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Groundwater Quality A Geographical Study of Pakur District Jharkhand

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ABSTRACT: Quality of water is high degree of goodness for use in different sectors. Water quality is generally expressed in terms of its bacteriological characteristics, physical characteristics like turbidity, colour, taste and odour, and chemical characteristics like total dissolved solids, electrical conductivity and total salinity. The constituents commonly determined are like calcium, magnesium, sodium, potassium and iron and of anion like sulphate, chloride, fluoride, carbonate and bicarbonate. The chemical composition of Groundwater is related to the soluble products of rocks, weathering and decomposition and change with respect to time and space. Geochemical study provides a complete knowledge of water resources of the hydrological regimen'. Bacteria and micro-organisms, present in water are of microscopic size. Harmful bacteria, causing different diseases are known as 'pathogenic bacteria' while the harmless ones are known as 'non-pathogenic bacteria'. The quality and composition of dissolved solids in water depends upon the nature of the rock or soil with which it has come in contact. Thus, Groundwater has generally a higher salt content as compared to surface water.

Keywords: Quality, bacteriological, electrical conductivity, constituents, Geochemical, micro-organisms, 'pathogenic bacteria'.

I. INTRODUCTION:

The pressure of increasing population, growth of industries, urbanization, energy intensive life style, loss of forest cover, lack of environmental awareness, lack of implementation of environmental rules and regulations and environment improvement plans, untreated effluent discharge from industries and municipalities, use of non-biodegradable pesticides/fungicides/ herbicides/insecticides, use of chemical fertilizers instead of organic manures, etc. are causing water pollution. The pollutants from industrial discharge and sewage besides finding their way to surface water reservoirs and rivers are also percolating into ground to pollute Groundwater resources (**Rajni kant and Keshav kant, 2010**).

Water has its multipurpose uses. About 80 per cent of the earth surface is covered by water but the qualitative aspect has rendered about 97 per cent of this vast natural resource unfit for human use. 'The polluted water may have undesirable colour, odour, taste, turbidity, organic matter contents, harmful chemical contents, toxic and heavy metals, pesticides, oily matters, industrial waste products, radioactivity, high total dissolved solids (TDS), acids, alkalies, domestic sewage contents, virus, bacteria, protozoa, rotifers, worms etc. The organic contents may be biodegradable or non-biodegradable (**Rajni kant and Keshav kant, 2010**).

II. OBJECTIVES

The main objective of the present Paper is asses the Groundwater quality in Pakur District. In this regards the following are the major objectives of the present Paper:

- To describe some demographic conditions related to groundwater consumption.
- To assess the groundwater resources of the study area in terms of its present pattern in different sectors of economy. utilization
- To assess the conservation and quality management for groundwater in the study area.
- To analyze the quality of Groundwater to find out its suitability in various uses.
- To estimate the factors attributing to the pollution of Groundwater.
- To suggest measures for its conservation.

III. METHODOLOGY

This present paper is based on government offices reports, some primary observations, researches conducted by the research scholars, review of related literatures, websites, Published reports and articles by different states, central government, local bodies and NGO's secondary data collected. All data sources have been applied to have a conception of the water conservation and crisis management problem in the study area

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STUDY AREA (PAKUR DISTRICT)

The district Pakur,is located between 21^0 58'N to 25 ^{0} 18' N and 83^0 22' E to 87^0 58'E in the north eastern part of the state of Jharkhand, is surrounded by Sahibganj, Dumka, Godda, and state of West Bengal. with geographical area of 1805.59 Sq. km. the district posses as 9.00422 lakh population.

The area and population of district are 2.27% & 2.83% of the state respectively. Almost all major rivers became dry in the district most of year shows the scarcity of water. Groundwater level is continuously decreasing due to over exploitation of water in crop producing area in the district. Because of falling groundwater table, people are making deeper hand pump or boring gradually. While recharging rate of underground water is much lesser than withdrawal of water. Due to cultivation surface soil continue to be used and degraded, Besides the soil degradation and erosion also help to decrease agricultural production.

GENERAL STANDARDS OF QUALITY OF WATER FOR DIFFERENT USES

In order to avoid ill effects of water quality on the human and animal health and agricultural use some standards, rules and guidelines have been devised for discharge of effluents from industries and municipalities, quality of drinking water, irrigation water, criteria for aquatic life in fresh water by various authorities including **Central Pollution Control Board of India, World Health Organization (WHO), World** Bank, Indian Standard Institution, Indian Council of Medical Research etc. Water quality criteria for irrigation water generally take into account such characteristics as crop tolerance to salinity, sodium concentration and phototoxic trace elements. A number of other factors have a bearing on water quality criteria for irrigation. The effect of water on irrigated crops depends, for example, on the texture of soil as well as the physical properties of the specific contaminants in the water. Keeping all this in mind suitability of water has been determined taking into account the following parameters:

I. Hydrogen Ion Concentration – (pH);
II. Total Dissolved Solids – (TDS);
III. Electrical Conductivity – (EC); and
IV. Sodium Adsorption Ratio – (SAR)

HYDROGEN IONS CONCENTRATION (pH)

The hydrogen ion value of water is very important indicator of its quality. It influences to a great extent the growth of both plants and soil micro-organisms; hence, it affects the suitability of water for irrigation. The pH value of water is controlled by the amount of dissolved carbon dioxide, carbonate and bicarbonate.

TOTAL DISSOLVED SOLIDS (TDS)

The concentration of total dissolved solids is an indicator of suitability of water. The salt present in the water, besides affecting the growth of the plant directly affects the structure, permeability and aeration which indirectly affect the plant growth.

In table, relative tolerance of crops to soil water salt concentrations is limited to major crop divisions. The criterion applied was relative yield of crop on a saline soil as compared to its yield on a non-saline soil under similar growing Condition.. Soil types, climatic conditions and irrigation Practices may influence the reaction of a given crop to the salt constituents; therefore, the position of each crop in the table reflects its relative salt tolerance under customary irrigation condition.Thus, suitability of water can be correctly judged with respect to TDS only if (1) percentage of constituents of TDS is known. (2) the soil type, concentration of salts in it and drainage conditions are known and (3) the crop pattern is known. The relative suitability of water for irrigation in relation to its TDS and pH values has been expressed in Table: 4.2.

Table 4.1: Relative Tolerances of Crops to Salt concentration (after Richards 1954)

Crop division	Low salt tolerance	Medium salt tolerance	High salt tolerance
Fruit crops	Lemon, Strawberry, Peach, Almond, Plum, Orange, Apple, Pear. 3000 µmhos/cm	Date, Olive, Fig, Pomegranate 4000 µmhos/cm	Date palm 10000 µmhos/cm
Vegetable crops	4000 mmhos/cm Green bean	10000 µmhos/cms Cucumber, Squash, Peas, Onions, Carrot, Potato, Cabbage	12000 µmhos/cm Spinach, Kela, Garden feet

Food crops	4000 µmhos/cm Gram, Arhar, Moong, Pea 6000 mmhos/cm	6000 µmhos/cm Wheat, Rice, Millet, Maize 10000 mmhos/cm	1000 µmhos/cm Barley, Sugarcane, Sugar Beet 16000 mmhos/cm

Source: Todd, D.K. (1959). Ground Water Hydrology; John Wiley $ Sons, New York

Note : Electrical conductivity values represent salinity levels of the saturation extract at which a 50 per cent decrease in yield may be expected as compared to yield on non-saline soil under comparable growin .g conditions. The saturation extracts is the solution extracted from a soil at its saturation percentage.

Table 4.2: Suitability of Water for Irrigation Based on TDS and pH Value

Contents of TDS	Suitable	Unsuitable
Up to 400 ppm	All water generally fit for irrigation	
400-600 ppm	pH < 9.0	pH > 9.0
600-800 ppm	pH < 8.5	pH > 8.5
800-1000 ppm	pH < 8.0	pH > 8.0
1000-1200 ppm		Doubtful for irrigation
Above 1200 ppm		Generally unfit for irrigation

Source: Jharkhand Irrigation Research Institute, Quality of Groundwater in Ganga valley, Tech. Memo, No. 42 R-R (G-5) Ranchi 1997.

TDS by EC

A rapid determination of total dissolved solids can be made by measuring the electrical conductance of a Groundwater sample. Conductance is preferred rather than its reciprocal resistance, because it increases with salt contents. Specific electric conductance defines the conductance of a cubic centimeter of water at a standard temperature of 25°C and increase of conductance by 2 per cent. Specific conductance is measured in microsiemans/cm (µs/cm). The unit microsiemans/cm is equivalent to micromhos/cm. Because the definition of electric conductance already specifies the dimensions to which the measurement applies, the length in units is offen omitted in practice.

ELECTRICAL CONDUCTIVITY (EC)

The electrical conductivity is a useful parameter of water quality for indicating salinity hazards. In general water with conductivity value below 750 µs/cm is satisfactory for irrigation except for salt sensitive crops that may be adversely affected with temperature and hence, it is necessary to refer them to a standard temperature, normally taken as 25^{o}C. The TDS values are closely related to the electrical conductivity values. The relationship may be expressed as follows:

EC x 10^{6}= 0.64

Whereas, EC is expressed as micro-mhos/cm.

Richards (1954) has classified the suitability of irrigation water on the basis of electrical conductivity (Tab. 4.3). It is observed that water of high electrical conductivity values generally has higher content of sodium and chloride ions

SODIUM ADSORPTION RATIO (SAR)

A high salt concentration in water leads to formation of a saline and alkaline soil. The sodium and alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cation and is expressed in terms of Sodium Absorption Ratio (SAR). **Kelley (1951)** first pointed out the importance of concentration of sodium in assessing the suitability of ground water for irrigation. It is observed that when water, high in sodium concentration, is applied to soil some of the sodium is taken up by the clay which in exchange gives up calcium and magnesium. This action is called Base Exchange. Clay that has a good excess of calcium and magnesium ions, is cultivated easily and has good permeability, if it takes up sodium, it becomes sticky and has a very low permeability. It shrinks, when dry, into clods which are difficult to break. High concentration of sodium salts develops alkali soil in which little or no vegetation can be grown. A sodium percentage exceeding 50 per cent is taken as warning of sodium hazard.

Table 4.3: Standard for Suitability of Irrigation Water in Relation to Electrical Conductivity

Electrical Conductivity (micro-mhos/cm)	**Type of Water**	**Suitability for Irrigation**
Below 250	Low Salinity	Entirely safe
250-750	Moderately Salinity	Safe under practically all conditions
750-2250	Medium to High Salinity	Safe only with permeable soil and moderate leaching
Above 2250		
2250-4000	High Salinity	Unfit for irrigation
4000-6000	Very High Salinity	Unfit for irrigation
6000 and above	Excessive Salinity	Unfit for irrigation

Sources: Richards, L.A. (ed.) Diagnosis and Improvement of Saline and Alkali Soil, Agric. Handbook Co, U.S.

Table 4.4: Standard for suitability of Irrigation Water in Relation to Sodium Adsorption Ratio

SAR	**Type of water**	**Classification of water**
0-10	Low Sodium Water (**S_1**)	Suitable for almost all soil
10-18	Medium Sodium Water (**S_2**)	Suitable only for coarse textured or organic soil with good permeability
18-28	High Sodium Water (**S_3**)	Harmful
Over 28	Very High Sodium Water (**S_4**)	Unsatisfactory

Sources: Richards, L.A. (ed.) Diagnosis and Improvement of Saline and Alkali Soil, Agric. Handbook Co, U.S. Department of Agriculture, WashingtonD.C. 1954.
Department of Agriculture, WashingtonD.C. 1954.

Percentage Na = $\frac{(Na + K) \times 10}{Ca + Mg + Na + K}$ ……………..I Where all ionic concentrations are expressed in mill equivalents per litre.

However, in 1954, the U.S. Salinity Laboratory proposed that the sodium percentage idea be replaced by a significant ratio termed as the Sodium Absorption Ratio (SAR), because it has a direct relation with the adsorption of sodium by soil. This ratio is calculated from the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{++} + Mg^{++}}} \quad ....II$$

Where, all ionic concentrations of the constituents expressed in mill equivalent per litre.

PERMEABILITY INDEX (PI)

The soil permeability is affected by long term use of irrigation water. It is influenced by sodium, calcium, magnesium and bicarbonate contents of the soil. **Doneen** (**1964**) evolved a criterion for assessing the suitability of water for irrigation based on permeability index.

$$PI = \frac{100 \times Na + \sqrt{HCO_3}}{Ca + Mg + Na} \quad ……………………..III$$

Where, the ions are expressed in milli equivalent per litre.

In the present study, all these five criteria, that is, pH, TDS, EC, SAR and PI have been considered to assess the suitability of water for irrigation purposes.

DETAILS OF THE STUDY OF QUALITY OF GROUNDWATER RESOURCES

The chemical characteristics of Groundwater are determined by the chemical and biological reaction in the zones through which the water moves. In specifying the quality characteristics of Groundwater, chemical, physical and biological analyses are normally required. (**Heath, 1998**)

A complete analysis of Groundwater sample includes the determination of concentration of the inorganic constituents present Organic and radiological parameters are normally taken into account when human generated pollution affects the water quality. The analysis also includes measurement of pH and specific electrical conductance. The physical properties of Groundwater evaluation include its temperature, colour, turbidity, odour, and taste. (**Todd and Larry, 2011**).

The quality of Groundwater is of great importance in agricultural development of an area.

Groundwater supplies are limited and hence, must be wisely managed and protected against undue exploitation and contaminated by pollution (**Danial 1990**). Generally in rural areas, Groundwater is preferred to surface water due to non-availability of other water sources and the consideration that surface soil strata acts as a natural filter providing safe and pure water. This necessitates the knowledge of quality of Groundwater because lack of such knowledge would be highly detrimental particularly to agriculture because Groundwater constitutes a major source of irrigation.

CHEMICAL ANALYSIS

Substances commonly determined in chemical analysis expressed as ions comprise the cations (positively charged ions) of calcium, magnesium, sodium and potassium, and the anions (negatively charged ions) of sulphate, chloride, fluoride, nitrate and those contributing to alkalinity which are usually expressed in terms of an equivalent amount of carbonate and bicarbonate.

Table 4.5: District Pakur: Total Dissolved Solids in Tube-well Water

Cocentration of TDS in ppm	Suitable	Unsuitable	Development Blocks
Up to 400	All water generally fit for irrigation	-	Pakuria,Maheshpur, Pakur
400-600	pH < 9.0	pH > 9.0	Amrapara, Hiranpr,
600-800	pH < 8.5	pH > 8.5	Litipara
800-1000	pH < 8.0	pH > 8.0	
1000-1200	-	Doubtful for irrigation	
Above 1200	-	Unfit for irrigation	

Sorce: Computed from the Groundwater Quality table on the basis of Jharkhand Research Irrigation Institute: Quality of Groundwater in Ganga-valley, Tech. Memo. No. 42-R.R (G-5), Ranchi, 1997.

TOTAL DISSOLVED SOLIDS (TDS)

The sample water analysis for the study area shows that total dissolved solids ranges from 211 to 495 ppm. So, all samples of Groundwater fall under the permissible limits. The highest value of TDS is observed in Litipara and the lowest value in Pakur development block (Tab. 4.5 and Fig.4.4). According to Table- 4.5. higher values of TDS in Groundwater in between 600 to 700 ppm occur in one development block namely Litipara. The remaining 5 blocks such as Amrapara, Hiranpur, Pakur, Maheshpur, and Pakuria show low salt concentration value less than 200 to 600 ppm of TDS are good and can be very safely used for irrigation purpose without any salinity control technique (Tab. 4.6 and Fig. 4.4).

Table 4.6: District Pakur: Electrical Conductivity in Tube-well Water

Electrical Conductivity (micro mhos / cm)	Type of water	Suitability for irrigation	Development Block
Below 250	Low saline (**C_1**)	Entirely safe	
250 – 750	Moderate saline (**C_2**)	Safe under practically all conditions	Pakuria, Amrapara, Hiranpur, Maheshpur, Pakur
750 – 2250	Medium to high saline (**C_3**)	Safe only with permeable soil and moderate leaching	Litipara
2250 – 4000	High saline (**C_4**)	Not suitable for irrigation	-
4000 – 6000	Very high saline(**C_5**)	Do	-
Above 6000	Excessive saline	Do	-

Source: Computed from the Groundwater Quality table on the basis of Richards, L.A. (ed.) Diagnosis and improvements of Saline and Alkali Soils, Agriculture Handbook No. 60, U.S. Department of Agriculture, Washington, D.C., 1954.

HYDROGEN IONS CONCENTRATION (pH)

The pH of water measures its acidity or alkalinity. The pH values of all the tube-well sample waters of the district indicate that all the waters are more or less alkaline in nature. The value of pH ranges from 8.00 to 8.22 (Tab. 4.5 and Fig. 4.2).. The highest pH value of 8.22 is found in Pakuria and the lowest pH value of 8.00 is found in Litipara block. The higher value of the pH in the study area may be attributed to the presence of white, brown and red Kankar formation at depth in the soil profile which supplies the required $CaCo_3$ to the Groundwater to keep it under alkaline condition. The pH value of less than 8 probably is related to the presence of carbonate in the study area.

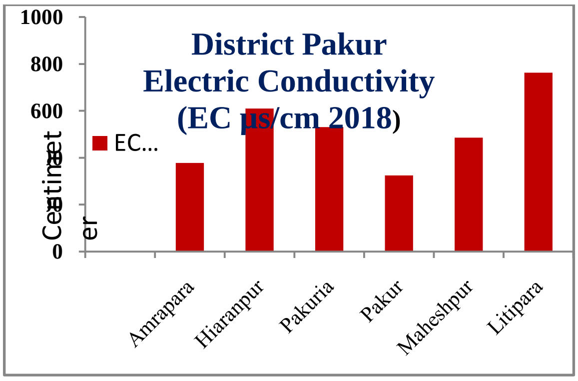

Fig: 4.1

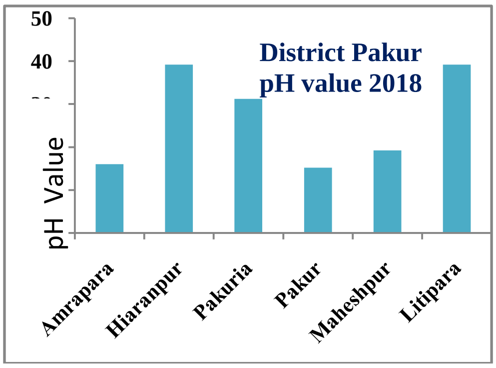

Fig: 4.2

TABLE:4.7: Chemical Analysis of Water Samples Collected from Existing HNS of Pakur District (2011)

Sr. No.	Location	Block	EC in micro siemens/ cm at 25^0c	pH	TH as $CaCO_3$	Ca	Mg	Na	K	HCO_3	Cl
						← mg / l →					
1	Pakuria	Pakuria	434	7.29	105	24	10.9	44.5	1	178.35	11
2	Maheshpur	Maheshpur	998	8.23	260	44	36.5	74	8	190.65	53
3	Amrapara	Amrapara	1014	8.08	235	54	30.4	92	7	264.45	85
4	Litipara	Litipara	790	8.24	180	40	19.4	82	3.8	166.05	142
5	Pakur	Pakur	327	8.12	95	22	9.7	21	1	153.75	89
6	Salgapara	Maheshpur	471	8.18	125	28	13.4	38	5	196.8	64
7	Hiranpur	Hiranpur	338	8.31	75	12	10.9	33	1.6	55.35	36

Source: Groundwater Samples Collected by the researcher from different blocks of Pakur District and tested in Groundwater Laboratory Dumka, 2018

ELECTRICAL CONDUCTIVITY (EC)

As discussed earlier, electrical conductivity is closely related with total Dissolved Salt (TDS) in the water. It varies between 325 and 762 micromhos/cm in the study area (Tab. 4.5 and Fig. 4.3). The highest value of EC is 762 µs/kcm in Litipara and the lowest value of EC is 325 µs/cm in Pakur block. According to Richard (1954) classification, the following result has been obtained in the study area (Tab. 4.7, Fig. 4.2 and 4.9). The Groundwater in all the development blocks of the study area is moderate by saline (C_2) excepting Litipara block where as it is medium

Table 4.8: District Pakur: Result of Chemical Analysis of Ground Water Samples, 2018

Sl. No.	Block	Village	Date of collection	Type of well	EC µs/cm	TDS in ppm	pH	Chemical Constituents (ppm)			
								Cl	HCO3	SO_4	Si
1.	Amrapara	Amrapara	20/11/2018	H.P.	378	245	8.01	07	205	10	-
2.	Hiaranpur	Hiaranpur	Do	Do	610	396	8.20	31	305	50	-
3.	Pakuria	Pakuria	Do	Do	531	345	8.22	33	244	40	-
4.	Pakur	Pakur	Do	Do	325	211	8.02	09	215	16	-
5.	Maheshpur	Maheshpur	Do	Do	486	324	8.20	37	205	30	-
6.	Litipara	Litipara	Do	Do	762	495	8.00	57	273	60	-

Sl. No.	Chemical Constituents (ppm)				Hardness in ppm	P.I.	SAR	Kelly Ratio's	Mg Ratio	Salinity group	Result
	Fe	Ca	Mg	Na							
1.	-	16.0	23.52	22.54	247.65	59.39	0.83	0.46	47.50	C2S1	Good
2.	-	39.2	35.52	24.15	292.10	42.09	0.67	0.32	47.54	C2S1	Good
3.	-	31.2	26.08	23.48	420.70	48.42	0.74	0.41	54.53	C2S1	Good
4.	-	15.2	23.52	22.08	313.17	60.43	0.82	0.57	60.74	C2S1	Good
5.	-	19.2	23.52	19.78	307.57	54.56	0.72	0.46	55.06	C2S1	Good
6.	-	39.2	26.88	28.52	489.41	47.61	0.86	0.46	43.30	C3S1	Moderate

Source: Groundwater Samples Collected by the researcher from different blocks of Pakur District and tested in Groundwater Laboratory Dumka, 2018

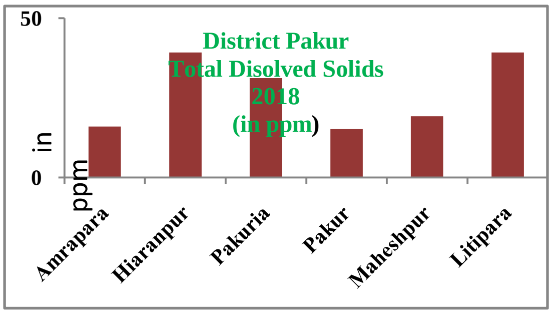

Fig: 4.3

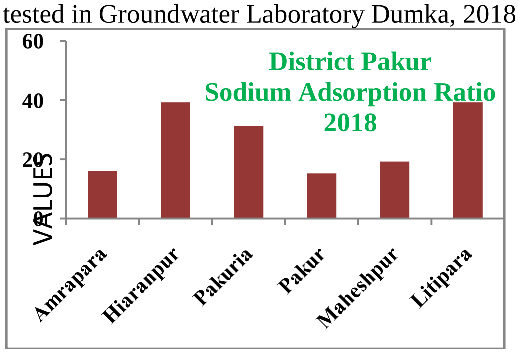

Fig: 4.4

SODIUM ADSORPTION RATIO (SAR)

The classification of ground water in the study area with respect to SAR shows that in all the six development blocks it has low sodium content. So, the water is suitable for irrigation for every type of soil. There is direct correlation between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. Plotting of SAR and EC values of the Groundwater of the study area indicates that SAR values for Groundwater samples range from 0.67 to 0.86 which fall under low sodium water (S_1). Thus, five blocks fall under low sodium content while only Litipara block falls under C_3 S_1 class (Tab.4.8, Fig. 4.6 and 4.9).

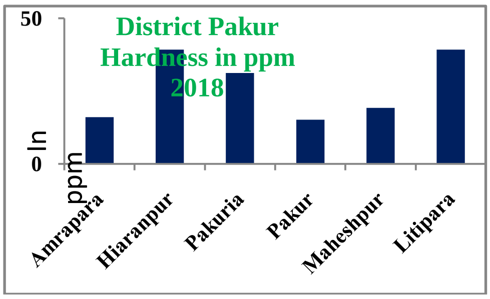

Fig: 4.5

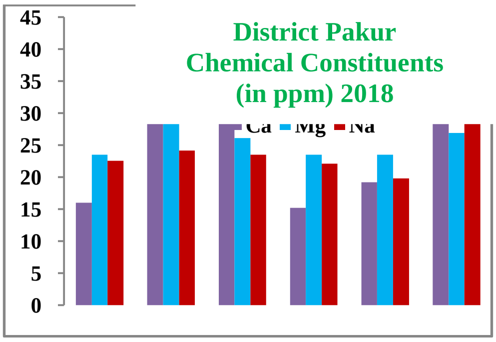

Fig: 4.6

QUALITY OF GROUND WATER FOR IRRIGATION

To high saline (C_3). Moderate saline water (C_2) is safe practically under all the conditions whereas, medium to high saline Groundwater is safe only with permeable soils and moderate leaching.

Table 4.9: District Pakur: Sodium Adsorption Ratio with reference to Irrigation water 2018

SAR	**Type of Water**	**Suitability of Irrigation**	**Development Block**
0-10	Low sodium water (**S_1**)	Suitable for almost all soils	All six blocks of the district
10-18	Medium sodium water (**S_2**)	Suitable only for coarse textured or organic soil with good permeability	
18-28	High sodium water (**S_3**)	Harmful	
Over 28	Very high sodium water (**S_4**)	Unsatisfactory	

Source: Computed from the Groundwater Quality table on the basis of Richards, L.A. (ed.) Diagnosis and Improvements of Saline and Alkali Soils, Agriculture Handbook No. 60, U.S. Department of Agriculture, Washington, D.C., 1954.

PERMEABILITY INDEX (PI)

The adverse effect on soil permeability due to long term use of irrigation water depends upon:

I. Total dissolved solids;
II. Sodium content;
III. Bicarbonate content; and
IV. Nature of soil.

In the study area PI ranges from 42.09 to 60.43. The highest PI is found in Pakur (60.43) and the lowest in Hiranpur(42.09) block. PI of more than 50 is observed in three blocks namely Amrapara, Maheshpur, Pakur the remaining blocks have less than 50 PI value.

Paliwal (**1967**) to calculate the Kelley's Ratio using the following formula **.**

KELLEY'S RATIO: Based on Kelley's ratio waters are classified for irrigation. Sodium measured against calcium and magnesium was considered by **Kelley** (**1946**) and

Kelley's Ratio = Na/Ca+Mg [where, ions are expressed in ppm.]

Excess level of sodium in water is indicated by the value of Kelley's ratio when it is more than one. Therefore, water with less than of one Kelley's Ratio are suitable for irrigation, while those with more than one are unsuitable. In the study area the Kelley's Ratio varies between 0.32 and 0.57 (Tab.4.5). The samples of Groundwater collected from all the blocks are found to be suitable for irrigation.

MAGNESIUM RATIO

In-equilibrium with more presence of magnesium in water will adversely affect the soil quality converting it into alkaline which in turn will affect the crop yield. The magnesium ratio is calculated by using the following formula:

Magnesium Ratio = (Mg/Ca+Mg) 100

Where, ions are expressed in ppm. In the study area the Magnesium ratio ranges from 43.30 to 60.74 (Tab. 4.5).

HARDNESS OF GROUNDWATER

The terms 'Hard' and 'Soft' as applied to water date from Hippocrates (460 – 354 B.C.), 'the father of Medicine', in his treatise on public hygiene 'Air, Water and Places' (**Todd and Larry, 2011**). The hardness of water is derived from the solution of carbon dioxide, released by bacterial action in the soil in percolating rainwater (**Sawyer and MacCarty, 1967).**

Table 4.10: Hardness Classification (after Sawyer and McCarty 1967).

Hardness, mg /l as $CaCO_3$	Water Class
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
Above 300	Very hard

Source: Todd, Devid Keith and Larry W. Mays, (2011). Groundwater Hydrology. 3rd ed. Wiley India Pvt. Ltd. New Delhi.

Low pH conditions develop and lead to the solution of insoluble carbonates in the soil and in limestone formations to convert them into soluble bicarbonates. Thus, hard water is likely to originate in areas where thick top soils overlie limestone formations.

Hardness (H_T) is customarily expressed as the equivalent of calcium carbonate. Thus,

$$H_T = \frac{Ca \times CaCO_3}{Ca} + \frac{Mg \times CaCO_3}{Ca} \quad \ldots\ldots I$$

Where, H_T = Ca and Mg are measured in milligrams per litre and the ratio in equivalent weights

Therefore, $H_T = 2.5\ Ca + 4.1\ Mg$ ………………II

The degree of hardness in water has been commonly considered on the basis of following classification.

Hard water contains excessive calcium and magnesium ions which react with soap to form scum. Hardness is generally defined as the calcium carbonate equivalent of calcium and magnesium ions expressed in ppm or mg/l. The present analysis shows that hardness of water in entire district ranges from 247.65 to 489.41 ppm. The highest value of hardness (489.41 ppm) has been found in Litipara and the lowest value (247.65 ppm) has been found in Amrapara, and Hiranpur, blocks are in the category of less than 300 ppm of hardness. Pakur and Maheshpur blocks are in the category of 300 to 400 ppm of hardness. In all the blocks of the study area, the Groundwater is moderate hard. Thus, very hard Groundwater is found in Litipara and Pakuria blocks. The Groundwater in these blocks are very hard which is not suitable for agricultural purposes. Hardness of Groundwater in the entire district is high except in Amrapara and Hiranpur blocks (247 ppm). So, on the basis of hardness, the Groundwater is not suitable for irrigational purposes (Tab. 4.10 and Fig. 4.10) and the lowest concentration is in Amrapara and Maheshpur. Remaining blocks are in between the range of 205 to 273 ppm. Except in Amrapara block the Groundwater in all blocks is suitable for all purposes.

Table 4.11: District Pakur: Hardness Classification of Groundwater in 2009

Hardness, mg / l as $CaCO_3$	**Water Classes**	**Blocks**
0 - 75	Soft	-
75 – 150	Moderately hard	
150 – 300	Hard	**Amrapara, Hiranpur**
Above 300	Very hard	**Maheshpur, Pakur, Pakuria Litipara**

Source: Computed from the Groundwater Quality table on the basis ofSawyer, C.N. and P.L. McCarty, (1967). Chemistry for Sanitary Engineers, 2nd ed. P.518 McGraw Hill, New York

CALCIUM CONTENTS

It ranges from 15.20 to 39.20 ppm. Hiranpur and Litipara have high concentration of calcium (39.20 ppm) in Groundwater.

DRINKING WATER USES

Water used for drinking purpose should be odourless, colourless and free from micro-organism. Chemically, the drinking water preferably needs to be soft, moderately low in dissolved solids and free from toxic constituents. The Table (quality standards table) reveals the fact that the Groundwater of Pakur district is approximately suitable for drinking purpose. The pH of different analyzed samples given in the main Table 4.5, varies from 8.00 to 8.22. showing slightly strongly alkaline nature. According to WHO, the acceptable limit for TDS in Groundwater is 500 ppm which may be extended to 1500 ppm in case of non-availability of any alternate water source in the study area, Groundwater does not have a large variation in EC (325 to 772 micromhos/cm) and TDS (211 to 495 ppm) (Tab.4.5, Fig. 4.3 and Fig. 4.4) likewise.

Table 4.12: Standards for Physical and Chemical Characteristics of Drinking Water

Characteristics	M.H.I.		ICMR		WHO International		WHO European	
	Per	Exc	Per	Exc	Per	Exc	Per	Exc
1. Turbidity (Fomagin)	5	25	5	25	5	50	5	-
2. Colour (Hazan)	5	25	5	25	5	25	5	-
3. Taste & Colour	Nothing	Disagreeable	Unobjectionable	-	Unobjectionable	-	Unobjectionable	-
4. pH	7.0-8.5	6.5-8.5	7.0-8.5	6.5-9.2	7.0-8.5	6.5-9.2	7.0-8.5	6.5-9.2
5. TDS	500	1500	500	3000	500	1500	-	-
6. Hardness	300	600	300	600	100	500	1500	-
7. Chloride	250	1000	250	1000	200	600	350	-
8. Sulphate	250	400	150	400	200	400	250	-
9. Nitrate	20	30	45	-	11.3	22.6	50	-
10. Fluoride	1-0	2-0	0.6-1.2	1.5	0.6-0.9	0.8-1.2	1.5	-
11. Calcium	75	200	75	200	75	200	-	-
12. Magnesium	50	150	30	100	30	150	125	-
13. Iron	0.30	1.00	0.3	1.00	0.10	1.00	0.05	0.30
14. Copper	1.00	3.00	0.05	1.50	0.05	1.50	3.00	-
15. Zinc	5.00	15.00	5.00	15.00	5.00	15.00	5.00	-

Source: 1. Ministry of Health, Government of India: Public Health Engineering Manual and Code of Practices, Section 1-4, Manual of Water Supply; 2. ICMR Manual of Standards of Quality from Drinking Water Supplies (2^{nd} ed.) 1975 Special Repot Series No. 44, New Delhi; 3. WHO International Standards for Drinking Water, Expert Committee on International and Standards for Drinking Water, Geneva, 1971; 4. WHO European Standards for Drinking Water; 5. All the items from S.N. 5 to 15 in ppm.

permissible limits of hardness, calcium and magnesium are 100, 75 and 30 ppm respectively while it is 200 ppm each for chloride and sulphate The hardness of the Groundwater of the study area ranges from 247.65 to 489.41 ppm (Tab.4.5 and Fig. 4.10). The data indicates that 77.78 per cent of well waters fall within the WHO and ISI permissible limit for total hardness. The Groundwater in 6 (5+1) blocks is within the permissible limit. In the study area calcium ranges from 15.20 to 39.20 ppm and thus the calcium content in Groundwater of all the blocks is under permissible limits (Tab. 4.5 and Fig. 4.5). The magnesium content ranges from 23.52 to 35.52 ppm. Thus, it is also within the permissible limit of MHI, Government of India (Tab.4.5 and Fig. 4.8).

Water with sulphate content of more than 200 ppm is unsuitable for domestic purposes. Water containing more than 500 ppm sulphate tastes bitter and beyond 1000 ppm it has purgative effect. The sulphate content in the well water of the study area ranges from 10 ppm to 60 ppm. Higher content of 60 ppm of sulphate is found in Groundwater of Litipara and. Hiranpur also has 50 ppm of sulphate but Amrapara has the least content of 10 ppm of sulphate in Groundwater (Tab. 4.5). Over all the content of sulphate ions is very less than the permissible limit of 200 ppm. So, Groundwater of the district is quite suitable for drinking and domestic purposes.

INDUSTRIAL USES

For manufacturing purposes, the desirable properties of water vary according to the type of industry. It is usually important that the water should be soft, especially if it is to be used in boilers for raising steam. If the water is hard, a deposit will be formed in the tubes of the boilers due to bicarbonates or sulphates present in the water which will quickly reduce the efficiency considerably. Qualitative specification of uses is given below:

1. Air Conditioning: - Cool, non-corrosive, low in taste and odour, iron and manganese less than 0.5 ppm.
2. Ice Factory:- Pure, low in colour, odour, taste and turbidity, silica less than 10 ppm, iron and manganese less than 0.2 ppm and low TDS.
3. Sugar Mill: - No turbidity of colour, moderate to low hardness and low sulphate and chloride content.
4. Textile Industry (including dyeing):- Low turbidity and colour. iron and manganese less than 0.2 ppm and TDS less than 0.5 ppm.

As discussed earlier, the hardness of water in the study area ranges from 247.65 ppm to 489.41 ppm and in 4 blocks Groundwater samples show high values (>300 ppm). Therefore, the Groundwater of these blocks is not suitable for use in boilers etc. Bicarbonate content ranges from 205 to 305 ppm and no sample have high bicarbonate concentration (>500 ppm) and thus, the Groundwater of all these blocks is fit for some industrial and laundry purposes.

IV. CONCLUSION

On the basis of SAR and EC, the diagram divides water into 20 water quality groups which represent ‘good’, ‘medium’ and ‘bad’ quality of irrigational Groundwater. Water belonging to group C_1S_1 and C_2S_2 is of good quality, while those belonging to C_1S_2, C_2S_2 and C_3S_1 of medium quality and the remaining being of bad quality. According to the U.S. Salinity Diagram Litipara block falling under the category of C_3S_1 has moderate quality Groundwater. It means the Groundwater of the study area for irrigation is safe only with permeable soils and moderate leaching. It is due to 762 µs/cm EC, 495 ppm TDS, 8.00 pH value, 273 ppm of bicarbonate, 60 ppm sulphate ions, 39.20 ppm of calcium ions, 48.41 ppm of hardness, 0.86 ppm of SAR and 47.61 PI in Groundwater. In these contents EC and SAR has greatly influenced to the Groundwater in Litipara block. So, it goes under C_3S_1 category of Salinity Hazard. In the Groundwater samples of the study area, TDS ranges between 211 ppm in Pakur to 495 ppm in Litipara; pH value varies from 8.00 in Litipara to 8.22 in Pakuria, EC fluctuates between 325 µs/cm in Pakur to 762 µs/cm in Litipara. SAR ranges from 0.67 in Hiranpur to 0.92 in Litipara; PI changes between 42.09 in Hiranpur to 60.63 in Pakur; Kelley’s Ratio varies from 0.32 in Hiranpur to 0.57 in Pakur; Magnesium Ratio fluctuates between 43.30 in Litipara to 60.74 in Pakur; Bicarbonate content varies from 205 ppm in Amrapara to 305 ppm in Hiranpur and Calcium carbonate ranges from 15.2 ppm in Pakur to 39.20 ppm in Amrapara and Hiranpur.

The present chemical anlysis shows that hardness of Groundwater over the district ranges from 247.65 ppm in Amrapara to 489.41 ppm in Litipara block. The highest value of hardness 489.41 ppm has been found in Litipara and the lowest value 247.65 ppm in Amrapara block. Litipara (489.41 ppm) and Pakuria (420.70 ppm) fall under the category of more than 420 ppm of hardness. In all the blocks of the study area, the Groundwater is hard, which is less suitable for agricultural purposes.

In the remaining blocks of the study area, the Groundwater falls C_2S_1 salinity category which denotes that Groundwater is safe under practically all conditions. For drinking purposes, the Groundwater quality is within the permissible limit prescribed by the M.H.I. Government of India in all the blocks. As such, the Groundwater is safe for human health all over the study area.

REFERRENCES:

[1]. Back, W. and B.B. Hanshaw, (1965). Chemical Geography, in Advances in Hydroscience, V.T. Chow, ed., V. 2, Academic Press, New York, pp. 49-109.

[2]. Bansil, P.C. (2004). Water Management in India, Concept Publishing Company, New Delhi.

[3]. Bureau of Indian Standard (1983). Indian Standard specification for Drinking Water, IS: 105001, I.S.I., New Delhi.

[4]. Danial, P.D. (1990). Quality of Groundwater in Part of Nalgonda and Rangareddy District of Andhra Pradesh. Journal of Indian Water Resources Society.

[5]. Heath, R.C. (1998). Basic Ground Water Hydrology, U.S. Geographical Survey Water Supply Paper 2220, http:// water.usgo.gov/pubs/wsp2220, Denver, Co.

[6]. Hem, J.D. (1970). Study and Interpretation of the Chemical Characteristics of Natural Water, 2nd ed., U.S. Geological Survey Water Supply Paper 1473, pp.363.

[7]. Kelley, W.P. (1946). Permissible Composition and Concentration of Irrigation Water. Proc. A.S.C.E.

[8]. Lagon, J.,(1961). Estimation of Electrical Conductivity from Chemical Analysis of Natural Water, Jour. Geographical Research, V. 66, pp.2479-2489.

[9]. Raghunath, H.M. (2009, 2007, 1987, 1982). Ground Water. New Age International Publishers, New Delhi.

[10]. Rai V.K. (2000). Water Resource Problem, Prospects and Management, Ganga-Ghaghara Doab, Publication House, Varanasi.

[11]. Ravi Prakash S. and Rao, G.K. (1989). The Chemistry of Groundwater in Paravada AreaWith Regard to their Suitability to Domestic and Irrigation Purposes. Indian Journal of Geochemistry, 4(1) pp. 39-54.

[12]. Richard, L.A. (1954). ed., Diagnosis and Improvement of Saline and Alkali Soils,Agriculture Handbook Co,U.S.Dept. of Agriculture, Washington, D.C. pp.160.

[13]. Todd, Devid Keith and Larry W. Mays, (2011). Groundwater Hydrology. 3rd ed. Wiley India Pvt. Ltd. New Delhi.

[14]. W.H.O. (1984). Guidelines for Drinking Water Quality. Vol.1, Recommendation of World Health Organizatin, Geneva, pp. 1-130.

[15]. World Bank, (1999). Ground Water Regulation and Management in India.