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ASSESSMENT OF GROUNDWATER QUALITY USING WQI METHOD AROUND VELLALORE MUNICIPAL SOLIDWASTE DISPOSAL SITE IN COIMBATORE, TAMILNADU, INDIA

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ABSTRACT

Groundwater is an essential and vital component of our life support system. The deterioration of groundwater quality due to geogenic and anthropogenic activities has drawn great attention as it is the major alternate source of domestic and drinking water supply. In developing countries like India, the rapid urbanization affect the availability and quality of the groundwater, due to its overexploitation and improper waste disposal[1]. WQI is defined as a rating reflecting the composite influence of different water quality parameters. Water quality index (WQI) is calculated from the point of view of the suitability of groundwater for human consumption. The objective of the present work is to discuss the suitability of groundwater for human consumption based on computed water quality index values. Eighteen groundwater samples were collected around Vellalore municipal solid waste dumpyard from 2010-2013 analysed for important physico-chemical characteristics by adopting APHA standard methods from the data obtained the water quality index (WQI) was calculated adopting the method developed by (Tiwari and Mishra, Brown's and Horton equation). From the study around Vellalore dumpyard that it indicates physico-chemical characteristic of ground water such as Total dissolved solids, calcium, magnesium, total hardness and chlorides were maximum than highest desirable limits were as potassium and fluoride were found within the permissible limit. It was observed that water quality index (WQI) of the present study area from 2010 to 2013 was within permissible limit, the overall view of the water quality index was fall as excellent WQI value.

Key words: Groundwater, WQI method, Vellalore, Solidwaste.

INTRODUCTION

Groundwater is essential for domestic and industrial water supply and irrigation all

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over the world. In the last few decades, there has been a tremendous increase in the demand for freshwater due to the rapid growth of population and the accelerated pace of industrialization. Groundwater contamination is a serious problem faced by developing countries because of solid waste or liquid waste discharge from domestic, agricultural activity and industrial effluents. The industrial waste water, sewage sludge and solid waste materials are currently being discharged into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water[2]. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. Water quality is now being recognized in India as a major crisis. According to World Health Organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source so it becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It thus becomes an important parameter for the assessment and management of groundwater[3]. High rates of mortality and morbidity due to water borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater[4].

Description of study area

Coimbatore district is situated in the Western side of the Tamil Nadu. The area experiences sub-humid and sub-tropical type of climate with hot dry summer and mild winter. Rainfall is obtained from the South-west monsoon during June-September and North-east monsoon during October-December. The soil in the area is clayey loam. The city has a population of 11 lakhs spread over an area of 105 Km^2. Coimbatore Municipal Corporation has been resorting to dumping of the MSW in an open land at Vellalore at located about 8 Km south of Coimbatore and is adjacent to north side of Podanur and Chettipalayam main road. The total area of the dumpyard is 643 acres, out of which Closure and landfill of 48 acres composting yard of 24 acres and four lagoons of total area about 40 acres. The daily waste dumped here is about 800 tonnes/day. The disposal yard is composed of meta sedimentary group comprising crystalline limestone and the topsoil of the site is sandy loam capped with rich organic humus followed by sandy clay loam to a depth of about 30 cm. The area is underlined by weathered gneiss of considerable thickness with calcium carbonate boulders. The groundwater table within the site is very shallow and in the western, north western and south eastern periphery.

EXPERIMENTAL

Materials and methods

The main objective WQI is to turn complex water quality data into information that is understandable and usable by the public, the concept of indices to represent gradation in water quality was proposed by Horton et al.[5] Eighteen groundwater samples in and around Vellalore dumpyard were collected for the period of 4 years from 2010-2013. Clean two liter plastic bottles were used to collect groundwater samples and these bottles were instantly sealed and capped with wax and transported to environmental engineering laboratory of Sri Ramakrishna Institute of Technology in Coimbatore for physico-chemical analysis. Tests conducted were pH, electrical conductivity, total dissolved solids, total hardness, chloride, calcium, magnesium bicarbonate, sulphate, sodium, nitrate, potassium and fluoride. The accuracy of results is verified using anion and cation summation. The sum of milli equivalents of cation should be equal to the sum of milli equivalents of anion. Various tests was carried out as per standard methods[6] and Trivedy et al.[7], which are given in Table 1. The results are compared with Bureau of Indian Standards[8] and World Health Organization[9] (WHO) standards for evaluation of water quality index (WQI) as given in Table 2, 3 & 4.

Table 1: Methods adopted for water quality Analysis[6]

S. No.	Quality parameter	Symbol	Units	Method used
1	pH	pH		Potentiometer (1:2.5 H_2O, v/v)
2	Electrical conductivity	EC	mS/cm	Conductometer (1:2.5 H_2O, v/v)
3	Calcium	Ca^{2+}	mg/L	EDTA (0.05N) Titration
4	Magnesium	Mg^{2+}	mg/L	EDTA (0.05 N) Titration
5	Sodium	Na^{+}	mg/L	Flame photometer
6	Potassium	K^{+}	mg/L	Flame photometer
7	Chloride	Cl^{-}	mg/L	Titration (with 0.05 N $AgNO_3$)
8	Bicarbonate	HCO_3^{-}	mg/L	Titration (with 0.01 N H_2SO_4)
9	Sulphate	SO_4^{2-}	mg/L	Spectrophotometer

Water quality index

The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organisation (WHO), and Bureau of Indian Standards (BIS) of the water body. The water quality Index can be obtained by Brown's equation and it was also calculated by weighted index method to determine the suitability of groundwater for drinking purposes[10]. To calculate the WQI twelve parameters have been considered they are pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, iron, manganese and fluorides. In the present study, nine water quality parameters, namely, pH, TDS, Total hardness, Ca hardness, Mg hardness, Bicarbonate, nitrate, chloride and sulphate were considered for computing WQI and the unit weight Wi of each parameter is obtained depending upon its weight age by adopting the following formula.

$$WQI = (\sum qi\ Wi)/(\sum Wi)$$

Where $qi = 100\ (Vi/Si)$

$$q\ pH = 100\ \{(VpH - 7.0)/(8.5 - 7.0)\}$$

$$Wi = K/Si$$

Where q_i = Quality rating for the i^{th} water quality parameters (i = 1, 2, 3,….N)

V_i = The measured value of the i^{th} parameter at a given sampling location

S_i = The standard permissible value for the i^{th} parameter

The standard permissible values for various pollutants for drinking water, recommended by WHO are given in Table for the parameters considered for WQI. It is well known that the more harmful a given pollutant is, the smaller is its permissible value for the standard recommended for drinking water. So the "weights" for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters i.e.; Wi = K/Si where Wi = unit weight for the i^{th} parameter and K = constant of proportionality. For the sake of simplicity, assuming that K = 1, for pH, assuming the same unit weight as that for chlorides; viz., 0.005. The unit weight $W_{i,}$ obtained from the above equation with K = 1, are shown in Table. According to this water quality index, the maximum permissible value is 100. Values greater than 100 indicate pollution and are unfit for human consumption. The water quality parameters, ideal value and standard value are presented in Table 3 water quality index (WQI) has been classified into 5 classes based on Arithmetic WQI Method is given in Table 2 and 3.[11,12]

Table 2: Values of S_i and C_{id} for WQI

S. No.	Parameter	Symbol	Units	S_i	C_{id}
1	Hydrogen ion concentration	pH		8.5	7
2	Electrical conductivity	EC	mS/cm	300	0
3	Total dissolved solids	TDS	(mg/L)	500	0
4	Total hardness	TH	mg/L)	300	0
5	Calcium	Ca^{2+}	(mg/L)	75	0
6	Magnesium	Mg^{2+}	(mg/L)	30	0
7	Bicarbonate	HCO_3^-	(mg/L)	200	0
8	Chloride	Cl^-	(mg/L)	250	0
9	Sulphate	SO_4^{2-}	(mg/L)	200	0
10	Nitrate	NO_3^-	(mg/L)	45	0

Table 3: Status of water quality based on arithmetic WQI method[11,12]

S. No.	Water quality index	Status
1	0-25	Excellent water quality
2	26-50	Good water quality
3	51-75	Poor water qualty
4	76-100	Very poor water quality
5	Above 100	Unsuitable for drinking

RESULTS AND DISCUSSION

The physico-chemical characteristics of groundwater samples around disposal Vellalore Dumpyard from 2010-2013 was analysed and compared with IS and WHO standards, drinking water specifications IS-10500 and WHO are given in the Table 4 and the statistics of groundwater chemistry analysed for two years 2012 and 2013 during January results are given in the Table 5 & 6. The physicochemical parameters were compared with the standards and presented in Table 5. WQI of groundwater was observed during 2012 & 2013, respectively as presented in Table 8 and 9.

Table 4: Drinking water specifications IS-10500 and WHO

Parameters	Units	BIS -1991		WHO (1993)		Unit weight
		Highest desirable	Maximum permissible	Highest desirable	Maximum permissible	
pH		6.5-8.5	No Relaxation	7.5-8.5	6.5-9.5	0.2190
EC	μmohs/cm	-	-	-	-	0.0037
TDS	mg/L	500	2000	500	1500	0.002
TH	mg/L	300	600	100	500	0.0037
Ca^{+2}	mg/L	75	200	75	200	0.061
Mg^{+2}	mg/L	30	100	50	150	0.0074
Na	mg/L	-	-	-	200	-
K	mg/L	-	-	-	12	-
Cl	mg/L	250	1000	200	600	0.005
HCO_3^-	mg/L	-	300	-	-	-
So_4^{2-}	mg/L	200	400	200	400	0.005
No_3	mg/L	45	100	45		0.002
F	mg/L	1	1.5	-	1.5	-

Table 5: Physico-chemical characteristics of groundwater samples around disposal Vellalore Dumpyard from 2010-2011

Parameters	Units	2010				2011			
		Min.	Max.	Mean	Median	Min.	Max.	Mean	Median
pH		6.4	7.85	7.05	7.265	6	7.97	7.05	7.115
EC	μmohs/cm	643.5	2925	1312.5	1023	651.3	2606.5	1312.53	988.1
TDS	mg/L	990	4500	2119.55	1574.5	1002	4010	2019.722	1523.5
TH	mg/L	120	1200	404.33	340	114	1200	435.055	375
Ca^{+2}	mg/L	20	178	52.155	39	27	222.7	60.866	44.5

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Parameters	Units	2010				2011			
		Min.	Max.	Mean	Median	Min.	Max.	Mean	Median
Mg^{+2}	mg/L	8	178.6	48.138	41.5	20	171.6	55.7	48.3
Na^{+}	mg/L	108	228	203.111	210.5	101	218	195.66	203
K^{+}	mg/L	8	16	11.277	11.25	9	14	11.327	11
Cl^{-}	mg/L	210	1500	655.55	593.5	212	4900	852.333	594.5
HCO_3^{-}	mg/L	300	390	334.111	333	289	380	322.833	313.5
SO_4^{2-}	mg/L	32	194	77.327	55	27	210	69.833	47.5
NO_3^{-}	mg/L	18	29	22.44	15.5	15	23	18.94	19
F	mg/L	0.5	.97	0.78	0.8	0.47	0.79	0.650	0.655

Table 6: Physico-chemical characteristics of groundwater samples around disposal Vellalore Dumpyard from 2012-2013

Parameters	Units	2012				2013			
		Min.	Max.	Mean	Median	Min.	Max.	Mean	Median
pH		6.38	7.91	7.22	7.18	6.48	7.8	7.16	7.3
EC	µmohs/cm	286	2497	981.54	1761.5	643.5	2925	1435.41	1130.3
TDS	mg/L	128	2694	1351.6	1.451	990	4500	2208.33	1738
TH	mg/L	150	888	436.66	400	150	1200	441.55	350
Ca^{+2}	mg/L	25	178	57.18	44.05	24	245.1	57.29	39.05
Mg^{+2}	mg/L	26	178.6	59.46	49.05	8	156.3	50.2	42.3
Na^{+}	mg/L	11	20	187.65	199	99	215	194.94	203
K^{+}	mg/L	7.5	11	9.422	10	9	12.5	104.722	10.25
Cl^{-}	mg/L	85	1300	655.05	687.5	210	1500	764.22	389.9
HCO_3^{-}	mg/L	25	360	293.27	304.5	269	370	311.77	304.5
SO_4^{2-}	mg/L	8	750	134.72	54	35	194	79.05	60
NO_3^{-}	mg/L	11	20	15.33	15	11	20	15.388	15.5
F	mg/L	0.27	0.67	0.491	0.50	0.4	0.87	0.69	0.70

Table 7: Percentage of groundwater samples based on IS and WHO around Vellalore Dumpyard

S. No.	Parameter	Range	Class	Percentage of samples	
				2012	2013
1	pH	7.5 to 9	Highest desirable limit	94.44	94.44
		< 7.5 to 9	Below the limit	5.55	5.55
2	EC	< 250	Excellent	0	0
		250-750	Good	0	0
		750-2000	Permissible	60	60
		2000-3000	Doubtful	40	40
		> 3000	Unsuitable	0	0
3	CL	< 0.14	Extremely fresh	0	0
		0.14-0.85	Fresh	0	0
		0.85-4.23	Very fresh	0	0
		4.23-8.46	Fresh brackish	0	0
		8.46-28.21	Brackish	0	0
		28.21-282.06	Brackish-salt	27.77	16.66
		282.06-564.13	Salt	27.77	33.33
		> 564.13	Hypersaline	44.44	44.44
4	TH	< 75	Soft	0	0
		75-150	Moderately hard	11.11	5.55
		150-300	Hard	33.33	38.88
		> 300	Very hard	55.55	55.55
5	TDS	< 500	Desirables for drinking	16.66	0
		500-1000	Permissible for drinking	22.22	5.55
		> 1000	Unfit for drinking	61.11	94.44
6	Ca^{+2}	75	Highest desirable limit	94.44	100
		> 75	Above desirable limit	5.55	0

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S. No.	Parameter	Range	Class	Percentage of samples	
				2012	2013
7	Mg^{+2}	30	Highest desirable limit	81.11	22.22
		> 30	Above desirable limit	11.11	77.77
8	Na^{+}	200	Highest desirable limit	72.22	44.44
		> 200	Above desirable limit	27.77	55.55
9	K^{+}	12	Highest desirable limit	100	88.88
		> 12	Above desirable limit	0	11.11
10	HCO_3^{-}	300	Highest desirable limit	50	50
		> 300	Above desirable limit	50	50
11	SO_4^{2-}	400	Highest desirable limit	88.88	100
		> 400	Above desirable limit	11.11	0
12	NO_3^{-}	45	Highest desirable limit	100	100
		> 45	Above desirable limit	0	0
13	F^{-}	1	Highest desirable limit	100	100
		> 1	Above desirable limit	0	0

pH

The pH is very important indicator of its quality, are controlled by the amount of dissolved carbon dioxide, carbonate and bicarbonates. It is stated that the addition of salts to water may cause reduction in its pH value depending added salts. The (pH) negative logarithm of hydrogen ion concentration ranged from 6.47 to 7.9 with a mean of 7.276 during 2012 and 6.2 to 7.88 with a mean of 7.154 during 2013, which indicates the alkaline nature of groundwater. The hydrogen ion concentration affects the taste of water. It is observed that 94.44% of samples are within the permissible limit and 5.55% samples above the limit during 2012 and 94.44% of samples within the permissible limit and 5.55% of samples above the limit during 2013, respectively.

Total hardness

The total hardness concentration of groundwater samples 150 to 1200 mg/L and the mean value is 441.55 mg/L in 2012 and the amount of potassium during 2013 is 150 to 888 mg/L and the mean value is 436.66 mg/L. It is observed that 38.88% of samples are within the permissible limit and 44.44% of samples above the limit during 2012 and 61.11% of samples were within the permissible limit and 55.55% of samples above the limit during 2013, respectively.

Total dissolved solids

The total dissolved solids concentration of groundwater samples 990 to 4500 mg/L and the mean value is 2208.33 mg/L in 2012 and the amount of potassium during 2013 is 128 to 2699 mg/L and the mean value is 1351.66 mg/L. It is observed that 100% of samples are within the permissible limit during 2012 and 100% of samples were within the permissible limit during 2013, respectively.

Sodium

Sodium salts are soluble and will not precipitate unless high concentrations are reached. Clay minerals may release large quantities of exchangeable sodium. Ancient brines, seawater, industrial waters and untreated sewage may add some sodium to groundwater. Sodium content in the study area during 2012 ranged from 170 to 215 mg/L and the mean value 200.5 mg/L and during 2013 presence sodium is 160 to 208 mg/L and the mean value 193.26 mg/L. It is observed that 72.22% of samples were within the permissible limit and 27.77% samples above the limit during 2012 and 44.44% of samples were within the permissible limit and 55.55% of samples above the limit during 2013, respectively. The maximum permissible limit of sodium is 200 mg/L. Most of the samples falls above the limit.

Calcium

Calcium is the most abundant of the alkaline earth minerals. The concentration up to 100 mg/L of calcium is capable of forming scales in pipes and boiler, fortunately it has no adverse physiological manifestation on human system. Calcium ion concentration of groundwater samples during 2012 have ranged from 24 to 68.3 mg/L and the mean value of 40.62 mg/land during 2013 presence of calcium is 25 to 178 mg/L and the mean value is 57.188 mg/L, respectively. It is observed that 94.44% of samples were within the permissible limit and 5.55% samples above the limit during 2012 and 100% of samples within the permissible limit during 2013, respectively.

Magnesium

Magnesiumion concentration of groundwater samples during 2012 have ranged from 18 to 62.7 mg/L and the mean value of 42.14 mg/L and during 2013 presence of calcium is 26 to 78.6 mg/L and the mean value is 48.35 mg/L, respectively. It is observed that 81.11% of samples were within the permissible limit and 11.11% samples above the limit during 2012 and 22.22% of samples within the permissible limit and 77.77% samples above the limit during 2013, respectively.

Chloride

Chloride is the major constituent of earth's crust but a major dissolved constituent of most natural waters the presence of chloride in large amounts may be due to natural processes, or it may be an indication to pollution from seawater or industrial or domestic. Chloride is a good indictor of sewage and manure inputs and has been extensively used to identify sources of contamination from anthrophogenic activities. Chloride ion concentration of groundwater samples 210 to 890 mg/L and the mean value is 531.44 mg/L in 2012 and the amount of chloride during 2013 is 85 to 854 mg/L and the mean value is 471.16 mg/L. Chloride is naturally occurring anion found almost in all types of water. It is observed that 27.77% of samples are within the permissible limit and 72.22% samples above the limit during 2012 and 11.11% of samples were within the permissible limit and 88.88% of samples above the limit during 2013, respectively during 2013, respectively.

Potassium

Potassium enters the structure of certain clay minerals and to higher resistance to weathering of potassium minerals potassium ion concentration of groundwater samples 9 to 12.5 mg/L and the, mean value is 10.47 mg/L in 2012 and the amount of potassium during 2013 is 7.5 to 11 mg/L and the mean value is 9.42 mg/L. It is observed that 100% of samples are within the permissible limit during 2012 and 88.88% of samples were within the permissible limit and 11.11% of samples above the limit during 2013, respectively during 2013, respectively.

Bicarbonates

Bicarbonates are derived from the carbondioxide in the atmosphere, soil and solution of carbonate rocks. Presence of carbonic acid is indicated when pH is less than 4.5. The bicarbonates concentration of groundwater samples 269 to 370 mg/L and the mean value is 311.77 mg/L in 2012 and the amount of potassium during 2013 is 293 to 279 mg/L and the mean value is 360 mg/L. It is observed that 50% of samples are within the permissible limit and 50% of samples above the limit during 2012 and 50% of samples were within the permissible limit and 50% of samples above the limit during 2013, respectively.

Sulphate

The sulphates concentration of groundwater samples 35 to 194 mg/L and the mean value is 79.05 mg/L in 2012 and the amount of potassium during 2013 is 80 to 750 mg/L and the mean value is 134.72 mg/L. It is observed that 88.88% of samples are within the permissible limit and 11.11% of samples above the limit during 2012 and 100% of samples were within the permissible limit during 2013, respectively.

Nitrate

The nitrates concentration of groundwater samples 11 to 20 mg/L and the mean value is 15.38 mg/L in 2012 and the amount of potassium during 2013 is 11 to 20 mg/L and the mean value is 15.33 mg/L. It is observed that 100% of samples are within the permissible limit during 2012 and 100% of samples were within the permissible limit during 2013, respectively.

Fluoride

The fluoride concentration of groundwater samples 0.4 to 0.87 mg/L and the mean value is 0.69 mg/L in 2012 and the amount of potassium during 2013 is 0.645 to 0.27 mg/L and the mean value is 0.67 mg/L. It is observed that 100% of samples are within the permissible limit during 2012 and 100% of samples were within the permissible limit during 2013, respectively.

Table 8: Estimated water quality index around Vellalore dumpyard from 2010 to 2013

Sample ID	Years				Mean
	2010	2011	2012	2013	
A_1	20.62	23.00	17.342	18.04	19.75
A_2	16.11	16.833	15.92	14.63	15.87
A_3	12.78	13.84	12.52	12.68	12.960
A_4	13.48	13.83	13.14	11.57	13.00
A_5	22.78	24.020	23.52	19.33	22.41

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Sample ID	Years				Mean
	2010	2011	2012	2013	
A_6	22.78	21.58	26.49	27.80	24.66
A_7	18.62	16.78	16.92	14.28	16.65
A_8	30.31	23.94	29.93	17.80	25.501
A_9	15.57	19.045	15.58	22.51	18.18
A_{10}	21.84	22.54	22.30	17.67	22.86
A_{11}	21.53	20.71	22.87	26.31	19.31
A_{12}	19.41	18.13	20.09	19.62	23.71
A_{13}	26.96	25.09	25.78	17.00	21.31
A_{14}	21.56	20.43	22.78	20.48	15.23
A_{15}	12.95	12.40	20.43	15.15	17.48
A_{16}	14.80	14.23	13.84	18.25	15.44
A_{17}	18.00	17.69	14.23	19.96	19.75
A_{18}	17.00	16.81	13.84	14.12	15.87

Table 9: Groundwater quality for Vellalore based on WQI for three years

WQI	Class	Percentage of samples			
		2010	2011	2012	2013
0-25	Excellent water quality	88.88	94.44	83.33	88.8
26-50	Good water quality	11.11	5.55	16.66	11.11
51-75	Poor water quality	0	0	0	0
76-100	Very poor water quality	0	0	0	0
> 100	Unsuitable for drinking	0	0	0	0

Water quality index

Water quality index is calculated to determine the suitability of water for drinking purpose. During 2010-2013 of the study area water quality index and the percentage of eighteen groundwater samples are compared with the limit were presented in Table 7 & 8 indicating that the water is unfit for human consumption. All most all the samples for four years were found to be within the limit. As the water quality index value increases, the quality of life is found to decrease. The changes in the quality of life'score in relation to changes in water quality index > 100 are minimal. This indicates that significant changes in quality of life can be achieved only if water quality index is brought down below 100.

CONCLUSION

The results indicates physico-chemical characteristic of ground water around Vellalore dumpyard. Most of the parameters such as total dissolved solids, calcium, magnesium, total hardness and chlorides were maximum than highest desirable limits. Potassium and fluoride values within the permissible limit. Water quality index (WQI) for all the four years were within permissible limit. The overall view of the water quality index of the present study area was fall as excellent WQI value.

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