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Physicochemical Indices of Ground Water and Their Geoponic Management, in Coastal Odisha, India

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Abstract

Agriculture can not exist without water. At present the old practice of arbitrary use of water in irrigation sector has become unethical. Odisha is an agrarian state in east coast of India. For better yield of crops, quality of water is intricately related to the aquifer geometry, ground water flow regime and its quality. Coastal Odisha is having an area of 14700 sqkm and demography of 1.26 million. The land has mostly water logged alluvial crop land, deciduous forests or sandy dunes with an astomosed channels of hexa-deltaic rivers. The edaphic factors demand improvement of quality of ground water which is brackish. The physicochemical properties like pH value, electrical conductivity, inorganic constituents (Na^+, Mg^{++}, Ca^{++}, K^+) of ground water used for lift irrigation have been studied. Data from thousand number of wells from the study area are covered in various seasons during the years 2009-2014 along with the yield of the major crop, i.e., paddy. The indices and parameters like EC, SAR, KI, ESP, SSP, MAR, PI and alkalinity of the ground water are determined to show its fitness for irrigation in the area. The different water management policies and present activities are discussed so that the ground water can be used efficiently for irrigation in coastal Odisha.

Keywords: irrigation, ground water, water quality, lift irrigation, Odisha coast

1. Introduction

The coastal Odisha is prone to erratic monsoon rainfall, cyclones, floods, salinity hazards, drought, crop failure and many other natural disasters. Yield in the area is meagre and the quality of water used for agriculture is unsatisfactory. The burgeoning demograophy, snooty energy production, urbanization, denudation, industrialization, food demand and deforestation have deteriorated the quality of water for plants. Under utilisation of irrigation potential, low cropping intensity (140-150% for Khariff and Rabi crops) and poor irrigation quality of water, contamination of Ground Water (GW) by sewage and storm water have drastically reduced the produce (from 30-40 quintals to 12-15 quintals per hectare) in coastal districts of Odisha (Aswini Kumar et al., 2014). Irrigation plays pivotal role in the economy of the agrarian state Odisha, in the east coast of India. Irrigation potential created between 2000-2014 was underutilised inthe state (maximum 80.5% (2007-2008) and minimum 45.9% (2002-2003)) (Agricultural statistics, Odisha, 2012).

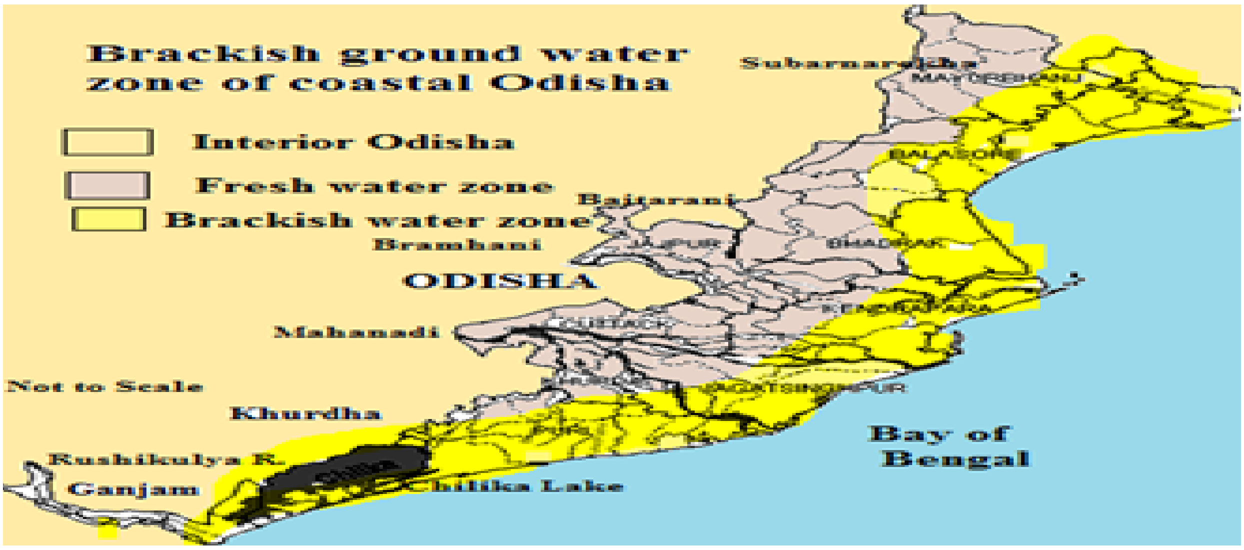


Figure 1. Status of fresh and brackish ground water and rivers in coastal Odisha

Source: CGWB India.

East coast of Odisha is a depositional coastal zone of six rivers like the Subarnarekha (S Rekha) in north, the Budhabalanga (B. Balang), the Baitarani, the Bramhani, the Mahanadi and the Rushikulya in south (Figure 1). They are debouching in Bay of Bengal directly or indirectly. The area comprises seven districts, i.e., Balasore (or Baleswar), Bhadrak, Kendrapada, Jagatsinghpur (J. S. Pur), Puri, Khurdha and Ganjam. The prograding nature of the coast has left imprints of 4-5 strand lines, fresh or brackish water bodies like Swamps, lakes, coast parallel channels, estuaries and lagoons and alluvial plains behind the smooth coast line. The coastal region comes under north eastern coastal plateau, east and south eastern plateau. The 480 km coastal tract consists of porous sand and loosely cemented old and new alluvium, paleo channels, sand dunes and gravel layers. The continental self of depth 0-20 km covers an area of 6820 sqkm (DPR ICZM, 2011-2012). The area consists of both shallow and deep brackish aquifers. The depth of shallow aquifers extends up to 8 to 10m. The GW is brackish and covers up to 5-25 km inland. The delta head is at 50-80 km from the coastal interface (Figure 3). The soil being unconsolidated alluvium, is the best repository to form shallow and deep aquifers of thickness from average 8m to 86 m (Choudhury et al., 2000).

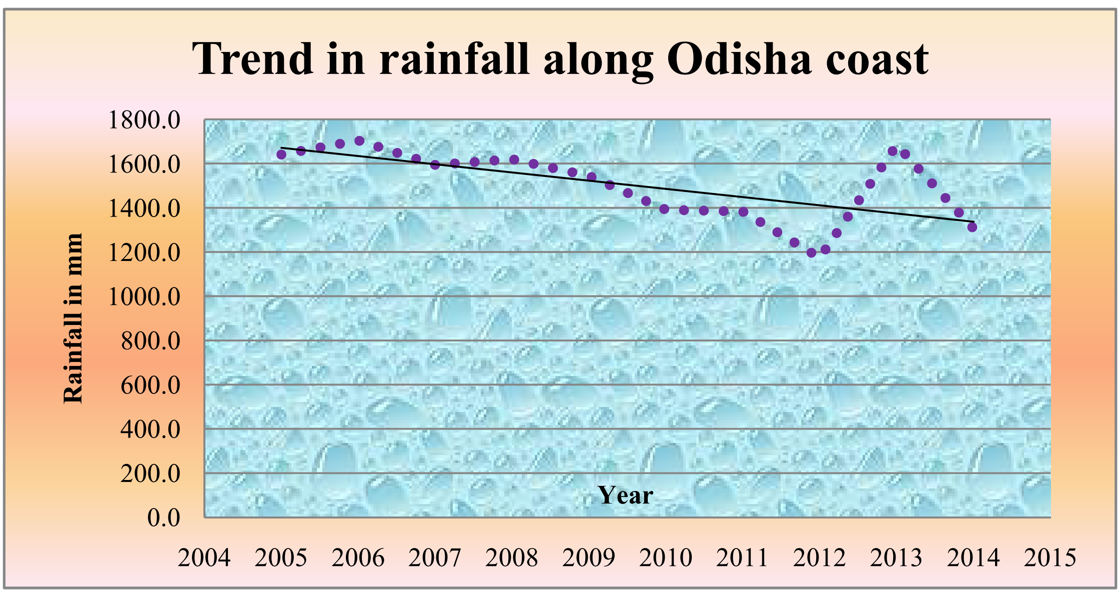


Figure 2. The rainfall in coastal districts of Odisha from the year 2005-2014

The coast is 140 to 120 million years old and was formed between the Post-Jurassic to Early-Cretaceous era. The water of the coastal zone is brackish and that of estuaries is saline (0.5 Mha from 2.66 Mha of land resources along the coast is composed of saline soil, barely fit for agriculture). The estuaries, Bhitarkanika wetland and other mangroves in Kendrapada, Balasore and Bhadrak districts cover 1435 sqkm. The lands within brackish water lagoon, Chilika in Puri, Khurdha and Ganjam districts are of 1165 sqkm, deprived of surface Irrigation. The soil and agriculture coverage map is shown in Figure 3.a and Figure 3.b. The Odisha coast possesses hot and tropical climate. The average temperature is 22-35^{0}C and average annual rainfall up to 1480 mm in the south coast and 1600 mm along the north coast. Rainfall of 70-80% occur during South West monsoon (JJAS months) in the year (Figure 2). The climate is humid and mean monthly PET rate is 45 mm in January and 320 mm in the month of May being highest Choudhury et al. (2000).

The average annual flow through all the rivers is 82.84 Bcum but only 17.24 Bcum of water potential is harnessed by 2385 projects, i.e., large (7numbers), medium (38 numbers) and minor (2340 numbers). The ground water potential explored for lift irrigation is only 0.381 Mha by 2014 out of 16.689 Bcum WR Department, Odisha, Annual Report (2014-2015). The coastal districts Odisha have 2.66 Mha of land (Table 1). The area covered under Khariff and Rabi were 0.4176 Mha and 0.33 Mha (63%) respectively in 2013-2014. The soil, land use and land cover and Ground water coverage map is shown in Figure 3 a, b and c.

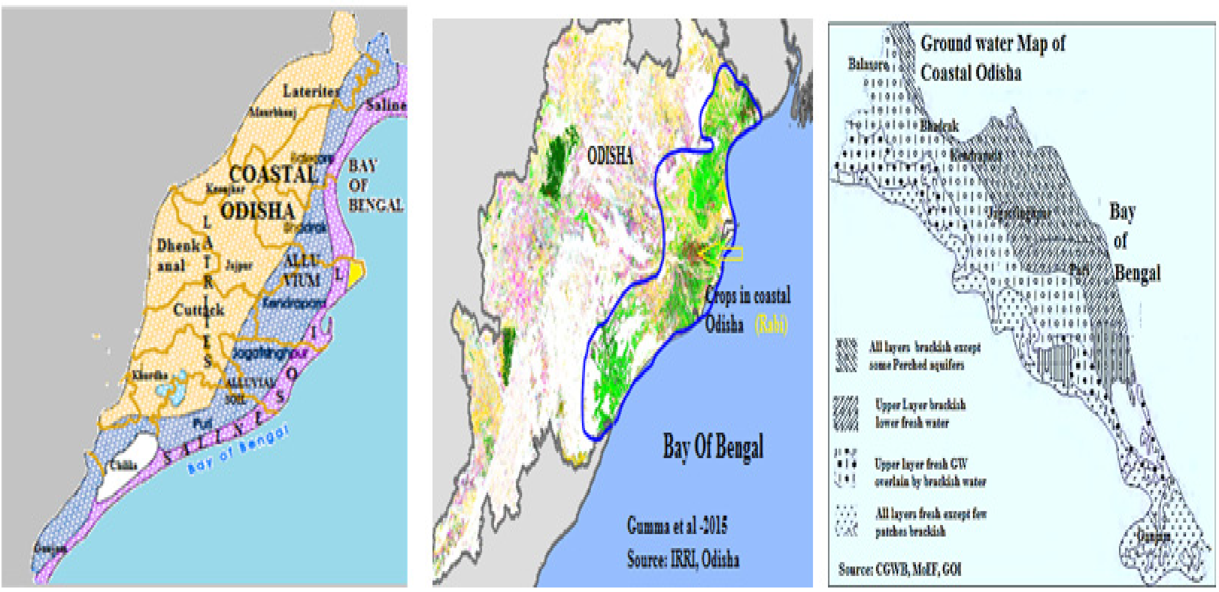


Figure 3. (a) Soil map (b) Satellite Image (c) GW map of coastal Odisha

Source : WR Deptt., Odisha; IRRI, CTK; CGWB, India.

The water logged areas (unfit for irrigation) of Puriand Jagatsinghpur (J S Pur) districts are 1520 and 1150 km^2. But partly the land is utilized during Rabi irrigation. The salinity affected areas in Puri and Jagatsinghpur block were 1948 and 7988 Ha respectively in 2013 (http://gopabandhuacademy.gov.in/sites/default/files/CHAPTER-WISE/Jagatsinghpur). The six rivers, the Subarnarekha Budhabalang, the Baitarani, the Bramhani, the Mahanadi and the Rushikulya allow average of 2.308, 3.111, 7.568, 18.577, 59.155 and 3.949 Mm^{3}of water to pass through the coast to the Bay. The irrigation statistics of the state are in Table 1.

Table 1. Irrigation (Surface and GW) status in coastal districts of Odisha

Coastal districts Odisha/	(Rivers/lagoons)	District Area (THa)	Rrepl enished (THam)	Lift Irrigation (THaM)	Gross draft (THaM)	Gross Irrign -2013 (THaM)	Total Irrign. (Tham)	GW used (%)
Balasore	(S. Rekhha, B.balanga)	373.37	110.06	44.443	57.94	220.06	264.50	52.64
Bhadrak	Baitarani	278.79	45.409	22.256	26.66	152.61	174.87	49.01
Kendrapaa	Bramhani	380.30	16.781	9.591	9.59	143.17	152.76	57.15
J.S.Pur	Mahanadi	175.90	45.029	12.223	23.21	96.52	108.74	27.15
Puri	Mahanadi	343.30	58.806	20.468	12.30	181.34	201.81	34.81
Khurdha	Salia/Chilika	288.75	47.618	10.192	15.71	88.56	98.75	21.4
Ganjam	Rushikulya	819.77	114.54	31.3	34.84	214.18	245.48	27.32
Total		2660.2	843.3	180.23	145.39	687.89	1246.9	38.57

The GW in Khurdha district which encompasses the west bank of the Chilika lagoonis brackish. Five urban local bodies such as Chandabali, Paradip, Puri, Konark and Gopalpurhave brackish GW near coast except few patches of sweet water. Ground Water of 22 out of 69 blocks in the seven coastal districts in Odisha is brackish and three of them are completely saline and unfit for cultivation. Lift Irrigation schemes available in Odisha were by shallow bore wells, surface lift and dug wells of 15543, 4681 and 1801 in numbers respectively by the year 2010-2011 (Table 2).

Table 2. Agriculture, demography and Irrigation status of GW table in coastal Odisha (GoO)

Coastal district	Block	Coast length (NASC)	2011-Census	Gross Irrigation area	Crop intensity-14	Av.Yield rice 2007-2011	Av. Area Irrigation cover	Av. GWT Jan-June	Av GWT Oct-Dec
	No	km	10^6	T Ha	%	Qtls/ km^2	%	m bgl	m bgl
Balasore	10	87.96	2.02	176.9	169	1638	40%	2-10	2-8 m
Bhadrak	7	52.61	1.33	139.4	139	1763	>50%	4-10	2-8 m
Kendrapada	9	83.55	1.3	119.7	186	1411	40%	4-10	<4m
J-Singhpur	8	58.95	1.06	96.8	197	1777	>50%	4-6	2-4m
Puri	11	136.48	1.50	153.5	191	1533	40%	4-6	<4m
Khurdha	08	Chilika	2.24	124.7	192	1660	65%	4-10	<4 m
Ganjam	22	60.85	3.14	271.6	181	2280	40%	4-10	2-06m
Total/av.	67	480.40	12.6	957.9	109	1734			

The total ground water volume of Odisha was 23.09 Bm^3 from which net replenished water was 21.01 Bm^3; draft 3.85 Bm^3 and underdevelopment 5.22 Bm^3 in 2012. The lower deltaic plain areas (5033.64 km^2) of Odisha have land covered by dense and sparse mangrove, vegetation, lagoon and other water bodies of l08.5 km^2, 84.4 km^2, 143.3 km^2, 790 km^2 and 7.7 km^2 respectively. The rest are mudflats, sandy beaches, beach ridges, barrier islands of 800 km^2 which are deprived of irrigation (Figure 4). The flood plains and other land cover area are of 3100 km^2 (http://shodhganga.inflibnet.ac.in/bitstream).

2. Review of Literature

Frank et al. (1935) reported that the concentration (conc.) of Boron>0.5 ppm in irrigation water was observed injurious for boron sensitive crops. Boron sensitive crops can with stand up to 1.0 ppm with reductions in yield under special care and tolerant crops could bear Boron conc. Up to 1.5-2.0 ppm in San Joaquín V alley, California. Oster and Rhoades (1977), Oster and Schroer (1979) and Suarez (1981) told that SAR over predicts the sodium hazard and introduced SAR (adjusted) by an 0.5 factor to evaluate more correctly the effects of

HCO_3 on calcium precipitation. On the basis of annual average values of water quality parameter in Danube shallow ground water in Danube areas, Russia, Burger et al. (2003) reported the Electrical Conductivity (EC) conc. in groundwater ranges from 600 µS/cm to 2100 µS/cm. SAR values from 1.7<SAR<22. He has classified ground water as low, medium, high to very high salinity/sodicity hazard. Gypsum maintains concentration levels of the electrolyte to maintain both physical and chemical properties of soils better over longer run told by Shainberg and Letey (1984).

Alaxander et al. (2011) opted for pilot farm studies before use of polluted tank water whose water quality parameters were exceeding norms. OPCB, MoEF, Government of India (GOI) (2011) studies reveal that increased level of biological oxygen demand (BOD), and coli form counts are alarming to agriculture as untreated domestic surplus water is directly discharged to drains. FAO had reported agriculture water widely vary in quality and parameters. Brouwer et al. (1985) prepared manual for FAO where in reported salts in water>2gms/lit is not fit for use. The usual method for qualifying the water quality standards either based on either SAR or RSC could not be satisfied as per field observations Suarez and Taber (2007).

Minhas and Gupta (1992) recommended Ca/Mg value for irrigation use. It is to be taken as one against adjusted SAR values recommended by Suarez (1981). Das Madhumita et al. (2009), reported that the SAR values has underrated the sodium hazard. Nayak et al. (2014) reported large variation in EC values in the ground water of the Chilika area than as fresh water having (Na^++K^+)-HCO_3 ion dominance and brackish water are resulting from (Na^++K^+)-(Cl+NO3) predominance. Bhadra et al. (2014) reported that the water quality of rivers debouching in Bay of Bengalin the coastal districts is safe and are within permissible limits.

Das et al. (2005) identified 5278 km^2 of poor agricultural area and 12940 km^2 of water logged areas in coastal districts of Odisha. Choudhury et al. (2010) stated coastal tracts can have salinity hazard and non-salinity hazard areas. Mishra et al. (2015) reported that the ground water and surface water in Krushnaprasad, Bramhagiri and few other coastal blocks are saline and at some places contaminated. Optimization of saline canal water is needed to avoid water logging and augment yield in the area. Bhatacharjee et al. (2008) studied the physico-chemical parameters of ground waters of Baleswar and Bhadrak districts and reported that there was change in water quality and presently unfit for irrigation at some places. The reasons were due to salinity intrusion. Bharadwaj et al. (2005) reported CPCB norms for irrigation water quality standards for pH are between 6.0 and 8.5, Electrical conductivity (ECw) <2250 µ mhos/cm, Sodium absorption ratio (SAR) <26 and Boron<2 mg/l. As per CGWB report (2010 and 2014), the electrical conductivity above 3000 µS/cm and Chloride ion concentration >1000mg/l of ground water are in the coastal district, Jagatsinghpur of Odisha. Flouride conc. was >1.5 mg/l in coastal districts of Bales war and Bhadrak was in 2008. The Iron concentration was>1.0 mg/l, not fit to be used for Irrigation water. MOEF, GOI, has prescribed as irrigation water needed E-class with safe use limits for different parameters are pH: 6.0-8.5, EC at 25^0 C as<2250 micro mhos/cm, SAR<26 and Boron as<2 mg/lit Cl should be<600 mg/lit, MOEF, GOI (2010)**.** Irrigation water contains dissolved salts in discrete variable quantities like NaCl, Na_2So_4 in moderate to large, $CaCl_2$, $CaSo_4$ $2H_2O$ (Gypsum), $MgCl_2$ in moderate and sulpahtes, carbonates and bicarbonates of Sodium, Potassium and Calcium in small quantities Longenecker and Lyerly (1974).

GW has been developed by 49% for use in coastal Odisha. Out of net GW potential of 4.06 Bcum of coastal districts of Odisha, only 1.46 Bcum is used for irrigation. Eutrophication, hypoxia and algal blooms are developed in canals due to excess nutrients in coastal areas. It is the main water quality problem globally, Sagasta et al., FAO (2010). Ground water development is found in the northern coastal districts of Odisha (Balesore-53%, Bhadrak-59%, Kendrapada-57% and Jagatsinghpur-51%), Padhi (2015). Ahamad et al., (2014) have reported ground water in and around Berhampur city is satisfactory except three places where water is hard. From ground water information booklet, Ganjam district, Odisha, the water quality of the district is suitable for moderate leaching and moderate salt tolerance crops CGWB report (2013). Pati et al. (2015) have reported that the water surface temperature of Gohdahada reservoir (Near coast) area was within ranges of 24.2^0C to 32.9^0C (29.49±2.42), from 6.74 to 7.39 for pH, dissolved Oxygen (D.O.) values varied from 3.88 to 5.32 mg/l and BOD from 2.09 to 3.73 mg/l in the year 2013. The soils of coastal tracts of form inland river deltas and consists of alluvium and lateritic formations Ahamad et al. (2015). Mohapatra et al. (2016) reported that excess of bicarbonates and carbonates of sodium in ground water used for irrigation causes suspension of organic matter and cause black strain on soil when it is dry.

3. Reasons for Study

Generally least problem salinity hazard is encountered in agriculture when water of good and standard quality is available as coastal Ground Water (GW) for irrigation. When GW is under severe restrictions, the physicochemical properties and need a high level of management for lift irrigation become important to have higher yield. The problems related to quality of water are salinity, reduction of water infiltration rate, specificion toxicity and excess nutrients.

Paddy (mostly mono-cropped) is the widely grown crop of coastal Odisha. The delta (Δ) for paddy is about one meter. Constant and prolonged use of brackish ground water for irrigation increases salinity and reduced the agricultural yield of the area. The water quality needs to be assured as quantity of water is a redundant factor in coastal areas. Also the quantity of the Total Dissolved Solid (TDS) is significant (10MT/year) if 1gram/lit of silt enter one hectare of irrigated land. So it is indispensable to study the quantity of sediment and quality of ground water added to the agriculture farms of 26,600 sqkm stretches of coastal districts of Odisha. The irrigation water used along the coast is brackish due to salt incursions in the shallow aquifers. During winter crops (Rabi), the ground water becomes less brackish because of salt dilution and flushing through leaching. The local farmers cultivate winter (Rabi) paddy in common where the land is not fallow. The coastal mono-cropped areas need assured irrigation during winter where SAR values are more than three but less than six.

The reason for study is to find the quality of the ground water available for Irrigation. It is also to find the management of GW and make it fit for plant growth in thickly populated areas of the coast.

4. Methodology

Most of the data for the study were compiled after collection from Ground Water Department of Govt. of Odisha (GoO), Water Resources Department (GoO) and published research works in various literatures like Bandopadhyay et al. (2008), Das et al. (2013), CGWB, GoI (2014), Bhadra et al. (2014), Nandi et al. (2015), Sahu (2016), and many others. The compiled data were of more than 1000 wells both tube and bore wells. Electrical conductance (EC), TDS, SAR, ESP, SSP, Adj SAR and others were calculated and their effect on the water quality in the ground water of coastal districts of Odisha are discussed. The data for quality of ground water for the districts of Ganjam, Bhadrak and Balasore were scanty. The observations were taken from nearby areas and before the year 2000 as available.

5. Respondent of Water for Irrigation

Poor irrigation water can be identified when applied in the field. There will be signs with signs of leaf burn, poor growth, reddish oily scale on water surface and moisture stress. The soil is saline if white crusts are found on soil surface; plants are water stressed, species change and exhibit burn leaf tip when applied. The Physical, and Chemical standards required for irrigation water and their effect on crop growth are given in Table 3.

Table 3. The water and soil respondent parameters, their impact and permissible limits of GW for irrigation

#	Constituent	Unit	Explanation	Tolerance limit	Impacts
			Water respondent		
1	Temperature	^0C	Degree of hotness	$<25^0$ C desired	Affect plant growth, more ET, early wilting point
2	CO_3^- (Carbonates)	Mg/lit	Present when pH>8.5	1.25<RSC<2.5	increases SAR value
2	Chloride	meq/l	Conc. of Cl^- ion in crops,	10-50meq/l (=16 meq/l need	Nontoxic, some plants chloride sensitive
3	HCO_3^- (Bicarbonate)	meq/l	Quantity of Ca and Mg ions present in irrigation water	10-20meq/l	Minimize Na hazard, High HCO_3 createiron chlorosis is in some plants
4	Nitrate	meq/l	Quantity of No_3 ion in irrigation water	No limit	Increase yield and plant growth
5	Sp. Conductance (µS/cm)	Micro-Sy mens/cm	EC (dS/m) x 640=TDS (mg/lit)	<1.5 desired >1.5 potential >3not desired	To measure conc. of dissolved solids (Ability of H_2O to conduct elec. at 25^0 C)

6	pH (Secondary Max. Toxin Level)	SMCL	Measure of H^+ ion concentration	6.0-8.5 (MOWR)	Corrosive, bacterial growth to clog pipes
7	Sodium Adsorption ratio (SAR)	Value	The proportion Na to Ca + Mg in Irrigation water	<6 desired >6 not desired	Make soil dry, hard, compact, impervious, yield less, leaf burn
8	Iron (Fe)	μg/lit	Reddish membrane on water surface	<300 μg/L	Nontoxic. Cause soil acidified/ loss of K and Mo ions
			Soil Respondent		
i	Salinity Hazard (Osmotic effect)	meq/lit	Adsorbed Na when >10-15% of total+ions,	SAR<6 desired >6 not desired	Soil gets dispersed, become dry, impervious, leaching occur, leaves burn etc.
ii	Sodicity Hazard (Property of soil)	meq/l	Found by conc. of cations. If Na^+conc. is high, the hazard is high. Low if Ca^{++} and Mg^{++}Conc. is more.	ECe<4 & SAR>4, diff. to estimate (James et al., 1982)	Soil, Low infiltration rate, crusting or hard setting, runoff, dark powdery residue on soil surface, erosion, stunted plants & leaf margins burned
ii	Toxic Hazard (Boron and other metals)	mg/lit	Not readily removed from soil but conc. depleted by numbers of leaching	<2mg/l (MOWR) 2-10mg/l range	Small quantity essential for growth in for max yields. Toxic to many sensitive plants

6. Some Important Parameters

The important parameters for good quality water for irrigation are EC, SAR, ESP, SSP, Adj SAR and others. The denotation of the parametric formulae used and their applicability are given in Table 4.

Table 4. Important formulae, parameters and applications of irrigation water quality

#	Measuring Parameters	Formulae used	Expansion symbols	Applications
1	a) Electrical cond. (EC) that crop resist) b) $\mathrm{Ec_e}$ = proportion E.C. of water used depending on % of irrigation water leached below root zone	a) EC (dS/m) x 640=TDS (mg/liter) b) $\%\ \text{yield} = 100 - \mathrm{b}\ (\mathrm{Ec_e}\ - \mathrm{a})$	EC=Elec. conductivity TDS=Total dissolvedsolid. b=loss percentage in relative yield/unit rise in salinity=EC of the saturated soil	Measure of Salinity Hazard.limit EC<2100-2250 (MOWR)
2	Sodium Adsorption Ratio (SAR) (excess Na content in irrigation water relative to conc (Ca and Mg inmeq/l).	$\mathrm{SAR} = \left(\frac{\mathrm{Na^{+1}}}{\sqrt{\frac{1}{2}[\mathrm{Ca^{+2}} + \mathrm{Mg^{+2}}]}}\right)$	Tolerance limit <3 (FAO) Soil is plastic and sticky when wet & hard when dry (Sod. hazard)	Poor tilth/low soil permeability affect at high SAR. Measure permeability
3	Exchangeable Sodium Percentage (ESP) for Sodicity of soil (Seilsepour et al., 2008)	$ESP = \frac{[100a + b\ (SAR)]}{[1 + a + b(SAR)]}$ Or ESP=Exchangeable $\left[\frac{(Na)*100}{(Ca+Mg+K+Na)}\right]$	a=intercept of the expt. error (0.06 to 0.01), b=slope of the regression line. (0.014-0.016) The desirable ESP values are 10-15	Better estimation of total salt content of Irrigation water the optimum value of ESP is 6
4	Leaching fraction (LF) (Fraction of applied irrigation water that must be leached through the root zone)	$\mathrm{LF} = \frac{\mathrm{ECe}}{\mathrm{ECw}}$=(depth of water leached below root zone) /(depth of water applied at surface)	ECw=electric conductivity of the irrigation water ECe=the electric cond. of the soil in the root zone	LF value needed for coastal Odisha (Ayers and Westcot, 1985)
5	Alkalinity hazard: (RSC) (IS Code 11624-1986)	RSC=[(Conc. of CO_3^{--}+Conc. H CO_3^-)-(Conc. of Ca^{++} + Conc. of Mg^{++})]	Conc. of CO_3^{++}, H CO_3^{++}, Ca^{++}, Mg^{++} expressed in meq/lit. Desired 1.25–2.5, unsuitable if >2.5	To find gypsum qty. or H_2SO_4 needed to reduce sodium hazard

6	Adjusted SAR	$\text{adj } R_{Na} = \frac{Na^{+}}{\sqrt{\frac{(Ca_{X} + Mg)}{2}}}$	Na+=Sodium ion meq/L. Caxas per *FAO Report* 29	Low infiltration capacity, Alkaline soil.
7	Soluble Na% (SSP): High Na^+ replaces Caand Mg clay.	SSP =(Na+K)*100/(Ca+ Mg+ Na+K) (Wilcox, 1948)	All anions are expressed in meq/l Tolerance limit as per MOWR <60%	Na clogging distorts soil's properties, poor drainage
8	MAR (Magnesium adsorption ratio) (Magnesium Hazard) (Nag et al., 2016)	$MAR = \frac{Mg * 100}{Ca + Mg}$ Ca and Mg are ions	Ca, Mg (meq/lit. needed MAR <50 for ground water	Essential for growth but high conc. is toxic, Cucolour & defoliation of leaves
9	Kelly's ratio (KR) Kelley (1940) and Paliwal (1967)	$KR = Na^{+} / (Ca^{2+} + Mg^{2+})$	Kelli Index <1 is suitable for irrigation. Na^+ , Ca^{2+}, Mg^{2+} are in meq/lit	Kelly's index (KI) >1 excess level of Na
10	Permeability Index (PI)	$PI\ (\%) = \frac{\{[Na^{+} + HCO3^{\frac{1}{2}}) * 100]\}}{(Ca^{2+} + Mg^{2+} + Na^{+})}$	All parameters should be in meq/lit. The safe value of PI be >75% and upper limit <25%	Doneen et al. (1964)
11	Mg content	Mg/(Ca+Mg)	If >0.5 adverse effects	Sodicity hazard (Raichaudhury et al., 2014)
11	α and β emitters	For α and β emitters	$<10^{-9}$μc/ml and $<10^{-}89$μc/ml	MOWR norms

Note 1. The conversion of different units used are (1) Concentration (Conc.): 1 mg/l=1 ppm (2) EC (mmhos/cm or dS/m) x 640=TDS (mg/l or ppm) and Ec of 1 dS/m=800mg/lit (3) Conductivity: 1 dS/m=0.1 S/m=1000 µS/cm=1 mmhos/cm=1000 µmhos/cm and (4) meq/l=(mg/l x Valence) /atomic weight.

Note 2. Dissolution of organic matter in soil occurs by excess concentration of carbonates and bicarbonates which is detrimental to plants.

Note 3. Plants transpire "pure" water for growth leaving salts to remain in soil–if not leached.

Note 4. High SAR value, the soil structure breaks and causes infiltration intricacy as soil turns hard and impervious. At very high values of SAR, the salt is not flushed with the irrigation water and sodium level increases gradually.

Note 5. Alkalinity**:** At high alkalinity (when pH>8.5), higher % of bicarbonates form insoluble salts of Calcium and Magnesium and sodium left in soil and water. This condition exacerbates a sodic soil condition. This affects phosphorous, iron and zink availability to plants.

Note 6. Boron: Essential in low amounts and Toxic to sensitive crops if % of boron>1.0 ppm.

Note 7. CO_3^{++} and H CO_3^{++} ion concentration in high % encourage formation of $CaCO_3$ and Mg_2 CO_3 and increases % of Na ion concentration. Consequently SAR value increases.

Note 8. The equation for Ca_xas per FAO Report 29, $Ca_x = [10^{0.283-(0.667\ x \log_{10}(\frac{HCO_3}{Ca})+0.022ds/m}]$ Where Mg=Mg ion present in meq/L.

7. Provision of IS Code 1624-1986

Indian Standard Code 1624-1986 (reaffirmed 2001) is followed in India as guide line for Irrigation water. The code recommends the WQP values for chemicals, as TSC (Total Salt Concentration as EC in micro Siemens), SAR (Sodium Adsorption Ratio in meq/lit), RSC (Residual Sodium Carbonate or bicarbonate ion conc.meq/lit) and Boron content in ppm. The values also depend upon the % of clay in the soil sample, quality of ground water and type of crop being tolerant and semi tolerant. The optimum parameters for WQP for irrigation is considered depending upon the % of clay as >10%, 10-20%, 20-30% and >40% but the rainfall must be >600mm (Table 5).

Table 5. Water Quality Parameters (WQP) for irrigation standards (India) as per Indian standard code 1624-1986 (re-affirmed 2009)

WQP for agriculture	TSS (EC in micro mho (℧))	SAR (meq/lit)	RSC (meq/lit)	Boron PPm
Low	< 1500	< 10	<1.5	<1.0
Medium	1500-3000	10-18	1.5-3.0	1.0-2.0
High	3000-6000	18-26	3.0-6.0	2.0-4.0
Very High	>6000	>26	>6.0	>4.0
% of clay in Soil				
>30%	1500-2000	10-15	2-3	2-3
20%-30%	4000-6000	15-20	3-4	2-3
10%-20%	6000-8000	20-25	4-5	2-3
>10%	8000-10000	25-30	5-6	1-2
<10%	>10000 Unfit	>30 Unfit	>6 Unfit	< 1unfit

8. Discussion

Water quality impacts can be judged by knowing the salinity, rate of infiltration and the % of toxic salts present in the soil. Most of wells in coastal Odisha have pH range between 7.0-8.5 but the river water may be acidic or alakaline depending upon the contamination by the effluents of Industry, Urban swerage or mining activities upstream. Total disolved solids in wells of coastal areas can be known when the measuring parameter EC is high.

The quantity of bicarbonate ions present in the ground water used for irrigation purposes in av.was 3.177 meq/lit which is within safe limits, i.e., 10-20 meq/lit (Table 7).

8.1 Physicochemical Parameters

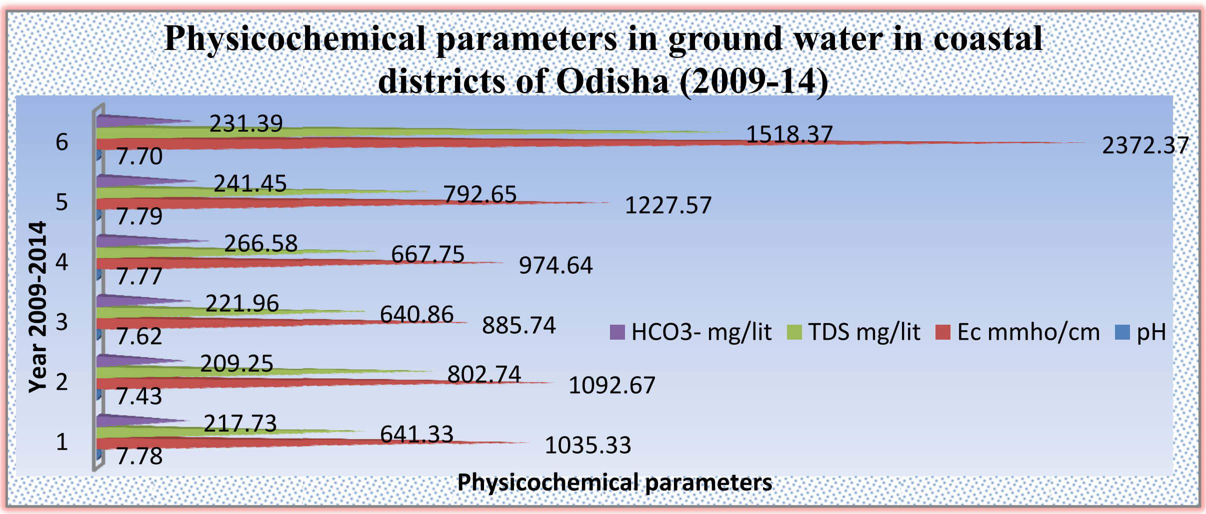


Figure 4. Average physicochemical parameters of ground water used in lift Irrigation in Coastal Odisha

The averaged pH value of the observations obtained is 7.68. It is slightly basic all along the coastal tracts of Odisha. Otherwise the values are within permissible limits, i.e., 6.0-8.5 except in small areas where it is high. The average electrical conductivity of the ground water 1264.72 which is far less than the required GW quality parameters used for lift irrigation, i.e., 2100-2250 which are mostly safe (Figure 4).

Table 6. Average inorganic and other paramters of GW used for Irrigation in coastal Odisha

Year	No obsn wells	pH	Ecwmmho/cm	TDS mg/lit	HCO_3^-meq/lit	CO_3^- mg/lit	Ca++ meq/ lit	Mg++ meq/ lit	Na^+meq/lit	K^+meq/lit	% of Na^+
2009	101	7.78	1035	641	3.63	2.39	2.61	1.90	4.33	0.75	73
2010	248	7.43	1092	803	3.49	1.48	2.66	1.75	5.26	1.14	82
2011	350	7.62	885	641	3.70	2.90	4.39	3.28	4.57	0.93	91
2012	318	7.77	974	668	4.44	6.53	12.04	5.68	11.0	2.97	124
2013	401	7.79	1227	793	4.02	2.72	2.67	2.84	5.44	1.71	95
2014	147	7.70	2372	1518	6.41	NA	5.84	3.27	14.1	4.23	218
Av.		7.68	1264	844	4.28	3.20	5.04	3.12	7.46	1.96	114

The concentration values of the inorganic elements such as Calcium, Magnesium, Sodium and Pottassium in the ground water used in coastal odisha are studied. It is observed that they were of gradual increasing trend from south to north. The salinity intrusion and excess drawal of ground water may be one of the causes. The water quality of the well have an increased deteriorating trend but were well within safe limits.

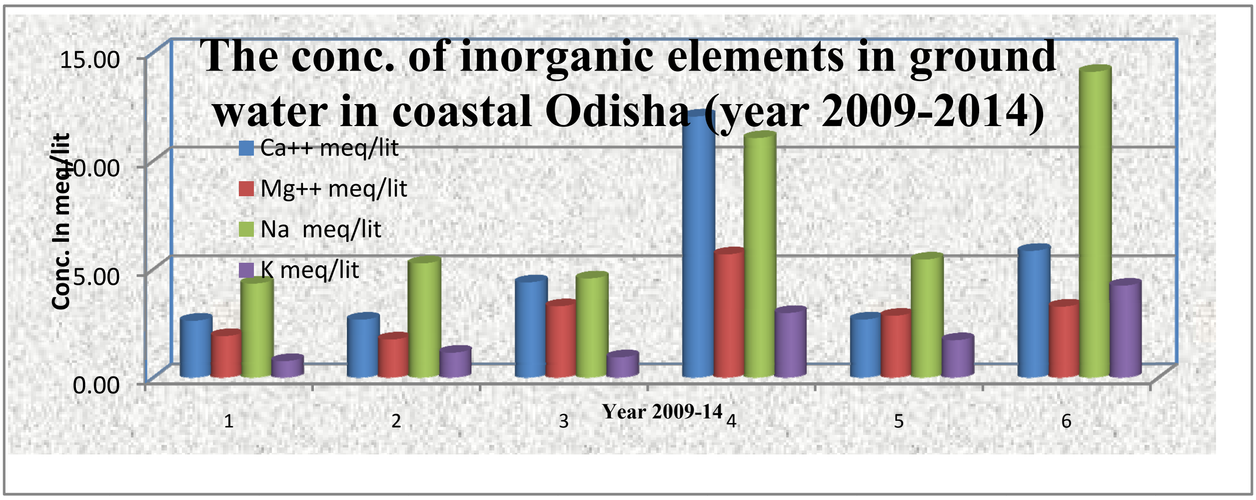


Figure 5. The average conc. of Calcium, Magnesium, Sodium and Pottassium in GW for 2009-2014

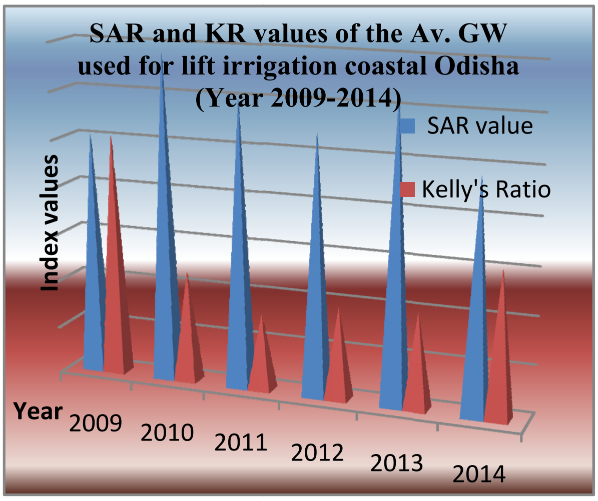
The water quality indices and norms used for irrigation purposes such as Sodium Adsorption Ratio (SAR), Kelly's ratio, Exchangeable Sodium Percentage (ESP), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Magnesium Adsorption Ratio (MAR) and Permeability Index (PI) were calculated for the data available for the years 2009-2014 for the coastal Odisha (Figure 5 and Table 8).

Table 7. Average water quality indices of ground water in seven coastal districts of Odisha (2009-2014) (IS: 11624-1986, Reaffirmed 2009)

Year	SAR	Kelly's Ratio	ESP	SSP%	RSC	MAR (%)	Permeability index (%)
Lower limit	<6	<1	<6	<60%	<1.5	<50%	>25%
2009	3	2.53	47.65	53	-0.81	42.15	70
2010	3.42	1.16	52.26	57	-0.87	38.78	74
2011	2.99	0.79	40.13	45	-5.14	41.89	53

2012	2.71	0.96	46.82	43	-13.8	37.45	46
2013	3.00	1.00	43.19	53	-1.40	49.66	68
2014	2.00	1.52	47.95	65	NA	43.55	72
classified	safe class	Na+ level excess	Low class	Safe(MOWR)	Safe	Safe	Safe

But the alkalinity, Magnesuim adsorption ratios and the permeability index are gaining safe results and the ground water can be used for irrigation. The negative values of residual sodium carbonate is due to excess of HCO_3 and CO_3 ions in the ground water.



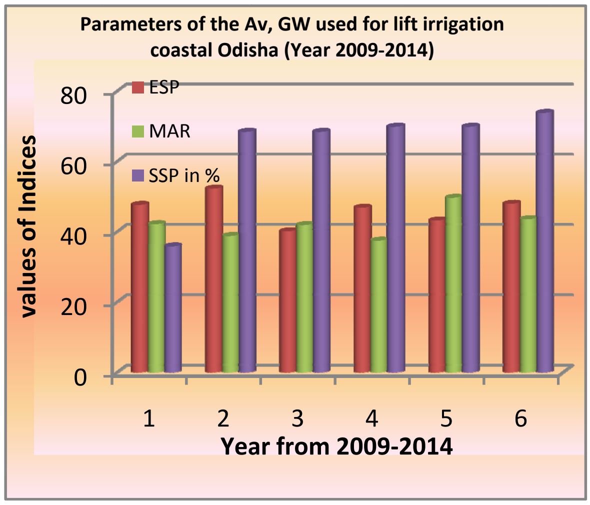


Figure 6. a: The av. SAR and KR values of GW of coastal Odisha (year 2009-2014) b: The av. ESP, MAR and SSP(%) values for GW for irrigation in coastal Odisha (year 2009-2014)

The study reveals that the average values of SAR is safe but Kelleys index indicate the insecurity of using ground water for lift irrigation all along the coastal districts of Odisha. The values of exchangable % of Na was indicating that the ground water is to be used less as it is unsafe for irrigation and can have sodium hazard (Figure 6. a and Figure 6. b).

8.2 Ranges of Observed Data

The GW is affecting the yeild of the crops in the seven districts of coastal Odisha (Raychaudhury et al., 2014). The ground water of the coastal area is detriorating due to modernisation and over exploitation of ground water for both domestic and industrial uses. The ranges of the chemical parameters of ground water in the coastal districys of Odisha are in Table 9.

Table 8. The observed minimum and maximum values of water quality parameters of coastal odisha (2009-2014)

Year	District	pH	EC (mmho/cm)	TDS (mg/l)
		Min-max	Min-max	Min-max
	Safe value (FAO)	6.0-8.5 (MOWR)	>6000	2100-2250 (MOWR)
1999-14	Ganjam	6.9-8.5	268-9337	233-5985
2009-14	Khurdha	5.93-8.6	109-5300	84-2012
2009-14	Puri	5.8-8.6	106-16720	68-11217
2009-14	J S Pur	6.3-8.9	142-25998	108 -15578
2009-14	Kendrapada	6.55-8.8	176-27400	89-18465
2009-14	Bhadrak	6.10-8.5	123-3900	95-2496
2009-14	Balasore	6.10-8.8	240-1370	186-309

The districts Puri, Jagatsinghpur and Kendrapada have higher upper range of pH, EC and TDS in their GW. So the areas like Krushna Prasad Block, Mahakalapada in Kendrapada, Raghunathpur and Ersama Blocks in Jagatsinghpur are having high values of those parameters (Table 10).

Table 9. The observed minimum and maximum values of water quality indices of coastal odisha (2009-2014)

Year	District	SAR	KR (%)	ESP	SSP (%)	RSC,	MAR (%)	PI (%)
		Min-max	Min-max	Min-max	Min-max	Min-max	Min-max	Min-max
	Safe range	3 to 26	0 to 01	10 to 15	<60%	<10	<50%	25 to 75%
1999-14	Ganjam	0.99-16.8	0.27-2.2	5.61-82	23-86.2	(-)58-4.2	6.7-52	30-43
2009-14	Khurdha	0.11-10.2	0.160-2.5	5.2-69.9	7-77.04	(-)6.7-2.0	9.0-64	42.6-125
2009-14	Puri	0.15-35.6	0.12-16.7	7.1-92.02	9.4-145	(-)26-12.4	7.0-90	25.0-185
2009-14	J S Pur	0.42-56.2	0.21-18.5	14.5-94.0	20-94	(-)87-4.3	3.9-67	42-134
2009-14	K.pada	0.2-10.15	0.2-13.1	9.6-88.5	12.3-93	(-)102-8.1	3.5-72	47-132
2009-14	Bhadrak	0.02-95.4	0.18-2.2	7.12-67.8	7.4-70.3	(-)9.7-1.9	23-57	7-69.52
2009-14	Balasore	0.15-4.4	0.15-1.15	3.21-38.3	8.0-60.0	(-)8.5-3.6	18-82	11-108

8.3 Water Quality Parameters

The GW is purer than surface water but gets contaminated during process of perpetual motion. The change in GW quality may be due to dissolution (gypsum, calcites, dolomites, silicates anhydrite etc.), addition of CO_2, hydrolysis, oxidation (pyrites and organic matters), reduction by O^{-2}, $NO_3^{-1}$and SO_4^{-2} etc., ion-exchange, precipitation, adsorption and bio-chemical mediated reactions and addition in the zone of unsaturation. The poor quality was due to (1) Addition of CO_2 gas into the unsaturated zone. (2) Dissolution of calcite and dolomite and precipitation of calcite. (3) Cation-exchange. (4) Oxidation of pyrite and organic matter. (5) Reduction of oxygen, nitrate and sulphate with production of supplied. (6) Reductive production of methane. (7) Dissolution of gypsum, anhydrite and halite. (8) Incongruent dissolution of primary silicates with formation of clays and others.

Irrigation water contains both dissolved and suspended contaminants varying in quantities during different seasons in a year. That may create three types of hazards (i) Salinity Hazard (ii) Sodium (sodicity) hazard and (iii) toxicity hazards causing low hydraulic conductivity, reduced infiltration, crusting, potential leaf burn and imbalance in nutrient intake.

Soil containing high sodium percentage makes it impermeable and hard when dry, difficult to plough and when wet, plastic and sticky to reduce germination and growth of plants. Magnesium (Mg^{++}), the 2nd abundant inorganic alkali metal is essential for growth of plants. It increases the electrical conductivity of water. Consequently the Ca^{++} uptake is reduced. But high concentration of both (Ca+Mg) has less effect on plant metabolism Srivastav et al. (2014). In brackish ground water have high concentration of Na and Cl ions that increases EC but have less effect on soil. The presence of HCO_3^+ ions if higher than Ca^{++} ions, after evapotranspiration HCO_3^+ions tends to precipitate Ca^{++} ions which are unfavorable for the yield. If Sodium to Calcium Activity Ratio (SCAR) and Sodium Adsorption Ratio increases (SAR) increases then EC increases with upsurge of Sodium hazard. The electrical conductivity and residual sodium carbonate decides the alkalinity hazard in Ground water used for irrigation. Alkaline irrigation water adds to sodium hazard and causes continual Ca, Mg and Fe deficiency. The problem is aggravated under poor drainage, eutrofication and salt accumulation.

On study of results of ground water samples and their physicochemical parameters from 7 districts of coastal Odisha it is concluded that the upper range limits of all the parameters are far exceeding the standard norms as prescribed by FAO, MOWR (India) and Indian standard specification.

8.4 Management of Water Forirrigation

Burger et al. (2003) reported that Saline Water for irrigation has been classified as low ($EC<250$ mmho/cm) for common crops, medium ($250<EC<750$ mmho/cm) for crops of moderate salt resistant crops, high ($750<EC<2250$ mmho/cm) for crops of high salt tolerance crops. Under inadequate drainage and very high values of EC ($EC>2250$ mmho/cm) is not suitable for irrigation. The coastal Odisha have saline soil of estuarine intrusion origin with brackish ground water within a narrow strip of 5-25km from the coast including the Chilika lagoon and its periphery. The water in these districts is rich in salts of chloride, sulphate, bicarbonates of sodium, calcium, potassium and Magnesium. During SW monsoon the subsoil salinity deplete with rise in ground water table and reaches its peak value during summer. The slogan “Salt loves bare soils” refers to the fact that exposed soils have higher Evapo Transpiration (ET) values than those covered by residues. Residues left on the soil surface reduce evaporation. Thus, less salt will accumulate. Rainfall will be more effective in providing for leaching activities and iron segregation as observed in coastal Odisha.

8.5 Ground Water Management (GWM) for Lift Irrigation in Odisha

For better Irrigation Water Management (IWM), steps involved in the study area are to (i) know the crop, soil and their limitations. (ii) adopt the suitable salt tolerant crops. (iii) study direct and indirect adverse effects like osmotic, specific ion and soil dispersion effects. (v) pre-plant irrigation and frequent discontinuous irrigation without water logging. (vi) changing irrigation system. (vii) blending irrigation water with canal water. (viii) strict implementation of federal laws. (Viii) keeping the farm uncultivated for some period Doneen et al. (1964).

The local government has framed laws to maintain proper irrigation qualities. They are the Odisha Irrigation Act 1959, Odisha Irrigation Rule 1961 (amended 1998), Orissa Pani Panchayat Act 2002 and Orissa Pani Panchayat Rules 2003, registered under Society registration Act, 1860, the Orissa Pani Panchayat Amendment Act, 2008 and Odisha Water Policy, 2007. Other acts intervening water quality are The Environment Protection act 2006, The Insecticides Act, 1968 and the Plastic sale and usage rules 1999. The federal institutions in state government have handed over the management of irrigation water supply by the water user associations (Called Pani panchayats) legally as participatory irrigation management. The quality of ground water and the surface water can be better managed by the water users in the coastal areas of the state Odisha, the Odisha ground water regulation, development and management bill 2011.

8.6 Management Procedure

(1) Management techniques which can be employed in coastal Odisha to have proper yeild are change in irrigation methods (Stressing on rabi crops in coastal areas), altering to sprinkler with more airification rather than the direct pumped and flow method, alternating the canal and lift water supply, land levelling and instalation of adequate subsurface drainages in coastal areas.

(2) Other important management methods are bed forming, preplant irrigation to augment leaching, frequent irrigation for additional leaching and selection of salt tolerant crops, changing duration of irrigation, proper plant selection.

(3) Consumptive use by using quality of water and proper crop diversification, management of nutrients, ground water, sunken raised bed method may add to improvement.

(4) As a solution to SAR problems it is required to change the irrigation source, blend irrigation water with canal water, lowering of sodium level by applying of lime, gypsum, sulphur or sulphuric acid etc.

(5) As advanced methods that can be adopted are reverse osmosis, desalination with system design, membrane technology and Nano tecnology.

(6) For augmentation of yeild, selection of crop water management to be given importance by indoctrinating Participatory Irrigation Management (PIM) through Water Users Associations (WUA).

9. Conclusions

The average water quality parameters and indices in coastal Odisha were within the permissible limits. But the upper limits of 20-25% data do not meet the proper GW quality criteria. Proper management policies are to be adopted so as to augment yield and to combat food crisis.

To start with, it is essential to have a field survey about cropping pattern and availability of GW and other sources of irrigation and its suitability in the coastal Odisha. Ample irrigation water should be available during the crop period instantly and to be applied uniformly in the agricultural fields. Adequate drainages are to be provided to discharge the surplus or leached water. Adopt proper tillage procedure so that soil moisture content to be maintained avoiding salinity accumulation on seed bed. Know the tolerance of the crop, soil characteristics and irrigation water quality. Constantly monitor irrigation water quality, adequacy and soil profile. Blending with profusely available canal water is also desired.

From the study of ground water sample it is found that fresh water conductivity values are around 1000 but the electrical conductivity increases as water become brackish or saline. It may be due to dominance of Na or K cat ions and HCO_3^- and Cl^-anions. There is gradual deterioration of ground water in the coastal districts of Odisha.

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