Vocational Training Report

On

Groundwater Quality Modelling for Irrigation Appraisal

Undertaken at

Centre for Flood Management Studies
National Institute of Hydrology
Patna – 801505 (Bihar)

By

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CERTIFICATE

This is to certify that the work presented in this vocational training report entitled "**Groundwater Quality Modelling for Irrigation Appraisal**" has been done by **Anshul Jain (Adm. No. 2012JE0647)** of B. Tech. (Environmental Engineering) 3rd year student, (Session: 2014-2015) of **Department of Environmental Science and Engineering, Indian School of Mines, Dhanbad (Jharkhand)**. The work was done during his Summer Internship undertaken at the Centre for Flood Management Studies, National Institute of Hydrology, Patna from **16th June 2014 to 15th September 2014** under my supervision.

12/3/15

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12/3/15

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ABSTRACT

Groundwater quality assessment is important to ensure sustainable safe use of water. However describing the overall water quality and assessing its suitability in Dhanbad town area is difficult due to the spatial variability of multiple contaminants and wide range of indicators that could be measured. The study was carried out by collecting twenty four ground water samples (hand-pumps). The present investigation and objective of this study was focused on the classification of physicochemical parameters, and to examine the quality of ground water and its suitability for irrigation purposes by using different types of classification criteria available such as Doneen's Permeability Index, US Salinity Laboratory classification, Soluble Sodium Percentage (SSP) etc. From the classification it is inferred that despite the mining and heavy industry, the quality of water is predominantly good to moderate for utilizing for irrigation purposes.

In the present study, toxicity problems to the crop from high concentration of ions like chlorides, sodium, boron etc. have also been reviewed. These parameters become important when the soil itself contains the considerable amount of these ionic species. The precautions to be taken regarding irrigation water quality depending on the soil type and need for awareness among the farmers have also been highlighted.

1.0 INTRODUCTION

Quantity of fresh water makes up a very tiny fraction of all water on the planet. While nearly 70 % of the world is covered by water, only 2.5 % of it is fresh, remaining is based on ocean. Apart from it, just 1 % of our freshwater having easy accessibility, with much of it trapped in snowfields and glaciers. In essence, only 0.007 % of the planet's water is available to fuel and feed its gigantic population of 7.24 billion people. Present geographic features, climate, engineering facilities and technologies, country's regulation, and competition plays a pioneer role in the unequal distribution of wholesome water resources, in which some regions seem relatively flush with freshwater, while others face severe drought and wearing pollution mask. In much of the developing world, clean water is either hard to come by or a commodity that requires laborious work or significant currency to obtain. Due to the high density of population in urban areas, water has become a scarcity and polluted.

Ground water has become a more important resource over the past decade due to increases in ground water usage and realization that once contaminated it is difficult, expensive and sometime impossible to clean up. It uses an estimated 230 cubic kilometers groundwater per year over a quarter of the global total. More than 60 % of irrigated agriculture and 85 % of drinking water supplies are dependent on groundwater.

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. Irrigation with poor quality waters may bring undesirable elements to the soil in excessive quantities affecting its fertility. The long-term application of moderate quality water in poorly drained land may accumulate high quantity of salts in agricultural land which may harm plants' growth and productivity. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. Once undesirable constituents enter the ground, it is difficult to control their dissolution. To cope up with such problems, the information concerning the quality of irrigation water and its effect on soils and crops is necessary. India accounts for 2.2 % of the global land and 4 % of the world water resources and has 16 % of the world's population. Intensive agricultural activities have increased the demand on water resources in India. Therefore water quality issues and its management need to be given greater attention.

Water is the next important input to fertilizer for crop production. If it is polluted, it may be dangerous for plants, animals as well as for human being. Before using water for irrigation, its quality, which is equally important to its quantity, should be assessed so that it could not create any health hazard. If low quality of water is utilized for irrigation, soluble salts and /or other toxic elements like arsenic may accumulate in the soil thus deteriorating soil properties and crop quality. Good quality water helps maintaining agricultural productivity and sustaining soil fertility (Johnson et al., 1990; Sheinberg et al., 1978).

Objectives

1. To review the classification systems (Doneen, Wilcox, USSL) available to classify the groundwater for irrigation according to its suitability.
2. To review the classification of ground water on the basis of its TDS and conductivity.
3. To review the limits of various toxic ionic species to crop and soil.
4. To classify the groundwater of Dhanbad town area on the basis of its suitability for irrigation.

2.0 REVIEW

The guidelines for interpreting water quality can be used to identify potential problems in the use of the particular quality of water for crop irrigation. Usually the quality of groundwater for irrigation purpose is evaluated on the basis of total concentration of soluble salts or salinity hazards, exchangeable sodium or sodicity hazards, toxicity hazards due to specific constituents and other miscellaneous effects. Various authors have depicted popular criteria to evaluate the quality of irrigation water (USDA, 1954; Ayers et al., 1985; Sheinberg and Oster, 1978; James, 1988). Accordingly, the quality of irrigation water could be evaluated on the basis of:

- Toxicity hazards due to specific constituents and
- Miscellaneous effects.

2.1 Toxicity Hazards

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. Accumulation to toxic concentrations takes time and visual damage is often slow to be noticed. The degree of damage depends upon the duration of exposure, concentration by the toxic ion, crop sensitivity, and the volume of water transpired by the crop. Presence of few specific constituents beyond a limit in irrigation water may adversely affect the satisfactory growth of some field crops. Boron, sodium and chloride are the most common phytotoxins found in natural irrigation waters. Woody perennial plants are sensitive to sodium and chloride (tree fruits and grapes). Besides these elements, selenium, molybdenum and fluorine are tolerated by plants but are toxic to animals that feed on them.

Boron

Boron (B) is an essential minor element that is toxic to many crops if present in excess. Boron sensitivity varies from crop to crop. Traces of boron >0.5 ppm are injurious to citrus, nuts and deciduous fruits; cereals and cotton are moderately tolerant to boron; while alfalfa, beet, asparagus and dates are quite tolerant (1-2 ppm). Boron toxicity symptoms normally show first on older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges. Most crop toxicity symptoms occur after boron concentrations in leaf blades exceed 250–300 mg/kg (dry weight) but not all sensitive crops accumulate boron in leaf blades. Boron toxicity guideline is given in Table 2.1 (www.spectrumanalytic.com).

Table 2.1 - Toxicity guidelines for toxicity to boron

	boron-ppm	boron-ppm		boron-ppm	
Excellent	< 0.33	< 0.67		< 1.00	
Good	0.33-0.67	0.67-1.33		1.00-2.00	
Permissible	0.67-1.00	1.33-2.00		2.00-3.00	
Doubtful	1.00-1.25	2.00-2.50		3.00-3.75	
Unsuitable	1.25 +	2.50 +		3.75 +	
	relative crop tolerance to boron				
	sensitive	semi-tolerant		tolerant	
	Pecan	Sunflower	Sorghum	Sugar beet	Turnip
	Black walnut	Cotton	Oat	Table beet	Cabbage
	Navy bean	Radish	Pumpkin	Alfalfa	Lettuce
	Pear	Field Pea	Sweet Potato	Gladiolus	Carrot
	Apple	Barley	Wheat	Onion	
	Peach	Corn			
Note: 0.02 ppm of boron (0.002 epm), or more, in the irrigation water may be required to sustain adequate plant growth (in the absence of fertilizer B)					

Sodium

Sodium toxicity is often modified or reduced if sufficient calcium is available in the soil. Leaf tissue analysis is commonly used to confirm or monitor sodium toxicity but a combination of soil, water and plant tissue analyses greatly increases the probability of a correct diagnosis. Toxicity due to sodium is given in Table 2.2 (Ayers and Branson, 1975).

Table 2.2 - Toxicity guidelines for toxicity to sodium

Sodium Adsorption Ratio (SAR) hazard levels					
application	none	increasing	significant	high	severe
most production systems	<1	1-2	2-4	4-5	>5
hydroponics	<3	3-7	7-8	8-9	>9

Chloride

The most common toxicity is from chloride in the irrigation water. Chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Toxicity due to chloride is given in Table 2.3 (Ayers and Branson, 1975).

Table 2.3 - Toxicity guidelines for toxicity to chloride

constituents	no problem	increased problem	severe
from root absorption (epm)	<4	4-10	10+
from folic absorption (epm)	<3	3+	-

2.2 Miscellaneous Effects

In this category, problems related with crop production due to water quality, such as excessive vegetative growth, white deposits on fruits or leaves due to sprinkling with high bicarbonate water, and problems related to pH, Mg, alkalinity, bicarbonate, TDS, drainage, etc. have been discussed.

pH

pH is an indicator of the acidity or basicity of a water, but is seldom a problem by itself. The main use of pH in a water analysis is for detecting an abnormal water. A water pH between 6.5 and 8.5 is normally considered to be the most desirable for irrigation. When the pH is outside of this range, it indicates that special actions may need to be taken to improve crop performance. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion. Such water normally causes few problems for soils or crops. Any change in the soil pH caused by the water will take place slowly since the soil is strongly buffered and resists change. The greatest direct hazard of an abnormal pH in water is the impact on irrigation equipment like distribution system, sprinklers and control equipment.

Effects of soil pH on nutrient availability

Soil pH can have a big effect on crop growth and yields. Most crops produce satisfactory yields within a pH range of about 5.5-7.5, with a pH of about 6.5 being ideal. Some crops like pineapple, coffee, potatoes, and sweet potatoes are especially tolerant of soil acidity. The influence of pH on nutrient availability is illustrated in the Fig. 2.1a. Iron, manganese and zinc become less available as the pH is raised from 6.5 to 7.5 or 8.0. Molybdenum and phosphorus availability, on the other hand is affected in the opposite way, being greater at the higher pH levels. At very high pH values the bicarbonate ion (HCO^{-}_{3}) may be present in sufficient quantities to interfere with the normal uptake of other ions and thus detrimental to optimum growth. Highly acid soils are conducive to both Al and Mn toxicity and to Mo deficiency. Highly alkaline soils are conducive to B toxicity but to Fe, Zn and Mn deficiencies. The tie-up (fixation) of phosphorus is greatly affected by soil pH. Phosphorus is most available within a pH range of 6.0-7.0. Very acid soils can be toxic to plants. Aluminum, manganese, and iron become more soluble as soil acidity increases and can actually injure plant roots at pH's below 5.0-5.5, depending on the soil and type of plant (Fig. 2.1b). Soil pH affects the availability of micronutrients to plant roots. Except for molybdenum, the other 5 micronutrients (iron, manganese, copper, zinc, boron) become increasingly available to plants as acidity decreases (i.e. as pH rises). Iron and manganese are the most affected and may become so insoluble at pH's above 6.5 that plants can suffer deficiencies (Fig. 2.1a).

Low pH reduces the availability of the macro and secondary nutrients. High pH reduces the availability of most micronutrients. The 'base' cations (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}) are bound more weakly to the soil, so can leach out of the surface soil at low pH. Therefore, they are less available at low pH (Foth and Ellis, 1997).

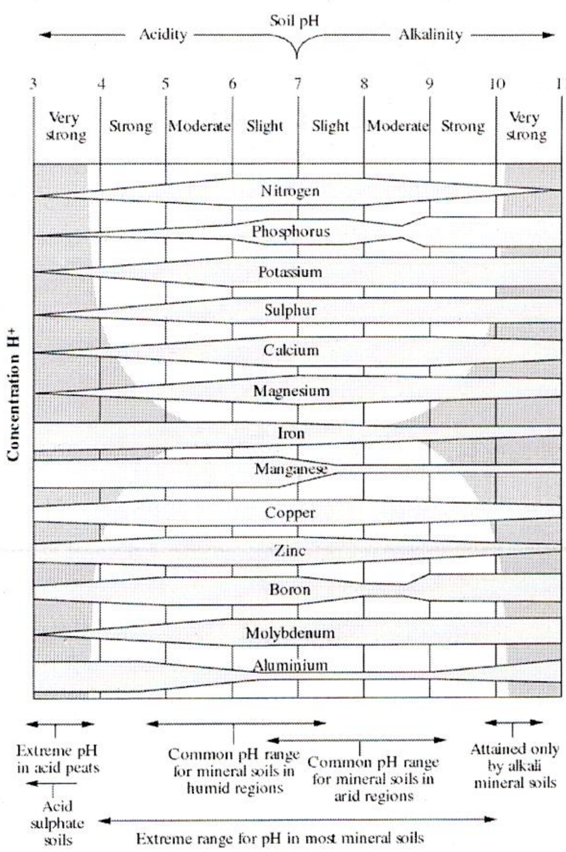

Fig. 2.1a: Effects of pH on nutrient availability
(Source: Polomski, 2007)

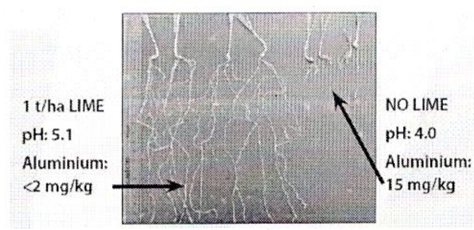

Fig. 2.1b: Roots of barley grown in acidic subsurface soil are shortened by aluminium toxicity
(Source: www.soilquality.org.au)

Magnesium Hazard

Soils containing high levels of exchangeable magnesium are often thought to be troubled with soil infiltration problems. Crop productivity is low on high magnesium soils or on soils being irrigated with high magnesium water even though infiltration problems may not be evident. The effect may be due to a magnesium-induced calcium deficiency caused by high levels of exchangeable magnesium in the soil. Paliwal (1972) has used the ratio $[(Mg^{2+})*(100)]/[(Ca^{2+} + Mg^{2+})]$ as an index of magnesium hazard to irrigation water. Mg hazard is likely to be developed in the soil when this ratio exceeds 50 %. The degree of hazardous effects would increase with the increase of Mg^{2+}/Ca^{2+} ratio. However the harmful effect of Mg^{2+} of irrigation water on soil is likely to be reduced by the release of Ca^{2+} on dissolution of $CaCO_3$ if present in the soil.

Alkalinity Hazard

This indicates the ability of the water to increase the pH of the soil or growing media, and the buffering power (resistance to change) of the water itself. Alkalinity is defined as the combined effect of bicarbonates (HCO^-_3) and the carbonates (CO^{2-}_3). High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acidic in nature for some plants. If the water is also somewhat acidic, the process would be accelerated.

Another aspect of alkalinity is its potential effect on sodium (Na^+). Alkaline water could intensify the impact of high SAR water on sodic soil conditions. Soil or artificial growing media irrigated with alkaline water may, upon drying, cause excess of available sodium. Several potential problems could result:

- The excess available sodium could become directly toxic to some plants.
- The salinity of the soil could be increased to the point that plant growth is damaged.
- Excess sodium could damage the structure of natural soil to the point that air and water infiltration are prevented, and root growth is restricted.

Danger from high alkalinity is governed in part by the volume of soil or artificial media involved. For example, greenhouse transplant production (plugs) have very little soil media and are less tolerant of a given alkalinity level than most other container production systems. Field production will typically be the most tolerant. The alkalinity effects in irrigation water are given in Table 2.4.

Table 2.4 - Alkalinity hazard levels

application	units	none	increasing	significant	high	severe
field crops	epm $CaCO_3$	<1.0	1.0-2.0	2.0-3.0	3.0-4.0	>4.0
	ppm $CaCO_3$	<50	50-100	100-150	150-200	>200
greenhouse and nurseries	epm $CaCO_3$	<1.0	1.0-1.5	1.5-2.0	2.0-3.0	>3.0
	ppm $CaCO_3$	<50	50-75	75-100	100-150	>150
greenhouse "plugs"	epm $CaCO_3$	<1.0	1-1.25	1.25-1.5	1.5-2.0	>2.0
	ppm $CaCO_3$	<50	50-63	63-75	75-100	>100

Bicarbonates (HCO^-_3) Hazard

Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. However, bicarbonates can be found in water of lower pH. Carbonates become a significant factor as the water pH increases beyond 8.0 and are a dominant factor when the pH exceeds about 10.3. High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3 epm (200 ppm) will cause lime (calcium and magnesium carbonate) to be deposited on foliage when irrigated with overhead sprinklers. This may be undesirable for ornamental plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging many tree species. Excessive bicarbonate concentration can also be problematic for drip or micro-spray irrigation systems when calcite or scale build up causes reduced flow rates through orifices or emitters. The bicarbonate effects in irrigation water (www.spectrumanalytic.com) are given in Table 2.5 and 2.6.

Table 2.5 - Bicarbonates hazard levels

application	units	none	increasing	significant	high	severe
field crops	epm HCO^-_3	<1.0	1.0-2	2.0-3.0	3.0-4.0	>4.0
	ppm HCO^-_3	<61	61-122	122-183	183-244	>244
greenhouse and nurseries*	epm HCO^-_3	<1.0	1.0-1.5	1.5-2.0	2.0-3.0	>3.0
	ppm HCO^-_3	<61	61-92	92-122	122-183	>183
greenhouse "plugs"	epm HCO^-_3	<1.0	1.0-1.25	1.25-1.5	1.5-2.0	>2.0
	ppm HCO^-_3	<61	61-76	76-92	92-122	>122

*Bicarbonate levels above 3.3 epm (200 ppm) will cause lime (calcium and magnesium carbonate) to be deposited on foliage when irrigated with overhead sprinklers. This may be undesirable for ornamental plants.

Table 2.6 - Effects of high bicarbonate in irrigation water

bicarbonate (epm)	effects
0-1.5	no problem
1.5-8.5	increasing problem
> 8.5	severe problem

Total Concentration of Soluble Salts (TDS)

The suitability of groundwater for agricultural purposes is contingent to the presence of dissolved constituents in water. The long term application of moderate quality water in poorly drained land may accumulate high quantity of salts in agricultural land. The presence of salts may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions such as those caused by toxic constituents. To cope up with such problems, the information concerning the quality of irrigation water and its effect on soils and crops is necessary.

Total salt concentration of soluble salts in irrigation waters can be adequately expressed for the purpose of diagnosis and classification in terms of electrical conductivity (EC). The total concentration of soluble salts in irrigation water can be expressed for the purpose of classification of irrigation water as follows (Table 2.7) (Johson-Zhang, 1990):

Table 2.7 - Salinity hazard zone on the basis of TDS and electrical conductivity

Salinity Hazard Zone	TDS (ppm)	EC (μ-mhos/cm)
Low	<500	<800
Medium	500-1000	800-1600
High	1000-2000	1600-3000
Very	>2000	>30000

Drainage

The important factor allied with the relation of crop growth to water quality is drainage. If a soil is open and well drained, crops may be grown on it with the application of generous amount of saline water, but on the other hand, a poorly drained area combined with application of good quality water may fail to produce satisfactory crop. For example, the application of 100 mm of irrigation water containing 1000 ppm of salt to a hectare of land may introduce one ton of salts in a poorly drained area (Rhoades, 1982). The reason is that the uptake of salts by plants is low and continuous withdrawal of water by plants and evaporation leaves the salts in the soil (Fig. 2.2).

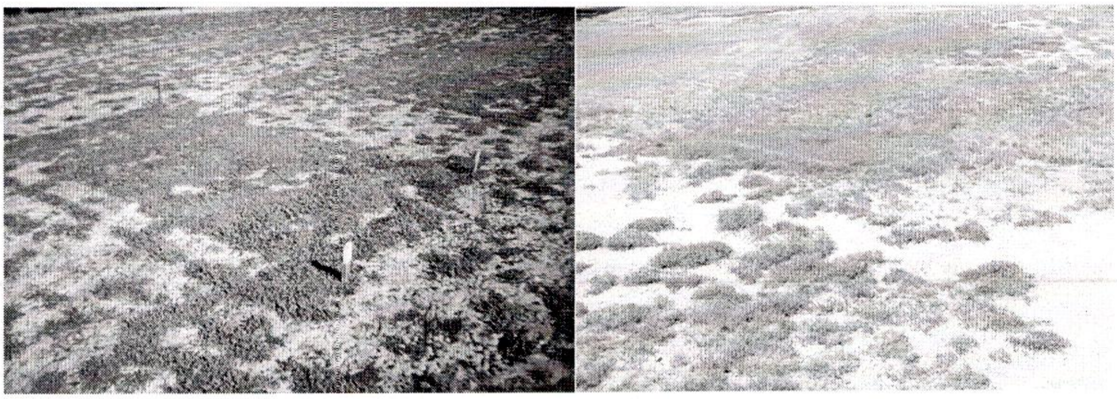

Fig. 2.2: Salt deposition due to drainage problem

2.3 Classification of Irrigation Water

2.3.1 On The Basis of Permeability Index

Doneen (1964) has developed a chart (Fig. 2.3) based on the Permeability Index (PI) given by:

$$PI = \{[Na^{+} + (HCO_3^{-})^{0.5}] / [(Ca^{2+} + Mg^{2+} + Na^{+})]\} *100 \qquad (2.1)$$

where all concentrations are in epm. According to this classification, water is good if:

- Its position in the US salinity diagram is within the zone of good or moderate waters.
- It belongs to class-I or II in the Doneen (1964) chart (Raghunath, 1987).

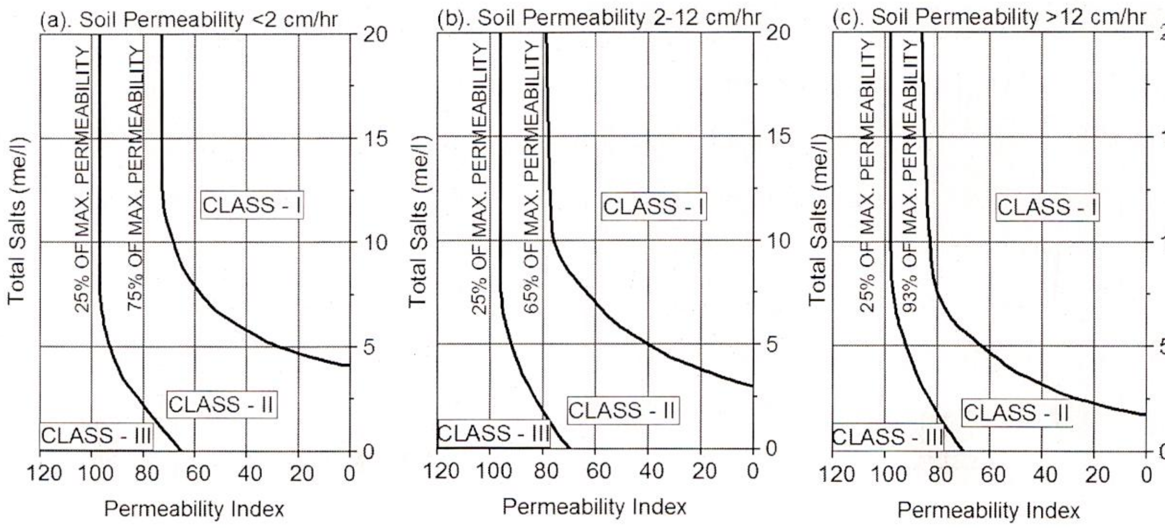

Fig. 2.3: Assessment of irrigation water quality for soils of different permeability

2.3.2 On the Basis of Residual Sodium Carbonate

A major factor affecting the final SAR value of soil water is the change in calcium and magnesium concentration due to precipitation or dissolution of alkaline earth carbonates. In irrigation water containing high concentration of bicarbonate ions, there is a tendency for calcium and, to a lesser extent, magnesium to precipitate in the form of carbonate as the soil solution becomes more concentrated, thus leading to an increase in the SAR of the soil solution. Although carbonate precipitation is common for many surface waters, its extent is often greater when well water is used. Eaton (1950) assumed that all calcium and magnesium would precipitate as carbonates and proposed the concept of residual sodium carbonate (RSC), for evaluating high carbonate water:

$$RSC\ (epm) = (CO^{2-}_3 + HCO^{-}_3) - (Ca^{2+} + Mg^{2+}) \qquad (2.2)$$

High RSC water is considered to be deleterious to the physical properties of the soils. If irrigation water contained carbonate and bicarbonate ions in excess of magnesium and calcium ions, then there is a tendency for calcium and magnesium ions to precipitate as carbonates. As a consequence, the relative proportion of sodium ion increases and gets fixed in the soil by the process of Base Exchange and thereby decreasing the soil permeability. Threshold values of RSC for irrigation water (USDA, 1954) are given in Table 2.8.

Table 2.8 - Irrigation water quality on the basis of RSC

	RSC hazard				
units	safe	marginal	significant	high	severe or unsuitable
epm	<1.24	1.25-1.7	1.7-2.1	2.1-2.5	>2.5

2.3.3 On the Basis of Soluble Sodium Percent or Na % (Wilcox Classification)

Wilcox (1948) has proposed another classification scheme for rating irrigation water on the basis of specific electrical conductance, soluble sodium percent (SSP) (Fig. 2.4). The SSP is calculated by the following formula:

$$\text{SSP or Na \%} = [(Na^{+}+K^{+})*100] / [(Ca^{2+}+Mg^{2+}+Na^{+}+K^{+})] \qquad (2.3)$$

where all concentrations are expressed in epm.

The following scheme (Table 2.9) of classification was given by Wilcox:

Table 2.9 - Wilcox classification on the basis of Na % and conductivity

water classes	SSP or Na %	Conductivity (μ-mhos/cm)
excellent	<20 %	<250
good	20 to 40 %	250-750
permissible	40 to 60 %	750-2000
doubtful	60 to 80 %	2000-3000
unsuitable	>80 %	>3000

2.3.4 On the Basis of US Salinity Laboratory Classification

High concentrations of exchangeable sodium in irrigation waters and soils cause the eventual deterioration of soil structure and resulting reduction in hydraulic conductivity. When calcium and magnesium are the predominant cations occupying soil exchange sites, soils tend to have a granular structure that is readily permeable to both air and water. As the concentration of exchangeable sodium in the soil increases, the ratio of sodium to calcium and magnesium ions rises and the number of exchange sites occupied by calcium or magnesium decreases. This causes soil mineral particles to disperse and hydraulic conductivity to decrease.

The sodium adsorption ratio (SAR) of soil extracts or irrigation waters is used to evaluate the exchangeable sodium status or sodicity hazards of soils and irrigation waters. The SAR is generally a good indicator related to exchangeable sodium status of soil. The SAR is defined by the equation as given below:

$$SAR = [Na^{+}] / [(Ca^{2+} + Mg^{2+})/2]^{0.5} \quad (2.4)$$

all concentrations are in epm in equation of SAR.

The U.S. Salinity Laboratory (USSL) has constructed a diagram for classification of irrigation waters describing 16 classes (Fig. 2.5), with reference to SAR as an index for sodium hazard and EC (μ-mhos/cm) as an index of salinity hazard (USDA, 1954). Thus, U.S. Salinity diagram is a combination of salinity and sodium hazards plotted on X and Y-axis, respectively.

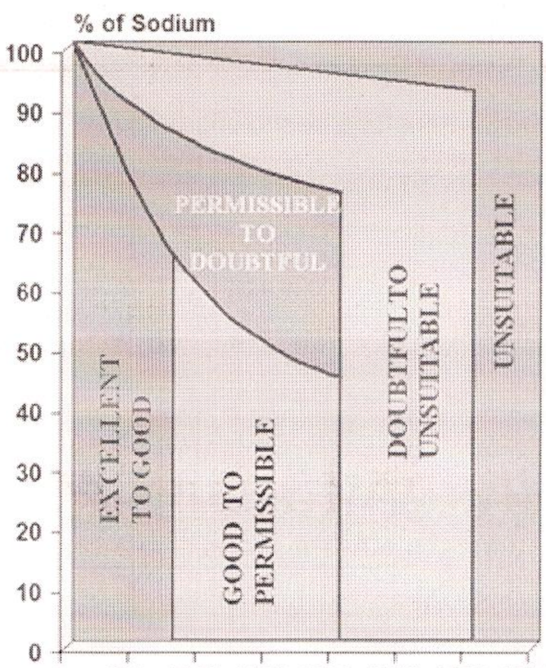

Fig. 2.4: Wilcox classification

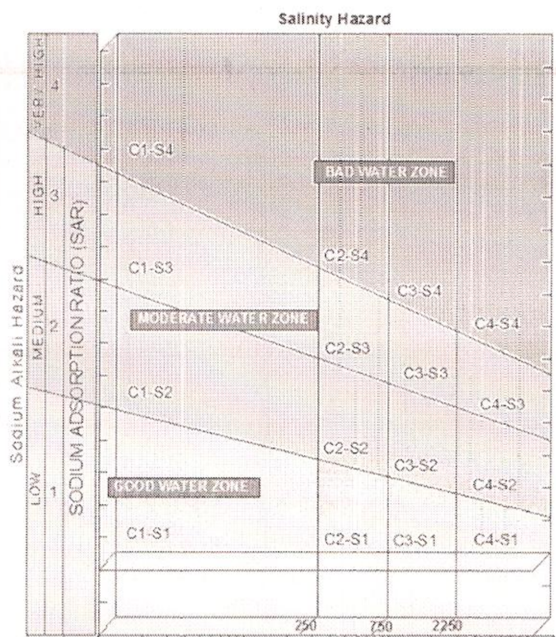

Fig. 2.5: USSL classification

Depending on salinity hazard and sodium hazard they are classified as low, medium, high, very high and are represented by C1, C2, C3, C4 and S1, S2, S3, S4 respectively.

The modalities and possible remedial characteristics of the above classification is as follows.

Classification of Irrigation Waters on the basis of Salinity Hazard	
Low Salinity (C1)	Low salinity water can be used for irrigation with most crops on most soils.
Medium Salinity (C2)	Medium salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.
High Salinity (C3)	High salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good tolerance should be selected.
Very High Salinity (C4)	Not suitable for irrigation water under ordinary conditions, but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate and irrigation water must be applied in excess to provide considerable leaching and very salt tolerant crops should be selected.
Classification of Irrigation Waters on the basis of Sodium or Alkali Hazard	
Low SAR (S1)	Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.
Medium SAR (S2)	Medium sodium water will present an appreciable sodium hazard in fine textured soils having good cation exchange capacity, especially under low leaching conditions. This water may be used on coarse-textural or organic soils with good permeability.
High SAR (S3)	High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching and organic matter additions.
Very High SAR (S4)	Generally unsatisfactory for irrigation purposes.

2.4 FAO Criteria of Water Quality for Agricultural Irrigation

Element	Max. Conc. (mg/l)	Remarks (FAO)
Aluminium	5.0	Can cause non-productivity in acid soils (pH<5.5), but more alkaline soils at pH>7.0 will precipitate the ion and eliminate any toxicity.
Arsenic	0.10	Toxicity to plants varies widely, from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Barium	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Cobalt	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Chromium	0.10	Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Copper	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient
Fluoride	1.0	Inactivated by neutral and alkaline soils.
Iron	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum.
Lithium	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Manganese	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Molybdenum	0.01	Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Nickel	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Lead	5.0	Can inhibit plant cell growth at very high concentrations.
Selenium	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium.
Vanadium	0.10	Toxic to many plants at relatively low concentrations.
Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

(Source: Ayers et al., 1985)

3.0 STUDY AREA

The Dhanbad district is situated in the state of Jharkhand and lies between 23°37'3" and 24°4' North latitude and between 86°6′30" and 86°50' East longitude. Dhanbad district shares its boundaries with West Bengal in the eastern and south part Dumka and Giridih district in North and Bokaro district in West (Fig. 3.1). Its geographical length extending from North to South is 43 miles and the breadth stretching across East to West is 47 miles. Dhanbad comes under the Chhota-Nagpur Plateau.

The climate is tropical in nature with hot summer. In winter, the minimum temperature remains around 8°C with a maximum of 22°C. Dhanbad town which have been taken into consideration for the study cover an area between G.T. Road and Bank More in N-S direction and between Govindpur East and Hirak Bye pass Road in E-W direction.

Two types of soil around the district, namely, Alfiso red sandy soil and Ultiso red and yellow soil. The Alfiso red sandy soil is found in north and northwest part of the district which is a densely wooded hilly terrain. The rest part of the district has cultivated lands having ultiso red and yellow soil. Although ground water potentiality is not very much encouraging for the whole district, even then Dhanbad town and its surrounding areas have moderately thick confined or unconfined aquifers beneath the surface. In the rest part of the district, the ground water is restricted to weathered zone having poor porosity. Over and above the soil of Dhanbad town and its adjoining areas has reasonably better water holding capacity compared to other part of the district.

The rocks beneath Dhanbad and its adjoining terrains are metamorphic rocks made up of older basement rocks-Mica-Schist, Amphibolites, quartze-felspatite, sniessis and granitite. These older basement rocks have been intruded by Dolerite and later on these rocks were again intruded by acid intrusive rock layers of quartzite, etc. Though, metamorphic rocks are impermeable but some associated fissured rock layers are in aquifers which might have joined with fault planes or shear planes but their exact location and depth are not known exactly. Their depth differs from place to place. Therefore, in deep borings for water, it has been found that at a particular location, no water is found, but in the same vicinity few meters near about water is found. Such phenomena have been found at many locations during deep tubewell boring for water. All these findings can be attributed to folding characteristic of rocks beneath the ground.

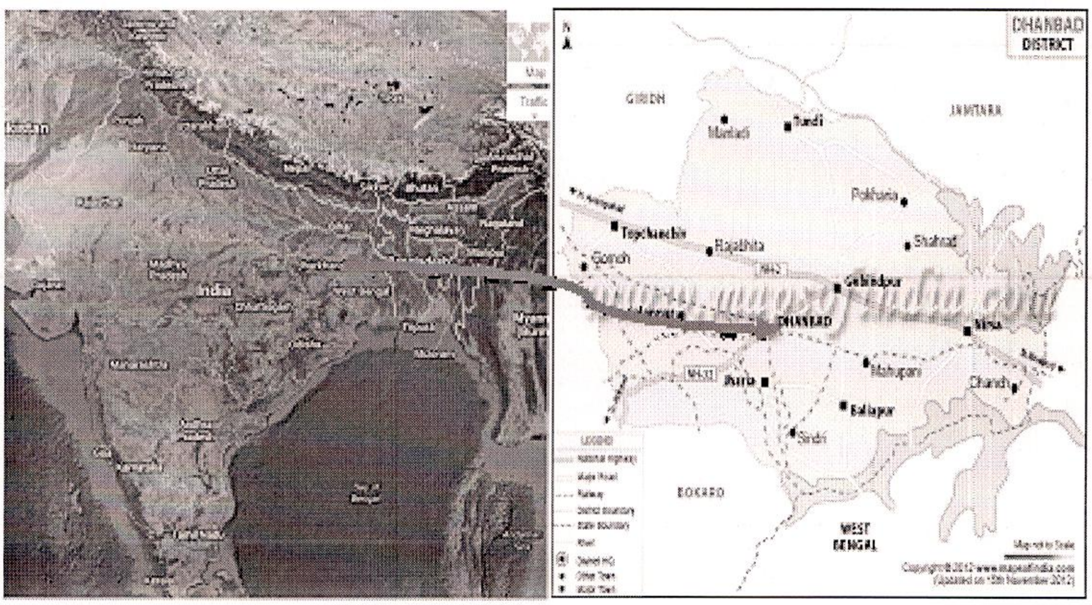

Fig. 3.1: Location of Study Area

4.0 METHODOLOGY

Sampling locations were selected in the residential area and ground water samples were collected from 24 different hand-pumps in pre washed plastic containers as per standard sampling methods (APHA, 1992). The ground water samples were collected from hand-pumps in one litre narrow-mouth pre-washed polyethylene bottles. Prior to field work, polyethylene bottles were washed in the laboratory with dilute nitric acid and then rinsed twice with double distilled water. At the sampling sites, before collecting the samples bottles were also washed with the sample water. About one litre water samples were collected from each site.

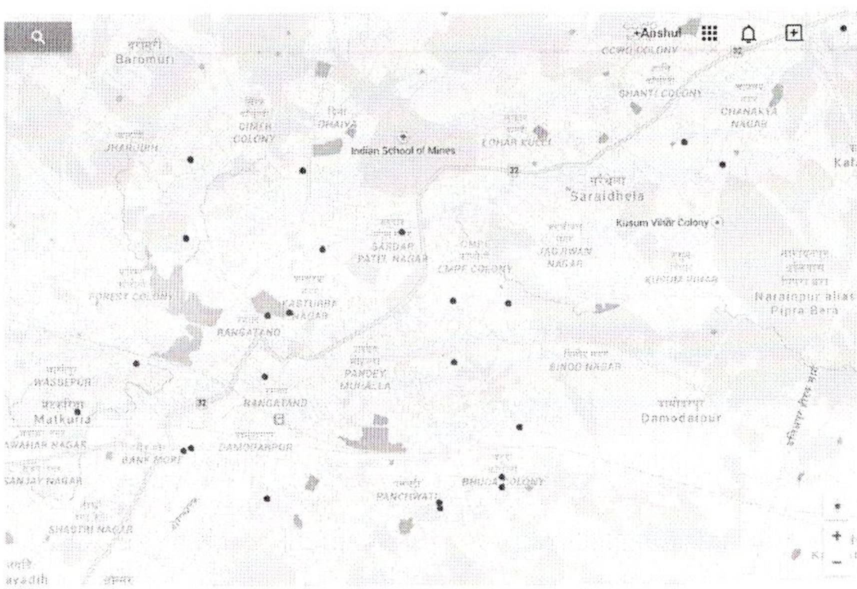

Fig. 4.1: Sampling Station

Different physicochemical characteristics of water such as pH, TDS, Salinity, and Conductivity had been analyzed at the site using potable water testing kit and the remaining parameters like Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-} have been analyzed in the laboratory as per the method described in APHA (1992).

5.0 RESULTS AND DISCUSSION

5.1 Classification of irrigation water on the basis of Soluble Sodium Percent (SSP) or Na % (Wilcox Classification)

Results of 24 samples in the study area show that SSP values in groundwater is varying from 6.51 to 92.43 with the average of 45.52 (Table 5.1). Its concentration is widely distributed with various proportions in the study area (Fig. 5.1). Site wise variation of SSP using graphical presentation is shown in Fig. 5.2 while individual site wise SSP class are presented in Table 5.2.

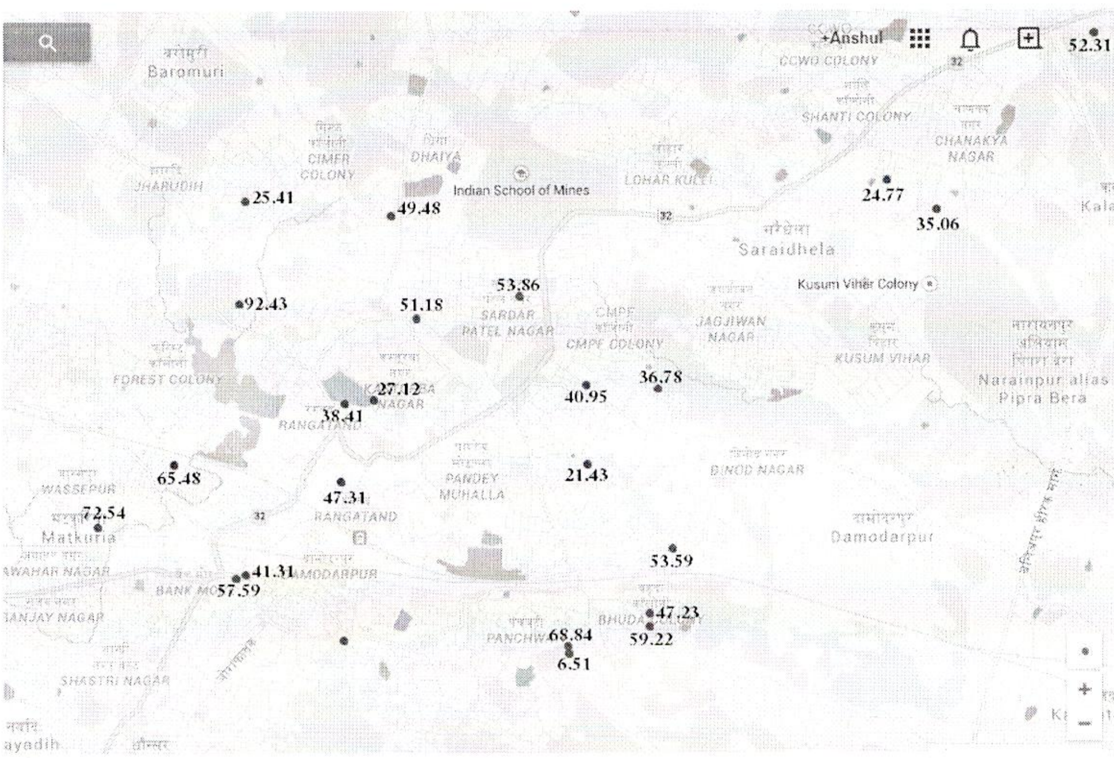

Fig. 5.1: Wilcox SSP value at various locations

Table 5.1 - Statistical analysis of various WQ parameters and SSP

Descriptive Statistics	Conductivity (μS/cm)	Na^{+} (meq)	Ca^{2+} (meq)	Mg^{2+} (meq)	Wilcox SSP
Minimum	107.49	0.06	0.70	0.02	6.51
Maximum	2460.63	13.64	10.04	3.48	92.43
Mean	869.00	4.43	3.02	0.98	45.52
Median	683.94	2.98	2.49	0.80	47.37
Standard Deviation	627.26	4.10	2.34	0.92	19.20
Kurtosis	1.45	0.47	3.10	2.92	0.42
Skewness	1.37	1.24	1.82	1.72	0.27
Coef. of Var. %	72.18	92.67	77.56	93.54	42.17

Table 5.2 - Individual site wise Wilcox SSP and related classification

Site No.	Sampling site	Wilcox SSP %	Wilcox Classification	Site No.	Sampling site	Wilcox SSP %	Wilcox Classification
1.	Polytechnic college	92.43	Doubtful to Unsuitable	13.	Chiragora	53.59	Excellent to Good
2.	Grewal colony	38.41	Excellent to Good	14.	Hari mandir	21.43	Excellent to Good
3.	Railway colony	47.52	Excellent to Good	15.	Telipara	36.78	Excellent to Good
4.	Bank more thana	41.31	Excellent to Good	16.	Heerapur	40.95	Excellent to Good
5.	Municipal office	57.59	Excellent to Good	17.	Saraidhela	35.06	Excellent to Good
6.	Washepur masjid	65.48	Permissible to Doubtful	18.	Steel gate	24.77	Excellent to Good
7.	Matkuria	72.54	Permissible to Doubtful	19.	Bhojpur mandir	52.31	Good to Permissible
8.	Barmasia	68.84	Permissible to Doubtful	20.	Dhaiya	51.18	Doubtful to Unsuitable
9.	Gandhi nagar	23.50	Excellent to Good	21.	Housing colony	53.86	Doubtful to Unsuitable
10.	Gaguatard	47.23	Good to Permissible	22.	CIMFR campus	49.48	Good to Permissible
11.	Tikkiapara	59.22	Permissible to Doubtful	23.	Bekar Bandh	27.12	Excellent to Good
12.	Barmasia	6.51	Excellent to Good	24.	Bishnupur	25.41	Good to Permissible

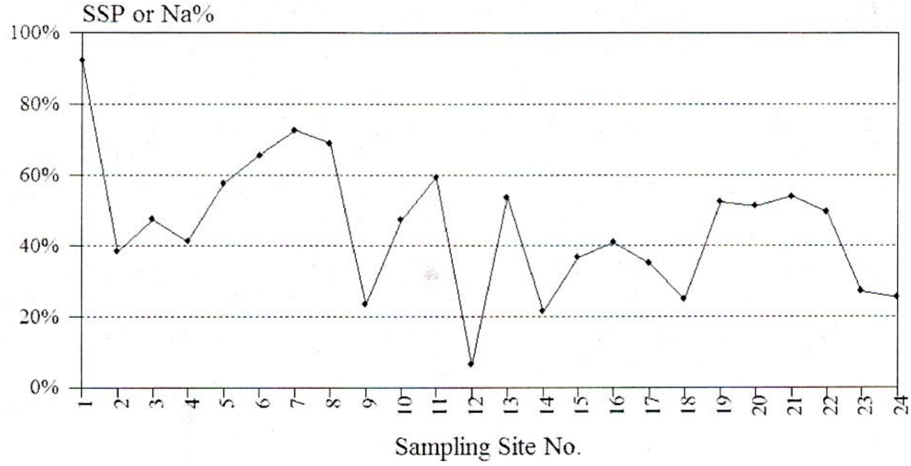

Fig. 5.2: Site wise variation of SSP

The hydro geochemical analysis according to Wilcox (1948) (Fig. 5.3) reveals that about 54.17 % samples are excellent to good, 16.67 % samples are good to permissible, 16.67 % are permissible to doubtful and 12.50 % samples are doubtful to unsuitable (Fig. 5.4). The groundwater near 3 stations (site no. 1, 20, 21) which fall in doubtful to unsuitable class (Fig. 5.3) should be avoided for irrigation purpose and other surface water sources should be utilized to meet the irrigation needs.

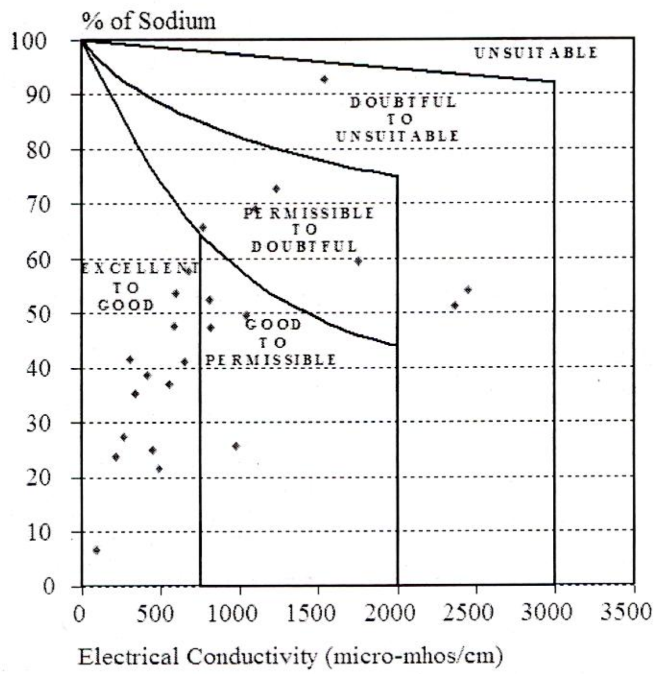

Fig. 5.3: Wilcox's SSP (Na %) plot

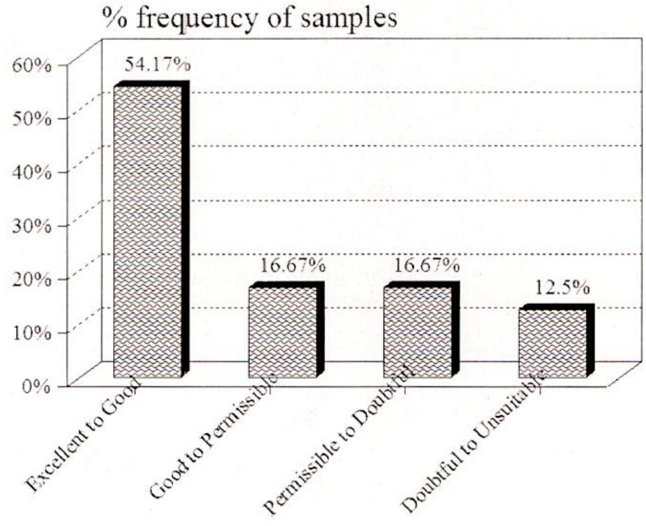

Fig. 5.4: % frequency of samples

5.2 Classification of irrigation water on the Basis of Permeability Index

The statistical measures such as minimum, maximum, average, median, mode are presented in Table 5.1 and 5.3 for the experimental analysis (conductivity, Na^+, Ca^{2+}, Mg^{2+} and HCO^-_3), Total salts (TDS) and Doneen's PI of the all 24 sampling sites. The Table 5.4 represents the Doneen's PI values and corresponding suitability class for the each sampling site. Fig. 5.5 represents the graphical comparison of Doneen's PI values at various sampling locations. Doneen's PI plot for the study area is presented in Fig. 5.6. It is the graphical representation of the study results.

Table 5.3 - Statistical analysis of various parameters

Descriptive Statistics	Total Salts (meq)	HCO^-_3 (meq)	Doneen's PI
Minimum	1.98	0.14	31.57
Maximum	50.54	7.44	102.49
Mean	17.38	0.88	60.75
Median	13.38	0.43	55.73
Standard Deviation	12.91	1.56	17.37
Kurtosis	1.79	15.02	1.15
Skewness	1.48	3.81	1.06
Coef. of Var. %	74.26	177.13	28.59

Table 5.4 - Doneen's PI and corresponding class of irrigation suitability

Site No.	Sampling site	Doneen's P.I. Value	Class	Site No.	Sampling site	Doneen's P.I. Value	Class
1.	Polytechnic college	95.96	CLASS-III	13.	Chiragora	64.71	CLASS-I
2.	Grewal colony	53.98	CLASS-I	14.	Hari mandir	38.56	CLASS-I
3.	Railway colony	58.46	CLASS-I	15.	Telipara	51.70	CLASS-I
4.	Bank more thana	58.18	CLASS-I	16.	Heerapur	52.77	CLASS-I
5.	Municipal office	66.72	CLASS-I	17.	Saraidhela	51.86	CLASS-I
6.	Washepur masjid	96.27	CLASS-III	18.	Steel gate	40.51	CLASS-I
7.	Matkuria	102.49	CLASS-III	19.	Bhojpur mandir	63.46	CLASS-I
8.	Barmasia	75.34	CLASS-I	20.	Dhaiya	54.31	CLASS-I
9.	Gandhi nagar	55.04	CLASS-II	21.	Housing colony	56.43	CLASS-I
10.	Gaguatard	53.28	CLASS-I	22.	CIMFR campus	53.07	CLASS-I
11.	Tikkiapara	62.24	CLASS-I	23.	Bekar Bandh	51.10	CLASS-I
12.	Barmasia	69.95	CLASS-II	24.	Bishnupur	31.57	CLASS-I

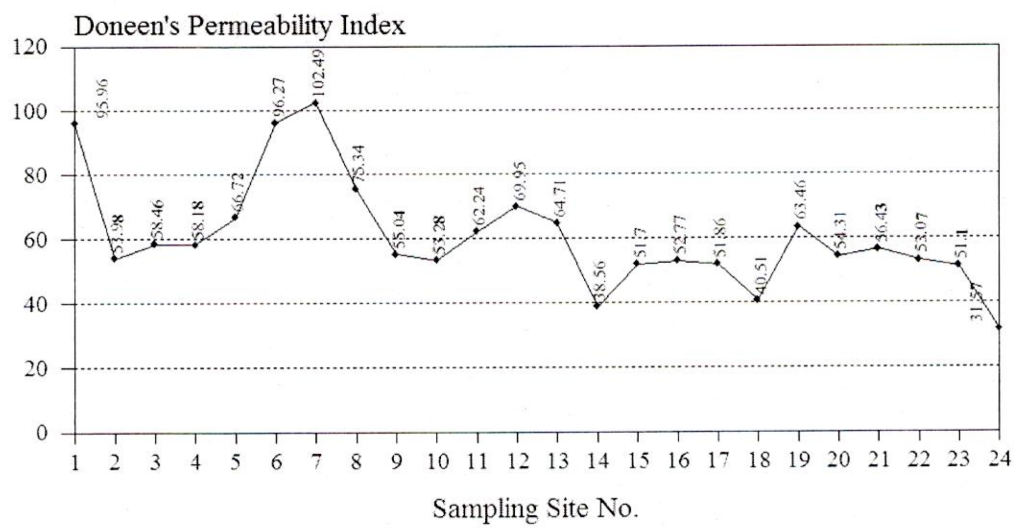

Fig. 5.5: Doneen's Permeability Index at various sites

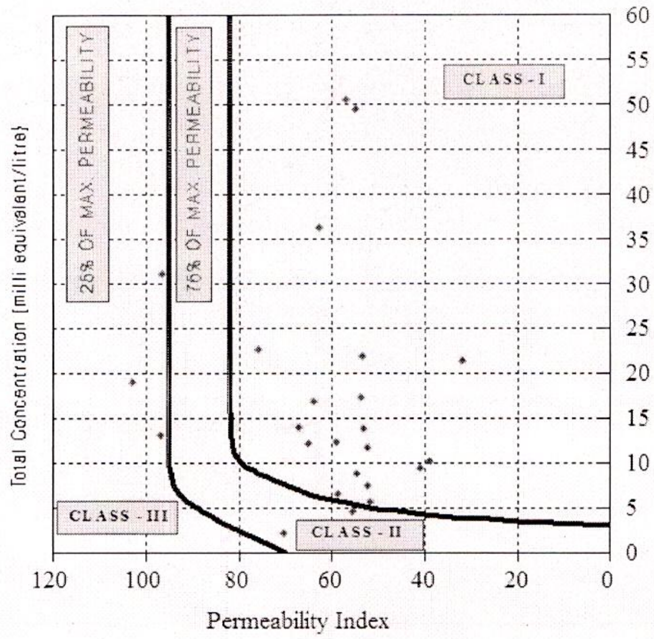

Fig. 5.6: Doneen's chart diagram for the study area

The % frequency of samples in various classes has been represents in Fig. 5.7. It is clear that about 80 % of the sampling site's groundwater is in CLASS-I, i.e. can be used unobjectionably for the irrigation purposes. However precaution should be taken before using the groundwater for irrigation near the sites which fall in CLASS-III.

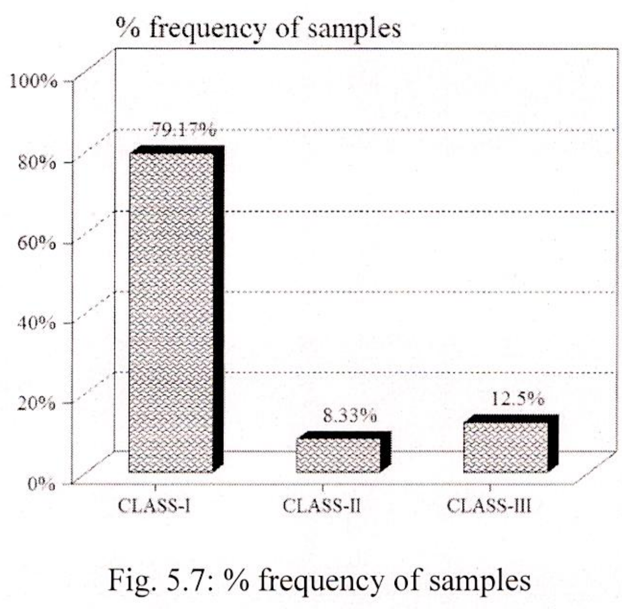

Fig. 5.7: % frequency of samples

5.3 Classification of irrigation water on the basis of SAR and US Salinity Laboratory Classification

Results of 24 samples in the study area show that SAR concentration in groundwater is varying from 0.03 to 9.49 (Fig. 5.8) with the average of 2.82 (Table 5.5). Its concentration is widely distributed with various proportions in the study area (Fig. 5.9). Site wise variation of SAR using graphical presentation is shown in Fig. 5.10 while individual site wise USSL class are presented in Table 5.6.

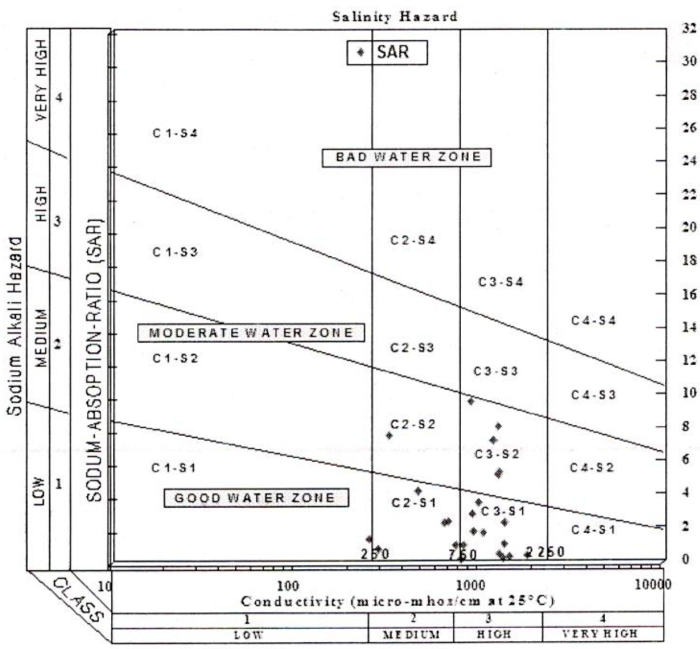

Fig. 5.8: SAR vs Conductivity on USSL classification system

Table 5.5 - Details of descriptive statistics of SAR

Descriptive Statistics	SAR
Minimum	0.03
Maximum	9.49
Mean	2.82
Standard Error	0.58
Median	1.95
St. Deviation	2.82
Sample Variance	7.96
Kurtosis	0.04
Skewness	1.07

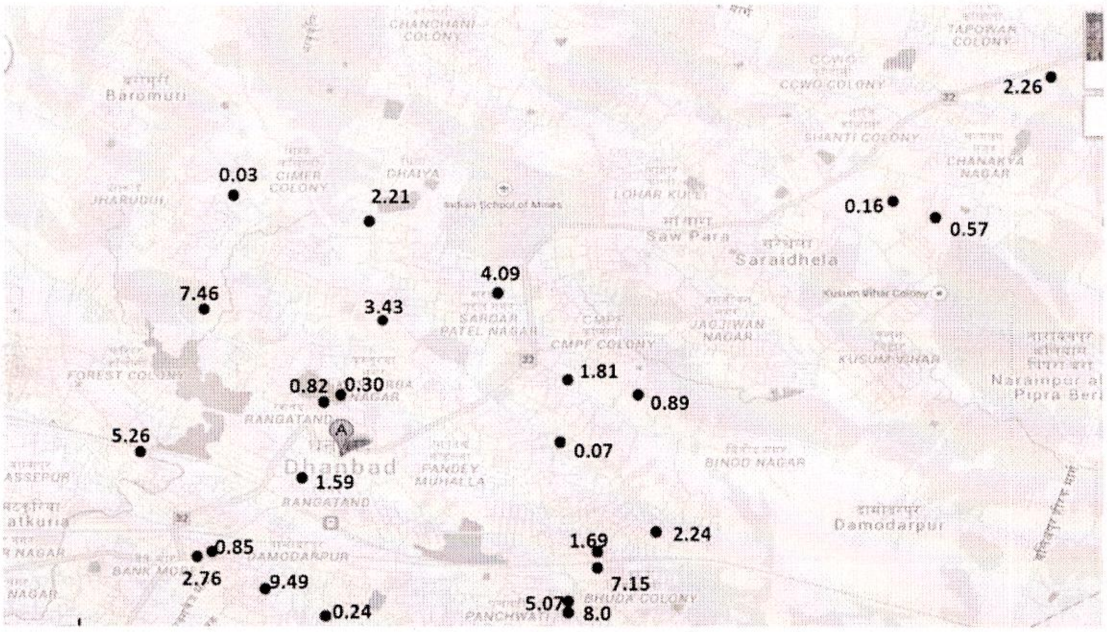

Fig. 5.9: Distribution of SAR values at different locations

Table 5.6 - SAR value and USSL classification for groundwater at different site

Site No.	Sampling site	SAR Value	USSL Class	Site No.	Sampling site	SAR Value	USSL Class
1.	Polytechnic college	7.46	C2-S2	13.	Chiragora	2.24	C3-S3
2.	Grewal colony	0.82	C3-S1	14.	Hari mandir	0.07	C3-S2
3.	Railway colony	1.59	C3-S1	15.	Telipara	0.89	C3-S4
4.	Bank more thana	0.85	C2-S1	16.	Heerapur	1.18	C1-S1
5.	Municipal office	2.76	C3-S1	17.	Saraidhela	0.57	C2-S1
6.	Washepur masjid	5.27	C3-S5	18.	Steel gate	0.16	C3-S5
7.	Matkuria	9.49	C3-S2	19.	Bhojpur mandir	2.26	C2-S1
8.	Barmasia	5.07	C3-S3	20.	Dhaiya	3.43	C3-S1
9.	Gandhi nagar	0.24	C3-S6	21.	Housing colony	4.09	C2-S1
10.	Gaguatard	1.69	C3-S1	22.	CIMFR campus	2.21	C2-S1
11.	Tikkiapara	7.15	C3-S2	23.	Bekar Bandh	0.30	C3-S1
12.	Barmasia	8.00	C3-S4	24.	Bishnupur	0.03	C3-S1

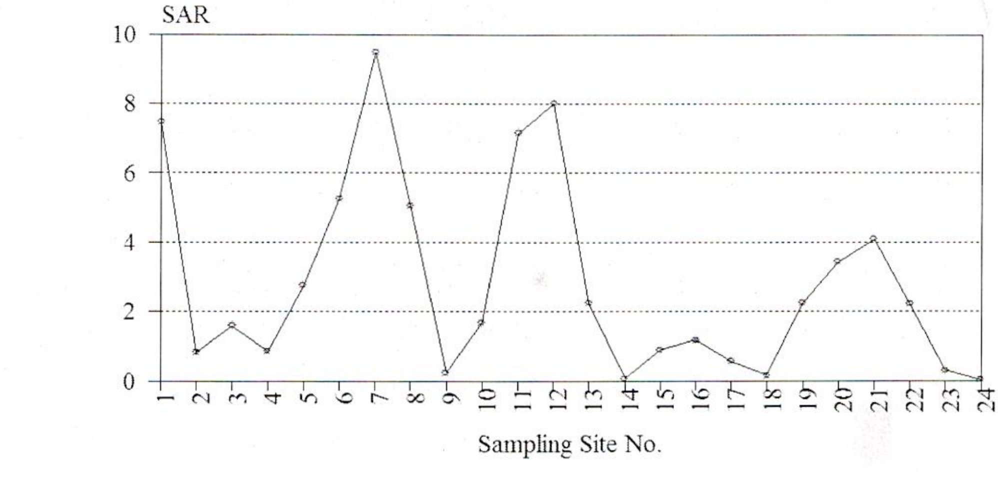

Fig. 5.10: Site wise variation of SAR

Box plots are also used to represent temporal concentration of the analysed water quality parameters and shown in Fig. 5.11. The upper and lower quartiles of the data define the top and the bottom of a rectangle box. The line inside the box represents the median value and the size of the box represents the spread of the central value.

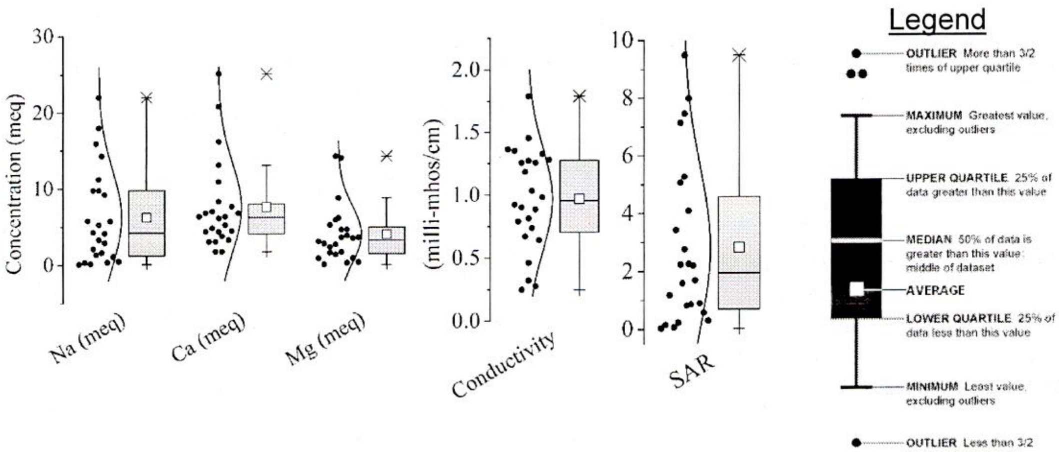

Fig. 5.11: Box Whisker plots of SAR and different parameters used for SAR analysis

Fig. 5.12 shows the percentage frequency of water samples that fall under different USSL classification criteria. As per the criteria of USSL classification it is found that, out of 24 water samples 1water sample (4.17 %) falls under C1-S1 type (low salinity-low SAR), 5 samples (20.83 %) fall under C1-S1 type (medium salinity-low SAR),12 samples (50 %) fall under C3-S1 type (high salinity-low SAR), 1 water sample (4.17 %) falls under C2-S2 type (medium salinity-medium SAR) and 5 samples (20.83 %) fall under C3-S2 type (high salinity-medium SAR).

Overall, we can say that according to the USSL classification of irrigation water, 75 % samples fall under good quality water type while 25 % samples fall under moderate quality water type (Fig. 5.12).

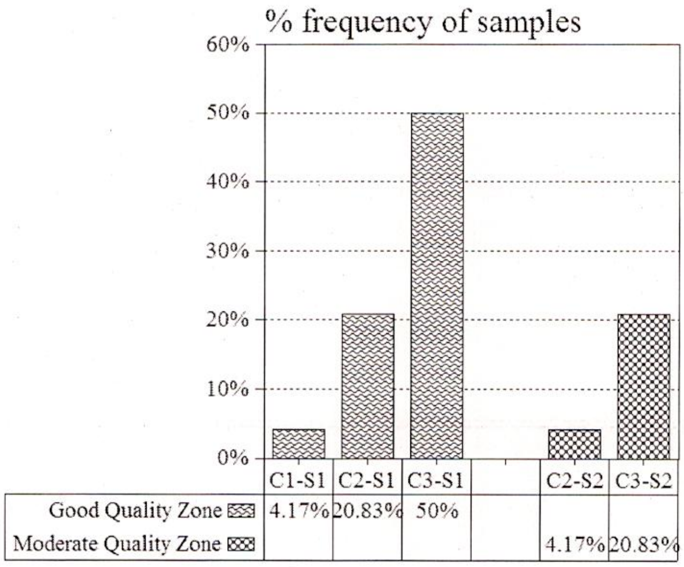

Fig. 5.12: SAR zone and % frequency of samples

5.4 Classification based on TDS and Electrical Conductivity

Total salt concentration of soluble salts in irrigation waters can be adequately expressed for the purpose of diagnosis and classification in terms of electrical conductivity (EC). The most significant water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity. The higher the EC, the less water is available to plants, even though the soil may appear wet. The primary effect of high EC water is the inability of the plant to compete with ions in the soil solution for water. The total concentration of soluble salts in irrigation water can be expressed for the purpose of classification of irrigation water as follows (Table 5.7):

Table 5.7 - Salinity hazard zone on the basis of TDS and electrical conductivity

Salinity Hazard Zone	TDS (ppm)	EC (μ-mhos/cm)
Low Salinity Zone	<200	<250
Medium Salinity Zone	200-500	250-750
High Salinity Zone	500-1500	750-2250
Very High Salinity Zone	1500-3000	2250-5000

(Source: www.spectrumanalytic.com)

Overall EC values in the study area of Dhanbad are found in the range of 107.49 to 2460.63 μ-mhos/cm (Table 5.1). It means groundwater samples of the study area fall under medium to high salinity zone and are free from very high salinity zone water. High salinity zone water cannot be used on soils having very low drainage. In such case special management criteria for salinity control may be required and plants of good salt tolerance should be selected (Ayers et al., 1975). It is observed that 29.17 % samples are in the capacity of moderate salinity hazard while rest 70.83 % samples show high salinity hazard (Fig. 5.8 and 5.11).

6.0 CONCLUSION

The hydro geochemical analysis according to Wilcox (1948) reveals that about 54.17 % samples are excellent to good, 16.67 % samples are good to permissible, 16.67 % are permissible to doubtful and 12.50 % (site no. 1, 20, 21) samples are doubtful to unsuitable. The analysis according to Doreen (1964) reveals that about 79.17 % samples are in CLASS-I (good for irrigation), 8.33 % samples are in CLASS-II and 12.50 % are fall under CLASS-III (site no. 1, 6, 7). The USSL classification shows that 29.17 % samples are in the capacity of moderate salinity hazard while rest 70.83 % samples show high salinity hazard.

After analyzing the all three classification systems it is found that the groundwater quality of Dhanbad town area is moderate to good for the irrigation use. The particular sampling sites whose ground water quality is poor should be avoided for irrigation. It is also observed that groundwater of the study area fall under medium to high salinity zone and are free from very high salinity zone water. High salinity zone water cannot be used on soils having very low drainage. In such case special management criteria for salinity control may be required and plants of good salt tolerance should be selected.

Groundwater is an important resource for meeting the water requirements for irrigation, domestic and industrial uses. Groundwater is annually replenishable resource but its availability is non-uniform in space and time. As 55 % of water demand for agriculture and irrigation is met from groundwater, the assessment of regional water quality is important in determining the feasibility of water use for the irrigation purposes. Good quality water helps maintaining agricultural productivity and sustaining soil fertility. Poor quality water can severely affect crop yields and damage soils. Therefore, information related to suitability of groundwater for irrigation purpose on quality aspect is necessary.

There is also a need to educate the farmers and increase the awareness among them regarding the importance and impacts of quality of irrigation water and its suitability according to their soil type. For this the awareness or small training should be made available to them during off-seasons.

6.1 What has been learnt in the training course?

The overall training modules undertaken at Centre for Flood Management Studies, National Institute of Hydrology, Patna dealt with the application of various classification criteria available to assess suitability of groundwater as irrigation water for the Dhanbad area.

The training methodology highlighted the crucial role of quality of water for the irrigation, its physico-chemical parameter to be considered for assessing its suitability and impacts of various quality parameters on the quality and quantity of crop produced. Moreover, this training has also made me familiar with the procedure to develop and present research or review paper. The training procedure encompassed the usage of AquaChem-2014.2, MS-Excell-2013 and other water quality analysis software.

6.2 Where can the training knowledge be applied in future?

The knowledge acquired from the training course can be applied for the increase of production and quality regional water resources management in study area.

By keeping detailed records of many aspects of the irrigation water, we can determine if the water is really affecting in one direction or another.

The classification of groundwater may be utilized to guide the farmers to adopt agricultural practices that minimize the adverse effect on their land, crop quality and quantity. The presented information can help in long term agricultural planning and adoption of new location specific agricultural technologies.

7.0 REFERENCES

APHA (1995). Standards Methods in the Examination of Water and Waste Water, 17th Ed., Washington, D.C.10.

Ayers, R.S. and Branson, R.L. (1975). Guidelines for Interpretation of Water Quality for Agriculture, University of California. Extension Mimeographed, 13 p.

Ayers, R.S. and West Cot, D.W. (1985). FAO Irrigation Drainage Paper 29 (Rev1), Rome, Italy.

Doneen, L.D. (1964). Notes on Water Quality in Agriculture, Water Science and Engineering Paper 4001, Dept. of Water, Science and Engineering, Univ. of California, Davis, USA.

Eaton, F.M. (1950). Significance of Carbonate in Irrigation Water, Soil Sci, Vol 69 no. 2 pp 123-133.

Ayers, R.S. and Westcot, D.W. (1994). Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. Reprinted 1989, 1994. Food and Agriculture Organization of the United Nations Rome, 1985.

Foth, F.M. and B.G. Ellis. (1997). Soil Fertility. 2nd Ed. CRC Press. Boca Raton, Florida. 290 p.

James, G. Lary. (1988). Principals of Farm Irrigation Systems Design. John Wiley & Sons, New York.

Johnson G. and Zhang H. (1990). Classification of Irrigation Water Quality, Oklahoma Cooperative Extension Fact Sheets (F-2401). *http://www.osuextra.com.*

Kelly W.P. (1951). Alkali soils-their formation, properties and reclamation. Reinhold, NY.

Kuipers J., MacHardy K. and Merschat W. (2004), Coal bed methane-produced water: management options for sustainable development. 11th International Petroleum Environmental Conference, Albuquerque, NM, USA.

Paliwal, K.V. (1992). Irrigation with Saline Water, IARI, Monograph no. 2 (new series), ND.

Polomski, R. (2007). The South Carolina Master Gardener Training Manual, Clemson University Cooperative Extension EC 678. 812 p.

Raghunath, H.M. (1987). Ground Water, Wiley Eastern Limited, New Delhi, India, 456 p.

Rhoades J.D. (1982). Reclamation and Management of Salt affected Soils after Drainage. Proc. 1st Annual Western Provincial Cong. on Water and Soil Resources Management. Lethbridge, Alberta Canada. pp 123-197.

Sheinberg, I. and Oster, J.D. (1978). Quality of Irrigation Water, IIIC Publication No. 2, International Irrigation Information Centre, Volcani Centre, P.O.B. 49, Bet Dagan, Israel.

USDA, U.S. Salinity Laboratory Staff Classification (1954). Diagnosis and Improvement of Saline and Alkaline Soils, USDA Handbook no. 60, 160 p.

Wilcox, L.V. (1948). The Quality of Water for Irrigation Use, USDA Tech. Bull. 162, Washington D.C., 40 p.

Wilcox L.V. (1955). Classification and use of irrigation water. US Department of Agriculture, Washington, 969.

www.spectrumanalytic.com, Guide to interpreting irrigation water analysis, Spectrum Analytic, Inc., USA.

www.soilquality.org.au/factsheets/soil-acidity.

Appendix: I

Achievements

Papers Published/Presented

(i) International Conferences

1. **Anshul Jain,** SR Kumar, KDSR Prashant and J. Ravi Kiran (2014). *The Quality of Groundwater for Irrigation Use in Dhanbad Town Area.* VIII WAC (World Aqua Congress) 2014: International Conference on Balancing Development and Environment at New Delhi during 20-21 Nov. 2014. Published in the proceeding, page no. 117-124. Paper was also presented.

2. **Anshul Jain** and SR Kumar (2014). *Effects of Unscientific Solid Waste Management on Groundwater Quality of Dhanbad.* 6th Bihar Science Conference (An International Conference on Science & Technology) at Patna (Bihar) during 23-25 Dec. 2014. Abstract volume, page no. 35 (proceeding is under printing stage). Paper was also presented.

3. **Anshul Jain,** SR Kumar, KDSR Prashant and J. Ravi Kiran (2014). *Classification of Groundwater for Irrigation Use at Dhanbad Town Area.* 6th Bihar Science Conference (An International Conference on Science & Technology) at Patna (Bihar) during 23-25 Dec. 2014. Abstract volume, page no. 36 (proceeding is under printing stage). Paper was also presented.

(ii) National conferences

4. **Anshul Jain,** SR Kumar, KDSR Prashant and J. Ravi Kiran (2014). *An Overview on Suitability Evaluation of Groundwater for Irrigation.* ASWEE-2014: National Conference on Advances in Soil, Water and Environment Engineering at Thanjavur (Tamil Nadu), 10-11 Oct. 2014. Published in the Proceedings, page no. 116-128. Paper was also presented.

5. J. Ravi Kiran, SR Kumar, **Anshul Jain** and KDSR Prashant (2014). *Graphical Presentation and Classification for Assessment of Groundwater Quality: A Review.* ASWEE- 2014: National Conf. on Advances in Soil, Water and Environment Engineering at Thanjavur (Tamil Nadu), 10-11 Oct. 2014. Published in the Proceedings, page no. 173-180.

6. KDSR Prashant, SR Kumar, J. Ravi Kiran and **Anshul Jain** (2014). *Review of Corrosivity Indices to Recognize the Corrosive Strength of Groundwater.* ASWEE-2014: National Conf. on Advances in Soil, Water and Environment Engineering at Thanjavur (Tamil Nadu), 10-11 Oct. 2014. Published in the Proceedings, page no. 161-172.

(iii) Int. Jr. of Engineering Research and Technology (ISSN: 2278-0181)

7. **Anshul Jain,** SR Kumar, KDSR Prashant and J. Ravi Kiran (2014). *Quality Valuation of Groundwater for Irrigation at Dhanbad.* ETWQQM-2014: National Conference on Emerging Trends in Water Quantity and Quality Management at Jaipur, 19-20 Dec. 2014. Abstract volume, page no. 39 (selected for publish online in IJERT journal). Also presented the paper.

8. J. Ravi Kiran, SR Kumar, **Anshul Jain** and KDSR Prashant (2014). *Groundwater Quality Scenario of Dhanbad Using Graphical Classification Methodologies.* ETWQQM-2014: National Conference on Emerging Trends in Water Quantity and Quality Management at Jaipur, 19-20 Dec. 2014. Abstract volume, page no. 105 (selected for publish online in IJERT journal)

9. KDSR Prashant, SR Kumar, J. Ravi Kiran and **Anshul Jain** (2014). *Application of Larson-Skold Model to Check the Corrosive Strength of Groundwater at Dhanbad.* ETWQQM-2014: National Conference on Emerging Trends in Water Quantity and Quality Management at Jaipur, 19-20 Dec. 2014. Abstract volume, page no. 104 (selected for publish online in IJERT journal). Also presented the paper.

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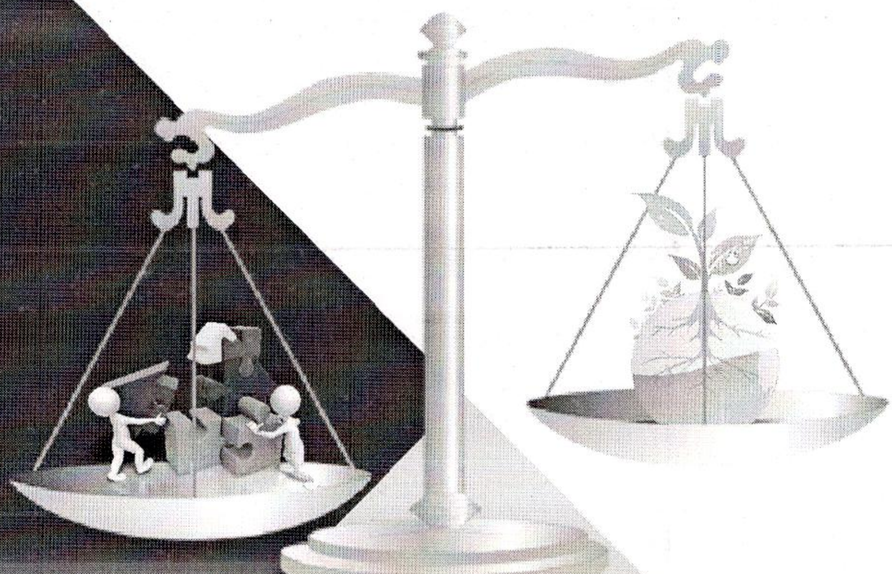

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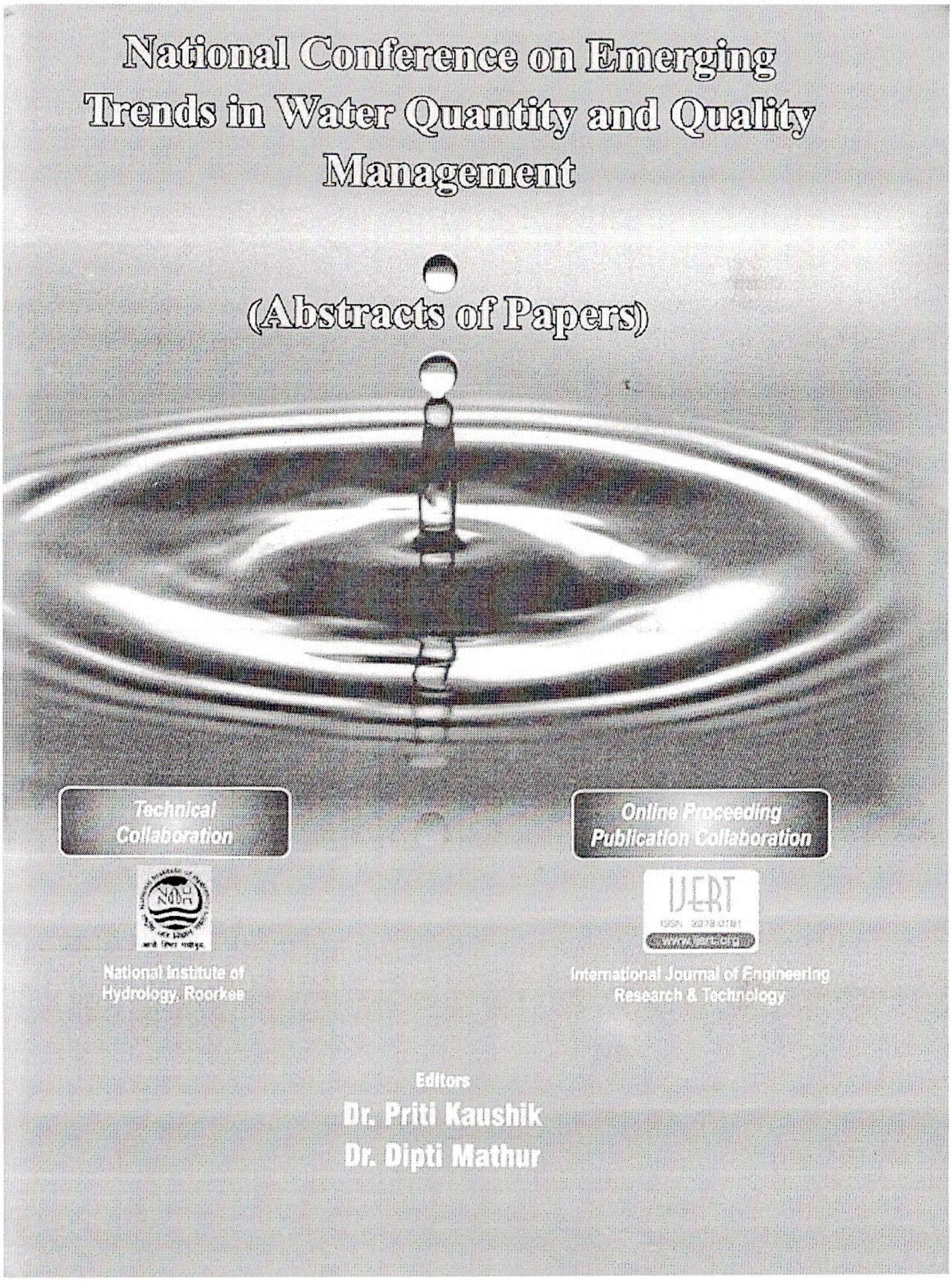

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