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RESEARCH ARTICLE

HYDROGEOCHEMICAL ANALYSIS AND QUALITY APRAISAL OF GROUNDWATER FOR IRRIGATION, PURI DISTRICT, ODISHA, INDIA.

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Abstract

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The present study is carried out in the Puri district, Odisha, India to ascertain the suitability of groundwater for irrigation purposes. The parameters used to ascertain the suitability of groundwater for irrigation purposes are synthesized. The physico chemical observations used for the purpose were ; pH, electrical conductivity, total dissolved solids, calcium, magnesium, potassium, carbonate, bicarbonate and the irrigation indexing parameters calculated were, sodium adsorption ratio, residual sodium carbonate, magnesium adsorption ratio, permeability ratio and Kelly's ratio. The parametric values obtained from present study shows margins of concentration ranges lies within the permissible limit which shows that as a whole ground water of the district is suitable for irrigation purposes. In most of the places the residual sodium carbonate, permeability index, Kelly ratio, magnesium absorption ratio exceeded or remain below its permissible limit. So the non-tolerant crops susceptible for less yield to high sodium content can be avoided in the area. Suitable recommended use of chemicals such as lime, sulphuric acid may be added to soil with pre crop irrigation for leaching.

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Introduction:-

When the well is dry we learn the worth of water. When ground water (GW) is scarce we save for tomorrow. The quality of GW is just as important as its quantity. Most of GW contains dissolved salts in high concentrations so as to make it unusable for ordinary water supply purposes and even for irrigation. Soluble salts in UGW originate primarily from natural dissolution of common rock minerals such as clays (kaolinites, elite, montmorillonite and feldspars), as well as Fluorides, hydroxides, chlorides, carbonates and silicates and many others,. Apart from natural processes, other controlling factors on the GW quality include heavy metals, pollution and contamination resulting from some uncontrolled effluent discharges from industries, liquid wastes of urbans, harmful agricultural practices (e.g., excessive application of pesticides and fertilizers). The quality required of a groundwater supply depends on its purpose of use such as drinking, industrial use, irrigation, recreation water sports and aqua culture *etc.*. The suitability of groundwater for irrigation is contingent. According to **Todd (1980[1]),** poor quality irrigation water (with high salt concentration) may affect plant growth physically by limiting the uptake of water through modification of osmotic processes. Effects of salts on soils could result in alterations in soil structure, permeability

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and aeration, which indirectly affect plant growth. Problems of groundwater quality degradation are much difficult to overcome as it often requires long period of time to detect the true extent of degradation.

The chemical parameters such as pH, electrical conductivity (EC),Ca^{2+}, Mg^{2+},Na^{+}, K^{+},HCO_3^{-},CO_3^{2-} plays a pivotal role in classifying and assessing water quality for irrigation. Considering the individual and paired ionic concentration, certain indices are proposed to find out the alkali hazards. For example, residual sodium carbonate (RSC), Kelly's index, sodium adsorption ratio (SAR), Magnesium adsorption Ratio (MAR) can be used as criterion for instituting the suitability of irrigation water **Sadashivaiah et al.,(2008)[2].**

Present work envisages the major ionic chemistry of groundwater samples in different blocks of Puri district are assessed by experimentally. Based on the results, their suitability of use for irrigation is highlighted. Salinity, sodicity and toxicity generally need to be considered in the evaluation of the suitability of groundwater for irrigation. Parameters such as residual sodium carbonate (RSC), magnesium adsorption ratio (MAR), sodium adsorption ratio (SAR), Kelly ratio (KR), permeability index (PI) were used to assess the suitability of water for irrigation. Continued use of water with a high SAR value leads to a breakdown in the physical structure of the soil caused by excessive amounts of colloidal absorbed sodium. This breakdown results in the dispersion of soil clay that causes the soil to become hard and compact when dry and increasingly impervious to water penetration due to dispersion and swelling when wet. Fine-textured soils, those high in clay, are especially subject to this action. It is hoped that this study would assist in determining the degree of salinity, sodicity and toxicity thereby removing some of the speculation concerning the quality of water used for agricultural purposes in the coastal Puri district, and its impact on crop yield.

Major ground water issues in the district are

1. The GW table is depleting continuously in and around Jagannath temple in Puri town area and the ground water is contaminated with high PO_4^{3-} and NO_3^{-1}.
2. Puri district has coastal area of 137Km and 3-7km from the coast is covered by sands, sand dunes, marshy land and salinity ingress up to 3 to 5 km have no agricultural land. In these mangrove belts, irrigation is not possible.
3. Beyond the sandy zone, the inland up to 20 to 25 km is covered with swamps, marshy land and the ground water is alkaline not fit for drinking. But the area has vast alluvial well irrigated agricultural lands
4. The rest of the land beyond the middle zone are well developed old alluvial terrain with fresh ground water fit for both irrigation and drinking.
5. Physico-chemically the ground water sporadically rich in iron, fluoride, calcium carbonate, sodium salts make both surface and ground water alkaline. Gradually the GW is being contaminated due to ingress of salinity from the sea.

Review Of Literature:-

Todd 1980[1] and Mohan et al, (2013)[3] have described about importance of groundwater for irrigation has been increasing day by day by bringing more area under cultivation. Contamination of such water source is a big problem creating health hazards. **Martinez et al.,(2002)[4]** identified that cation exchange processes and calcite equilibrium are the important hydro geochemical processes that control groundwater composition. **Anbazhagan et al., (2004)[5]** have used the geographical information system (GIS) to represent and understand the spatial variation of various geochemical elements present in Panel Basin, Maharashtra, India. **Msonda et al., (2007)[6]** carried out a study to determine fluoride concentration in groundwater of Nathenje area which follow a geological pattern in which fluoride is a serious contaminant of most ground water in the area. **Siebert et.al (2010)[7]** a global inventory of groundwater and surface water use in irrigation has been compiled using mainly census based statistical data. Uncertainties remain on the areas equipped for irrigation with groundwater and on the related water uses either due to missing data or use of a variety of definitions for irrigated land and its water sources and conjunctive use of groundwater and surface water. **Jalal A. et al., (2012)[8]** reported that groundwater is important for irrigation which has been increasing to have more cultivated area but contamination of the GW source is creating problem of health hazards. **Bhadra et. al. (2014)[9]** aimed at assessing the current water quality standard of Brahmani river in terms of physico-chemical parameters where temperature is an important factor to influence the physico-chemical parameters and the biological reaction in water. Higher values of temperature accelerate the chemical reaction and reduce the solubility of gases and DO.N. **Subba Rao (2016)** investigate on groundwater quality with reference to F^{-} ion concentration in rural parts of Guntur district, Andhra Pradesh, India indicates that the ground waters are alkaline, of medium to very hard category and mostly brackish. **Mishra S. P. (2016)[10]** reported that the parameters like alkalinity, EC, SAR, ESP, KI, SSP, PI, and MAR of the GW are fit for irrigation in coastal districts of Odisha.

Fig 1: Block wise morphology of Puri district in Odisha, Source: Central Ground Water Board

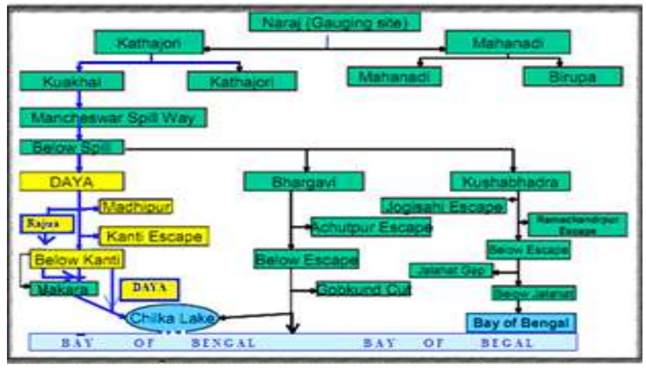

Fig 2: Surface drainage system, Puri dist

Selvakumar et al, (2017)[11] reported that the GW quality isdeteriorating by contamination due to manmade pollution due to population rise, industrial wastes and effluents and use of fertilizer, germicides and insecticides in irrigation water. **Dash et al (2015)** studies physic chemical parameters of ground water of Chandanpur, in Puri district and reported that GW is brackish. It is not fit for domestic use and soberly hard for irrigation.

Study Area:-
Puri district is one of the nine alluvial coastal districts in Orissa state with an area of 3479 km^2. The population was 1.7 billion (Census 2011) of the district and about 84.3 % of are agrarians. It lies between latitudes 19°28'N to 20° 10'N and longitude 85° 09' E to 86°25'E. The district has only one subdivision. There are 11 community development blocks in the district these are Pipili , Kakatpur, Astaranga, Brahmagiri, Delanga, Gop, Kanasa, Krushna Prasad, Nimapara, Puri and Satyabadi blocks (Fig 1). The population density is 138 persons/ Km^2 against the state figure of 236 persons/ km^2. The district lies in the southern deltaic fringes in the arcuate shaped Mahanadi river delta and the main anastomosed drainages are the rivers Daya, Devi, Kushabhadra, Bhargavi, una and Prachi. Other important rivers flowing in the area are Kadua, Ratnachira, Nuna, Dhanua and Kandal.

The district is covered by well anastomsed irrigation network covered by Mahanadi Delta Stage-II canal system. The net sown area in the district is 131thousand hectares. Only 59% of the cultivable area is irrigated. The low statistics is because of lack of irrigation in Krushnaprasad (6%) and Brmhagiri block due to its location amidst the Chilika lagoon. The total irrigation area of the district is 105106 Ha out of 188745 Ha of cultivable land. There are three crop seasons in command area and two crop seasons in non-command area. The Kharif crops are paddy, jute, oilseeds, and pulses etc. The Rabi crops are paddy, grams, pulses, groundnut, mustard, vegetables and potato etc. and summer crops include summer paddy, cowpea, vegetables, and groundnut. The main source of horticulture is coconut farming and major livelihood from fisheries.

Geohydrology of study area:-
Puri district has av. annual rainfall of 1450 mm.Coastal sands along the east, laterite bed in west, alluvial green plains in the middle delta and the large Chilika lagoon towards south. The soils in the district are Alfisols, Aridsols, Entisols and Ultisols. Major ground water table was 0.16 mbgl to 5.96 mbgl in the pre-monsoon and 0.08 mbgl to 5.13 mbgl in post monsoon in the year 2011. Remarkable characteristics in the ground water quality as reported by the CGWB was having high EC Fe and F (sporadically) above the permissible limit of 1.5 mg/l. From irrigation point of view, CGWB report was high concentration ofNa, K,Ca, Cl , NO3 HCO_3, Fe ions. EC and pH, was higher than the permissible limit (2011). The annual replenishment of GW was 58006Ham against draft of 10448 Ham during 2009.

The choice of the wells were in Balipatna, Kakatpur, Gop, Puri Sadar and Nimapada. The eastern part of the district have fresh water aquifers at a depth of 50 to110m. Parts of Pipili, Delang and Sakhigopal blocks have intermittent fresh water aquifers within a depth of 130 to 220m. In rest areas the ground water is completely saline with small patches of perched aquifers.

Materials And Methods:-

A total of 18 samples from dug wells were collected from different locations within the study area for hydrogeochemical analyses whereas; physical tests (pH and electrical conductivity) were carried out in situ. All the hydrochemical analyses were carried out in the laboratories of the department of Civil Engineering, College of Engineering and Technology, BBSR.

Clean 1 L volume plastic containers were used for the sampling. For the pH values of the samples (determined in the field), the portable pH meter was employed. Analyses of ions were limited to the major elements ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, CO_3^{2-}. These were carried out (in the laboratory) employing standard procedures recommended by American Public Health Association (APHA 1994).

Statistical analysis:-

Statistical average and ranges for each of the parameters represent the mean value and the lowest and highest values, respectively, for all the locations considered. Sodium adsorption ratio (SAR) according to **Wilcox (1948)**[13] and **(1995)**[15] is a better measure of the sodium hazard which is used to express reactions with the soil. It was computed by using the relationship given in Equation: $SAR = \frac{Na}{\sqrt{Ca+Mg}}$

The relative proportion of sodium in the water in the form of sodium carbonate was also determined using Equation :$RSC = [HCO_3 + CO_3] - [Ca + Mg]$

Doneen (1964)[14] developed a criterion to assess the suitability of water for irrigation based on permeability index which can be determined from the expression given in The variation of PI values in the area indicates that the groundwater have PI in between 25-50% $PI = \frac{(Na + \sqrt{HCO_3}) \times 100}{Ca + Mg + Na}$

In **Kelly's Ratio (KR) (1951)**[15], sodium is measured against calcium and magnesium to determine the suitability of irrigation water. When KR is >1, it indicates higher calcium & magnesium and vice versa.KR is calculated by using the formula:$KR= \frac{Na^{+}}{Ca^{+2} + Mg^{+2}}$

Ca and Mg maintain a state of equilibrium in most groundwater. During equilibrium, more Mg in groundwater will adversely affect the soil quality by decreasing crop yield. MAR categorizes water into two broad classes – water having MAR < 50 is considered suitable for irrigation whereas water with MAR > 50 is considered unsuitable, based on which it can be concluded that almost two thirds of the water samples are suitable for irrigation in post monsoon .During pre monsoon MAR values change rendering about half of the samples suitable for irrigation .MAR is calculated using the formula: $MAR= \frac{Mg \times 100}{Ca + Mg}$

Results And Discussion:-

The results of the hydro chemical analyses of the water samples are presented in Table 1.The fluctuation of pH in the samples is from 7.23-8.37. Electrical Conductivity in groundwater varies from 294 to 1688mmohs /cm.It is highest at P Ramchandrapur Village,Kanas block which exceed the permissible limit and lowest at Dhauli temple ,Pipili which is within the permissible limit. The total dissolved solids in the study area varies from 223 to 1911 meq/l .

Table 1:-Chemical Analysis of groundwater samples of the study area (in meq/l)

SL No	Block Name	Location of well	pH	EC mmhos/cm	TDS mg/l	Ca meq/l	Mg meq/l	Na meq/l	K meq/l	CO_3^- meq/l	HCO_3^- meq/l
1	Astarang	Jharling	7.77	585	473	2.4	0.6	2.87	0.22	0.00	4.40
2	Brahmagiri	Bentapur Matha	8	1092	742	3	2.8	4.61	0.36	0	4.40
		Rabana Nuagaon	7.43	408	306	1.5	0.9	0.95	0.57	0	1.30
3	Delang	Bada ankula	7.3	1447	963	4	2.70	6.70	0.35	0	5.00

		Kalyanpur Market	7.48	1057	761	4	1.9	4.26	0.38	0	1.30
4	Gop	Ramchandi	7.63	482	350	2	0.8	1.38	0.8	0	2.10
		Gop Block	8.22	659	514	0.4	0.20	5.65	0.26	0	4.20
5	Kakatpur	Basin Pada	8.37	442	304	1.20	1	1.90	0.06	0.4	1.8
6	Kanas	Manpur	7.97	917	694	0.80	4.30	3.96	0.25	0	2
		PRamchandrapur	8.32	2880	1911	4.10	8.00	2.70	2.10	0	2
7	Krushnaprasd	Malud	7.69	555	394	1.8	1.4	1.40	0.86	0	2.70
8	Nimapara	Balanga	7.63	1036	807	3.3	2.5	4.74	0.17	0	7.50
9	Pipili	Dhauli temple	7.62	294	223	0.9	1.60	0.33	0.1	0.2	1.8
		Hanuman Temple	8.35	460	376	1.20	3	0.86	0.006	0	4.4
10	Puri sadar	Malatipatapur	7.38	1688	1295	5	3	4.43	4.15	0	10.2
		Puri police stn.	7.19	1019	802	3.8	1.6	3.78	0.84	0	5.90
11	Satyabadi	Sakhigopal	7.23	548	408	2.4	1.3	1.59	0.29	0	3.30
		Satyabadi	7.58	793	562	3.2	1.4	3.57	0.16	0	3.70

The TDS concentration is highest in P Ramchandrapur, Kanas and lowest in Dhauli temple , Pipili which is within the permissible limit. The range of calcium in the study areas varies from 0.4-5 .All the sample are lies within the permissible limit. Magnesium adds to the hardness of water and along with calcium posses the problem of scale formation. At study area the range of magnesium lies between 0.2-8.00.

At Ramchandrapur Kanas the magnesium concentration is highest which exceed within the permissible limit and at Gop block compound it is lowest which is within the permissible limit. At study area the range of potassium lies between 0.006-4.15meq/l.At pipili hanuman temple, pipili the potassium concentration is lowest and at malatipatapur, puri sadar it is highest. The $CO3^-$ range in the study area varies from 0-0.4. The maximum value at basin pada, Kakatpur. The Bicarbonate content of the ground water at all the sampling station is within the limiting value. The $HCO3^-$ range varies from 1.30-10.20 .The maximum value 10.20 at Malatipatapur, Puri sadar & minimum value 1.30 at R.Nuagaon,Brahmagiri & Kalyanpur market complex,Delang.

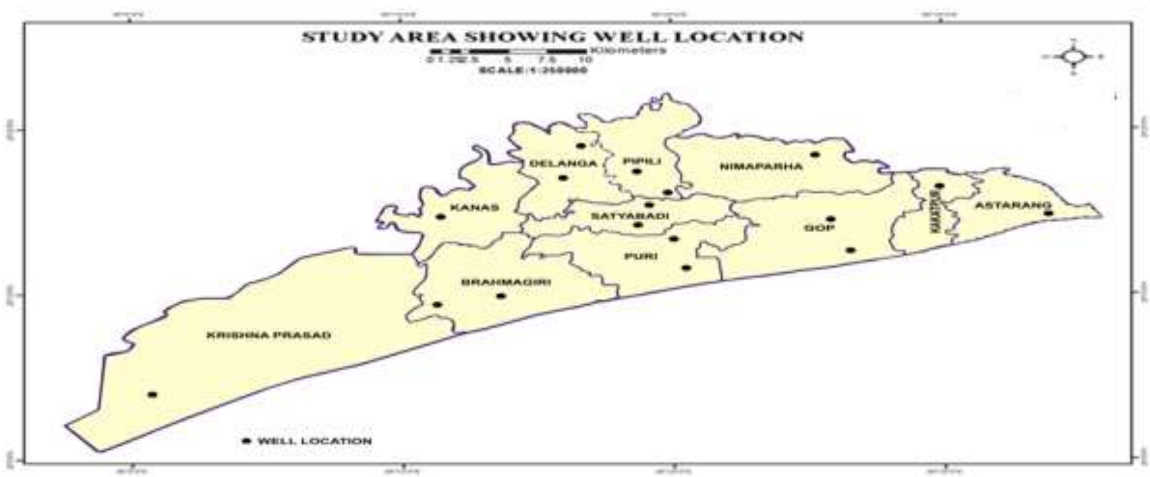

Fig 3:- The location of the wells selected in different blocks of Puri district located by GIS

Comparison of GW quality parameter of present study with FAO:-
The ground water quality is evaluated by comparing the range of values of different geochemical parameters with quality of irrigation water of FAO (IS: 11624/1986) which is tabulated in Table-2.

Table-2: Comparison of ground water quality with FAO (IS: 11624/1986) standard

Sl.No	Parameter	Minimum	Maximum	Mean	FAO standard Maxm Limit
1	pH	7.23	8.37	7.8	6.5-8.5
2	EC(mmhos/cm)	294	2880	1587	0-1500
3	TDS(meq/l)	223	1911	1067	0-2000
4	HCO_3^-(meq/l)	1.30	10.20	5.75	0-10
5	CO_3^-(meq/l)	0.0	0.4	0.2	0-1
6	Na(meq/l)	0.33	6.70	3.515	0-40
7	Ca(meq/l)	0.4	5	2.7	0-20
8	Mg(meq/l)	0.2	8.00	4.1	0-5
9	K(meq/l)	0.006	4.15	4.156	0-2

Evaluation of ground water quality parameters limit:-

1. pH

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse affect on health, however, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. A pH range of 6.5 – 8.5 is normally acceptable as per guidelines suggested by FAO. In the present study, the fluctuation of pH in the samples is from 7.23-8.37.

2. Electrical Conductivity

Electrical Conductivity in groundwater varies from 294 to 1688mmohs /cm (Table-1). It is highest at P Ramchandrapur Village, Kanas block which exceed the permissible limit and lowest at Dhauli temple, Pipili which is within the permissible limit.

3. Total Dissolved Solid

The total dissolved solids in the study area varies from 223 to 1911 meq/l .The large variation of TDS may be attributed to the lithological composition and anthropogenic activities like application of fertilizer is prevailing in this region. It is highest in P Ramchandrapur, Kanas and lowest in Dhauli temple , Pipili which is within the permissible limit.

4. Calcium:

Calcium is the most important Cation, in the study of water quality and calcium content above 25 meq/l is classified as calcium rich water. Calcium is one of the most important elements, which influence the distribution of diatoms in water bodies high calcium content favors rich growth of diatoms when followed with high temperature. The range of calcium in the study areas varies from 0.4-5 .All the sample are lies within the permissible limit.

5. Magnesium:
Magnesium is an essential mineral for the living body and is relatively non-toxic in concentration normally encountered in nature. Magnesium also adds to the hardness of water and along with calcium posses the problem of scale formation. At study area the range of magnesium lies between 0.2-8.00. At Ramchandrapur Kanas the magnesium concentration is highest which exceed within the permissible limit and at Gop block compound it is lowest which is within the permissible limit.
6. Potassium:
The range of potassium lies between 0.006-4.15meq/l at Pipili Hanuman temple. Pipili where the potassium concentration is lowest and at Malati Patapur, Puri Sadar, is highest.
7. Carbonate:
The carbonate content of the ground water at all the sampling station is within the limiting value as prescribed by FAO. The $CO3^{-}$ range in the study area varies from 0-0.4 is the maximum value at Basin Pada in Kakatpur Block. The Carbonate reflects the status, physical and biological process in water, shows the metabolic balance and $CO3^{-}$ level acts as an indicator of ground water.

Calculation of various Irrigation indices:-
The different types of irrigation indices were calculated as shown below .

Table 3:- Different Irrigation Indices obtained in study Area, Puri district

Block	Location of well	SAR	RSC	PI	KR	MAR
Astarang	Jharling	2.34	1.31	84.62	0.96	20
Brahmagiri	Bentapur Matha	2.71	0.03	65.76	0.79	48.28
	Rabana Nuagaon	0.87	-0.22	62.41	0.40	37.50
Delang	Bada ankula village	3.66	-2.05	66.67	1.00	40.20
	Kalyanpur Market	2.48	1.36	66.04	0.72	32.20
Gop	Ramchandi Temple	1.16	-0.08	67.66	0.49	28.57
	Gop Block	10.32	-1.71	123.1	9.42	33.33
Kakatpur	Basin Pada	1.82	1.92	0.93	1.21	45.45
Kanas	Manpur	2.48	3.98	0.87	1.33	84.31
	PRamchandrapur	5.16	12.77	1.02	1.63	66.12
K-prasad	Malud	1.11	0.44	66.18	0.44	43.75
Nimapara	Balanga	2.78	2.59	70.95	0.82	43.20
Pipili	Dhauli temple	0.30	0.37	0.24	0.21	64.0
	Hanuman Temple	0.59	0.87	0.34	0.33	71.43
Puri sadar	Malatipatapur	2.22	1.61	61.34	0.55	37.50
	Puri police station	2.30	1.28	67.64	0.7	29.63
Satyabadi	Sakhigopal	2.35	-0.22	67.22	0.78	30.43
	Satyabadi	1.17	1.42	64.3	0.43	35.14

1. Sodium Adsorption Ratio(SAR) **:**
A better measure of the Sodium hazard for irrigation is the Sodium Adsorption Ratio (SAR) which is used to express reactions with the soil. During pre –monsoon 2016, the SAR values of 17 samples were found to be less than 10 and are classified as good for irrigation &1 sample is found as in medium range for irrigation

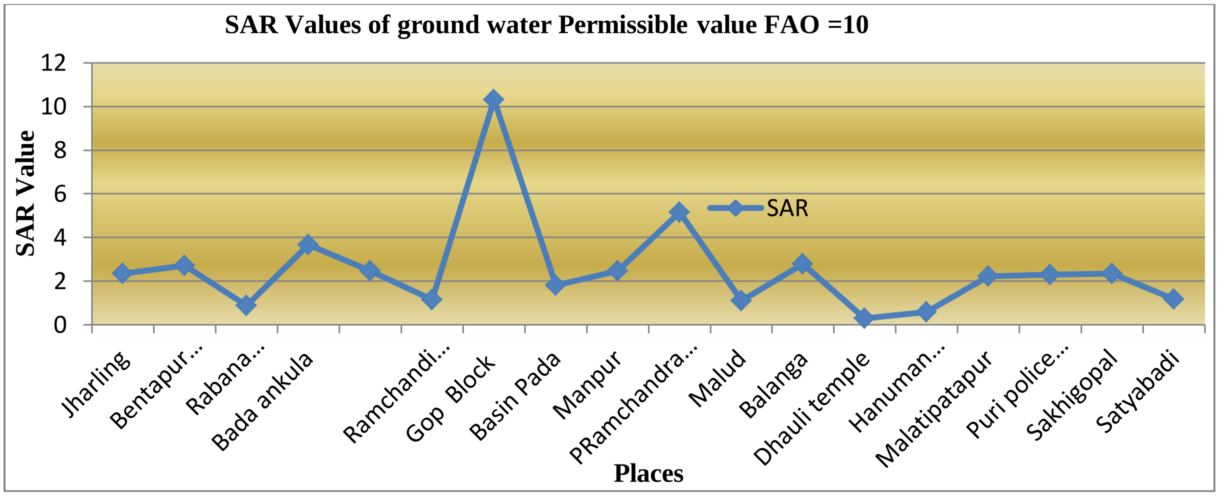

Fig 4:- Sodium adsorption ratio of ground water in various blocks of Puri district

Residual sodium carbonate (RSC)

The relative sodium concentration in the exchangeable complex increases resulting in the dispersion of soil. When the RSC value is lower than 1.25 meq/litre, the water is considered good quality, while if the RSC value exceeds 2.5 meq/litre, the water is considered harmful. The 9 sample of ground waters of the study area have values less than 1.25 fall under good category.3 sample of ground water found to be in unsuitable catagories for irrigation .

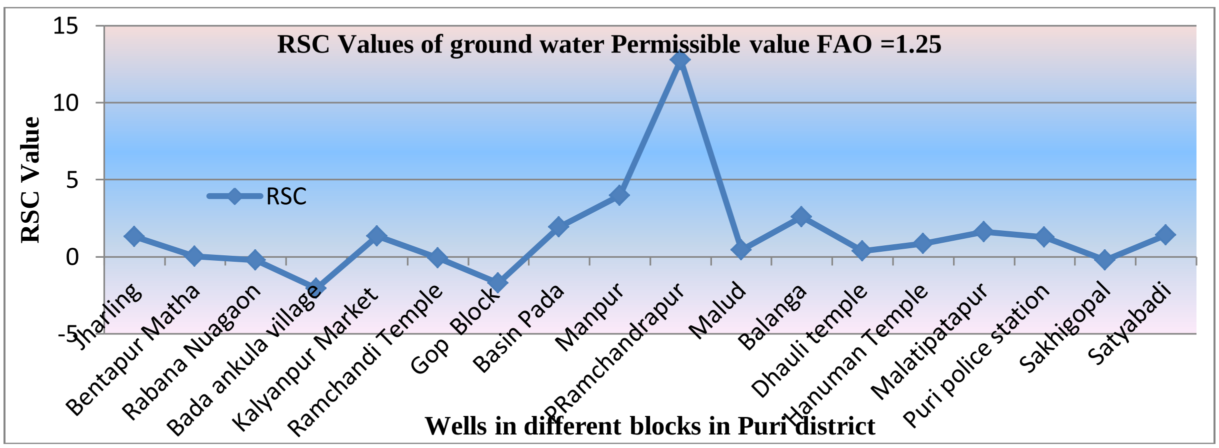

Fig 5:-Residual Sodium carbonate value of ground water in various blocks of Puri distirict

Permeability index (PI)

The permeability of soil is affected by the use of irrigation water if they contain higher levels of TDS, sodium, bicarbonate etc. The variation of PI values in the area indicates that the ground waters have PI in <5 is good for irrigation purposes that 5 samples came under this category & 13 sample came under unsuitable category in for irrigation purposes.

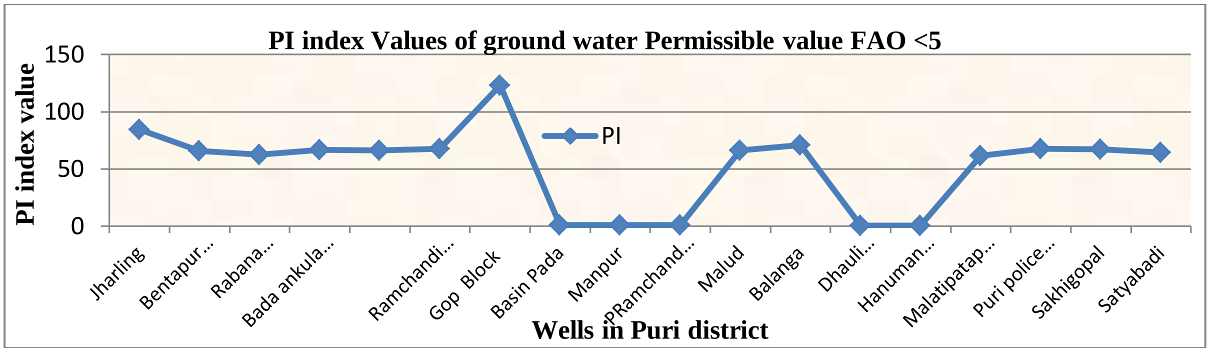

Fig 6:- Permeability index value of ground water in various blocks of Puri distirict

Kelly Ratio (KR)

Water having KR more than one indicates an excess level of Sodium (Kelly, 1946).Excess sodium levels make water unsuitable for irrigation. The KR values of water samples of the study area ranged between 0.21 and 9.42. 13 samples fall within the permissible limit of 1.0 making water suitable for irrigation purpose and 5 samples have KR >1 indicating the unsuitable water quality for irrigation.

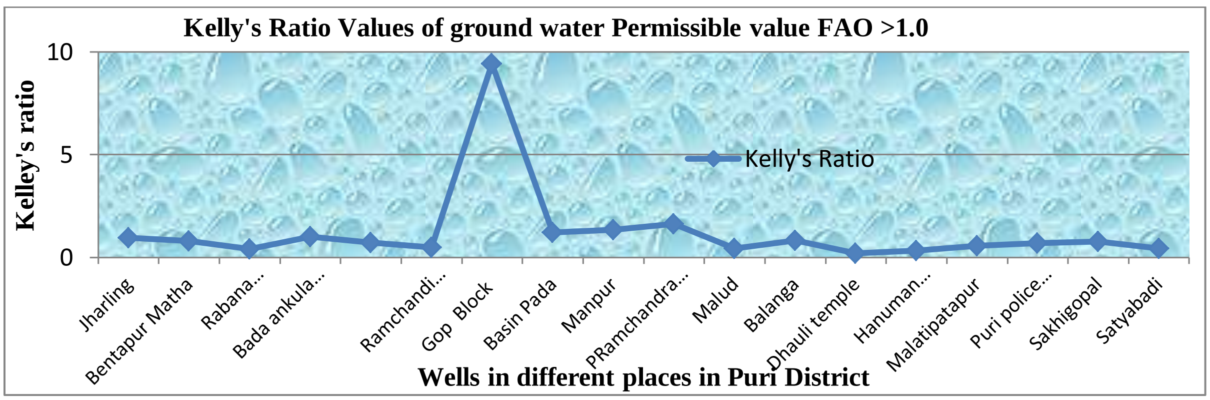

Fig 7:- Kelly's ratio values of ground water in various blocks of Puri distirict

Magnesium Adsorption Ratio (MAR)

MAR categorizes water into two broad classes – water having MAR < 50 is considered suitable for irrigation whereas water with MAR > 50 is considered unsuitable. Here 14 sample came under the categories where it is suitable for irrigation & 4 sample came under the categories which is unsuitable for irrigation in pre monsoon.

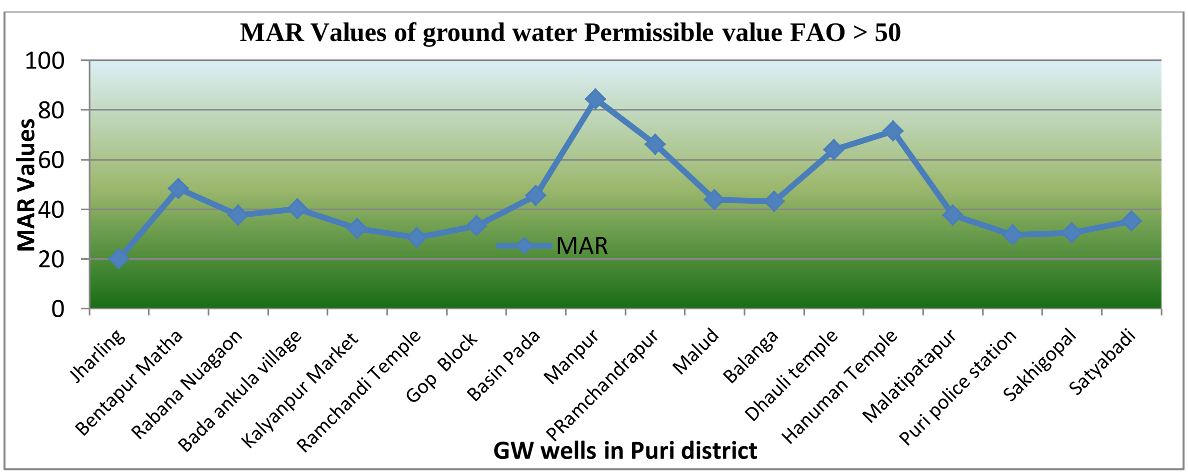

Fig 8:- Magnesium Adsorption Ratio (MAR)values of ground water in various blocks of Puri distirict

5.4 Comparison of irrigation indices of present study/ FAO standard((IS: 11624/1986)

Parameter	Minimum	Maximum	Mean	Food Agriculture Organisation Standard		
				Good	Medium	Unsuitable
SAR	0.3	10.32	5.31	<10	10-18	>26
RSC	-0.08	12.77	12.69	<1.25	1.25-2.50	>2.50
PI	0.24	123.1	61.67	<5	5-10	>10
KR	0.21	9.42	4.81	<1	-	>1
MAR	20	71.43	45.71	<50	-	>50

Conclusion:-

Puri is a coastal district so salinity hazard is very common in both shallow and deeper aquifer and electrical conductivity reaches as high as 2880mg/l at Pratap Ramachandrapur. High value of chloride and sodium is reported in deeper aquifer. The quality of ground water varies from fresh to saline. Saline ground water near coast is NaCl type. The ground water quality in the shallow aquifers shows gradual deterioration towards the coast.

In Delang and Gop block the SAR values are >3 (higher) indicate that the ground water quality is unfit for agriculture. The alkalinity hazard RSC whose upper range should be <2.5. From the observation it is found in Kanas, Nimapara and Gop block it is more than the value 2.5. The safe value for permeability index should 25% < PI < 75%. From our observation we found groundwater of Kakatpur, Gop, Kanas and Astaranga blocks are unfit for agriculture. Groundwater of Delanga, Kakatpur and Kanas have Kelly ratio>1 hence unfit for irrigation. The upper range of Magnesium Absorption Ratio for quality water is >50%. The observations indicate the groundwater of Kanas and Pipili is unfit for irrigation.

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