Studies on Seasonal Variation of Groundwater Quality in Central Delta of Godavari, East Godavari District, Andhra Pradesh State, India

*K. Vishnu Vardhana Rao, T.Vinoda Rao and G.Vijayakumar
Department of Geology, Andhra University, Visakhapatnam. Andhra Pradesh (India)

Abstract - The present study is to assess the seasonal variations of the hydrochemistry and quality of the groundwater in the central Delta of Godavari River, Andhra Pradesh, India. Fifteen groundwater samples were collected from the observation wells during the periods from 2015 to 2017. Hydrochemical analyses including major and minor elements were done for the spatial distribution of the element concentrations and for the assessment of seasonal variations. Based on the results of the field investigations, it has been indicated that the quality of groundwater has observed in both the seasons were distinctly different**.** The western and central part of the study area, the values are within the tolerable range, whilst, the groundwater nearer to the coast showed high variations, possibly influenced by salt-water intrusion, ion exchange and agricultural activity. It is recommended that during the pre-monsoon periods, pumping from bore wells be minimized to control the seawater intrusion.

I. INTRODUCTION

Water is a dynamic renewable natural resource. Its availability with good quality and adequate quantity is very important for human life and other purposes. In general, the quality of water is equally important as the quantity. Thus water quality is considered to be an important contributing factor to predict the possible environment changes associated with social and economic development. In developing countries around 3.4 million peoples mostly children, sufer from water borne diseases every year due to groundwater contamination (WHO). Nowadays, surface water quality became a critical issue in many countries; especially due to the concern that freshwater will be a scarce resource in the future therefore, water quality monitoring program is necessary for the protection of freshwater resources. Monitoring programs of aquatic systems play a significant role in water quality control since it is necessary to know the contamination degree so as not to fail in the attempt to regulate its impact. However, the quality is difficult to evaluate from a large number of samples, each containing concentrations for many parameters, thereby choosing the observation wells seasonally for the spatial and temporal assessment.

Major techniques to evaluate the groundwater chemistry is the salinization (Durov 1948; Stiff 1951; Back and Hanshaw 1964) represented by the contamination processes, especially in coastal aquifers, and by the increases of total dissolved solids (TDS) and some specific chemical constituents such as Ca^{+}, Na^{+}, Mg^{+}, and SO_4^{2-} (Nadler et al. 1981; Morell et al. 1996; Sukhija et al 1996). The hydrochemical differentiation of salinization processes in coastal areas is very complex as there is considerable amount of hydrogeochemical variability due to the superposition of different processes, such as seawater intrusion and pollution phenomena (Morell et al. 1996). It has been reported by the earlier investigations (Biksham and Subramanian (1988)) that major ion composition and rate of chemical erosion are major contributing factors to determine the elemental flux of the Godavari Basin, as part of their work, to determine fluxes of various elements transported by these systems to the Bay of Bengal.

Groundwater chemistry based on the hydro chemical data is used for obtaining preliminary information on water types, classification of water resources for various purposes to different ground-water aquifers and study of different chemical processes (Saxena et al. 2003; Jalali 2007; Sarwade et al. 2007). Groundwater chemistry plays an important role for the study of groundwater quality in the coastal aquifers (Hem 1970). In the assessment of fresh groundwater potential, hydrochemistry plays an important role in coastal regions. Hydrochemical parameters were used to evaluate the seawater intrusion process, the knowledge of which can be helpful to control the water quality in the coastal areas (Mercado 1985). A number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in the different parts of India (Subba Rao et al. 1999; Sujatha and Reddy 2003; Sunitha et al. 2005). The study area mostly comprise of predominantly agricultural land with varied agricultural activities.. Majority of the people in this region depend on agriculture (i.e., cultivators and agricultural laborers). Substantial amount of groundwater is being used in this area for both drinking as well as irrigation purposes. The purpose of the present study is to determine the hydrochemistry of groundwater, factors affecting the seasonal variations of groundwater quality, and classify the water in order to evaluate its suitability for domestic and agricultural uses.

II. DISCRIPTION OF STUDY AREA

Location and Topography

The Godavari Delta is geographically located on the east coast of India (Fig. 1) between 16°25 N to 16°55 N latitude and 81°44 E to 82°15 E longitude with the rivers Gothami Godavari in the north, the river Vasistha Godavari in the west and the Bay of Bengal in the east serving as its hydrological boundaries. The coastal line along the study area measures about 40 km and the general elevation varies from about 2 m (a.m.s.l.) near the sea to about 13 m at the upper reach. The Godavari basin receives an average rainfall of 92.3 cm during monsoon season (June–September), which is about 85 % of the total annual rainfall. Most of the rainfall occurs during the southwest monsoon season (June–September) contributing nearly 72 % of annual rainfall. During the northeast monsoon (October–December), the rainfall varies from 226 to 456 mm. July is the wettest month contributing to about 26 % of the annual rainfall and nearly 57 % of the SW monsoon rainfall. December is the coldest month with normal mean maximum temperature of about 26.1 °C and mean minimum temperature of 18.2 °C. During May and early June, the maximum temperature goes occasionally to 46 °C. Relative humidity varies from 75–80 %. The important drains, viz., Kunavaram, Vilasatippa, Lower Kousika, and Pikaleru drain the irrigated water with nutrients and residual fertilizers to Kandikuppa Mangrove Reserve Forests and the sea.

Climate

The region exhibits a hot tropical climate characterized by a range of oppressively low daily temperatures in summer, high humidity and moderate annual rainfall. The temperature continuously increases from the end of February to the hottest month (May) to between 35°C and over 46°C in the interior. In the coldest month (January), 22°C is recorded in the coastal regions and 19-20°C in the interior. It is obvious, therefore, that there is little variation in the normal annual temperatures, mainly because of the low relief and the moderating influence of the sea. The diurnal range of temperature is lower in coastal regions than in the interior, being of the order of 2-3 °C during June-December and 4-6°C during January-May. The Godavari basin receives an average rainfall of 92.3 cm during monsoon season (June–September), which is about 85 % of the total annual rainfall. Most of the rainfall occurs during the southwest monsoon season (June–September) contributing nearly 72 % of annual rainfall. During the northeast monsoon (October–December), the rainfall varies from 226 to 456 mm. July is the wettest month contributing to about 26 % of the annual rainfall and nearly 57 % of the SW monsoon rainfall. December is the coldest month with normal mean maximum temperature of about 26.1 °C and mean minimum temperature of 18.2 °C. During May and early

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Agriculture

The Godavari Delta is under the command of Godavari Central Canal System and is served by a main canal, three branch canals, one main distributor channel and a large number of irrigation channels. The canal system remains operational for 11 months with a one-month closure period during April-May. The delta soils are considered to be the most fertile lands, paddy (rice) being the major crop of the region. The study area is predominantly a rice growing area in both "Kharif" and "Rabi" seasons: the Kharif season commences on June, when irrigation water is released through the canal system, and extends up to November; the Rabi season is from December to April of the following year. Crops such as sugar cane and paddy are irrigated by canal water. The vegetable gardens are irrigated partly by tube wells and partly by canal water. A large number of coconut trees also grow in the study area and account for about 15% of the total area. There is no forest in the study area.

III. GEOLOGY AND HYDROGEOLOGY

Godavari River started discharging large amounts of sediments into the Bay of Bengal thus initiating the delta-building processes during the Quaternary. The upper deltaic sediments are essentially fluvial while those in the lower delta region are fluvio-marine. In the Godavari delta, five strandlines indicating five stages in the progradation of the delta are observed. There is evidence of uplift even during the Quaternary and the process of physical and chemical weathering, and deposition continued to operate and modify present day physiography. The area has rich alluvial plains formed by the river Godavari and has a very gentle land slope of about 1 m/km (Bobba 2002). Major part of the area consists of sandy loams and sandy clay loams (Fig. 2). A major NE–SW trending lineament from the west of Mogalturu to south of Amalapuram is interpreted to have caused a major shift in the distributaries of the Godavari River. The sediments of the area lying south of this lineament are of marine origin and those to the north of the lineament are of fluvial origin (Naidu et al. 2012). The deltaic plain shows relief between 15 m at its apex to 2 m near the coast. Among the fluvial landforms, active channel (Gautami Godavari and Vasista Godavari) with associated braided/channel bars and levees form a part of the sub aerial top-set beds of the delta.

The occurrence and behavior of groundwater are controlled by topography, climate, geology, and structure of the area. CGWB (2010) has reported from their hydrographic network stations that the general flow of groundwater in phreatic aquifer is controlled by the drainage network and is a subdued replica of the surface topography. Groundwater in the deltaic alluvium occurs under both water table and confined conditions. Permeability varies from 2 to 75 m/day with specific yield 0.05–0.2 and yield prospects are 100 m3/h. The impact of surface water irrigation is very important on the dominant groundwater regime. The lateral surface water flow through the river channels and canals as well as the return flow from irrigated field and infiltration of precipitation forms the principal source of ground-water recharge. In general, the hydrogeological scenario of the study area is controlled by distribution of the flow in the river channels, canals and rainfall (CGWB 2010).

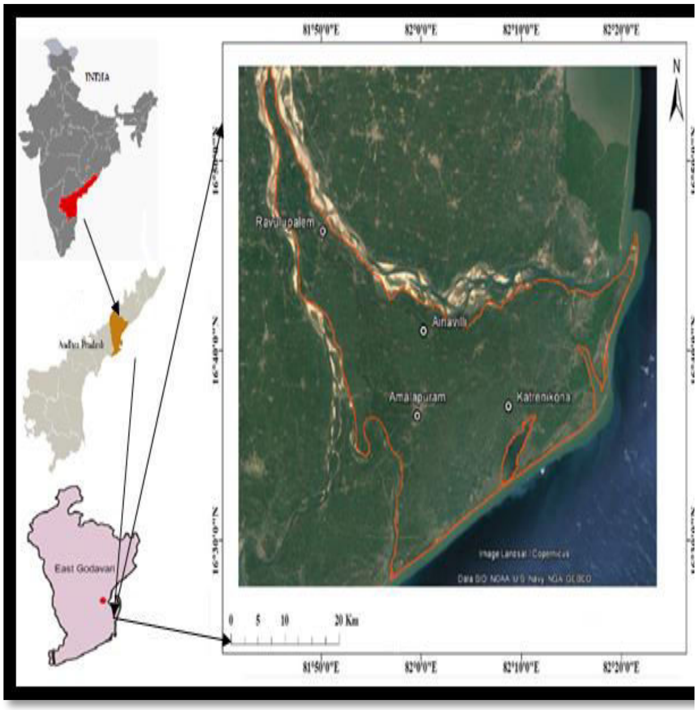

Fig.1 Location map of the study area

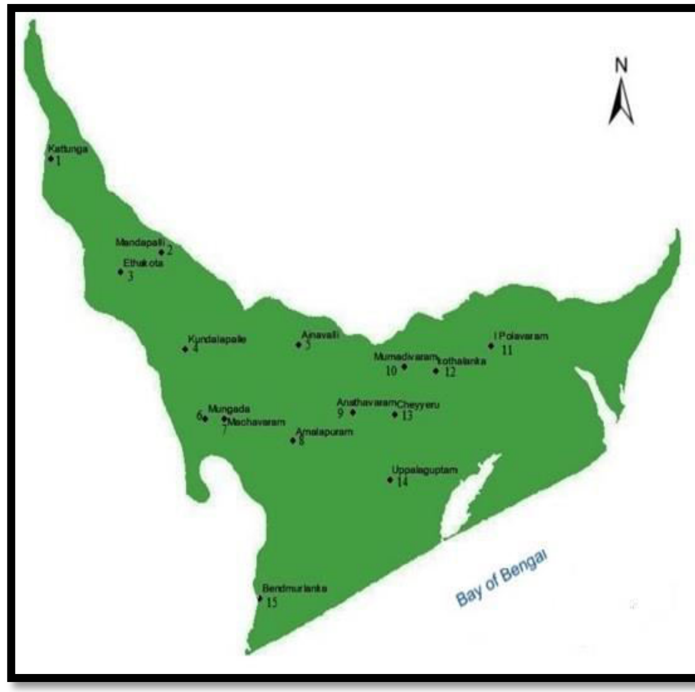

Fig.2. Observation wells location in the study area

IV. MATERIALS AND METHODS

Groundwater sampling and analysis

A total of 15 water samples from the observation wells were collected during different seasons in the years 2015, 2016 and 2017. These samples were collected as per the standard procedures .Each bottle was washed with 2% nitric acid and then rinsed three times with distilled water. Samples were analyzed to determine the concentrations of pH, temperature, total dissolved solids (TDS), electrical conductivity, hardness, chloride, sulfate, alkalinity, fluoride, iron, calcium, magnesium, and nitrate. All the tests were conducted in accordance with the techniques described by American Public Health Association (APHA 1995; BIS 1991).The precision of the chemical analysis were confirmed by ionic error balanace which is within -+5%and the analysis of the data is presented in Table 1.

Analysis of samples

Parameters like pH, temperature and conductivity were measured at the collection site with portable water analyser kit and the remaining parameters were analysed in the laboratory. Different parameters were analysed by Standard Methods (APHA 2005).

Cations like sodium and potassium were determined by flame photometer. Calcium and magnesium were determined by EDTA titration methods. Anions like carbonate and bicarbonate were calculated monographycally by acidimetric method. Chloride was determined by using silver nitrate titration method and sulphate by turbid metric method using a spectrophotometer having light path 2.5 cm. Nitrate was determined by UV spectrophotometric method. Apart from that, alkalinity was determined by titrimetric method and hardness was analysed by EDTA titrimetric method. After conducting the analysis of the water samples the major and minor ions,

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validation tests in terms of cation-anion balance was conducted for each sample. Necessary re-analysis has been done wherever the error exceeded 10%. The analysis results are tabled in 1.

Table 1. Statistical analysis of physic- chemical parameters of groundwater samples

WHO			Pre Monsoon				Post Monsoon			
Parameter	Desired limit	Maximum permissible limit	Min	Max	Mean	SD	Min	Max	Mean	SD
pH	6.5	8.5	7.8	9.3	8.6	0.5	7.5	8.8	8.2	0.4
EC		1500	902	4107	2112	982	365	3377	1494	931
T.D.S	500	2000	440	2698	1458	763	234	2159	956	596
T.A	200	300	122	614	331	156	85	537	280	137
T.H	200	300	179	1393	645	461	123	589	276	124
Na		200	37	534	247	150	19	512	159	131
K		12	4	412	114	110	4	315	76	97
Ca	75	200	21	296	125	104	15	97	45	24
Mg	30	100	16	171	81	52	12	96	39	23
HCO_3		380	100	415	249	97	74	430	221	106
SO_4	200	400	21	501	214	161	17	217	92	61
NO_3		12	17	234	92	63	7	180	65	51
Cl	250	1000	49	983	386	288	40	760	206	206
F	1	1.5	0.1	0.6	0.2	0.1	0.1	0.2	0.1	0.1

V. RESULTS AND DISCUSSION

The results of chemical analysis of the groundwater samples are shown in Table 1, collected during the pre-monsoons and post-monsoons of 2015, 2016 and 2017. The concentration of various ions are expressed in mg/l.

The pH of groundwater in the study area varied from7.8 to 9.3 and 7.5 to 8.8, for both pre- and post-monsoons respectively. The spatial plot of pH shows that western and central parts of the study area is mainly with alkaline ground water, but acidic nature increases towards eastern parts. The WHO (1993) recommended limit for potable water is 6.5 to 8.5. All the samples are fallen within the permissible limits except a few samples nearer to the coast showed high values up to 9.3 due to the increases of acidic nature.

The electrical conductivity (EC) of the water samples varied from 902 to 4107µS/cm and from 365 to 3377 µS/cm. Most of the samples that are shown high electrical conductivity in the upstream were due to the accumulation of in situ clay formation of subsurface and those in the downstream of the study area was due to the seawater contamination (Rao et al. 2011). Based on this value, the water samples of the study area were classified as brackish in nature. The TDS in the water samples varies from 440 to 2698 mg/l and from 234 to 21589 mg/l for both pre-and post-monsoon seasons. According to the salinity classification by Rabinove et al. (1958), groundwater were classified into non-saline/fresh water (TDS < 1,000 mg/l), slightly saline (TDS=1,000–3,000 mg/l), moderately saline (TDS=3,000–10,000 mg/l), and highly saline (TDS>10,000 mg/l).

Higher TDS content was detected in the water samples in both seasons near the coast compared to the western parts. This may indicate the possibility of high rate of incursion/intrusion of saline water. The total alkalinity (TA) of water samples range from 122 to 614 mg/l and from 85 to 537 mg/l. Higher alkalinity (TA) is noted in the western part of the study area. The total hardness (TH) of the well water samples ranged from 179 to 1393 mg/l and from 123 to589 mg/l for the both seasons. Spatially higher TH is noted in the northern and eastern parts of the study area as compared to the western parts. The higher TH indicating groundwater composition in alluvial aquifers are largely influenced by seawater intrusion/ ion exchange.

The sodium (Na) concentration varies from 37 to 534 mg/l and from 19 to 512 mg/l for both pre- and post-monsoons. The main source of sodium concentration in the area was the weathering of silicate mineral along with supply from saline deposit in catchment area. The calcium (Ca) concentration varies from 21 to 296 mg/l and from 15 to 97bv mg/l for both pre- and post-monsoons. Calcium in the river water was attributed from weathering of carbonate and silicate mineral in the study area. The potassium (K) concentration varied from 4 to 412 mg/l and from 4 to 315 mg/l for both pre- and post-monsoons. Elango et al. (2003) reported that concentrations of potassium in natural waters are usually less than 10 mg/l, whereas concentrations of 100 and 25,000 mg/l can occurs in brines. Therefore, high levels of K^+ concentrations indicate the saline water contamination in the area. The magnesium (Mg) concentration varies from 16 to 171 mg/l and from 12 to 96 mg/l both for pre- and post-monsoons and this indicates that dolomite dissolution or Mg enrichment caused by mixing with seawater.

The chloride (Cl) concentration varies from 49 to 983 mg/l and from 40 to 760 mg/l for both pre- and post-monsoons. Further high TDS, Cl, and Na^+ concentrations have been found due to the in situ salinity of the overlying clay formations in the upstream and downstream of the study area (Rao et al. 2011). The sulfate (SO_4^{2-}) concentration varies from 21 to 501 mg/l and from 17 to 217 mg/l for both pre- and post-monsoons. The WHO (1993) recommended guide-line for sulfate in groundwater is 400 mg/l. The SO_4^{2-} concentrations fell within the permissible limits. The nitrate as (NO_3–N) concentration varies from 17 to 234 mg/l and from 17 to 217 mg/l for both pre- and post-monsoons. The WHO (1993) recommended upper limit of NO_3–N is 45 mg/l. The high concentration of NO_3–N in both monsoons indicates contribution from the leaching of fertilizers from the agriculture residues in the study areas.

The post-monsoon samples are also shown high concentration of nitrate which may be due to mineralization of N-containing compounds by microorganisms (Hakanson 1980). The relatively low concentration of NO_3–N in pre-monsoon was due to its consumption in biological processes. The bicarbonate (HCO_3) concentration varies from 100 to 415 mg/l and from 74 to 430 mg/l for both pre- and post-monsoons. The WHO (1993) recommended limit for HCO_3 is 380 mg/l. Chapelle et al. (1987) also attributed HCO_3 concentration in natural waters to the dissociation of HCO_3. The elevated concentrations of HCO_3 reflect the contribution from water–rock interaction.

VI. CONCLUSION

Understanding temporal and spatial variability of groundwater quality is important due to its influence on hydrogeochemical processes controlling the chemical composition of groundwater by sea water intrusion in both seasons and also for the efficient management of water resources. This research presents a case study of temporal seasonal variations of groundwater quality in the central delta of Godavari, located on the east coast of India. The results indicate that have different temporal variations during 2015, 2016 and 2017 in the study area. Overexploitation of groundwater and sea water intrusion into the fresh water pockets near the coast may be the main driving force affecting the water quality in the central deltaic regions, The study results can help in the management of water resources and allow better prediction, risk assessment and management caused by sea water intrusion and anthropogenic activities.

VII. REFERENCES

1. APHA (2005) Standard methods for the examination of water and wastewater, 21st edn. American Public Health Association, Washington, DC.

2. APHA. (1995). Standard methods for the examination of water and wastewater (19th ed.). Washington: American Water Works Association, Water Environment Federation.
3. Biksham, G., & Subramanian, V. (1988). Nature of solute transport in the Godavari Basin, India. Journal of Hydrology, 103, 375–392.
4. Back .W., Hanshaw, B. B., and M. Rubin, Radiocarbon determinations for estimating groundwater flow velocities in central Florida, Science, 148(3669), 494-495, 1964.
5. Indian standard drinking water - specification (First Revision) IS-10500:1991. BIS, New Delhi, India .
6. Chapelle, F. H., Zelibor, J. L., Jr., Grimes, D. J., & Knobel, L. L. (1987). Bacteria in deep coastal plains sediments of Maryland. A possible source of CO2 to groundwater. Water Resources Research, 23(8), 1625–1632.
7. CGWB. (2010). Groundwater resources and development prospects in East Godavari District, Andhra Pradesh. Ministry of Water Resources, Government of India.
8. Durov, S.A. (1948) Natural Waters and Graphic Representation of Their Composition. Doklady Akademii Nauk SSSR, 59, 87-90.
9. Elango, L., Kannan, R., & Senthil Kumar, M. (2003). Major ion chemistry and identification of hydrogeochemical processes of groundwater in a part of Kancheepuram district, Tamil Nadu. Environmental Geosciences, 4, 157–166.
10. GHOSH BOBBA (2002) Numerical modeling of salt-water intrusion due to human activities and sea-level change in the Godavari Delta, India, Hydrological Sciences Journal, 47:S1, S67-S80, DOI: 10.1080/02626660209493023
11. Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. Water Resources, 14, 975–1001.
12. Hem, J. D. (1970). Study and interpretation of chemical characterization of natural water. US Geol Survey paper (1473).
13. Jalali, M. (2007). Hydrochemical identification of groundwater resources and their changes under the impacts of human activity in the Chah Basin in Western Iran. Environmental Monitoring and Assessment, 130, 347–364
14. Mercado (1985) The use of hydrogeochemical patterns in carbonate sand and sandstone aquifers to identify intrusion and flushing of saline water. Groundwater 23(1985):635–645.
15. Morell, I., Gime'nez, E., & Esteller, M. V. (1996). Application of principal components analysis to the study of salinization on the Castellon Plain(Spain). Science of the Total Environment, 177, 161 –171.
16. Nadler, A., Magaritz, M., &Mazor, E. (1981). Chemical reactions of seawater with rocks and fresh water experimental and field observations on

brackish waters in Israel. Geochemica Cosmotica Acta, 44, 879 –886.

17. Naidu, L. S., G. Rao, V. V. S., T. Rao, G., Mahesh, J., Padalu, G., Sarma, V. S., Prasad, P. R., Rao, S. M., & R. Rao, B. M. (2012). An integrated approach to investigate saline water intrusion and to identify the salinity sources in the Central Godavari delta, Andhra Pradesh, India. Arabian Journal of Geosciences. doi:10.1007/ s12517-012-0634-2.
18. Rao, V. V. S. G., Tamma Rao, G., Surinaidu, L., Rajesh, R., & Mahesh, J. (2011). Geophysical and geochemical approach for seawater intrusion assessment in the godavari delta basin, A.P., India. Water Air Soil Pollution. doi:10.1007/ s11270-010-0604-9.
19. Saxena VK, Singh VS, Mondal NC, Jain SC (2003) Use of chemical parameters to delineation fresh ground water resources in Potharlanka Island, India. Environ Geol 44(5):516–521.
20. Sarwade, D. V., Nandakumar, M. V., Kesari, M. P., Mondal, N. C., Singh, V. S., & Singh, B. (2007). Evaluation of sea water ingress into an Indian atoll. Environmental Geology, 52, 1475–1483.
21. Stiff, H.A., Jr. 1951. The interpretation of chemical water analysis by means of patterns. J. Pet. Technol. 3:15–17. doi:10.2118/951376-G
22. Subba Rao, N., Srinivasa Rao, G., Venkateswara Rao, S., Madhusudhana Reddy, P., & John Devadas, D. (1999). Environmental control of groundwater quality in a tribal region of Andhra Pradesh, India. Journal of Geology, 71, 299–304.
23. Sujatha, D., & Reddy, R. B. (2003). Quality characterization of groundwater in the south-eastern part of the Ranja Reddy district, Andhra Pradesh, India. Environmental Geology, 44, 579–586.
24. Sunitha, V., Sudarsha, V., & Rajeswara Reddy, B. (2005). Hydrogeochemistry of groundwater, Gooty area, Anantapur district, Andhra Pradesh, India. Pollution Research, 24, 217– 224.
25. Sukhija, B. S., Varma, V. N., Nagabhushanam, P., & Reddy, D. V. (1996). Differentiation of paleomarine and modern seawater intruded salinities in coastal groundwaters (of Karaikal and Tanjavur, India) based on inorganic chemistry, organic biomarker fingerprints and radiocarbon dating. Journal of Hydrology, 174, 173–201.
26. WHO. (1993). Guidelines for drinking water quality, vol. 1 recommendations. Geneva, Switzerland.