resulting in more bio-mass prpduction of crop leading to their positive residual effect on soil organic matter.

Availability of nitrogen was low in 92 per cent soils in command and uncommand areas. Eight per cent soils were rated as medium in nitrogen incommand and uncommand.

Phosphorus availability was medium (76 % soils) to high (24 % soils) in command area and medium (80 % soils) and high (20 % soils) in uncommand area.

Available potassium was medium to the extent of 12 per cent soils and high in 88 per cent soils in uncommand area and 98 per cent soils were high in command area.

Low nitrdgen availability in command area have been recorded by several workers (Gawande et al., 1979; Bhaskaran et al., 1976).

In agreement with these results Bharambe and Ghonsikar (1985) recorded medium phosphorus and high potassium in soils of Jayakwadi command area. Whereas, Bhaskaran et al. (1986) recorded low to medium available phosphorus and medium to high available potassium in Krishnagiri reservior command area.

6. SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

Groundwater is one of the main source of irrigation, quality of which is affected due to climate, hydrological conditions soil type and irrigation status. The irrigation in Purna project has commenced in 1964 and intensive cultivation is practiced with more irrigation management for last 25 years in this command. The groundwater was raised due to excess use of irrigation water, seepage from canals and existence of non drainable soil posing the problem of waterlogging and salinity. Further the farmers in Purna command regularly using percolation waters from canal for irrigation without knowing chemical composition and suitability for irrigation. Therefore, present investigation was conducted to know the effect of long term use of canal irrigation on groundwater quality in Purna command . Further the groundwater quality in uncommand area was compared with that of command area. It was also aimed to know the effect of canal irrigation on soil characteristics and fertility status in command area. These characteristics were compared with the soil propoerties of uncommand area.

For this, twenty five water samples were collected each from various villages of command and uncommand area in Purna project. The samples were analysed for pH, EC, anions as $Co_3^{=}$, HCO_3^{-}, Cl^{-}, $SO_4^{=}$ and cations as Ca^{++}, Mg^{++}, Na^{+} K^{+}. The water quality parameters as SAR, RSC, SSP, Boron were calculated. The soils samples were also collected from different villages in command and uncommand area and were subjected to analysis for pH, EC, free $CaCO_3$, organic carbon, available N, P, K. The results are summarized as below.

The highest and lowest pH in waters of command and uncommand waters were 8.95 and 8.50 7.45 and 7.75 respectively and average pH values of command and uncommand were 8.4 and 8.07 respectively.

The highest and lowest EC in waters of command and uncommand were 3.195 and 1.633 dsm^{-1}, 0.568 and 0.497 respectively, and average EC of command was 1.165 dsm^{-1} and uncommand was 0.699 dsm^{-1}.

The highest carbonates in command area water was 4.8 mel^{-1} and lowest was 1.6 mel^{-1}. In uncommand area highest and lowest carbonates were 4.8 and 1.6 mel^{-1} respectively. The average carbonates in command and uncommand were 3.20 and 2.72 respectively.

The maximum and minimum HCO_3^- in command area were 6.0 and 1.20 mel^{-1} and in uncommand area these values were 5.2 and 0.8 mel^{-1} respectively. The average HCO_3^- in command and uncommand area were 3.53 and 3.28 mel^{-1} respectively.

Chlorides range in uncommand area waters were 2.0 to 5.2 mel^{-1} and incase of command area the range was 1.80 to 9.60 mel^{-1}. The mean value of chlorides in uncommand and command area waters were 3.5 and 2.54 mel^{-1} respectively.

Sulphates content in command area water varied from 0.59 to 6.40 mel^{-1}, whereas in case of uncommand area these values had the range of 0.98 to 3.00 mel^{-1}. Average of sulphates in command and uncommand were 2.54 and 1.80 mel^{-1} respectively.

Calcium cationi c values of command area were in the range of 2.0 to 6.30 mel^{-1}. While in uncommand area, these values were ranging from 1.00 to 8.00 mel^{-1} and the average calcium content in groundwaters of command and uncommand were 4.25 and 4.14 mel^{-1} respectively.

Magnesium content in groundwaters of command and uncommand area were 2.30 to 14.00 and 1.11 to 7.30 mel^{-1} with an average value of 5.48 and 4.39 mel^{-1} respectively.

Sodium content in waters of Purna command area were varied from 1.40 to 15.00 mel^{-1} whereas in uncommand area these values were in the range of 1.60 to 7.80 mel^{-1} with mean value of 5.73 in case of command and 4.30 mel^{-1} in uncommand area.

Command area waters had potassium range of 0.27 to 1.00 mel^{-1} with an average value of 0.60 mel^{-1} and potassium range in uncommand area was 0.22 to 0.84 with an average value of 0.52 mel^{-1}.

Highest and lowest SAR values of command area waters were ranged from 0.74 to 6.03 with an average of 3.5. Groundwaters of uncommand area had the SAR values varied from 0.69 to 3.12 with a mean value of 2.14.

Adjusted SAR values of groundwaters from command and uncommand area had the range of 1.77 to 15.67 and 1.72 to 8.42 having the mean value of 6.31 and 5.15 respectively.

The maximum SSP of command and uncommand waters were 56.45 and 46.87 while minimum values were 16.66 to 18.11. The average SSP of command area waters was 35.18 and in uncommand area it was 34.02.

RSC values of command area and uncommand area waters varied from -12.20 to 3.00 and -8.10 to 2.10 respectively. The average RSC values of command and uncommand area waters were -2.96 and -2.56 respectively.

Boron content of command area groundwaters was in the range of 0.60 to 1.95 ppm whereas these values were 0.46 to 1.25 ppm in case of groundwater from uncommand area. The average Boron content in waters from command area was 0.93 and 0.83 ppm in case of waters from uncommand area.

Soil pH varied from 7.90 to 8.42 in case of command area soils. In case of uncommand it was from 7.80 to 8.32. Average soil pH of command soils was 8.18 and for uncommand soils it was 8.08.

Highest EC values for command and uncommand area were 1.84 and 1.50 dsm^{-1} and lowest values were 0.71 and 0.56 with average values of 1.15 and 0.95 dsm^{-1} respectively.

Free calcium carbonate range in command area soils was 1.5 to 19.00 whereas in case of uncommand area it was ranged from 2.5 to 17.5 per cent. The mean values of calcium carbonate in soils of command and uncommand area soils were 8.2 and 9.4 per cent respectively.

Organic carbon content varied from 0.35 to 1.77 and 0.41 to 0.90 per cent in the soils of command and uncommand area respectively. The mean values of organic carbon in command and uncommand area were 1.10 and 0.54 per cent respectively.

Available nitrogen content of Purna command soils was varied from 190.0 to 329.2 kg per ha. Whereas in case of uncommand soils it was ranged from 160 to 370 kg per ha. The average available nitrogen content in soils of command and uncommand area was 220 and 200 kg per ha.

The maximum and minimum available phosphorus in soils of Purna command were 14.21 to 65.94 with a mean value of 46.79 kg per ha. Whereas available phosphorus was ranged 33.41 to 56.46 kg per ha. with an average of 44.2 kg per ha in soils of uncommand area.

The range of available potassium in Purna command area soils was 224 to 490 kg per ha with a mean value of 394 kg ha. Whereas this range was 207 to 470 kg per ha. in soils of uncommand area having the mean value of 361 kg per ha.

The present investigation lead to envisage the following conclusions.

The long term use of irrigation water in Purna command area th ough affected groundwater. quality with respect to pH, EC, anions and cations, These characteristics were found to be in normal and safe range. PH of water was neutral to slightly alkaline in reaction. 96 per cent of the ground waters were safe and suitable for irrigation with respect to salinity and could be used for irrigation on most soil for all crops without the possibility of any problem.

In command area, 84 per cent of groundwaters were rated as normal waters which can safely used for all crops on all soils without creating any problem. All the waters were normal with respect to boron. The groundwaters from Purna command area was also found to be in safe limit based on soluble sodium percentage. On the basis of RSC value, 88 per cent samples in command area were of good quality and can be safely used for irrigation.

The canal irrigation in Purna command although resulted in higher values of pH, EC, as

compared to soils in uncommand area. The problem was not severe in the samples surveyed. The fertility constituents as organic carbon, available N, P and K were found to be rich in soils of command as compared to uncommand soils.

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* Originals not seen.