

Seasonal Groundwater Chemistry along Coastal and Inland Aquifers of Tuticorin, Tamil Nadu, India

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Abstract

This paper focuses on seasonal groundwater chemistry of coastal and inland aquifers in Tuticorin District. The water samples are collected from dug wells, tube wells and bore wells for pre and post-monsoon season of 2012 and analyzed for its chemical characteristics. For both the season, the cations in the dug wells, tube wells and bore wells are maintaining the order of abundance (Na> Ca> Mg> K); whereas the anions are dominated by Cl ions for the dug wells and tube wells (Cl> HCO₃> SO₄) and SO₄ ion for bore wells (SO₄> Cl> HCO₃) during pre-monsoon 2012. During the post monsoon period, the order of abundance of anion for the dug wells is HCO₃> SO₄> Cl; for tube wells Cl> SO₄> HCO₃; for bore wells SO₄> Cl > HCO₃ respectively. The Na/Cl ratio of the samples collected for the pre-monsoon period reveals that, the wells surrounding Tuticorin port and northern region of the study area is showing the deterioration of fresh water by saline water intrusion. Majority of the wells are contaminated by anthropogenic input probably wastewater and some samples indicates the leaching from evaporates. However, during the post monsoon season most of the samples showed Na/ Cl more than 1.0, indicating wastewater input. In the case of tube well samples, Na and Cl ions is dominating for both the season. In fact, of all the ground water samples these ions recorded highest in the tube well samples, indicating possible source from evaporates. Other ionic ratios such as Mg/Ca also indicated contamination from brines. A unique distribution of ions was observed for the bore well samples. The high concentration of Sulphate especially during the premonsoon season for the bore wells indicates dissolution from the aquifer material.

Keywords: Groundwater chemistry, coastal and inland aquifers, Tuticorin District

1. Introduction:

The major activities leading to pollution in the groundwater system of Tuticorin is due to harbour activities and maritime transport, salt production, discharge and disposal of domestic and industrial waste. The study area includes Tuticorin coastal belt, which is lying within the Gulf of Mannar Biosphere Reserve under Ecologically Sensitive Zone of Wildlife Protection Act 1972, consists of highly productive ecosystems of great biological diversity. It comprises 21 islands with estuaries, mudflats, beaches, forests of the near shore environment, including 22 marine components like algal communities, sea grasses, coral reefs, salt marshes and mangroves. In recent decades, this ecosystem is subjected to growing stress from natural and human-induced changes which have many and varied causes. The development of infrastructure, improper use of the resources and extensive contamination by pollution, have all exacerbated the degradation. Most of the coastal and inland regions rely on groundwater as their main source of fresh water for domestic, industrial and agricultural purposes. Besides seawater intrusion, alternative origins of groundwater salinization are also common from natural sources of

mineral salts, evaporate dissolution, downward seepage from saline water, and return flows of irrigation with sewage effluent, deep brines or upward flow from deep saline water and fossil seawater [9, 11, 13]. To understand the extent of saline water intrusion and finding management schemes to stop its significance are monitoring water levels, abstractions, saline profiles in observation wells networks and modifying abstraction, managing both water supply and water demand [7]. The amount of each ion in water is dependent on the rock mineralogy. During rock weathering Ca²⁺, Mg²⁺, SO₄²⁻, HCO₃⁻, and SiO₂ are getting added to water. However, the use of major ionic chemistry to identify rock mineralogy can be useful. Mineral precipitation, ion exchange and evaporation can modify chemical composition. It is possible to indicate the minerals of source rock types using ionic ratios [5]. The natural balance between freshwater and saltwater in the aquifers is disturbed by groundwater withdrawals and other human activities that lower groundwater levels, reduce fresh groundwater flow to coastal waters, and ultimately cause saltwater to intrude coastal aquifers. Groundwater development has lowered water levels

and caused saline water to intrude into many of the most productive aquifers. The periodic evaluation of the adequacy of these networks is to monitor changes in groundwater levels and approaches to detect and track saltwater movement. Successful management of coastal ground water resources depends not only upon planning and regulation, but also on the

1.1 Environmental Settings:

The area under investigation includes inland and coastal aquifers near the Tuticorin Port, where the inland aquifer extent up to 20km towards west direction. The area is located geographically 8° 42' to 8° 49'N latitude and 78° 0' to 78° 16' E longitudes with an area 226 km². The region experiences a tropical climate, where the southwest monsoon contributes only very little towards the annual rainfall. Rainfall is moderate to heavy during October to December under the spell of northeast monsoon. The mean annual rainfall varies from 762mm to 1270mm. It is influenced by both southwest and northeast monsoons and hence the physical, chemical and biological characteristics are different from other areas. The geologic processes carry critical roles in determining the composition and structure of coastal

aquifers and the short-term and long-term dynamic forces that drive the flow of freshwater and saltwater within these aquifers. The chief water bearing formations of the region are Quaternary Alluvium, Tertiary sediments, Teri sand, Weathered fractured pink granites, Charnockites and Gneisses. However, the alluvial/ tertiary aquifers established to have hydraulic connection with the sea and hence these aquifers may be anticipated to be vulnerable for saline water ingress in the coastal Tuticorin [2]. The study area along with the sampling locations is in Figure 1.

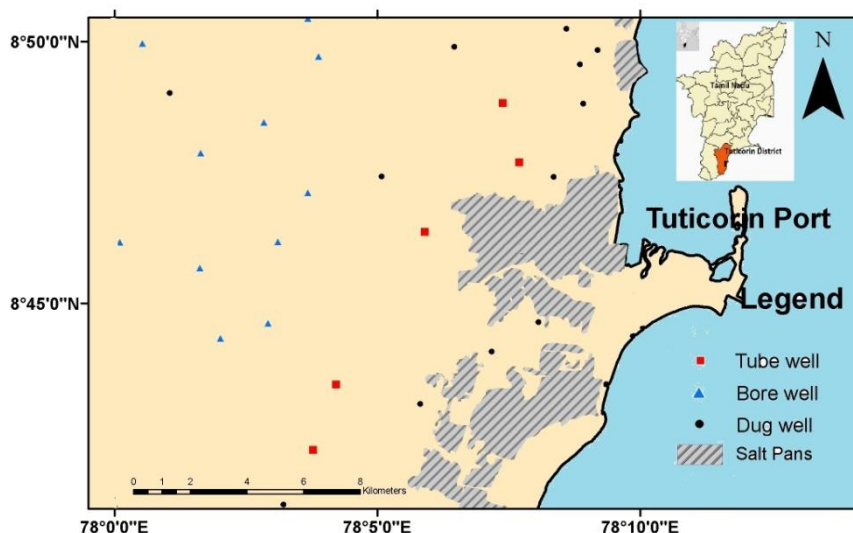


Figure1. Location map

2. Materials and Methods:

Water samples were collected from 12 dug wells, 5 tube wells, 9 bore wells, one surface water (Figure 1) for the pre-monsoon and post-monsoon period of 2012 along the inland and coastal aquifers near Tuticorin port. The pH and electrical conductivity (EC) were measured at the sampling location, whereas the concentration of major cations and anions are measured by the following standard analytical procedures [1, 4]. Na⁺ and K⁺ were analyzed using flame photometry (Systronics FPM digital model Elico CL223-Flame Photometer). Ca²⁺ and Mg²⁺ were analyzed by Ethylene Diamine Tetra Acetate (EDTA) titrimetric method, whereas Cl⁻ was determined by

argentometric titration using standard silver nitrate as the reagent. HCO₃⁻ concentrations of the groundwater were determined titrimetrically [1, 4]. Sulphate concentrations were determined following the turbidity method [1] using a double-beam ultraviolet-visible spectrophotometer, the UV-VIS61 (Model U-2000, Hitachi, Tokyo, Japan). Analytical reproducibility was checked by performing duplicate analyses for each sample; thus, final analytical data are presented as the average of triplicate values. The map representation for all major ions in the analysis was done using ArcGIS 10 software. Isocone maps for all the cations and anions in the samples are

generated by using the Inverse Distance Weighted

method using Spatial Analyst tool.

3. Results and Discussion:

The cations in the dug wells, tube wells and bore wells for the both the season are maintaining the order of abundance (Na> Ca> Mg> K); whereas the anions are dominated by Cl ions for the dug wells and tube wells (Cl> HCO₃> SO₄) and SO₄ ion for bore wells (SO₄> Cl> HCO₃) during pre-monsoon 2012. During the post monsoon period, the order of abundance of anion for the dug wells is HCO₃> SO₄> Cl; for tube wells Cl> SO₄> HCO₃; for bore wells SO₄> Cl> HCO₃ respectively. The pH of the samples for the pre-monsoon period is ranging from 6.9 to 8.3 and for the post-monsoon period it is from 6.39 to 8.16, which lies in the desirable limit (6.5-8.5) given by BIS. The EC of the groundwater samples reveals the poor ground water quality and the non-

equilibrium condition. EC and Na⁺, HCO₃⁻ and CO₃⁻ play a vital role in suitability of water for irrigation.

Higher concentration of these salts causes changes in soil structure, permeability and aeration, which indirectly affects the plant growth [3, 10]. The higher value of pH is observed towards the Tuticorin Port, which is because of saltpan. The major cations (Na⁺, Ca²⁺, Mg²⁺, K⁺) and anions (HCO₃⁻, SO₄²⁻, Cl⁻) present in the samples during the pre-monsoon period of 2012 is showing high concentration along the coastal region of Tuticorin Port. The chemical composition of the groundwater samples for the pre-monsoon and post-monsoon 2012 is as shown in the Figure 2a and 2b given below.

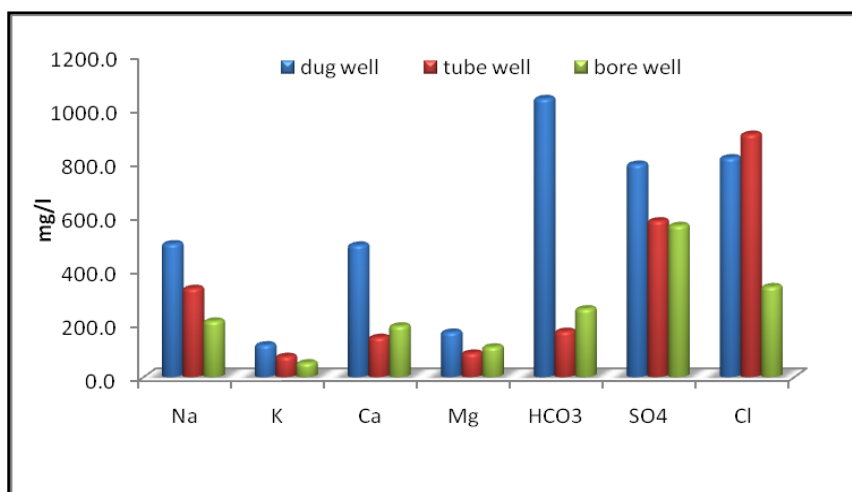


Figure 2a. Bar chart showing the chemical composition of the groundwater samples in the study area for Pre-monsoon 2012

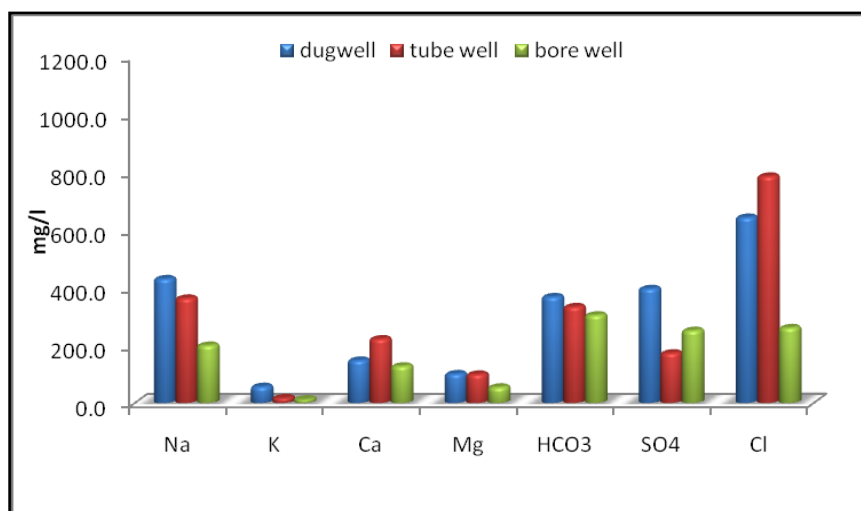
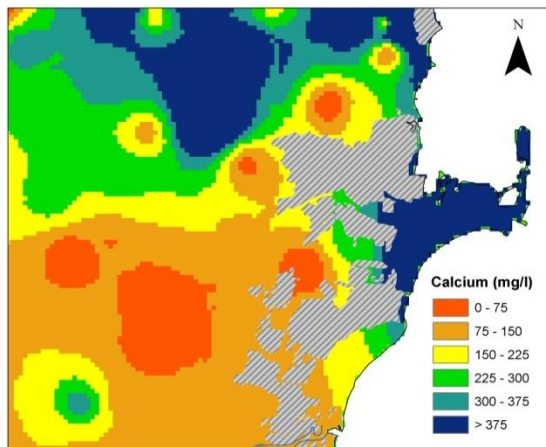


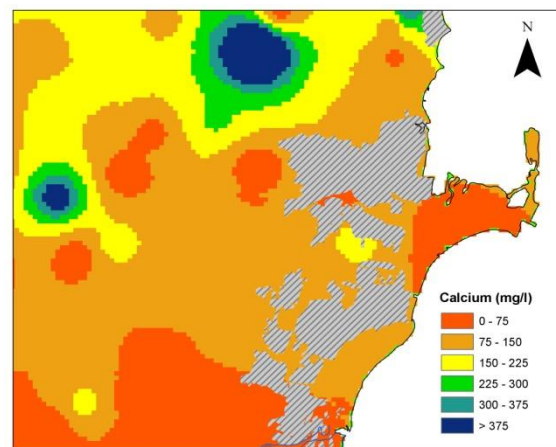
Figure 2b. Bar chart showing the chemical composition of the groundwater samples in the study area for Post-monsoon 2012

For dug wells, the Na/Cl ratio indicated groundwater contamination with seawater for very few wells during the pre-monsoon period. However, during the post monsoon season most of the samples showed Na/Cl more 1, indicating waste water input and a few samples indicated leaching from evaporites. The tube well samples were dominated by Na and Cl ions for both the seasons. The Na/Cl ratio is greater than 1 indicating the anthropogenic input of the ions. In ground water samples, these ions recorded highest in the tube well samples, indicating possible source from the evaporites. However, other ionic ratios such as Mg/Ca also indicated contamination from brines. The average value of sulphate and calcium concentration for the 26 samples during the pre-monsoon period is 677 mg/l and 327 mg/l respectively; which is far beyond the permissible limit according to BIS. During the post-monsoon period, sulphate and calcium concentration is

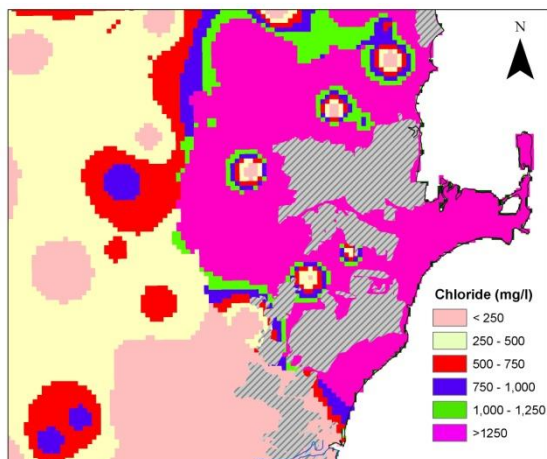
showing only 300mg/l and 155 mg/l respectively. The high concentration of sulphate especially during the pre-monsoon season indicates dissolution from the aquifer material. The ionic ratios also did not provide evidence for seawater intrusion. Instead, they were pointing to anthropogenic source of salinity. The average concentration of potassium is 250mg/l. The relative increase of potassium content is seen near the Tuticorin port during the pre-monsoon period. The HCO_3^- is ranging from 31 to 3664.465 mg/l with an average value of 640 mg/l. The isocone maps of Na^+ , Ca^{2+} , Mg^{2+} , K^+ , HCO_3^- , SO_4^{2-} , Cl^- are shown below in figure 3. The figures clearly show that the highest concentrations of ions are found in the wells near to saltpan and the Tuticorin Port. In most of the areas in the study area shows calcium concentration above the permissible limit as per BIS.



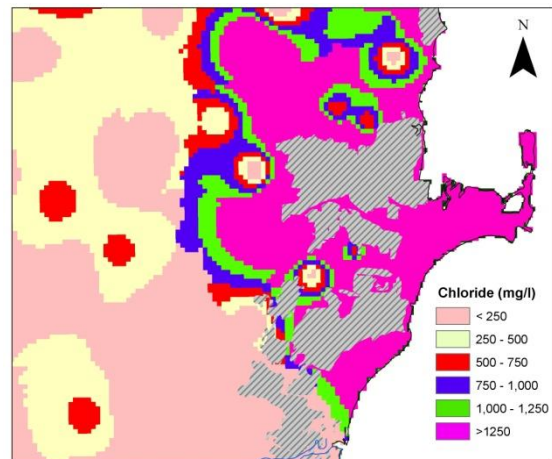
Pre-monsoon 2012 (Calcium)



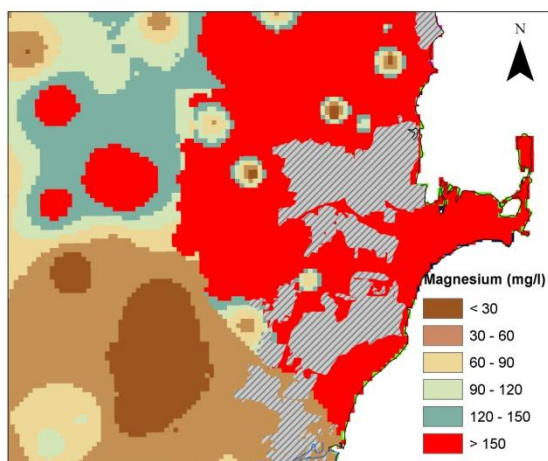
Post-monsoon 2012 (Calcium)



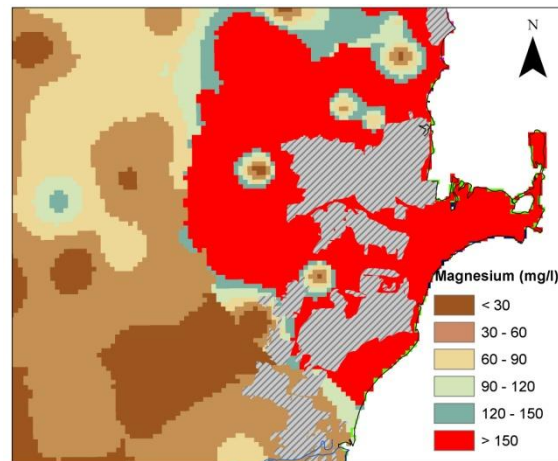
Pre-monsoon 2012 (Chloride)



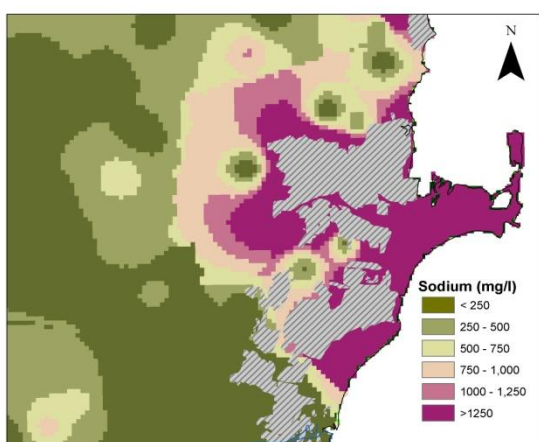
Post-monsoon 2012 (Chloride)



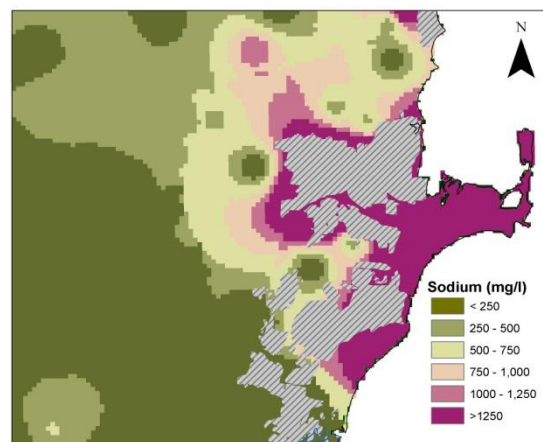
Pre-monsoon 2012(Magnesium)



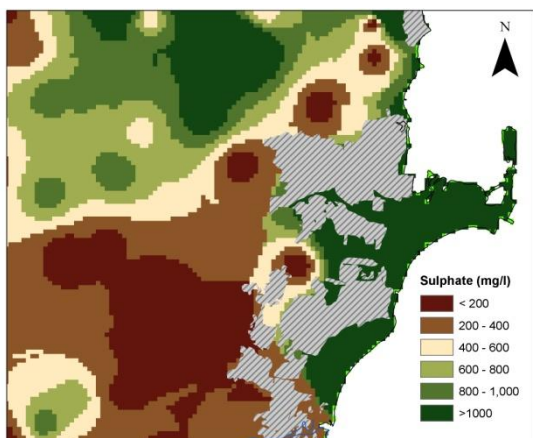
Post-monsoon 2012(Magnesium)



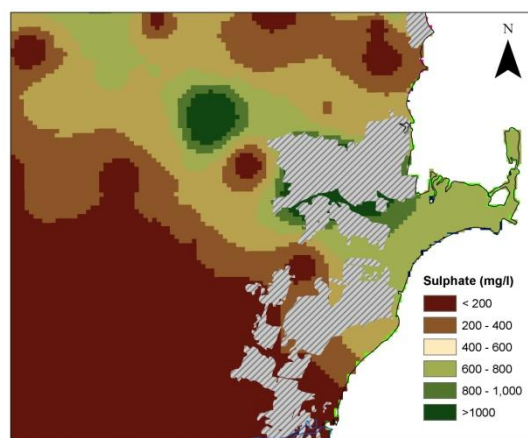
Pre-monsoon 2012 (Sodium)



Post-monsoon 2012 (Sodium)



Pre-monsoon 2012 (Sulphate)



Post-monsoon 2012 (Sulphate)

Figure 3. Isocone maps of Ca^{2+} , Cl^- , Mg^{2+} , Na^+ , SO_4^{2-} in the study area

Among the 26 wells, six dug wells, 2 tube wells and three bore wells are showing Na^+ and Cl^- concentration above the permissible limit [6, 8, 12]. The concentration levels of major cations and anions in most of the samples were beyond the desirable limit given by ISI, BIS and WHO. The wells in the northern region of the study area and

4. Conclusion:

Qualitative understanding of spatial groundwater chemistry plays a vital role in the sustainable groundwater development and management. In both the season, the cations in the dug wells, tube wells and bore wells are maintaining the order of abundance ($\text{Na} > \text{Ca} > \text{Mg} > \text{K}$); whereas the anions are dominated by Cl ions for the dug wells and tube wells ($\text{Cl} > \text{HCO}_3 > \text{SO}_4$) and SO_4 ion for bore wells ($\text{SO}_4 > \text{Cl} > \text{HCO}_3$) during pre-monsoon 2012. During the post monsoon period, the order of abundance of anion for the dug wells is $\text{HCO}_3 > \text{SO}_4 > \text{Cl}$; for tube wells $\text{Cl} > \text{SO}_4 > \text{HCO}_3$; for bore wells $\text{SO}_4 > \text{Cl} > \text{HCO}_3$ respectively. The concentration levels of major cations and anions in most of the samples were

5. Acknowledgements:

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wells surrounding the Tuticorin Port are showing the deterioration of groundwater by saline water intrusion for the premonsoon period of 2012. Therefore, wells in these aquifers need more recharging, in order to maintain fresh-saline water equilibrium stressing the significance of a sustainable management action plan.

beyond the desirable limit given by ISI, BIS and WHO. The inland region of the study area shows the deterioration of groundwater by the anthropogenic activities. Majority of the wells are contaminated by anthropogenic input probably wastewater and some samples indicates the leaching from evaporates but the Na/Cl ratio of the samples collected for the pre-monsoon period reveals that, the wells surrounding Tuticorin Port and northern region of the study area is showing the deterioration of fresh water by saline water intrusion. Therefore, wells in these aquifers need more recharging, in order to sustain fresh-saline water equilibrium stressing the significance of a sustainable management action plan.

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