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Assessment of water quality index and its seasonal variation in hard rock and soft rock domains along the coastal regions of Tamil Nadu and Pondicherry, India

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Abstract
Water Quality Index and its seasonal variation of samples from hard rock and soft rock domains were calculated along the coastline of Tamil Nadu and Puducherry. Certain parameters like pH, TDS, Ca, Na, K Mg, Cl, NO_3, HCO_3, SO_4, and F were utilized to establish the water quality index. A sum of 38 samples from soft rock domain and 28 samples from hard rock domain were collected during pre and post monsoon seasons. In hard rock domain the water quality index ranges from 29.31 to 164.14 in POM and 55.03 to 519.59 in PRM whereas, in soft rock domain it ranges between 25.61 to 150.49 in POM and 22.08 to 258.49 in PRM. Water Quality Index for hard rock domain is higher than that of soft rock samples. The values varies seasonally, higher values where observed in the PRM. Spatial distribution maps prepared for water quality indicates that hard rock terrain is highly affected than soft rock terrain. The seasonal variation of WQI might be due to the difference in seasonal precipitation, weathering, ion exchange and leaching of minerals.

Keywords: water quality index, groundwater, coastal region, Tamil Nadu, Puducherry

1. Introduction
Water, one among the most valuable natural resource, which is relevant for the sustainable development of human life. Groundwater plays a major role in fulfilling the various human needs such as domestic agricultural and industrial purposes. Higher demand for water due to demographic upsurge and developmental activities has made the use of groundwater more than surface water (Chandrasekar *et al*. 2013) [6]. This in terms leads to the depletion of groundwater level. The ground water quality depends on various factors such as precipitation, recharged water quality, aerial and sub aerial geochemical processes (Vasanthavigar *et al*. 2010; Kumar *et al*. 2013) [21, 15]. Water quality Index is a powerful tool to quantify the quality of water in particular area. It aids in the assessment and management of water (Ramakrishnaiah *et al*. 2009) [13]. It rates the water based on the composite influence of various water quality parameters. It is used by various workers worldwide (Ramakrishnaiah *et al*. 2009; Tyagi *et al*. 2013; Shah & Joshi 2015; Krishna *et al*. 2016) [13, 19, 16, 10]. The present study are is situated in the coastal zone which encompasses both hard rock and soft rock domains.

1.1 Study area
The study area forms parts of Villupuram and Kancheepuram districts and the coastal regions of Puducherry forming a linear land mass parallel to the Bay of Bengal. It falls between North latitudes 11°29’-11°44’ and East longitudes 79°35’-79°46’ with a total aerial extent of 1570 Sq.km. Geologically the area can be separated into two lithological domains, such as charnockites of Archaean age and sedimentary rocks of Upper Jurassic to recent age. The earlier comes under hard rock domain and the later is soft rock domain. The sedimentary rock occupies almost 70% of the area along the coastal stretch, which includes sand stone and conglomerate, sand and silt, limestone marl and shale, shelly limestone, shaly sand stone, sandstone with clay intercalation and coastal alluvium.

The area possesses varied geomorphic constituents such as Pediplain and residual hills of denudational origin, low dissected hills of structural origin, flood plains of fluvial origin, older and younger coastal plains, alluvial plains, uplands and water bodies. Almost 70% of the total area is occupied by shallow and moderately weathered pediment or pediplain, complex, coastal plains attributes 15% and rest by alluvial plains and water bodies. The alluvial plains are located both in northern and southern part of the area, which is associated with the Palar and Gingee river respectively. The LULC pattern of the study area reveals that almost 65% of the area is covered by agricultural crop land and agricultural plantation; 25% is occupied by wetlands, coastal wetlands, rivers, water bodies, lakes, ponds and remaining 10% includes reserved forest and builtup lands. The main soil types found within the area are red soil, red sandy brown clayey soil, clayey soil, alluvial soil, colluvial soil, and black soil. The most common type of soil is red soil and brown clayey soil. Alluvial soils occurs along the major river channels. Coastal areas were characterized mainly by the occurrence of sandy coastal alluvium, which is dominated by sand sized particles.

Groundwater occur in all the formations from Archean to recent age. It can be broadly classified into two major hydrogeological units namely, fissured and fractured crystalline formation and porous sedimentary formation. Groundwater occurs at deeper levels in the weathered, fissured and fractured zone under phreatic and semiconfined conditions. In porous sedimentary formation the groundwater occur und confined and water table conditions (CGWB 2007) [5].

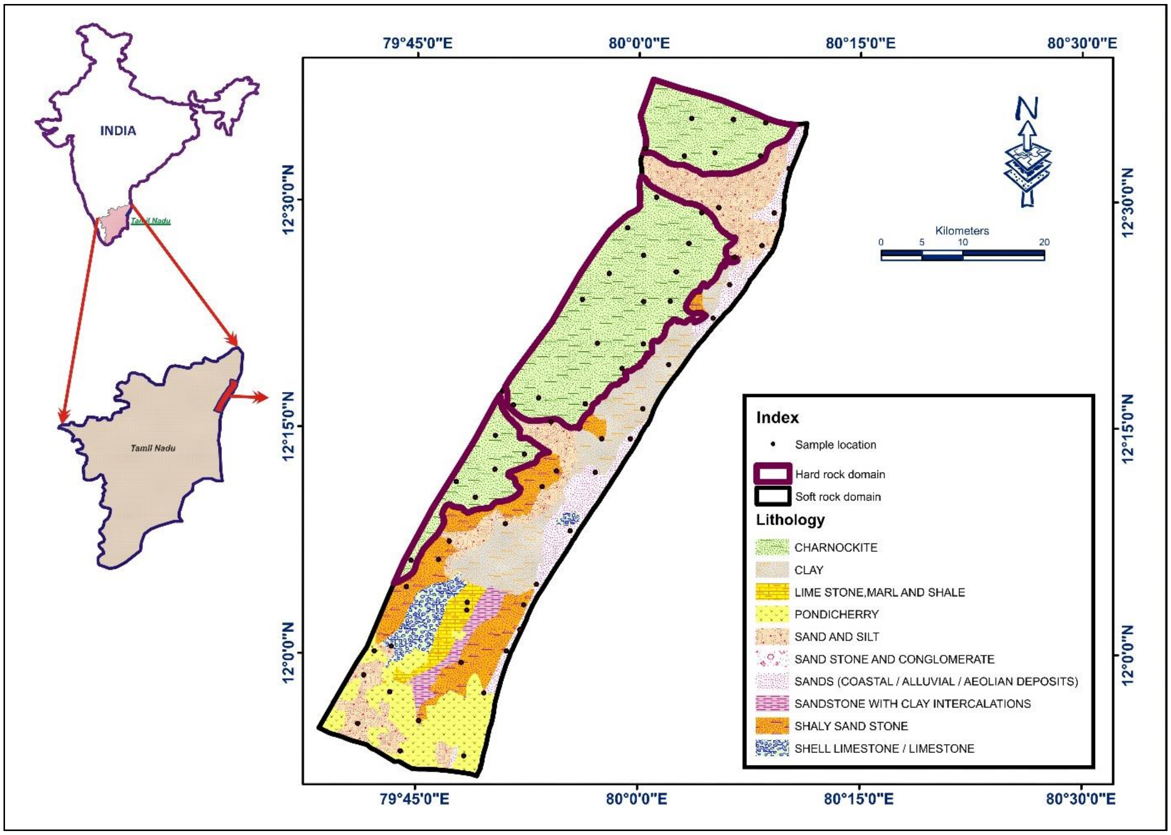

Fig 1: Study area map with geology and sample locations

2. Methodology

A total of 66 samples (28 from hard rock and 38 from soft rock domain) were collected during the pre and post monsoon seasons (February and May 2014). The physio-chemical parameters such as temperature, pH, EC and salinity were calculated in the field using portable water quality analyser. In laboratory all the samples were analyzed using the standard procedures (APHA, 1995; Kumar *et al*. 2013; Vadiati *et al*., 2016) [1, 15, 20]. Calcium and magnesium determined by titration using standard EDTA, Bicarbonate with AgNO3 and chloride by HCl. Flame photometry was used to determine Sodium and potassium and spectrophotometer for silicate phosphate and sulphate. Analytical reliability for the samples were determined by charge balance and TDS/EC ratio, which varies from 5-10%.

3. Results and discussion

The maximum, minimum, mean and standard deviation of physiochemical parameter of water sample during pre and post monsoon were given in Table no.1. In Hard rock terrain samples pH varies from 6.6 to 7.8 and 6.2 and 7.7 with an average of 7.2 and 7; EC varies between 209 to 5620 µS/cm and 410 to 3330 µS/cm with an average of 1588.3 and 1610.4; TDS varies between 110 to 2970 mg/L and 217 to 1760 mg/L with an average of 837.6 and 818.6 mg/L in pre and post monsoon respectively. In sedimentary terrain samples, pH varies between 6.2 to 8.7 and 5.1 to 7.7 with an average of 7.1 and 6.7; EC varied between 102 to 8930 µS/cm and 130 to 4350 µS/cm with average of 1385.9 and 1351.1 µS/cm; TDS rages from 53.9 to 4710 mg/L and 101 to 1730 mg/L with an average of 731.6 and 667.4 mg/L during pre and post monsoon respectively.

3.1. Water quality index

Water Quality Index is a salient tool to establish the quality of groundwater for domestic as well as agricultural purpose (Subba Rao 2005; Vasanthavigar *et al*. 2010; Raju *et al*. 2010) [18, 22, 8]. Which determines the composite impact of different parameters in the overall water quality (Mitra *et al*., 2006; Singaraja *et al*., 2015) [2, 17]. To calculate WQI, for drinking water WHO (2004) standards is being used. Water quality index is acquired by computing the parameters such as pH, TDS, Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}, Cl^{-}, NO_3^{-}, HCO^3, SO_4^{2-}, and F^{-}. Weight values (wi) were assigned to the selected parameters based on their influence over water quality. The values of weight were given in the scale of 1 to 5. A maximum value of 5 is given to the parameters like pH, TDS, and chloride whereas weight 4 is given to nitrate and fluoride due to their higher influence in assessing the water quality (Raju *et al*., 2015) [22]. The remaining parameters were assigned with the values in between 1 and 5 (Table 2). The relative weight (Wi) for each parameter is obtained by the following equation.

$$Wi = wi / \sum^{n}_{i=1} wi \qquad (1)$$

Table 1: Maximum, minimum, average and standard deviation of physico-chemical parameters of groundwater samples. (All values in mg/L except EC in µS/cm and pH.)

Parameters	Pre monsoon								Post monsoon							
	Hard rock				Soft rock				Hard rock				Soft rock			
	Max	**Min**	**Avg**	**Stdv**	**Max**	**Min**	**Avg**	**Stdv**	**Max**	**Min**	**Avg**	**Stdv**	**Max**	**Min**	**Avg**	**Stdv**
pH	7.8	6.6	7.2	0.3	8.7	6.2	7.1	0.6	7.7	6.2	7.0	0.3	7.7	5.1	6.7	0.6
Ec	5620.0	209.0	1588.3	1103.1	8930.0	102.0	1385.9	1526.5	3330.0	410.0	1610.4	789.3	4350.0	130.0	1351.1	978.6
TDS	2970.0	110.0	837.6	582.9	4710.0	53.9	731.6	804.6	1760.0	217.0	818.6	427.0	1730.0	101.0	667.4	403.2
Ca	302.0	3.0	65.1	57.6	118.0	9.0	38.7	25.8	140.0	4.0	51.8	35.8	108.0	11.0	36.7	21.5
Mg	128.0	5.0	31.3	25.3	76.8	2.4	22.6	18.9	68.0	6.0	27.6	12.6	87.0	5.0	20.9	14.6
Na	200.0	12.0	91.9	61.3	288.0	8.0	88.5	74.0	156.0	4.0	62.8	45.0	300.0	12.0	77.8	58.3
K	372.0	0.8	21.1	71.0	420.0	0.8	33.5	77.3	355.0	0.0	29.8	85.0	235.0	0.0	25.6	50.0
Cl	1395.0	40.0	252.8	286.9	2020.6	15.0	215.6	326.0	455.0	20.0	170.1	119.1	660.0	46.0	167.2	128.4
HCO3	428.0	40.0	254.3	116.8	591.7	40.0	252.0	170.5	560.0	105.0	280.2	112.0	540.0	40.0	217.2	131.1
SO4	1.9	0.0	0.4	0.4	5.3	0.0	0.7	1.1	2.8	0.0	0.2	0.6	4.9	0.0	0.5	1.3
NO3	32.5	0.2	9.1	8.9	82.5	0.5	14.5	17.9	3.5	0.1	0.8	1.0	6.3	0.0	1.3	1.6
PO4	7.3	0.0	2.4	1.3	6.4	0.0	2.0	1.3	32.5	0.2	4.2	6.7	56.0	0.0	14.2	18.2
F	0.6	0.0	0.1	0.1	0.7	0.0	0.1	0.2	1.6	0.4	0.7	0.2	1.3	0.2	0.6	0.3

Table 2: WHO standards (mg/L), weight and Relative weight

Parameters	**WHO Standards (WHO 2004)**	**Weight (wi)**	**Relative weight** $W_i = w_i / \sum_{i=1}^{n} w_i$
	8.5	5	0.139
TDS	1000	5	0.139
Ca	75	3	0.083
Mg	30	2	0.056
Na	200	3	0.083
K	20	2	0.056
Cl	200	5	0.139
HCO_3	350	1	0.028
SO4	200	1	0.028
NO_3	50	4	0.111
F	1	4	0.111
		∑wi=35	∑Wi=0.972

Where *Wi* is the relative weight and *wi* is the weight of each parameters. Relative weight of individual parameters where given in (Table 3). A quality scale (*qi)* is consigned for each parameter by dividing its concentration by WHO (2004) standards and further it is multiplied by 100 (Vasanthavigar *et al*., 2010) [22], which is expressed as:

$$q_i = (C_i / S_i) \times 100 \quad (2)$$

Where *Ci* corresponds to concentration of ions and *Si* for stands for WHO standards (Bairu *et al*., 2013) [3]. In order to calculate the water quality index, sub index SI is calculated for each parameters by multiplying relative weight and quality rating scale using the equation:

$$SI = W_i \times q_i \quad (3)$$

Finally the WQI is calculated by the equation

$$WQI = \sum SI \quad (4)$$

Water quality index was classified into Excellent, Good and Poor on the basis of their range, which is given in the Table 4. In hard rock domain the WQI ranges from 29.31 to 164.14 in POM and 55.03 to 519.59 in PRM whereas, in soft rock domain it ranges between 25.61 to 150.49 in POM and 22.08 to 258.49 in PRM. In hard rock terrain during PRM, it is found that 58% of the samples represents poor water and 42% of the water represents good water. The samples from Alathur and Manamai during the PRM are found to be not suitable for drinking purpose. During the post monsoon 7% of the samples indicates excellent water, 58 % shows good water and rest 35% were found as poor water. In soft rock terrain, 48% of the PRM and 42% of POM samples represents excellent water, 44% and 42% of pre and post monsoon samples represents good water. The 8% and 16% of the samples from PRM and POM shows poor water. Water quality of the hard rock terrain is worse than soft rock terrain especially in the pre monsoon. The poor quality of the water in hard rock terrain might be due to leaching of ions, agricultural activities, anthropogenic sources and over exploitation of water (Sahu and Sikdar 2007; Jasmin and Mallikarjuna 2013) [14, 9]. In sedimentary terrain more poor water reported during POM than PRM, this might be due to dissolution of ions immediately after precipitation.

Table 3: Classification of ground water samples based on WQI.

WQI Range	**Water type**	**% of samples**			
		PRM		**POM**	
		Hard	**Soft**	**Hard**	**Soft**
<50	Excellent		48	07	42
50-100	Good	42	44	58	42
>100	Poor	58	8	35	16

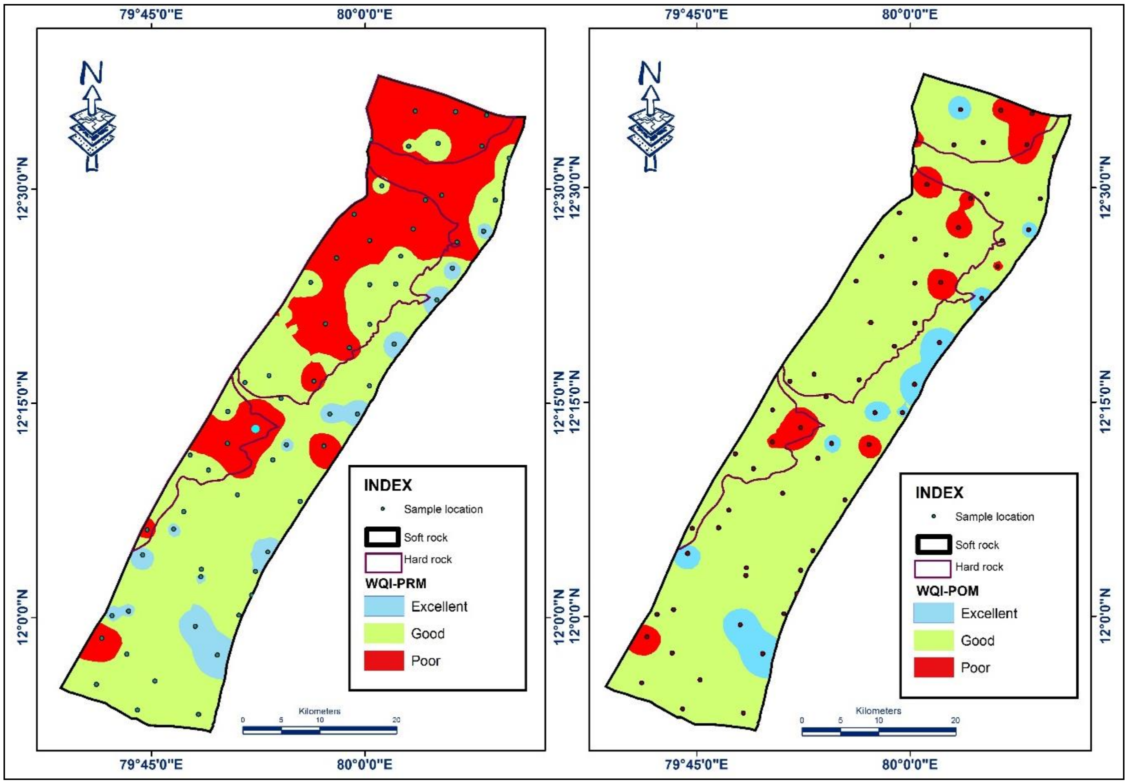

Fig 2: Spatial distribution of WQI during pre-monsoon and post monsoon

3.2. Mechanism controlling the water chemistry

Gibbs plot (1970) [7] is prepared separately for cation and anion to decipher the mechanism controlling water chemistry. Gibbs ratio were plotted in a linear axis against TDS in logarithmic axis. The ratios for cations and anions were obtained from the equation:

For cations: Na^{+}+ K^{+} / (Na^{+}+K^{+}+Ca^{2+}); for anions: Cl^{-}/ (Cl^{-} +$HCO3^{-}$) (6)

From the Gibbs plot it is found that majority of the samples from both PRM and POM falls in the rock dominance field and few towards evaporation dominance (Madhav *et al*., 2018) [11]. This might be due to the dominant chemical weathering of rock forming minerals (Venugopal *et al*. 2009; Manikandan *et al*. 2011; Thivya *et al*. 2014.) [23, 12, 19]. Few samples were found outside the preview plot indicating anthropogenic impact over water chemistry (Thivya *et al*. 2014) [19].

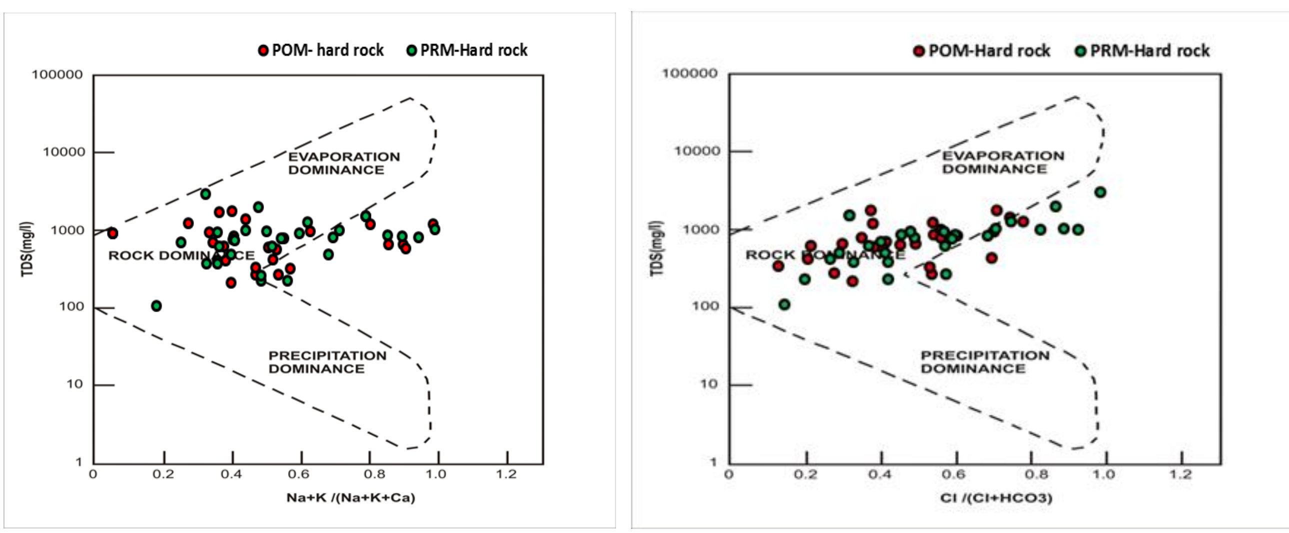

Fig 3a: Gibbs plot (1970) for Hard rock

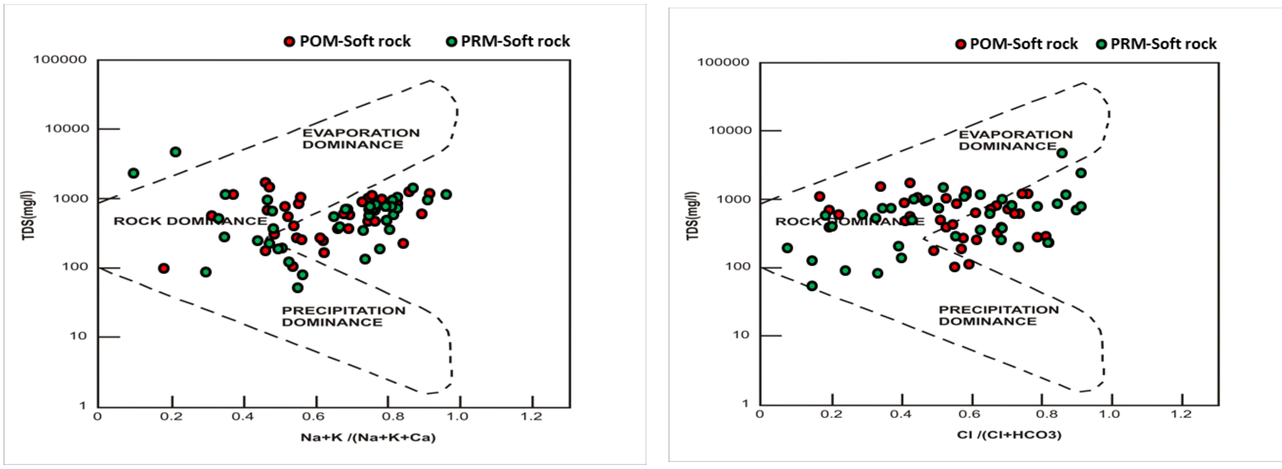

Fig 3b: Gibbs plot (1970) for Soft rock

4. Conclusion

The present study reveals that dominant cations in groundwater is Na^+ and Ca^{2+} whereas Cl^- and HCO_3^- are the dominant anions. Groundwater the soft rock terrain is found to be better in quality in terms of WQI. Pre monsoon samples from both terrain are found worse than post monsoon samples. This might be due to the dilution of ions after monsoon. The major mechanism controlling the water chemistry is rock water interaction, chemical weathering and ion exchange. The higher concentration of ions such as Cl and Na in some samples might be due to its vicinity towards saline sources like sea water and salt pan. Higher concentration of certain ions in the samples from hard rock terrain might be due to the overexploitation of groundwater, excess agricultural activities and anthropogenic sources.

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