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RESEARCH ARTICLE

STUDY OF SEAWATER INTRUSION IN A COASTAL AQUIFER BY HYDROCHEMICAL METHOD – A REVIEW.

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Abstract

With two thirds of the earth's surface covered by water and the human body consisting of 75 percent of it, it is evidently clear that water is one of the prime elements responsible for life on earth. Water plays an important role in the field of agriculture, industries and domestic. In this concern about 70% of world's population lives in coastal region. One of the major factor most commonly encountered in coastal aquifers is the induced flow of saltwater into freshwater aquifers caused by groundwater over pumping known as Saline water intrusion or Seawater intrusion (SWI). It is the landward migration of sea water into freshwater coastal aquifers. This study review is focuses on the SWI vulnerability which were studied by hydrochemical analysis in the coastal aquifers. The water quality is depends upon the chemical parameters such as pH, Electrical conductivity (EC), Total Dissolved Solid (TDS), chloride and Total alkalinity etc., The review shows that all the water quality chemical parameters are considered as per the standards of APHA. Hence it can be concluded that in post-monsoon period the water level gets lowered which reduces the water quality. This mainly leads to seawater intrusion to certain extent. The chemical parameters were analysed in various research works and it is concluded with certain range of values.

Introduction:-

Water is a major source for agriculture and drinking. The reason at which the water quality gets affected due to excess pumping, urbanization, industrial waste and reduction of water level in the aquifer. As the coastal aquifers are generally connected hydraulically to the sea and which the seawater is slightly denser initially intrudes at the bottom of the aquifer and the fresh water is present at the top. Over exploitation of groundwater from such coastal aquifers to meet the increasing demand accelerates the progress of seawater further towards the land. This will lead to the abandoning of production wells due to contamination of groundwater owing to the mixing of seawater. This leads to seawater intrusion which is ingress of seawater into confined or unconfined coastal aquifers.

Seawater is characterized by the dominance of Na and Cl with the total dissolved solids of about 35,000 mg/l. The molar ratio of Na/Cl in seawater is 0.86 with an excess of Cl over the alkali ions (Na) while the molar ratio of Mg/Ca in seawater is 4.5 to 5.2 with an excess of Mg (Jones et al. 1999). In contrast, continental fresh groundwater is characterized by a highly variable chemical composition, although the predominant anions are HCO3, SO4 and Cl (Fritz et al. 1979; Korfali et al. 2010). The total dissolved solids in fresh groundwater generally vary from 150 mg/l to 1500 mg/l. Thus, the mixing trends between seawater and groundwater can be understood from total dissolved solids (> 2000 mg/l), Cl (>1000 mg/l) and some minor ions. Mixing can also be identified when electrical conductivity (EC) of groundwater exceeds 3000 µS/cm (Karahanoglu et al. 1997). United Nations Environment programme (EPA) under the Global Environment Monitoring system have proposed the accepted values for chlorides as 250 mg/l, pH as 6.5 to 8, TDS as 600 mg/l and Electrical conductivity up to 250µs/cm as excellent

when Total alkalinity at 200 mg/l. Since the water quality parameters or hydrochemical parameters are discussed and the effort has been made to give a brief idea of an approach to monitor and control the seawater Intrusion.

The Study Area:-

Several research studies on seawater intrusion in coastal aquifers were carried out in various parts of the world making use of the geochemical indicators (McCaffrey et al. 1987; Custodio and Bruggeman, 1987; Gonfiantini and Araguás, 1988; Todd, 1989; FAO report 1997; Jones et al. 1999; Moujabber et al. 2004, 2006; Appelo and Postma, 2005; Slama et al. 2010). Sukhija et al. (1996) used the inorganic water chemistry as a tool to differentiate the current and palaeo salinities in coastal part of Cauvery basin, India. Desai et al. (1979) studied the sources of salinity and geochemical evolution of seawater in coastal aquifers in part of Gujarat, India. Over pumping of groundwater has lead to the seawater intrusion up to a distance of 4 km in coastal aquifer (Subramanian, 1975). A detailed study on hydrogeological and artificial recharge in coastal aquifers area by UNDP (1987) reported that the salinity ingress has been identified up to a few km from the coast. Thus, all the study carried out and indicated that the intrusion of seawater up to a distance of 8 km from coastal region (Indu et al. 2013) can be analysed and results the level of sea water intrusion.

Seawater Intrusion:-

The migration of salt water into freshwater aquifers under the influence of groundwater development is known as seawater intrusion. There is a tendency to indicate occurrence of any saline or brackish water along the coastal formations to sea water intrusion. The salinity can be due to several reasons and mostly it can be due to the leaching out of the salts from the aquifer material. In order to avoid mistaken diagnoses of seawater intrusion as evidenced by temporary increases of total dissolved salts, Revelle recommended Chloride-Bicarbonate ratio as a criterion to evaluate intrusion.

Causes:-

Several process lead to seawater intrusion. Most of the problems are:

- •Over pumping
- •Unplanned aquifer management
- •Tidal effect
- •Sea level rise
- •The seasonal variance of influx

Losses:-

- •Loss due to salinity impact on crop
- •Increase in energy cost due to deepening of wells
- •Agricultural losses due to drying up of Aflaj
- •Losses of domestic customers who shift to another water source
- •Irreversible loss of the aquifer as a store for freshwater
- •Increased water scarcity
- •Poor public health

The above are the major losses that occur in the world due to contamination of groundwater in coastal aquifer regions. In order to overcome these, seawater intrusion should be analysed which leads to its future control. Several methods have been suggested by various authors to assess seawater intrusion. They are Chemical parameter analyses, modelling, geo physical method, physical scaled down model, Ghyzan-Herberg interface. In this review, only chemical parameters and geo physical methods are considered for seawater intrusion analyses.

Hyrdrochemical Analyses:-

Table1 shows that the summary of hydrochemical analyses of seawater intrusion in different areas studied by various authors. From the table it was clear that electrical resistivity and total alkalinity are calculated by only few authors however it is sufficient enough for the analyses of seawater intrusion in many areas (Lamiya, Gopinath

S et al., K.F.Oyedele et al.). The analyses of pH, TDS, EC, Ca, Mg, Na and Cl are done in most of the papers which shows that these are the basic parameters to be calculated in this problem (Mohan Basu, Dr. Yerr V. Noell, S.Venkateshwaran, Pallavi Banerjee Chattopadhyay et al., Brahim Askri et al.).

Table 1: Summary of study on the Hydrochemical parameters of seawater intrusion

REFERENCE	pH	TDS mg/l	EC mg/l	TH mg/l	Ca mg/l	Mg mg/l	Na mg/l	Cl^- mg/l	SO_4^- mg/l	NO_3 mg/l	ER Ωm	TA mg/l
K.S.Anil Kumar et al.	8.70	774	1926	410	108	68.5	518	2304	270	-	-	499
K.F.Oyedele et al.	-	-	-	-	-	-	-	-	-	-	37.2	-
E. Giménez et al.	-	1000	-	-	>200	>200	-	>250	-	300	-	-
Annapoorani A et al.	-	13390	-	725	730	1456	4624	4500	-	-	-	-
B. I. Desai et al.	7.1-8.4	-	618-55178	-	-	-	-	>250	-	-	-	-
Gounari christina et al.	7.1-8.12	4736	>900	-	-	-	-	-	-	45	-	-
Gopinath S et al.	8.4	8368.6	12430	567	416	411	1330	5060	430	-	0.15-1.5	-
P. Daskalaki et al.	-	-	12000	-	-	-	-	1465	-	88	-	-
Brahim Askri et al.	7.9-8.7	838-16280	1560-31460	600	716	51-1186	4780	8236	1720	76	-	-
Gopal Krishan et al.	-	-	5000	-	-	-	-	-	-	-	-	-
Pallavi Banerjee Chattopadhyay et al.	6.6-7.3	2308-38920	3550	506	126	131	452	865	806	122	-	-
J. K. Klassen	-	71000	72000	-	-	-	-	-	-	-	-	-
Tran Dang An et al.	7.95	13329	24300	-	-	-	-	-	-	-	-	-
S.Venkateshwaran	9.02	3668.9	5162.6	692	341	179	530	-	169	-	-	-
Jinook	-	-	-	116	922	769	3090	813	928	-	-	-
S. K. Sharma	-	3301	-	553	-	-	1024	1566	302	-	-	-
Lise Cany	7.57	-	1044	-	-	-	-	-	-	-	-	-
Dr. Yerr V. Noell	7.9	-	330mv	237.9	200	3961	3301	6159	864	-	-	-
Dv k minkin	6.9-7.9	3924-5124	-	-	-	-	1050-1350	>1000	-	-	-	-
Mr. Lamiya	-	5166	-	-	-	-	-	2844	-	-	6-15	-
Indu S. Nair	-	-	75000	-	-	-	-	19500	-	-	-	-
K. S. Sylus	-	18000	2500	-	-	-	-	-	-	-	-	-
Abdul Monen	7.8	5460	3000	485	-	-	-	855	245	>250	-	-
Mohan Basu	8.85	4096	-	>1025	80	986	97	1193	666	1.5	-	-

Legends:-
TDS - Total Dissolved Solid, EC - Electrical conductivity, TH - Total hardness, Ca - Calcium, Mg - Magnesium, Na-Sodium, Cl - Chloride, SO4 – Sulphate, NO3 – Nitrate, ER – Electrical resistivity, TA – Total alkalinity.

Assessment of Common Indicators:-
A variety of common indicators used in previous studies were applied to the data in order to determine which wells may be affected by SWI. The fresh water predicted or indicated (Konstantin J. Sylus et al. 2012) by the chemical ratios as below,

Freshwater
Ca/Mg = 0.091 < 0.05
Na/Cl = 1.86 to 22.357 < 1
Cl/(Co3+HCo3) = 1.67 to 17.60 < 0.05

In seawater intruded regions, the concentration of Mg will be greater than SO4+HCO3, and Cl greater than Na, whereas in regions with meteoric waters salinised by the marine salts will have Na greater than Cl (Howard and Llyod, 1983). Further, minor ions such Br, F and I are also playing a vital role in the identification of seawater intrusion. Apart from this, the various ionic ratios (e.g., Cl/Br, Na/Cl) are also used to identify seawater intrusion. In order to study the origin and dynamics of groundwater, the analysis of the variations in the stable isotopes of oxygen-18 (δ18O) and hydrogen (δ2H) have been widely used. The distribution of these isotopes in natural waters is used to investigate the source of various water types and possible interconnection between them.

Conclusion:-

Based on the literature review it has been concluded that the sea water intrusion can be predicted with the minimum values or ranges are as in the following table 2,

Table 2: Numerical ranges of seawater intrusion

Sl.No	Hydro chemical Parameters	SWI Predictable Ranges
1	pH value	7.1 - 8.9
2	Total Dissolved Solids (TDS)	3300-71000 mg/l (1000 – 3000 indicates saline and > 3000 indicates over saline)
3	Electrical Conductivity (EC)	1900 – 72000 µS/cm (> 1300 indicates seawater intrusion)
4	Electrical Resistivity (ER)	7.6 mΩ - 42 mΩ (< 120 mΩ indicates sea water intrusion)
5	Magnesium (Mg)	200-1456 mg/l
6	Calcium (Ca)	200-922 mg/l
7	Sodium (Na)	200-4750
8	Chloride (Cl)	250-19600 mg/l (Above 700 indicates seawater intrusion)
9	Sulphate (SO_4)	250-928 mg/l
10	Nitrate (NO_3)	50-300 mg/l
11	Total Hardness (TH)	237-1025 mg/l

Control Methods:-
The summaries of salt water intrusion control methods are,

Non-engineered Prevention
- Conservation/reduced pumpage
- Leak control
- Financial incentives/disincentives
- Variable water rates
- Pumping pattern management

Engineered Prevention
- Relocated wells - same aquifer
- Relocated wells - alternative aquifer
- Increased surface water use
- Passive aquifer recharge
- Active aquifer recharge
- Induced recharge wells
- Hydraulic barriers
- Physical barriers - in aquifer
- Electrical barriers
- Saltwater interception
- Flownet modification
- Combined extraction/injection
- Aquifer storage/recovery

Utilization of Contaminated Water
- Scavenger wells (skim freshwater from
- Contaminated aquifer)
- Desalination
- Use of brine in salt-tolerant industry

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