WATER QUALITY AND ITS GEOCHEMICAL ASSESSMENT

INTRODUCTION

The quality of water is as significant as its quantity. But it is never found in a pure state. As water comes from the atmosphere it is contaminated with atmospheric carbon-di-oxide and falls on the ground in the form of unstable weak carbonic acid and it acts as a powerful corrosive agent. It reacts with surface geometerial and aquires certain characteristics before percolating into the ground. However, during percolation into the ground its chemical properties may change from its place of entry to the point of exit. Where it accumulates in the form of reservoir, the chemical character of the water provides striking evidence of physico-chemical processes under different reservoir conditions (Trainer, 1981). Natural quality of water depends upon its interaction with rocks and various geometrical reaction taking place within the lithological frame work (Drever, 1982). Water quality varies in its concentrations of dissolve substances depending upon the hydro-chemical conditions of the area and according to seasons (Kale, et al 1993). The usability of water available is generally exposed in terms of its chemical, physical and bacteriological properties. A programme of study of the quality of water envisages field observations regarding the source and environment of water occurrence, sources of pollution and other related aspects having a bearing on the quality of water (Karanth, 1990).

Geochemical assessment are also of value with respect to water use. They provide a better understanding of possible changes in quality as development progresses which can turn provide information about the limits of total development, or can permit planning for appropriate treatment that may be required as the result of future changes in the quality of water supply. Analysis of water samples for geochemical assessments require a high degree of accuracy. The chemical characteristics of water are very important with respect to requirements for various uses. Temperature measurements are usually made in groundwater assessment. These are particularly important in places where wide variations in the temperature are recorded. Temperature results may lead to the discovery of an unsuspected source of pollution.

7.1 SAMPLING METHOD

Under the chemical sampling programme of sub-surface water for analysis of its quality, the water samples from different sources at different depths have been collected from the entire Terai area of Darjiling district. 88 samples for entire area from dug wells have been taken in order to have an idea of salt as well as Iron content and their extension with time and space. 8 shallow tube wells and 4 deep tubewells samples were collected from the exploratory bore holes. Surface water has been collected from the 6 major rivers of the study area. After rinsing the bottle with the water being sampled, it is then collected and securely corked. The water was stored in a cool place and transferred promptly to a laboratory for detail analysis. With each sample a record was made regarding location, depth of sample, size of casing, date, water temperature, odour, colour, turbidity and operating condition of the well immediately prior to the sampling. The water samples had been collected in November '97, '98 and April '98, '99 to know its pre and post monsoon chemical composition.

7.2 ANALYSIS AND MEASURES OF WATER QUALITY

The quality characteristics of water sample in details, a complete statement requires chemical, physical, sanitary, bacterial and biological analysis. But in case of groundwater samples, the chemical, physical and bacterial analyses are most important and the others being pertinent only for unusual situations of local condition.

The chemical analysis of a water sample includes the determination of the concentrations of all of the inorganic constituents present. Dissolved salts in groundwater occur as dissociated ions; in addition, other minor constituents are present and reported in elemental form only. Properties of a water sample evaluated in a physical analysis include temperature, colour, turbidity, odour and taste. Bacteriological analysis consists of tests to measure the presence of coliform organisms, which indicate the sanitary quality of water for known consumption.

7.3 CHEMICAL ANALYSIS

Chemical analysis forms the basis of interpretations of the quality of water in relation to source, geology, climate and use. Water being an excellent solvent, it is important to know the geochemistry of the dissolved solid constituents and methods of reporting analytical data. The collected water samples both surface and groundwater were analyzed for complete and partial analysis in the Regional Chemical and Hydrological Laboratory-IV, State Water Investigation Directorate (SWID), Jalpaiguri, West Bengal, India. Amongst the many chemical properties pH, T.D.S., E.C., total hardness, cationic constituents like Ca, Mg, Na, K, Fe and anaionic constituents like CO_3, HCO_3, Cl, SO_4, NO_3, F, As etc. have been studied, followed the standard procedure (Brown et al., 1974; Hem, 1989). The result of the chemical analysis of water samples from rivers, dug wells and tube well have been shown in Appendices–IV, V & VI. In a chemical analysis of groundwater, as well as surface water, concentrations of different ions are expressed by weight or by chemical equivalence. Total dissolved solids has been measured in terms of electrical conductivity. These and other measures of chemical quality are described in the following sections.

7.4 CHEMICAL QUALITY OF SURFACE WATER

The chemical quality of surface water has been assessed from an analysis of water samples collected, one each, from the river Mahananda near Air View More, Panchanai near Darjiling More, Balason near CWC Office, Buri Balason near West Bengal Forest Check-Post, Bagdogra, Chenga near Trihana Tea Garden and the Mechi near roadways bridge, in the last week of November, 1998. The results of the chemical analysis of different parameters thus obtained and are presented in Appendix-IV.

The water samples have calcium as the main cation and bicarbonate as the main anion or acid constituent. The pH value of river waters ranges between 6.9 to 7.2 which show that they are slightly acidic to alkaline in nature. The suitability of water samples for drinking purposes, it becomes obvious from a comparison of Appendix-IV and Tables 7.2 that pH and Total dissolved solids (TDS) are within permissible limits. In all of the six samples analyzed, total hardness is above 100 ppm but it is within permissible limits for the drinking purposes. Other chemical constituents such as magnesium, sodium, potassium, chloride, fluoride etc. are also within the limit.

Iron is present in all the samples and ranges between 0.12 and 0.5 ppm, which are within the safe limit. All the water samples are colourless and have no odour and objectionable taste. But during the rainy season the waters become unsuitable for direct domestic use on account of their turbidity.

As regards suitability for irrigation purposes, the waters are within safe limits in respects of T.D.S., chemical constituents, electrical conductivity and sodium adsorption ratio. The total dissolved solid varies between 68 and 95 ppm, the electrical conductivity varies from 106 to 155 micro-mhos/cm, and the sodium adsorption ratio (SAR) ranges from 0.33 to 0.69 (Appendix-IV). Four water samples fall in C_1S_2 group and two samples fall in the C_1S_1 group of the U.S. Salinity Diagram, they are low saline with low to medium sodium hazards and are suitable for irrigation on almost all the soils in the study area.

7.5 CHEMICAL QUALITY OF SUB-SURFACE WATER

The chemical quality is a very important factor for considering the economic utilization of groundwater for public water supply, irrigation and industrial purposes, and the quality has been assessed from an analysis of water samples collected from different sources – dug wells, shallow and deep tube wells, in the last week of November'98 and April'99. During the present investigation, out of 251 observed dug wells, only 80 dug well samples have been considered by taking 20 water samples from each police station for partial chemical analysis. But in case of complete chemical analysis – 2 dug well samples, 2 shallow tube well samples and 1 deep tube well sample have been considered from each police station of the study area. The results of the partial and complete chemical analyses are presented in Appendix-V and VI respectively. The various constituents determined in the complete chemical analyses of the 20 groundwater samples are expressed below successively.

7.6 REPORTING OF CHEMICAL ANALYSIS

Concentration of dissolved salt or ions in groundwater are commonly expressed by weight, weight and volume, or chemical equivalence through different parameters. The methods of expression of these parameters are outlined below —

QUALITY OF GROUNDWATER IN AQUIFERS TAPPED BY DIFFERENT WELLS

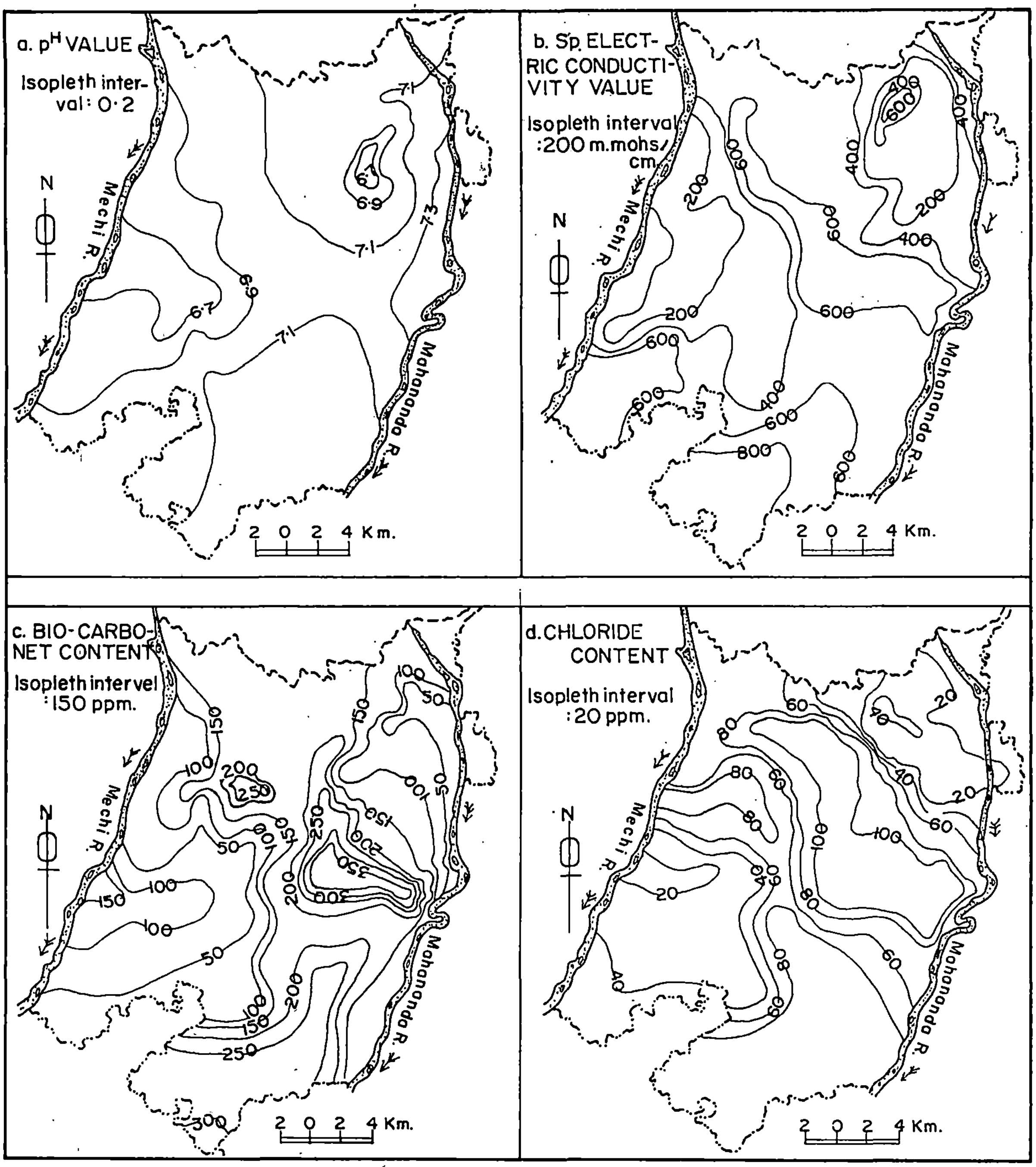


Fig. 7·1

Hydrogen ion concentration (pH) :

The hydrogen-ion concentration of water is expressed by its pH values. The pH value of most ground water is controlled by the amount of dissolved CO_2 gas and the dissolved CO_3 and HCO_3 in the mineral salts presence of phosphates, silicates, borates flurides and some other salts in dissolved form may also affect the pH. The pH value of the groundwater samples in the Terai area of Darjiling district ranges from 6.8 to 7.9 indicating thereby that the groundwater has been given alkaline reaction. These are within the range of permissible limits for domestic, irrigation and industrial purposes (Appendix-VI and Fig.–7.1).

Specific electrical conductance (EC) :

Specific electrical conductance is the conductance of a body of unit length and unit cross-section at specific temperature. The specific conductance of groundwater in the study area ranges between 103 and 2100 and for surface water (river) ranges between 106 and 155 micromhos per centimetre at 25°C. But the specific conductance value more than 750 micromhos per centimetre at 25°C to some extent of 2100 micromhos per centimetre at 25°C, observed only in dug well samples located at Champasari, Salbarihat, Kelabari, Debiganja, Bandi and Dhakpara villages of the study area. The specific conductance value of the surface

Table – 7.1 : Specific Electrical conductivity ranges and quality of the different well samples of the study area.

Electrical conductivity ranges (micromhos per centimetre at 25°C.)	Quality of water	No. of dug well samples	No. of Tube wells (shallow & deep) samples	No. of surface water samples	% of G.W. Wells
Below 250	Entirely safe or fresh water	32	10	06	42%
250-750 (moderately saline)	Safe under practically all conditions	46	02	Nil	48%
750-2250 (medium to high salinity)	Safe only with permeable soil and moderate leaching	10	Nil	nil	10%

water (river) samples are all below the range of 250 micromhos per centimetre. The areal distribution of specific conductance in the shallow groundwater of the area is shown in Fig.–7.1. The distribution of low, moderate, medium to high salinity of groundwater zone of the study area were also delineated based on the U.S. Salinity Classification (Richards, 1954) recommended ranges are expressed in the Table–7.1.

Total Hardness of Water (TH) :

The present chemical analysis shows that the hardness of water in the study area ranges from 35 ppm to 220 ppm. The water of the area is moderately hard to hard under Durfor and Becker (1964) classification of hardness (Table-7.2). Most of the dug well samples and river water samples have the nature of moderate hardness. Only one deep tube well sample, located at Purba-Madati of Phansidewa P.S. block registers very high hardness value.

Table – 7.2 : Hardness of water ranges and water class of different well samples of the study area.

Hardness Ranges (mg/L. of $CaCO_3$) or ppm.	Description or water class	No. of dug well samples	No. of Tube wells (shallow & deep) samples	No. of surface water samples
0-60	Soft	18	Nil	Nil
61-120	Moderately hard	57	Nil	04
121-180	Hard	13	11	02
More than 180	Very hard	Nil	01	Nil

In recent years, some works as mentioned later have reported apparent statistical correlation between the hardness or other properties of drinking water supplies and the death rates from cardiovascular diseases. Muss (1962) reviewed literature on this subject and expressed the belief that in a very general way the lower death rates from heart and circulatory diseases occurred in United States where the public water supplies are highest in hardness. Neri and others (1975) presented data from Canada supporting the hypothesis that hard water provided some protection from heart disease because of its increased magnesium content. Hopps (1979) reviewed the general subject of health in relation to the geochemical environment.

Total Dissolved Solids (TDS) :

The total concentration of dissolved minerals in water is a general indication of the overall suitability of water for many types of uses. The total dissolved solids may be determined from the weight of the dry residue remaining after a sample of water has evaporated. In the present investigation, the total dissolved solids determined by the complete chemical analysis of 20 groundwater samples and 06 surface water (river) samples range from 120 to 247 ppm and 68 to 98 ppm respectively, and are considered satisfactory for industrial, domestic and irrigation uses. Among the ranges in groundwater, the higher values occur in the south-western and south-eastern parts of Phansidewa Block. In comparison of these two sources of water, surface water is much more safe water for different uses, especially in the industrial uses.

7.7. DISSOLVED SUBSTANCES

The various minerals carried in solution determine in suitability of water for various purposes. Following are the most important minerals constitutents present in the investigated area that occur in substantial quantities.

Calcium (Ca) :

Calcium is the most abundant of the alkaline-earth metals and is a major constituent of many common rock minerals. It is an essential element for plant and animal life forms and is a major component of the solute is most natural water. In fresh water, calcium may contain only 20 to 30 ppm at saturation point.

The calcium content in the study area ranges from 18 ppm to 47 ppm and 18 ppm to 25 ppm in groundwater samples and surface water samples respectively. The calcium concentration is thus generally within safe limits for drinking as well as irrigation purposes.

Magnesium (Mg) :

Magnesium is one of the most abundant elements in igneous, metamorphic and sedimentary rocks. Magnesium together with calcium, whose behaviour it resembles, it causes hardness in water. Its solubility is about 10 times that of calcium. Concentration of magnesium in groundwater varies from about nil to as much as 50 ppm in waters.

The concentration of magnesium in the study area ranges from 10 ppm to 36 ppm, and 10 ppm to 20 ppm in groundwater and surface water samples respectively. Except for tube well located at Purba Madati of Phansidewa Block which has a high value (36 ppm) and with compare to that of calcium content, it indicates a tendency of contamination. But all other samples have the values within the safe limit for different uses.

Sodium (Na) :

Sodium is the most abundant member of the alkali-metal group which dissolved in ground water. It does not affect the hardness of water, though it is very important in determining the quality of irrigation waters. Sodium content in groundwater ranges from 1 ppm to over 100,000 ppm in brackish water.

The sodium content in groundwater of the investigated area ranges from 8 ppm to 22 ppm and 8 ppm to 16 ppm in groundwater and surface water samples respectively. The concentration of sodium in groundwater is much higher than potassium contents, but is less than Ca and Mg ions individually. The sodium content is thus generally within safe limits for different uses and specially has no effect in determining the quality of irrigation waters.

Potassium (K) :

Potassium is slightly less common than sodium in igneous rocks but more abundant in all the sedimentary rocks. The concentration of potassium ranges from 1 ppm or less to about 10 to 15 ppm in potable water and from 100 ppm to over several thousand ppm in some saline water.

The concentration of potassium in groundwater of the area of investigation ranges from 2 ppm to 12 ppm and 1.8ppm to 4 ppm in groundwater and surface water samples respectively. In comparison of this two sources, surface water are more suitable than groundwater, but all the values of potassium ions in the study area is within the permissible limit for all purposes.

Arsenic (As) :

Arsenic is a non-metallic element which is generally associated with intermediate and acid igneous rocks and metamorphic rocks into which acid igneous rocks have intruded. The common mineral of arsenic is sulfides. As small amounts of arsenic can be toxic to human body, hence it is considered a highly undesirable impurity in water supplies and an upper concentration limit of 50 μg/L (USEPA, 1976b).

Arsenic has been used as a component of pesticides and thus may enter into river or sub-surface water through waste disposal or agricultural drainage. Arsenic is present in volcanic gases and is a common constituent of geothermal water. It may also be released in the burning of coal and the smelting of ores, and it is a minor impurity in phosphate rock. Concentrations of Arsenic upto 1.0 mg/L have reportedly been present in water used for drinking and at least for short periods of time, have produced so apparent ill effects, but long-term use of a concentration of 0.21 mg/L was reported to be poisonous (McKee and Wolf, 1963).

Fortunately, the concentration of arsenic in water of the area of investigation is below detecting level (Appendix - VI). Hence the people of this area has no health hazards due to arsenic contamination in water. All the samples are suitable for drinking, agricultural and industrial purposes.

Carbonate and Bicarbonate (CO_3 & HCO_3) :

Bicarbonate either alone or along with carbonates or hydroxides constitutes the alkalinity of water. Alkalinity in water is its ability to neutralize acid. Under usual conditions the bicarbonate concentration of the natural water ranges mainly from 0 ppm to 800 ppm and most surface streams contain less than 200 ppm.

Bicarbonate ions and in some cases carbonate ions have been found in low to medium concentration in the groundwater of the study area. Normally, there is no carbonate ions in groundwater because of its acidic nature of water. The range of bicarbonate in groundwater is 21 ppm to 545 ppm with an average to 130 ppm and in surface water is 22 ppm to 50 ppm with an average to 33 ppm. The concentration of bicarbonate in waters of the study area have been grouped in Table–7.3, on the basis of bicarbonate classification of Baweja *et al* (1969). The aerial distribution of bicarbonate concentration in shallow groundwater of the area is shown in Figure–7.1. In some exceptional case, the low to moderate concentration of bicarbonate in most of the area are suitable for domestic purposes but are unfit for some industrial and laundry purposes, because bicarbonate is directly related to the hardness of groundwater.

Table – 7.3 : The Bicarbonate concentration ranges in water of the study area and their classes of different well samples.

Bicarbonate (HCO_3) ranges in ppm	Description of water quality	Number of Dug well samples	No. of Tube well (shallow & deep) samples	Number of surface water samples
0 to 150	Suitable	56	12	06
151 to 500	Permissible	31	Nil	Nil
More than 500	Undesirable	01	Nil	Nil

Boron (B) :

Boron is a light element and its ionic and solute species tend to be somewhat volatile. It is an essential plant nutrient and is required in micro-quantities for the normal growth of all crops. It is found in practically all natural waters, the concentration ranging from traces to several parts per million.

In the area of investigation, the concentration of boron in different water samples is also shown in Appendix-VI. Boron is present in all waters ranging from 0.04 ppm to 0.71 ppm. Mostly boron content is within permissible limit of 1 ppm.

Chloride (Cl) :

The element chlorine is the most abundant of the halogens. In groundwater it is generally present as dissociated chloride (Cl^-) ions. Chloride is present in all natural waters, but mostly the concentrations are low and normally do not exceed 5 ppm. Indian Standards Institution (1983) permits the chloride content in potable waters upto 1000 ppm.

Chloride content in water samples of the study area ranges from 05 ppm to 380 ppm having an average value of 57 ppm in groundwater and in surface water is 05 ppm to 15 ppm with an average to 11 ppm. The concentration of chloride in water samples of the study area have been grouped (Table–7.4). According to Johnson's (1966) chloride classification and the areal distribution of this shallow groundwater of this area is shown in Fig.–7.1. Except the three dug well water samples located at Bandi, Liusi Pukuri, and Dhakpara of Phansidewa block recorded the highest chloride concentration of 380 ppm where as it was less than about 100 ppm in the rest of the wells both in surface and sub-surface water samples.

Table –7.4 : Chloride concentration ranges and quality classes of the different water samples of the study area.

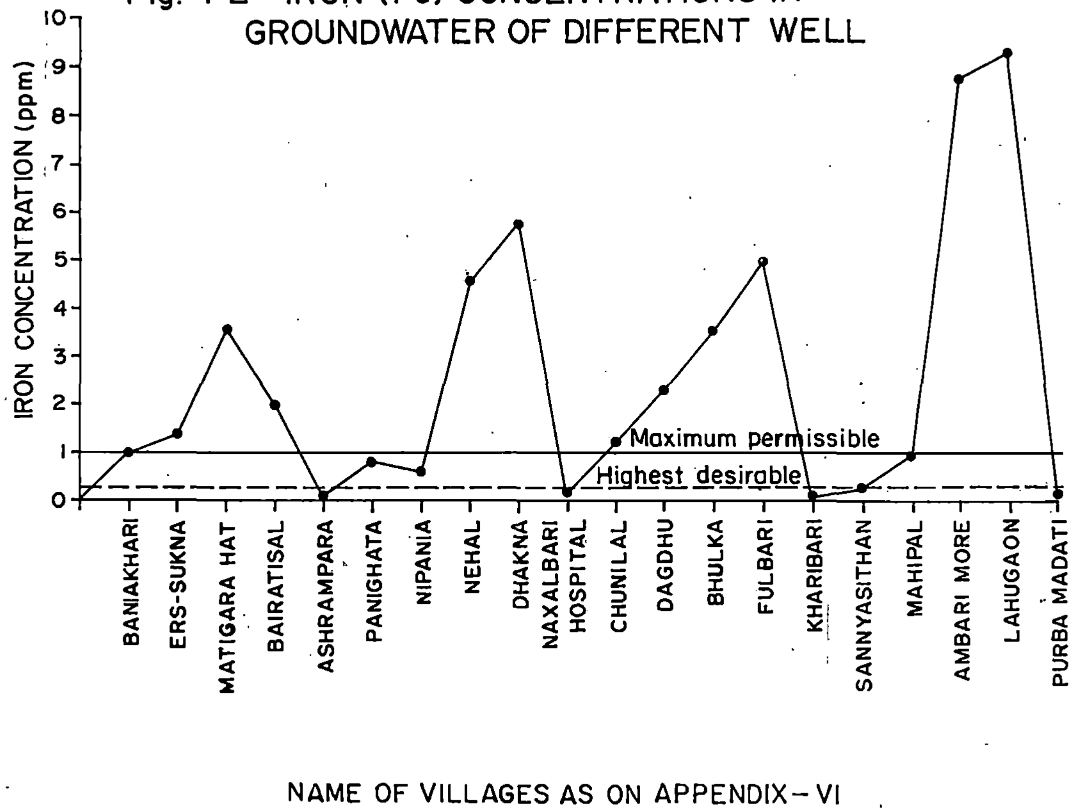
Chloride Ranges in ppm	Description of water quality	No. of dug well samples	No. of Tube wells (Shallow & Deep) sample	No. of surface (river) water samples
0 – 150	Class-I (satisfactory)	85	12	06
151 – 500	Class-II (objectionable)	03	Nil	Nil
501 and above	Class-III (disagreeable)	Nil	Nil	Nil

Iron (Fe) :

Iron is the second most abundant metallic element in the earth's out crust, concentrations present in surface and subsurface water generally are small. Usually, iron occurring in groundwater is in the form of ferric hydroxide. Which is an essential element in the metabolism of animals and plants. If present in water in excessive amounts, however, it forms red-oxy-hydroxide precipitates that stain laundry, plumbing fixtures, incrustation of the well screens and plunging of pipes, and therefore, is an objectionable impurity in domestic and industrial water supplies. The concentration of ferrous iron upto 10 ppm is common though it may rise up rarely to 50 ppm.

The iron contents in water of the study area ranges from 0.02 ppm to 9.24 ppm and 0.12 ppm to 0.5 ppm in groundwater and surface water respectively. Except the filtered i.e., the chlorinition and iron elimination plant for deep tube well and surface water samples, and all other samples have the much higher concentration of iron than the permissible limit. Dug well water is usable in some

Fig.-7·2: IRON (Fe) CONCENTRATIONS IN GROUNDWATER OF DIFFERENT WELL



area only in the winter season, but most of the dug well water has the iron concentration upto 2.35 ppm. The maximum iron concentration is observed in the shallow tube well samples and ranges from 2.05 ppm to 9.24 ppm in the overall study area (Fig.-7.2.) Some of the dug well samples, filtered deep tube well samples and all the surface water samples are suitable for all kinds of purposes, but all the samples of shallow dug wells and tube wells are commonly disagreeable for all purposes especially for drinking and industrial purposes. This high concentration of iron in drinking water is too much harmful for human body in the study area. The common health hazard is observed in the area are gastrointestinal disease, respiratory disorders especially asthma and chronic bronchitis, loss of hair and spinal cord system involving arthritis, muscle and joint pains. But till now no proper remedial measures have been taken for the safety of human as well as other animal life. Only aeration and elimination or carbon-di-oxide can achieve the removal of iron followed by sedimentation and filtration. Excess of iron can be treated with lime. Contact oxidation and zeolites can also aid in eliminating iron.

Sulphate (SO_4) :

Sulfur is extensively distributed in reduced form in both igneous and metamorphic rocks as metallic sulfides. Concentration of these sulfides commonly constitutes ores of economic importance. This element is essential in the life processes of plants and animals. The sulphate content of atmospheric precipitation is only about 2 ppm, but gypsum ($CaSO_4$) or oxidation of pyrites can dissolve in pure water upto about 1,500 ppm of sulphate. Water can have sulphate concentrations in excess of 100,000 ppm if little or no Ca is present and even upto 299,000 ppm in certain types of magnesium brines (Hem, 1989).

In the present investigation, the sulphate concentration in water ranges from 5 ppm to 42 ppm with an average to 19 ppm in groundwater samples and in surface water samples is 3 ppm to 9 ppm with an average of 6 ppm. The sulphate (SO_4) concentration in the area is within permissible limits for drinking as well as other purposes, as the values are less than 250 ppm. A number of people of the study area are largely affected by the respiratory disorders such as asthma, chronic bronchitis and emphysema due to the presence of sulphate (SO_4).

Nitrate (NO_3) :

The forms of nitrogen of greatest interest in water are nitrate, nitrite, ammonia and organic nitrogen. Nitrite generally occurs in trace quantities is the surface water but may attain high level in groundwater. In unpolluted surface water is generally less than 1 ppm, and seldom exceeds 5 ppm, but in groundwater, the range may vary largely from almost zero to 1,000 ppm. But the World Heath Organisation (WHO) has recommended the limit of 45 ppm NO_3 for drinking water and the same is also accepted in India by the Indian Council of Medical Research (ICMR). A nitrate content exceeding 45 ppm is considered harmful to infants and can cause a disease called cyanosis, though it is not harmful to children and adults.

In the present study, the nitrate (NO_3) concentration ranges from 0.95 ppm to 18 ppm and 2 ppm to 3 ppm in groundwater and surface water samples respectively. The experimental value of nitrate of groundwater samples have been tabulated in Appendix-VI and has been observed that shallow tube wells and dug wells show the high concentration of NO_3 than that of deep tube wells (0.95 ppm) located at Naxalbari 50 bedded Hospital. Moreover, southern part (Kharibari and Phansidewa block) of the study area is rich in nitrate concentration than northern part (Matigara and Naxalbari block), only because of the presence of huge amount of irrigated lands and uses of nitrogenous and manure fertilizers in those cultivated area. On the basis of previous data, it has been noted that the study area (Kharibari and Phansidewa block) has come under intensive agriculture during the last two decades. But all the samples in the area is under permissible limit as per USGS norms.

Fluoride (F) :

Fluoride is the lightest member of the halogen group of the elements. The inclusion of fluoride among the major solutes in natural water is arbitrary. The drinking water contains fluoride more or less limits mentioned above poses serious health hazards. The element fluorine is used by higher life forms in the structure of bones and teeth. The concentration of fluoride in natural water of the study area are ranges from 0.20 ppm to 0.90 ppm within an average value of 0.52 ppm in groundwater and 0.35 ppm to 0.80 ppm having an average value of 0.56

ppm in surface water respectively. About 35% of the analyzed samples have the fluoride value in groundwater, which is less than the lower limit of the international drinking water standards ranges (Appendix-VI). As a result, the hazards of fluoride concentration in this area are apparent such as dental carries, tooth decay, skeletal fluorosis and blindness and mottling of tooth enamel.

7.8 PHYSICAL ANALYSIS

Groundwater is generally clean, colourless and odourless, with little or no suspended matter and relatively constant temperature in comparable to surface water. Because of these natures, in the most hydrological situations groundwater can be considered to direct use without treatment. But exceptions are found, such as the groundwater derived from caverns and other large openings that may permit suspended matter and pollutants to enter into water reservoir. Some of the physical characteristics may be critical to restrict the usability of water for specified purposes. Hence, it is necessary to assess the physical analysis of water, in addition to the chemical analysis. The characteristics determined in standard physical analyses of water include taste, odour, turbidity, colour and temperature.

During the present investigation in the terai region of Darjiling district area the water from dug wells and tube well, which were inventoried, was examined physically in the field.

Colour, odour, taste and turbidity :

Water for drinking purposes should be free of colour and objectionable odours. The presence of organic matter and iron may impart colour. The presence of hydrogen sulphide imparts the smell of rotten eggs. Gases and some organic compounds and minerals may also impart unpleasant taste and odour to groundwater. The turbidity in groundwater is caused by the presence of insoluble sediments, organisms and organic matters. In the present investigation, water samples from the dug wells in the area, in general, colourless. Odours are generally absent and the taste not objectionable. But due to the presence of undesirable amount of iron ion and sulphate (SO_4) in some dug well samples, hence, the water of those areas (Appendix-V&VI) is yellowish in colour and smell of rotten eggs and the taste is unpleasant. But most of the tube wells yield yellowish coloured and rotten eggs scented water, except the filtered tube well waters. The tube wells, which pump very fine-grained sand at the start, yield turbid water. The water in such tube wells remains turbid for some time till the sand settles. Besides the tube wells, most of the dug well waters become turbid in the monsoon period because of the high permeable structure of the area.

Temperature :

The temperature of the groundwater is largely dependent on atmospheric temperature, terrestrial heat, and exothermic reactions in rocks, infiltration of surface water, insulation, thermal conductivity of rocks, rate of movement of groundwater and interference of man on groundwater regime.

In the study area, temperature of the water from dug wells and tube wells was recorded in the field. The water from the dug wells are generally cooler and ranged in temperature from 18.2°C to 23.8°C in summer season and is 22.1°C to 25.8°C in winter season respectively. But the water from tube wells are comparatively warmer and ranging in temperature from 20.3°C to 25.5°C in summer season and is 26.4°C to 29.0°C in winter season respectively.

7.9 BACTERIAL ANALYSIS

Bacterial analysis is important for detecting sewage contamination in groundwater. Bacteria and microorganisms present in water are of microscopic size (1 to 4 microns). Some of the bacteria are harmless while some are disease-causing, known as pathogenic bacteria. Coliforms, which are present in intestines of human beings and other warm-blooded animals, are transmitted through fecal matter. Although coliforms are harmless, their presence in groundwater indicates the possibility of the presence of pathogenic bacteria. But due to some sorts of problems the bacteriological test of the study area has not been done in the laboratory.

7.10 WATER QUALITY CRITERIA IN RELATION TO ITS USES

The instantaneous purpose of the usual quality of water study is to determine if the water is satisfactory for a proposed use. Most groundwater is free from suspended impurities and pollution and are of constant temperature, in which respect they are superior to surface water supplies. Certain chemical quality standards have been established for evaluating the suitability of water for drinking, domestic, agricultural and industrial uses. Mandatory limits have been set for certain poisonous constituents, but no rigid limits can be set for water required for other uses.

a) Quality of Water for Domestic Uses:

The Quality of water suitable for drinking and domestic purposes varies considerably and depends generally on the locality and in the individual users of the study area. The dug well waters are used for drinking purposes. The tube well waters though mainly used for irrigation purposes, it is often used for supply of drinking water to the neighbouring villages. Normally, the samples are colourless, tasteless, odourless and free from turbidity and generally the chemical quality of water samples as discussed above and tabulated in Appendix-V&VI, which meets the drinking water standards as recommended by the World Health Organization (WHO), 1971 and Indian Standards Institution,1983 in Appendix-VII. However, a number of groundwater samples of different sources show the objectionable criteria of some parameters of the physical as well as the chemical quality as compared to the standard values shown in Appendix-VII. Hence, it is considered advisable to check the bacterial content of the drinking water from time to time.

The presence of iron, above the stated limits, except the filtered deep tube well waters, is objectionable because they leave stains of oxide or hydroxide on laundry, sanitary articles and plumbing fixtures. At concentrations above 0.5 ppm iron imparts an unpleasant taste and smell of rotten eggs. Except the iron elimination plant deep tube well water, most of the water samples are yellowish in color and some how turbid. Such a high concentration of iron in drinking water is too much harmful for human body. But the removal of iron ion can only be achieved by aeration and elimination or CO_2 followed by sedimentation and filtration. Excess of iron can be treated with lime. Contact oxidation and zeolites can also aid in eliminating iron.

Though the nitrate concentrations in groundwater is within the desirable limit but the overall trend of concentrations especially in the shallow tube wells and dug wells are alarming because of the maximum uses of nitrogenous and manure fertilizers in the irrigated lands. In quantities over 45ppm., nitrate is harmful for infants whose feeding formula is include these water sources. On the basis of Table-7.2, it is observed that more than 82% of groundwater samples are moderately hard to hard water, which are objectionable for domestic purposes because it needs a lot of soap for forming a lather. With respect to total dissolved solids (TDS) and chlorides concentration present in the study area are mostly governed more by the palate than by the adverse physiological effects. Only a few groundwater well sites of the study area, the available domestic water supplies contain the maximum permissible limits of total dissolved solids and chlorides. However, it may be concluded from the above studies that more or less the investigated water wells are suitable for domestic purpose. Most animals can tolerate water that is considerably higher in total dissolved solids concentration than that which is considered satisfactory for humans.

b) **Quality of Water for Irrigation Uses :**

Irrigation has become indispensable practice in modern farming and bringing more and more areas under irrigation is the foremost step in attaining self-sufficiency in agriculture production. Irrigation system should be operated with the knowledge of irrigation water quality and of various methods for applying water. The chemical quality of water is an important factor to be considered in evaluating its usefulness for irrigation. The most significant factors which affect the suitability of water quality for agriculture are as follows:

The total concentration of soluble salts is the prime important of the chemical quality of water for the successful uses of water for irrigation purposes. Water containing excessive salts may harm the plant growth physically by limiting the uptake water through osmotic pressure difference or chemically metabolic reactions caused by several toxic constituents. In this regard, Scofield (1933) has suggested certain limits for characteristics of irrigation water as shown in Table–7.5.

Table – 7.5 : Limit of some common constituents in Irrigation Water.

Constituents	Parts per million		
	Lower	Intermediate	Upper
Total dissolved solids (TDS)	0.700	700-2000	2000+
Sulphate (SO_4)	0.192	192-480	480+
Chloride (Cl)	0.142	142-355	355+
Hydrogen ion concentration (pH)	7.01	8.00	9.00

The T.D.S. and pH values are within permissible limits for irrigation purposes except 6 pH values of groundwater samples (Appenix–VI). The water samples for which chemical analysis are available generally seem to be within the lower limits with respect to chloride and sulphate content exempt three dug well samples having intermediate limits of chloride concentration. The water samples of the study area from different sources, therefore, will not be harmful on soil and crops when used as compared to the Tables– 7.4 & 7.5.

The suitability of groundwater for irrigation has further been classified by L.V. Wilcox (1955), based on EC values, sodium content expressed as percent sodium and the boron concentration, which is given in Table–7.6. In the study area, 10 out of 100 groundwater samples have permissible to doubtful EC values with more than 750 micro-mhos/ cm and can be used for irrigation only in permeable soils with moderate leaching. But the rest of the 90 samples have EC values below 750 micro-mhos/ cm as in Table–7.1.

Table – 7.6 : Classification of quality of Irrigation water.

Water class	Percent sodium	EC x 10^6 at $25^{\circ}C$	Boron in ppm		
			Sensitive crops	Semi-tolerant crops	Tolerant crops
Excellent	<20	<250	<0.33	<0.67	<1.00
Good	20-40	250-750	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	40-60	750-2000	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	60-80	2000-3000	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	>80	>3000	>1.25	>2.50	>3.75

The chemical constituents Selenium, Molybdenum and Fluorine are tolerated by plants but are toxic to animals that feed on them but elements such as Boron and Lithium are toxic to plants. Groundwater is richer in Boron than surface water. The concentration of Boron in the groundwater samples of different sources have been determined and these does not exceed 1 ppm i.e., ranges from 0.04 ppm to 0.71 ppm and average value is 0.26 ppm (Appendix–VI).

The soluble sodium percent (SSP) is an important variable defining the quantity of irrigation water because this plays a significant role in irrigation water which reacts with soil to reduce its permeability. The sodium concentration has

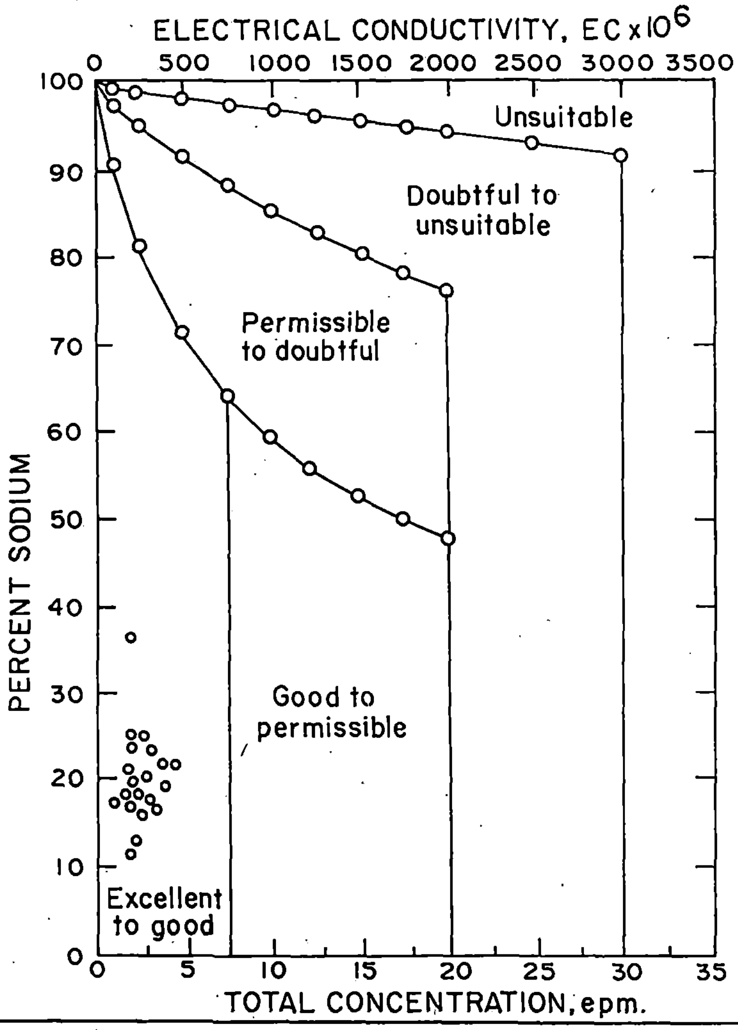


Fig.-7.3: CLASSIFICATION OF GROUNDWATER FOR IRRIGATION USES (Adapted from Wilcox, 1948)

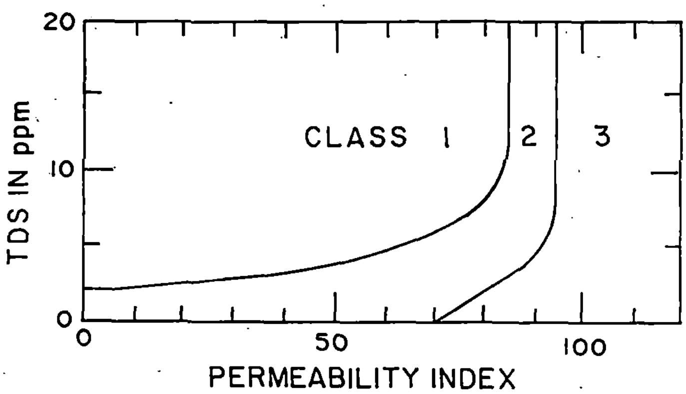


Fig.- 7.4: CLASSIFICATION OF IRRIGATION WATER FOR SOILS OF HIGH PERMEABILITY (After Donnen, 1962) been calculated by the relationship :

$$\% \ Na = \frac{Na + K}{Ca + Mg + Na + K} x\ 100$$

In the study area soluble sodium percent ranges from 11 ppm to 27 ppm (Appendix–VI). As the sodium percentage in the tube well water is comparatively high ranging from 20 ppm to 27 ppm and by using this water to soil may increase sodium percentage in the soil causing defloculation and reducing the permeability. The well waters of the study area are 60 % excellent to good and 40 % good to permissible classes in accordance with the Wilcox's (1948) classification of irrigation waters is shown in Fig.–7.3.

Residual sodium carbonate results when irrigation water contains carbonate and bicarbonate ions in excess of calcium and magnesium ions and sodium percentage in the water or soil solution increases due to the precipitation of the divalent cations which may also influence the suitability of water for irrigation purposes. Residual sodium carbonate (RSC) is determined by the formula (Richard, 1954, ed.) –

$$RSC = (CO_3^{--} + HCO_3^{-}) \ x\ 2 - (Ca^{++} + Mg^{++}).$$

The concentration of the additional hazard in the groundwater samples have been determined and shown in column 26 of Appendix–VI. According to the RSC classification (Richard, 1954, ed.), out of the 20 sub-surface water samples for the study area, none of the samples shows the tendency of residual Sodium carbon. Hence, the entire land is suitable for irrigation in the district as far as the RSC values are concerned.

Permeability of the soil is influenced by the sodium content of the irrigation water. Its determination, for estimating the quality of irrigation water, is based on the solubility of salts and the reactions occurring in the soil solution from cation exchange. The permeability index (PI) is obtained by considering the ions of the first three items and expressed as follows of which all the ions are in ppm by the relations–

$$PI = \frac{Na + HCO_3}{Ca + Mg + Na} x\ 100$$

The concentration of this criteria in groundwater samples of different wells have been calculated which is shown in column 27 of Appendix–VI, and the

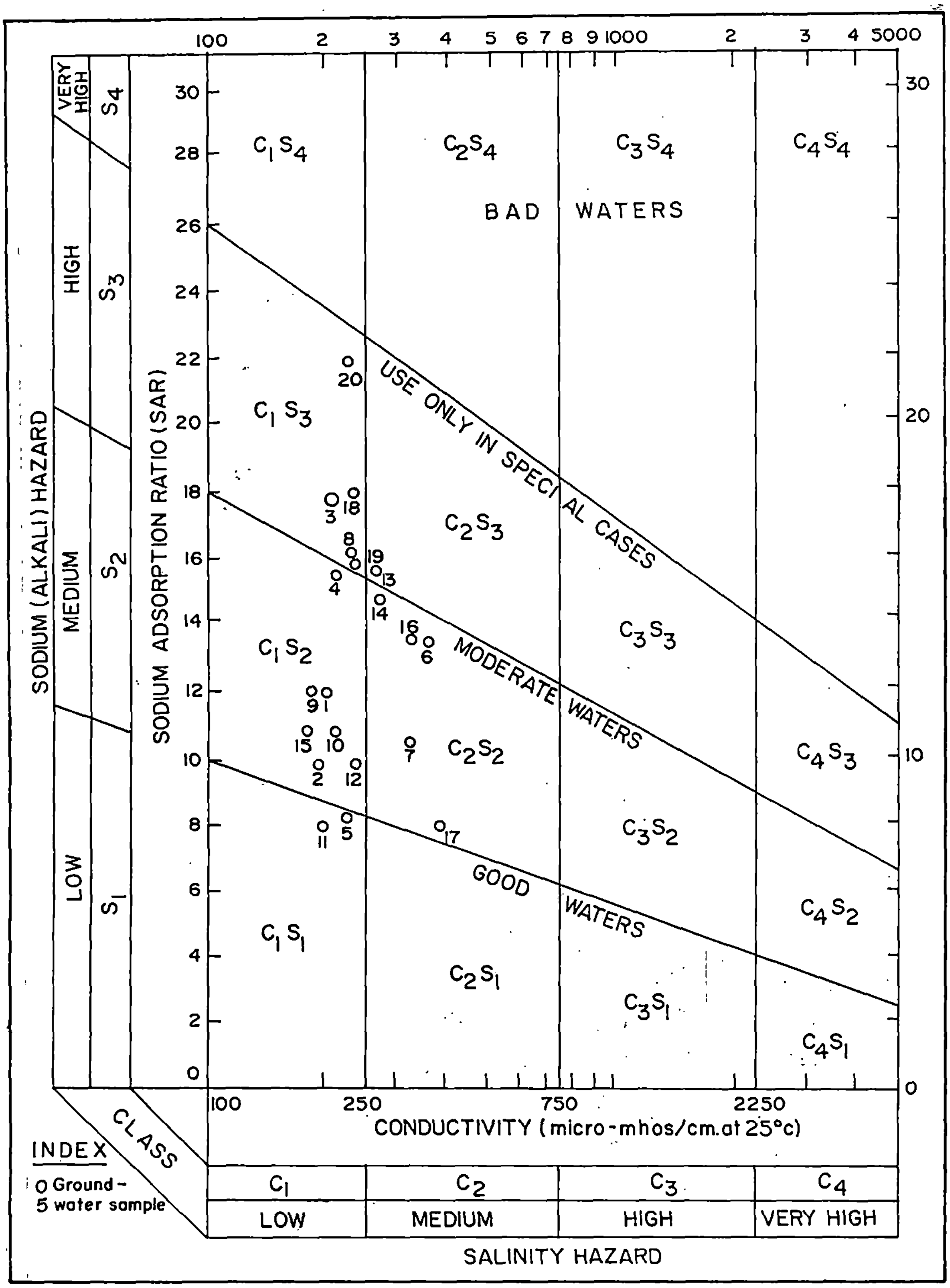


Fig.-7·5: CLASSIFICATION OF GROUNDWATER FOR IRRIGATION PURPOSES (Adapted from U.S.S.L.S., 1954) finding results of the permeability index are mostly belong to class I (Doneen, 1962) as such all the waters are generally suitable for irrigation uses (Fig.7.4).

To assess the water quality for irrigation, it is necessary to know the ratio of Na to Na+Mg as the higher amount of Na in irrigation water makes the soil less permeable, sticky and hard. The most suitable used ratio is the Sodium Adsorption Ratio (SAR) proposed by the U.S. Salinity Laboratory (Richards, 1954) is expressed by :

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

where, all concentrations of the constituents are in milli-equivalent per litre.

The SAR values of groundwater for different wells which have been drilled in several stratigraphic sequences of the Terai region are given in column 25 of Appendix–VI. The classification of well waters from the study area with respect to SAR values and compared to the quality of irrigation water, it has been observed that all the samples fall in the excellent group. Hydrochemical data plot of the well waters in USSL diagram is shown in Fig.–7.5, which are, classify the well waters into 16 groups. Based on the SAR values and USSL diagram, it is observed that the groundwater of different sources are of good quality for irrigation and drinking purposes equally.

c) Quality of water for industrial uses :

The quality requirements for industrial water supplies vary widely, and almost every industrial application has its own standards (Collins et. al., 1934). The uses of single-pass condensing of the steam or for cooling or for concentrating ores, chemical quality is not particularly critical and almost any water may be used. At the opposite extreme, water approaching or equaling the quality of distilled water is required for processes such as the manufacture of high graded paper or pharmaceuticals, the purest of water is required, otherwise, the water would seriously affect the quality of the product. In comparison with the quality of water for industrial uses as suggested by Anon, 1940 (Appendix–VIII), the chemical constituents in groundwater samples of the study area (Appendix–VI) reveal that the waters used by the different industries of the area are not good quality in nature due to the presence of high concentration of iron (Fe) except the

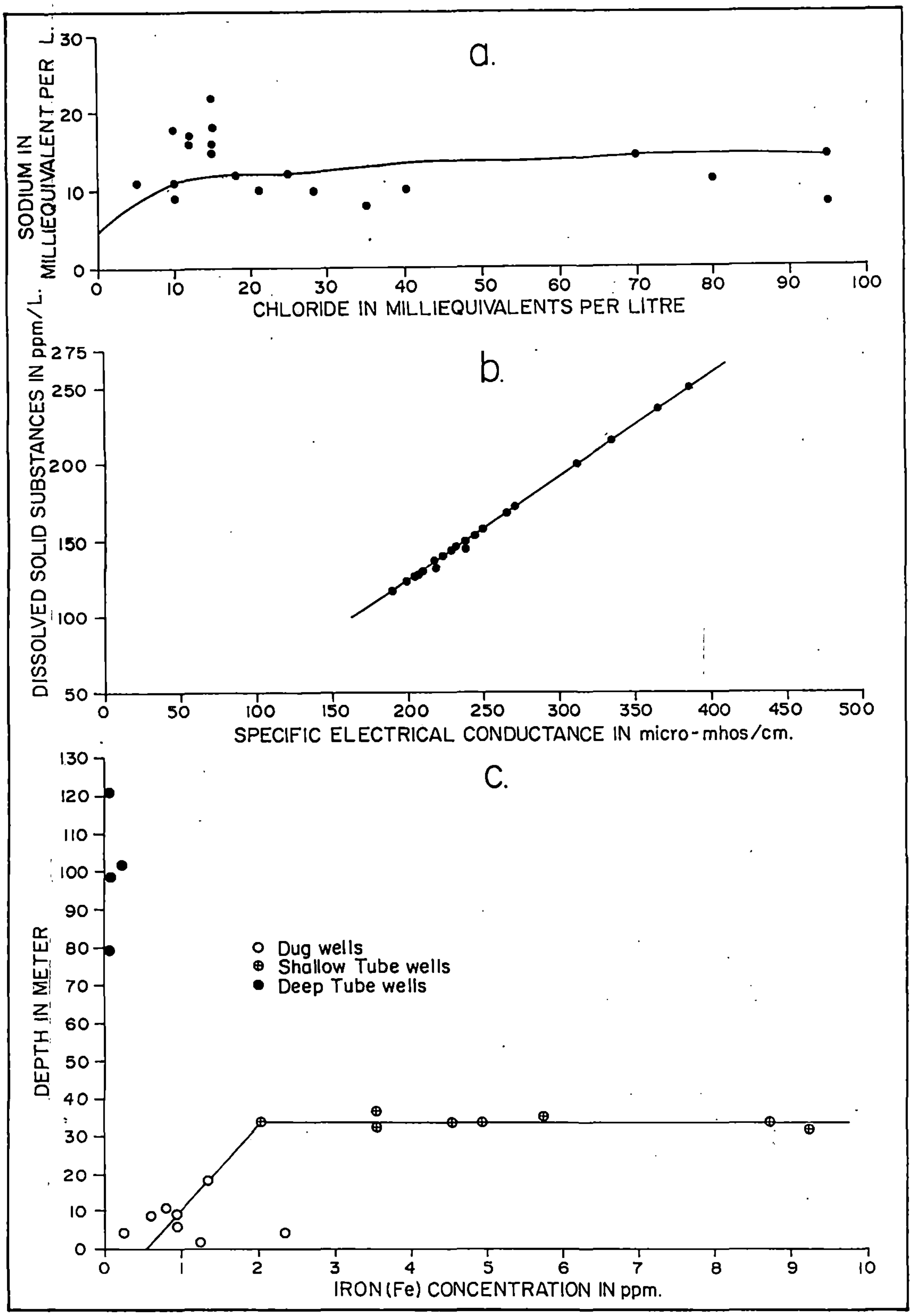


Fig.-7·6: RELATION BETWEEN – a. CHLORIDE AND SODIUM, b. EC AND T.D.S. AND c. Fe CONCENTRATION AND DEPTH OF WATER WELLS filtered deep tube well water and the presence of bicarbonate above the permissible limits are also renders the waters unfit for use in boilers, laundry purposes. But normally they can be used for ice-making, air conditioning and cooling purposes.

The hardness of water is an another important factor to be considered while using the water for industrial uses. The hard water, due to its soap consuming capacity and formation of scales in boilers, water heaters, radiators and pipes is generally considered undesirable for such purposes. The water from the dug wells in the study area as well as tube wells are considered moderately hard to hard in nature and need to be softened at the time of using for industrial uses.

7.11 GRAPHICAL REPRESENTATION OF GEOCHEMICAL DATA

Geochemical studies often involve synthesis and interpretation of a mass analytical data. Graphical representation of the concentrations of different ions in a water sample has been progressed from time to time, which make understanding easier and quicker. Some of the important methods, generally used are described as follows :

a) Scatter Diagram :

The scattered diagrams are important to study the analyses of interdependent samples. Fig.–7.6a shows an inter relationship between chloride (Cl) and sodium in groundwater of the study area. The figure reveals that there is a direct relationship between sodium and chloride, i.e., if chloride increases, the amount of sodium is also increases proportionately. It is observed that when specific electrical conductance increases at the same time the total dissolved solids values are also increasing proportionately (Fig.-7.6b). Another Fig.–7.6c represents the relationship between the depth of wells and their ion concentration in ppm. It is observed that the ion concentration is directly related to the depth of wells except the filtered well waters. In general, the minimum iron concentration is observed in the dug wells.

b) Ionic Concentration Diagrams :

The graphing analyses of most methods are designed to represent simultaneously the total concentration and the proportions assigned to each ionic species for a single analysis or a group of analyses. Some of them are as follows—

Table – 7.7 : Hill-Piper Analytical Values of Groundwater in the study area.

Sl.No.	Locality	Ca %	Mg %	Na+ K %	Cl %	SO_4 %	CO_3+ HCO_3 %	Ca + Mg %	SO_4+ Cl%
Matigara P.S	Baniakhari	50.79	25.40	23.81	32.05	10.26	57.69	59.26	40.74
	ERS, Sukna	49.10	25.45	25.45	30.11	5.38	64.52	55.41	44.59
	Matigara Hat	42.25	21.13	36.62	67.07	18.29	14.63	62.50	37.50
	Bairatisal	45.53	21.14	33.33	63.55	19.63	16.82	51.25	48.75
SMC	Ashrampara	59.58	24.11	16.31	77.87	8.20	13.93	68.60	31.40
Naxlbari P.S.	Panighata Bazar	51.03	26.21	22.76	50.97	46.12	2.91	35.67	64.33
	Nipania	48.33	28.33	23.33	51.35	43.24	5.41	33.82	66.18
	Nehal	53.33	16.00	30.67	72.92	15.63	11.46	66.67	33.33
	Dhakna	39.29	30.36	30.36	72.82	17.48	9.71	58.21	41.79
	50 Bedded Hosp	63.51	18.92	17.57	76.19	4.76	19.05	70.93	29.07
Kharibari P.S.	Chunilal	48.98	24.49	26.53	43.01	37.63	19.35	40.45	59.55
	Dagdhu	43.33	36.67	20.00	36.08	41.24	22.68	43.64	56.36
	Bhulka	31.88	34.78	33.34	53.21	11.01	35.78	47.42	52.58
	Fulbari	43.48	31.88	27.54	56.52	13.04	30.44	50.98	49.02
	Kharibari	47.14	25.72	27.14	59.70	14.93	25.37	65.38	34.62
Phansidewa P.S.	Sannyasithan	46.97	22.73	30.30	39.18	40.94	19.88	30.67	69.33
	Mahipal	45.00	25.00	30.00	38.29	42.79	18.92	16.97	83.03
	Ambari More	44.16	28.57	27.27	60.98	12.20	26.83	63.64	36.36
	Lahugaon	36.84	26.32	36.84	64.71	14.12	21.18	61.54	38.46
	Purba Madati	30.85	38.30	30.85	65.93	16.48	17.58	67.71	32.29

COMPOSITION OF WATER FROM DIFFERENT SOURCES

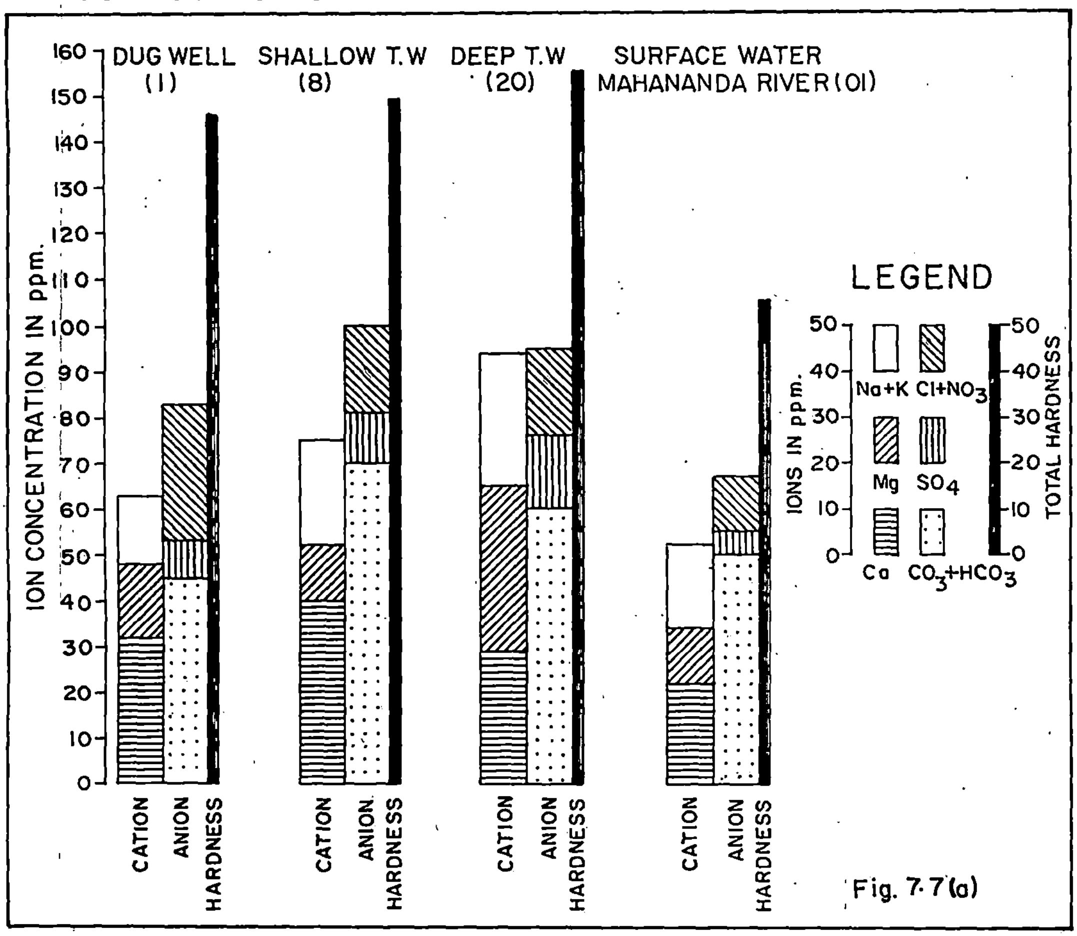


Fig. 7·7(a)

ANALYSES REPRESENTED BY PATTERNS BASED
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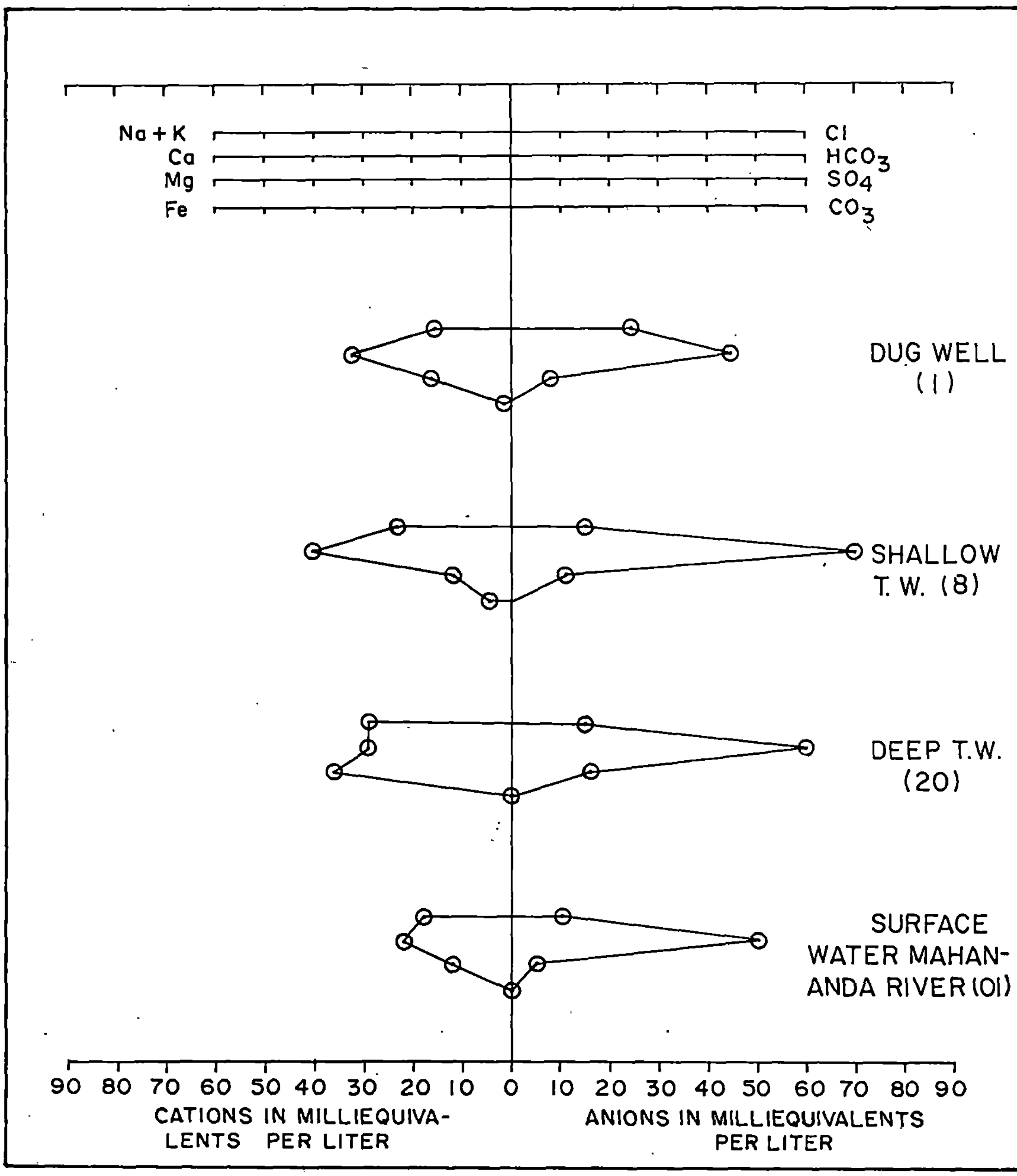

Fig. 7·7 (b)

ANALYSIS OF SUB-SURFACE WATER SAMPLES ON HILL-PIPER DIAGRAM (After, Piper, 1953)

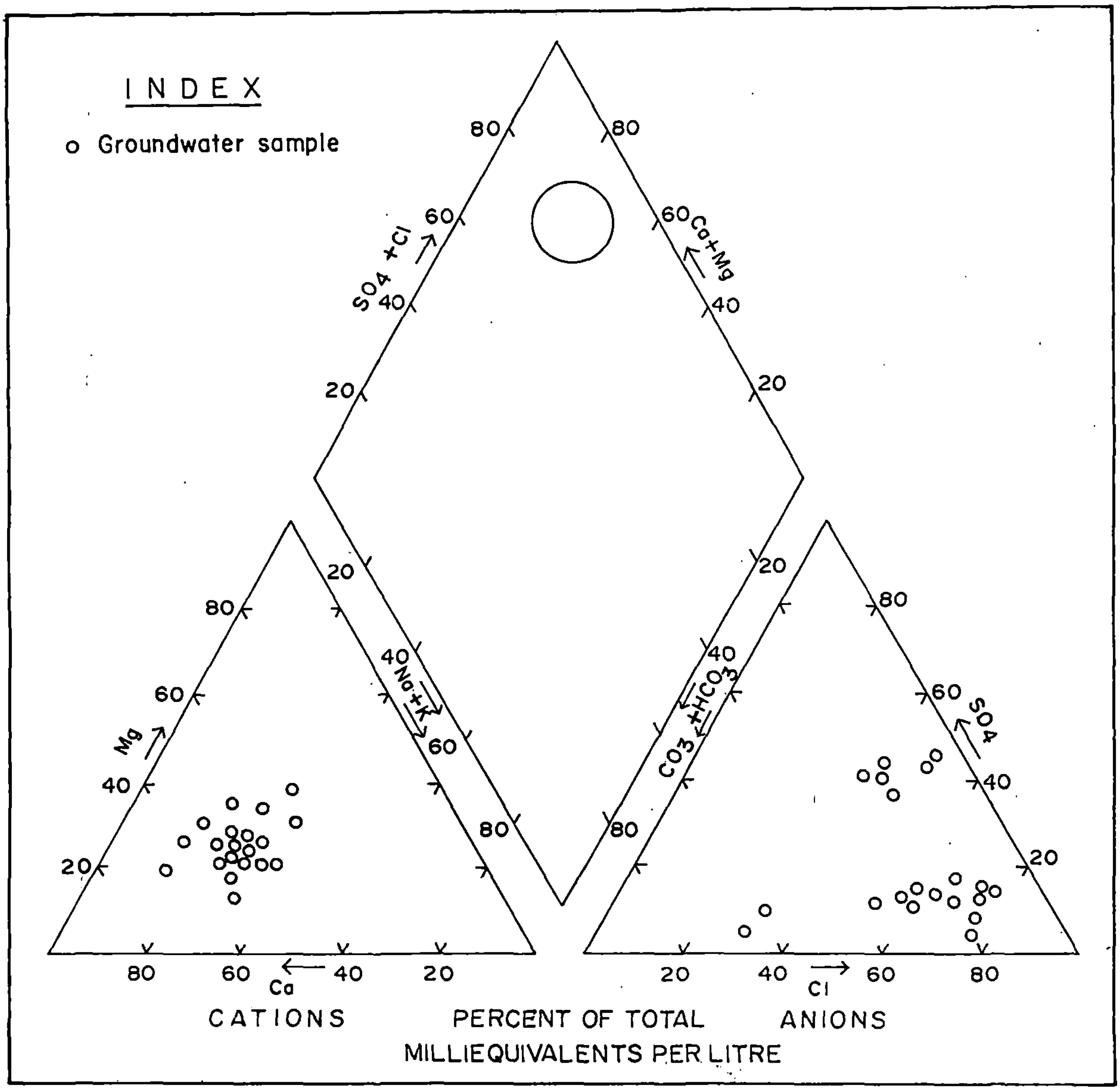

Fig. 7·7(c).

i). Collin's Bar Diagrams : From Collin's Bar Diagrams (Fig.-7.7a), it is observed that most of the cations except the magnesium (Mg) in deep tube well samples are of equal proportionate. In all the four cases, CO_3+HCO_3 contents are the maximum in the anions and the total anions are greater than the total cations, which may depict the quality of water, i.e., of moderately good water. In all the cases, the hardness is maximum than the permissible limit, which normally indicates the nature of moderately hard water.

ii). Stiff's Polygon Diagrams : From Stiff's Polygon Diagrams (Fig.-7.7b), it is observed that the four wells sample, the anion content are more than that of the cations, which also determine the quality i.e., moderately good type of water are existing in the study area.

iii). Hill-Piper's Trilinear Diagram : Hill-Piper's Diagram (Fig.– 7.7c and Table – 7.7) have been prepared to identify the quality of water of different wells. It is inferred that the water of this category comes under Ca-Mg-HCO_3 type of water which is suitable for drinking and irrigation purposes and based on the U.S. Salinity diagram, majority of the samples come under C_2, C_3 grade which is moderately hard type of water.

7.12 CHANGES IN QUALITY OF GROUNDWATER

Groundwater quality depends upon the quality of its source and the changes of its quality pattern become significant. These changes may involve either new source of water or reduce the quality of normal supplies. Practically, water pollution consciousness in India has developed after considerable laps of time. As a result, heavy backlog of liquid and solid pollution has made the problem of pollution more complex. During the last few decades it became increasingly evident that pollution was impairing different uses of groundwater and in certain cases destroying possible utilization of important sources of supply. In recent times on account of the increase in population, urbanization and industrialization, there is an over increasing thrust to the quality of water in underground as well as river, lakes and other water bodies. The increasing use of pesticides in raising agricultural production has resulted in an embryonic degradation of groundwater quality in rural areas. Nuclear development programmes, whether peaceful for human being or for purpose of war, have introduced a new dimension to the problem known as radioactivity. Hence, it is to be said that in spite of the technological advance that man has achieved, there is hardly a phase of his activity that does not pollute or contaminate the environment he lives in.

7.13 FACTORS INCREASING GROUND WATER POLLUTION

Water pollutant can be defined as a physical, chemical or biological factors causing aesthetic or detrimental effects on aquatic life and on those who consume water. Most of the water pollution are in the forms of chemicals which remain dissolved or suspended in water and give an environmental response which is often objectionable. In some cases, physical and biological factors also acts as a water pollutant. Pollution by itself destroys water's usefulness and causes hazardous environmental imbalances. More or less all town and villages in India heavily depend for their domestic, agricultural, and industrial water supply on groundwater. Groundwater pollution is less visible but often more serious, because it takes decades for the purification of the polluted aquifers (CPCB, 1995). Pollution of groundwater is caused by a number of factors. But the most significant of them are summarized as follows :

- Pollution is caused by waste generated from different courses— urban, agricultural and industrial sectors. It is estimated that municipal sewage alone accounts for 80 percent of polluting influence in our country.
- Sometimes, industrial effluents are directly discharged into groundwater.
- Agricultural effluents mainly arising from excessive use of chemicals may pose a major threat to groundwater quality due to contamination of ammonia, nitrates and pesticides.
- Dumping of city waste at land fills followed by rains cause heavy damage to groundwater quality. Acid rains also cause groundwater pollution.
- Industrialization coupled with intensive farming are posing serious danger to groundwater.
- Inadequate sanitation is another important cause of groundwater pollution.

- Uncontrolled and rapacious exploitation of this resource are mainly responsible for depletion in certain areas.
- Heat and radiation are of important pollutant which have marked effects on organisms, and
- Certain micro-organisms present in water which may cause diseases of man and animals and can be referred to as bio-pollutants.

7.14 DETERIORATION OF GROUNDWATER QUALITY

The nature or the origin of the groundwater pollution factors can be traced to their natural occurrence on the earth, formation by transformation and concentration of natural substances and their man made composition. Some of the pollution factor can be formed by the way of transformation and concentration of naturally occurring compounds during their domestic, agricultural or industrial uses. The origin of sewage and waste waters containing agrochemical, certain pesticides and surfactants, petrochemicals, hydrocarbons, heavy metals and radioactive are the best examples pollution factors originated in the above mentioned way. The water pollution may be caused by wide variety of pollutants either in dissolved or non-dissolved form as well as sediments. The most important sources of water pollution can range from purely natural to several man-made sources like discharge of domestic and industrial waste waters etc. are summarized as follows :

a) Natural Sources and Surface Run-Off :

The natural entry of pollution factors in water bodies can take place through rain; from atmosphere by dry deposition, environment and reaction; periodic submergence of surrounding vegetation and falling of dry parts of nearby vegetation directly on surface waters. The surface water originated from different areas are quite rich in nutrients and organic matters. The run-off from sparsely populated or rural areas can pick up several substances from soil, including nutrients and organic debris. The run-off originating from the urban areas can collect large quantities of substances from roadside waste water drains, surface of roads, open areas and from houses.

b) Domestic Sewage :

Domestic and municipal sewage consists of waterborne wastes of the community, and contains maximum percentage of water and a very few percentage of solids. Of these solids present in sewages, 70 percent are organic and 30 percent are inorganic in nature. Another important producer of pollution load is from the domestic kitchen and bathing places. Bacteria and nitrogen and phosphorous contents derived from decaying vegetable and animal wastes, alkyl benzo sulphonate (ABS) from use of detergent soaps and other wastes from commercial and industrial establishments contribute to the sewage discharged from municipalities. Cesspools and septic tanks may pollute water derived from wells owned by individual house holds.

c) Agricultural Waste :

India has one of the lowest man land ratio. In one hand constant decline in the man land ratio, on the other hand, increasing demand of food to meet the demand of increasing population, forcing the farmers for producing more crop from the squeezing land. This has led to use the agrochemical, in the forms of fertilizers, organic manures, pesticides, insecticides, growth hormones, nutrient solutions and others. All the residual forms of these chemicals along with organic debris from the remains of the harvested crops are either percolate to the groundwater aquifer or move to the river through surface run-off and finally contribute to the pollution of water bodies. The surface run-off is considerably rich in nutrients like nitrogen and phosphorus, organic matter and pesticides like DDT, malathion, para-malathion, aldrine, dialdrins etc. Especially, pesticides are responsible for causing toxicides to aquatic life. Several pesticides have been reported to get bioaccumulated and biomagnified through food chains resulting in the secondary poisoning of Man and Predatory birds.

7.15 DETECTION AND CONTROLLING OF WATER POLLUTION

The overall monitoring of water quality is a pre-requisite for establishing pollution. Water table maps are useful in tracing the source and direction of movement of the pollution factors. By applying tracer methods, whether a pollution factor has followed a certain flow path or not can be established. From the foregoing discussion, it is apparent without any doubt that environmental pollution is the most burning problem, requiring immediate attention by the society. A survey of basic needs of man in the study area revealed that people wanted consideration of issues of degradation of their environment in preference to other important issues. To stop the environmental degradation the following steps have to be taken to control water pollution in the study area –

- By renovating the existing sewer lines and connecting them to the central sewer line by branch and trunk lines.
- All the industrial and municipal wastewater be centrally collected and be treated upto requisite acceptable level and finally be used for different beneficial uses or could be discharged to the rivers with minor risk of pollution.
- Domestic and community solid wastes be centrally collected in a place from where the municipal body should take the responsibility for disposing of in safe open place where people habitation non exists and there is no chance of contaminating water bodies. Wastes from other sources like cattle fields and livestock may be centrally collected.
- In irrigated areas, changing cropping patterns and providing adequate drainage and keeping the groundwater level below optimum depth can control salinisation of groundwater.
- Controlling against surface contamination of wells, sanitary protection should be provided by improving surface drainage around the well. Unused wells should be properly sealed and should in no case be used as refuse dumps.
- In case of locating sites for wells, a point on the up-gradient side of villages and sources of pollution must be selected. If the wells position in the down-gradient and the soil material has a higher permeability, the wells location will have to a greater distances.

CONCLUSION

The foregoing discussion in this chapter has provided an unique opportunity to understand the quality and interpretation of the chemical analysis of water samples of different sources at different depth of the study area. The chemical quality of groundwater, as well as surface water are, except locally, excellent and suitable for different uses. Chemically, groundwater in the study area is fresh and potable having low chloride concentration except three dug well samples which vary from 5 ppm to 380 ppm. The pH value ranges from 6.8 to 7.9 which shows the alkaline nature of water. The specific electrical conductance of groundwater ranges between 103 and 2100 micro-mhos/cm of which 48 percent of the total samples are safe water under all considerations. Bicarbonate concentration in groundwater ranges from 21 ppm to 545 ppm, whereas 70 percent of the total samples belong to low concentration group. The water hardness ranges from 35 ppm to 220 ppm which belongs to moderately hard to hard water type generally shows that the water in this area are not normally good for use in boilers and water heaters. The study area is badly affected by the iron component which ranges from 0.02 ppm to 9.24 ppm and 0.12 ppm to 0.5 ppm in groundwater and surface water respectively. For the safety of human as well as other animal lives the higher concentration of iron can be removed by simple aeration and elimination or CO_2 followed by sedimentation and filtration. Excess of iron can be treated with lime. Contact oxidation and zeolites are also aid in eliminating iron. Depending upon the permissible limit of other chemical constituent of groundwater, it has been observed that more than 60 percent of the water samples have been classified as excellent to good quality and the rest are classified as good to permeable quality for agriculture, domestic, livestock and industrial uses.

The anthropogenic interventions in environment are attaining such an alarming proportion that groundwater pollution could become one of the scourges of our time. The risk of the progressive decline in quality and lowering groundwater table is increasing both from rapacious exploitation and irrational disposal of toxic industrial wastes, solid wastes, massive demographic pressure, lack of treatment of domestic and industrial effluents and wide spread use of agro-chemicals. Uneven distribution of groundwater across the study area and growing pollution sound a great challenge to its usefulness and optimum utilization and protection of groundwater quality is of paramount importance. This qualitative nature of water is largely influence the exploitation of subsurface water for uses and requirements in different sectors which have been discussed in the following Chapter.