ANALYSIS OF CORROSION RATES OF MILD STEEL, COPPER AND ALUMINIUM IN UNDERGROUND WATER SAMPLES OF KRISHNA DISTRICT, ANDHRA PRADESH, INDIA

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ABSTRACT

A few underground water samples are collected from various mandals located adjacent to Krishna river in Krishna district of Andhra Pradesh, India. The quality parameters of water samples are determined using volumetric and instrumental methods. The parameters determined include chloride content, hardness, alkalinity, dissolved oxygen, total dissolved solids, total suspended solids, pH and conductivity. Corrosion rates of commercially important metals viz., mild steel, copper and aluminium are determined in all the collected water samples using conventional gravimetric measurements. An attempt is made to correlate the water quality parameters with the corrosion rates of metals. A clear correlation was observed in case of majority of water samples with reference to certain parameters like pH, conductivity and chlorides which have a direct impact on corrosion rate of a metal.

Keywords*: *Commercial Metals, Corrosion Tendencies, Krishna District, Underground Water Samples, Water Quality Parameters

I. INTRODUCTION

Metals like carbon steel, copper, aluminium, etc. are commercially much significant due to their use in various engineering and construction fields due to their better mechanical, physical and chemical properties. However, these metals exhibit high susceptibility to corrosion in environments in which they are expected to work. Metallic structures in contact with natural surface water and underground water can easily undergo corrosion due to presence of aggressive chemical species like chlorides. Water quality parameters strongly influence rate of corrosion of metals. Particularly, underground water consisting of high levels of dissolved salts is much aggressive to metallic corrosion. Hence, it is important to determine water quality parameters in predicting the rate of corrosion of a particular metal in underground water environment. These parameters include pH, dissolved oxygen, conductivity, alkalinity, chlorides, total dissolved solids, etc. Presence of impurities and quantity of impurities in an underground water sample depend on several factors like nature of soils through which water flows from the earth surface, depth of penetration, influence of nearby surface water sources, etc. Hence, the type of impurity and extent of impurities vary from sample of one place to the sample of another. When underground water comes in contact with metallic structures like underground pipelines, motors, metallic tools used in agricultural fields, industrial cooling water systems, heat exchangers, etc., they undergo corrosion and the rate of corrosion depends on water quality parameters. A few studies on corrosion behavior of metals in contact with natural waters are reported in literature [1-5]. The primary objective of the present study is to determine water quality parameters of the selected underground samples of water at different sites located in different mandals, to determine corrosion rates of carbon steel, aluminium and copper in the collected samples and to correlate the corrosion rates with the results of water quality parameters.

II. EXPERIMENTAL

The study area and sampling sites are shown in Fig. 1. All the sampling sites are restricted to Krishna district of Andhra Pradesh state, a state of South India. Totally eleven underground water samples were collected at the indicated points in nine mandals along the Krishna river. The first sampling site is in Chodavaram of Penamaluru mandal and the last being in Nagayalanka of Nagayalanka mandal, which are separated by a distance of about 90 km along the river. The geographical position of each site is mentioned in Table 1 including the allotted sample number.

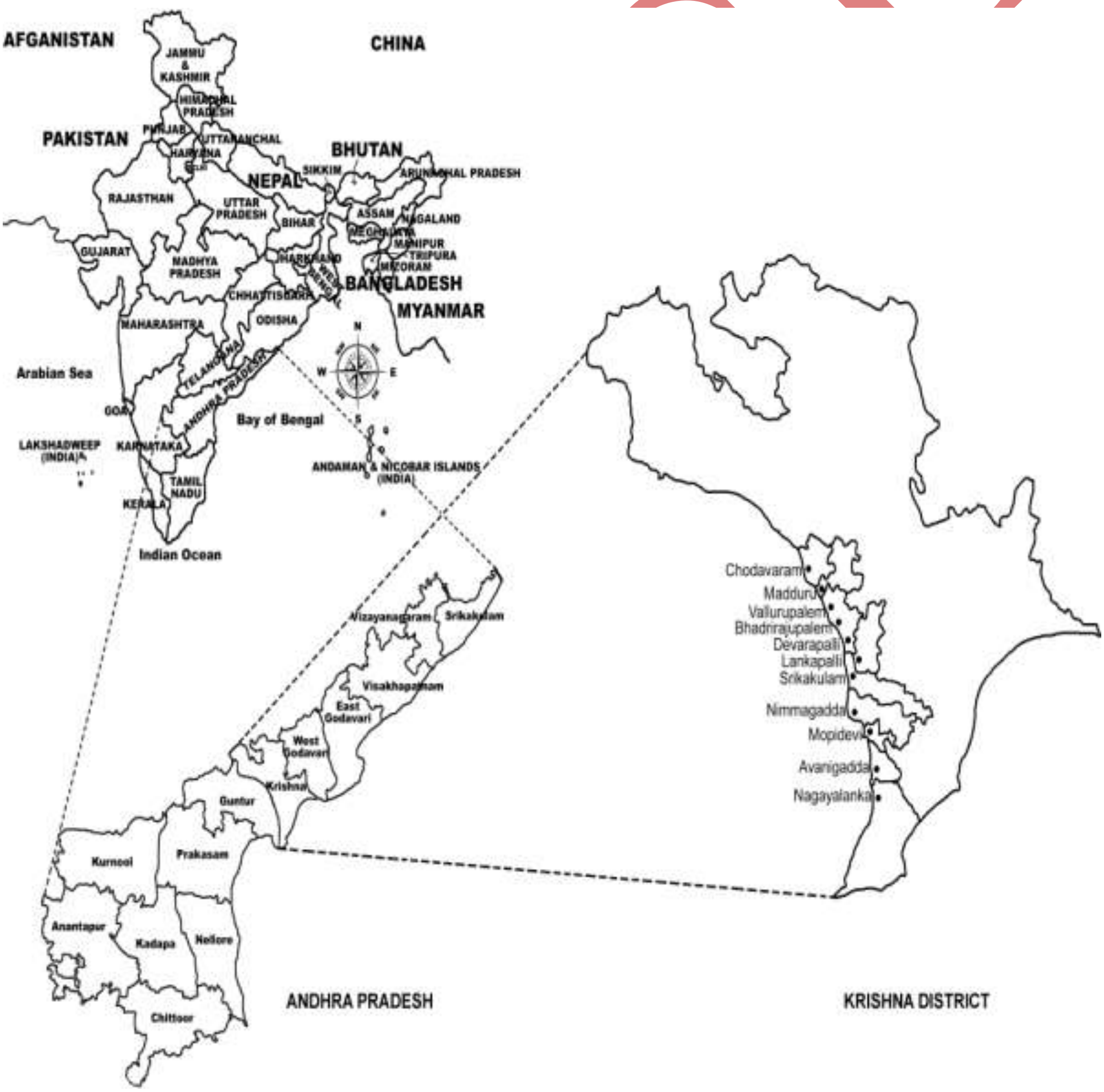

Fig. 1 Map Showing Study Area and Sampling Sites

The underground water sampled bottles were labeled, tightly packed and transported immediately to the laboratory. The volumetric and instrumental methods used for the determination of various water quality parameters are given in Table 2. The detailed procedures of these methods are not included here as they are very

Table 1

Names of the sampleing sites, locations and corresponding sample numbers

Sampling site	Location	Sample number
Chodavaram	Penamaluru mandal (16°25'41" N 80°41'52" E)	1
Madduru	Kankipadu mandal (16°24'11" N 80°43'32" E)	2
Vallurupalem	Thotlavalluru mandal (16°22'13" N 80°46'08" E)	3
Bhadrirajupalem	Thotlavalluru mandal (16°19'55" N 80°47'34" E)	4
Devarapalli	Thotlavalluru mandal (16°17'48" N 80°49'09" E)	5
Lankapalli	Pamidimukkala mandal (16°13'17" N 80°50'39" E)	6
Srikakulam	Ghantasala mandal (16°11'44" N 80°50'43" E)	7
Nimmagadda	Challapalli mandal (16°08'25" N 80°52'50" E)	8
Mopidevi	Mopidevi mandal (16°03'47" N 80°55'25" E)	9
Avanigadda	Avanigadda mandal (16°01'07" N 80°54'52" E)	10
Nagayalanka	Nagayalanka mandal (15°56'53" N 80°55'00" E)	11

Table 2

Volumetric and instrumental methods used for chemical analysis of underground water samples

Chemical parameter	Unit	Method/Instrument
pH	–	pH meter (Elico Limited)
Electrolytic conductivity (EC)	µS/cm	Conductometer (Elico Limited)
Total hardness (TH)	mg/L	Volumetric method (EDTA method)
Total alkalinity (TA)	mg/L	Volumetric method (Neutralization titration)
Chlorides (Cl^-)	mg/L	Volumetric method (Argentometric titration)
Dissolved oxygen (DO)	mg/L	Volumetric method (Winkler's method)
Total suspended solids (TSS)	mg/L	Gravimetric method
Total dissolved solids (TDS)	mg/L	Gravimetric method

fundamental aspects and are well-known to the researchers working in this field. The parameters, viz., pH and conductivity of all the samples were measured using pH meter and conductometer respectively, immediately after collection of the samples at the sites. Total hardness, dissolved oxygen, chlorides and alkalinity were determined by conventional volumetric method. Total suspended solids and total dissolved solids were determined by gravimetric method. Total hardness and alkalinity are expressed in terms of milligrams of $CaCO_3$. For studies on corrosion, the specimens taken from single sheets of carbon steel, aluminium and copper were used. Prior to the tests, specimens of carbon steel as well as copper were polished to mirror finish with 1/0, 2/0, 3/0 and 4/0 emery polishing papers respectively, washed with distilled water, degreased with acetone and dried. The polished specimens of the dimensions, 3.5 x 1.5 x 0.2 cm, were used. In all the gravimetric experiments, the polished specimens were weighed and immersed in duplicate, in 100 mL water samples for a period of seven days. Then the specimens were reweighed after washing, degreasing and drying. Accuracy in weighing up to 0.01 mg and in surface area measured up to 0.1 cm2, as recommended by ASTM G31, was followed [6]. The immersion period of seven days was fixed in view of the considerable magnitude of the corrosion rate obtained after this immersion period. The immersion period was maintained accurately up to 0.1 h in view of the lengthy immersion time of 168 h. Under these conditions of accuracy, the relative standard error in corrosion rate determinations is of the order of 2 % or less for an immersion time of 168 h [7].

Weighing of metal specimens before and after immersion in various water samples was carried out using Mettler analytical balance with readability of 0.01 mg. Corrosion rates (in mdd) of the specimens were calculated using the expression,

Corrosion rate (CR) = (Δw/st), where Δw is the loss of metal in milligrams, ‘s’ is the surface area in dm2 and ‘t’ is immersion time in days.

III. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

Water quality parameters of underground water samples of Krishna district, Andhra Pradesh, India are listed in Table 3.

Table 3

Quality Parameters Of Underground Water Samples

Sample No.	Quality parameters							
	TSS	TDS	pH	EC	Cl^-	DO	TH	TA
1	308	364	7.88	427	53.4	6.6	170.2	287.6
2	338	310	7.41	337	50.4	6.9	151.3	260.8
3	270	272	8.15	303	38.5	5.0	149.4	326.0
4	1244	1208	8.38	1142	127.6	5.1	242.1	760.8
5	428	442	7.54	421	84.6	6.4	192.9	293.4
6	718	714	8.77	622	102.4	7.1	227.0	423.9
7	866	570	8.94	480	31.1	7.5	151.3	521.7
8	380	410	8.06	478	63.8	7.1	194.8	304.3
9	1166	1134	8.22	1353	200.3	6.7	211.6	663.0
10	1782	1698	8.79	2026	354.7	5.3	280.0	771.6
11	904	932	8.56	1102	224.1	5.9	219.4	400.8

From the table, it can be observed that pH is varied between 7.41 and 8.79 for all the eleven samples. The electrolytic conductivity as well as total dissolved solids were found to be highest in case of the sample 10 collected at Avanigadda. The chloride content of sample collected at Vallurupalem is found to be 38.5 mg/L, the minimum among all the samples, while it is maximum (354.7 mg/L) for sample collected at Avanigadda. The same samples are found to record minimum and maximum values of total hardness respectively. Alkalinity of water samples ranged from 260.8 mg/L for the sample 2 collected at Madduru to 771.6 mg/L for the sample 10 collected at Avanigadda. Dissolved oxygen is found to be in the range of 5.0 to 7.5 ppm. The sample of Avanigadda is found to exhibit maximum values of most of the quality parameters measured.

3.2 Corrosion Tendencies

Corrosion rates of carbon steel, aluminum and copper in the collected underground water samples of Krishna district are shown in Figs. 2, 3 and 4 respectively. The figures show that the corrosion rates of all the three metals are highest in case of the sample 10 (Avanigadda) and lowest in case of the Madduru sample. In addition, the order of corrosion rate of the metals in any water sample is found to be carbon steel > aluminium > copper. The water quality parameters listed in Table 3 play significant role in affecting the corrosion behaviour of metals. It is found from the Figs. 2, 3 and 4 as well as Table 3 that the quality parameters viz., total dissolved solids, electrolytic conductivity and concentration of chloride have proportionate impact on corrosion rates of the selected metals. Electrolytic conductivity of a solution in contact with a metal surface is essential for any metal to undergo corrosion. It is well-known that corrosion rate of metal increases with increase in free chloride concentration of the electrolyte [8], due to high penetrating power of these ions. Results show that electrolytic conductivity, chloride content and total dissolved solids are highest for the sample 10.

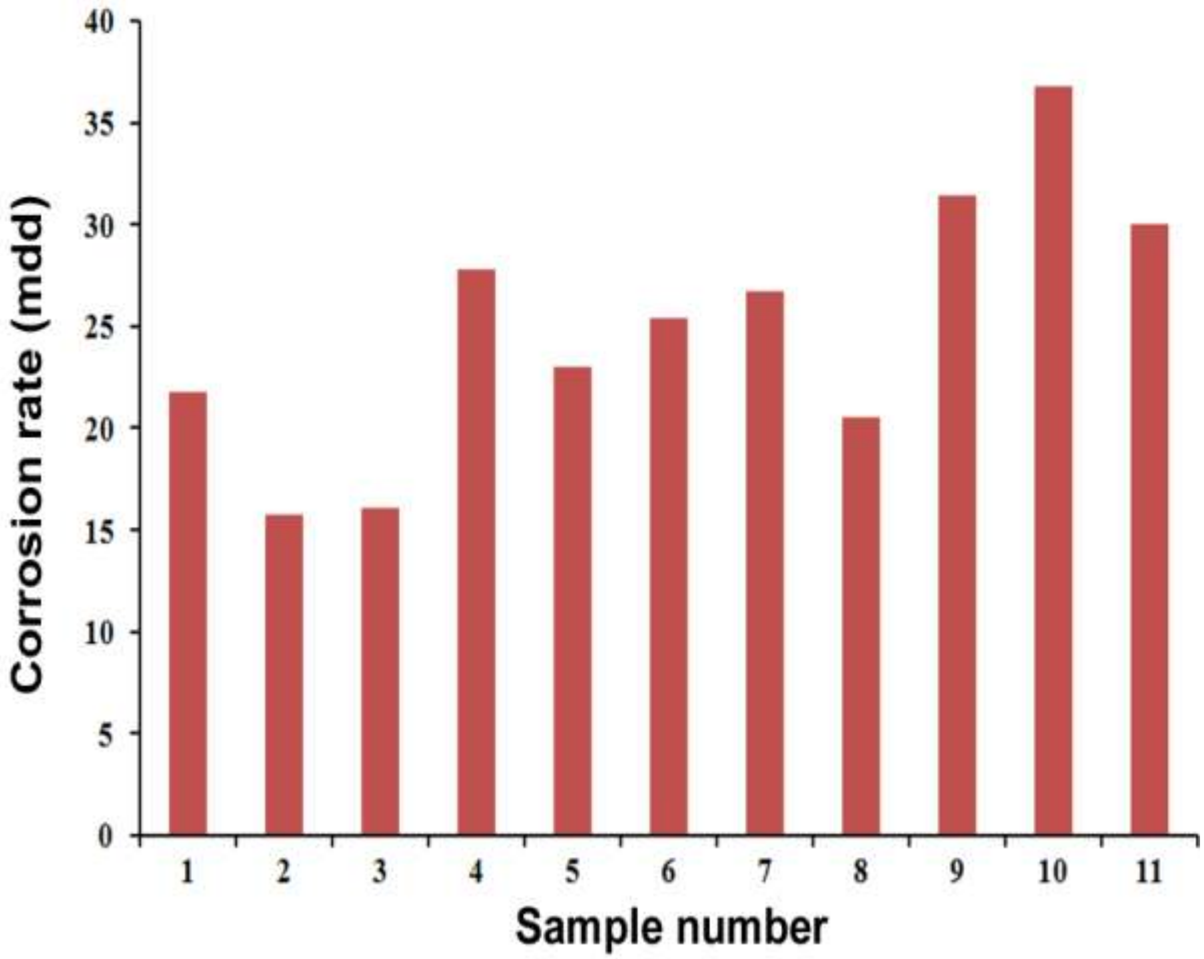

Fig. 2 Corrosion Rates of Carbon Steel In the Underground Water Samples

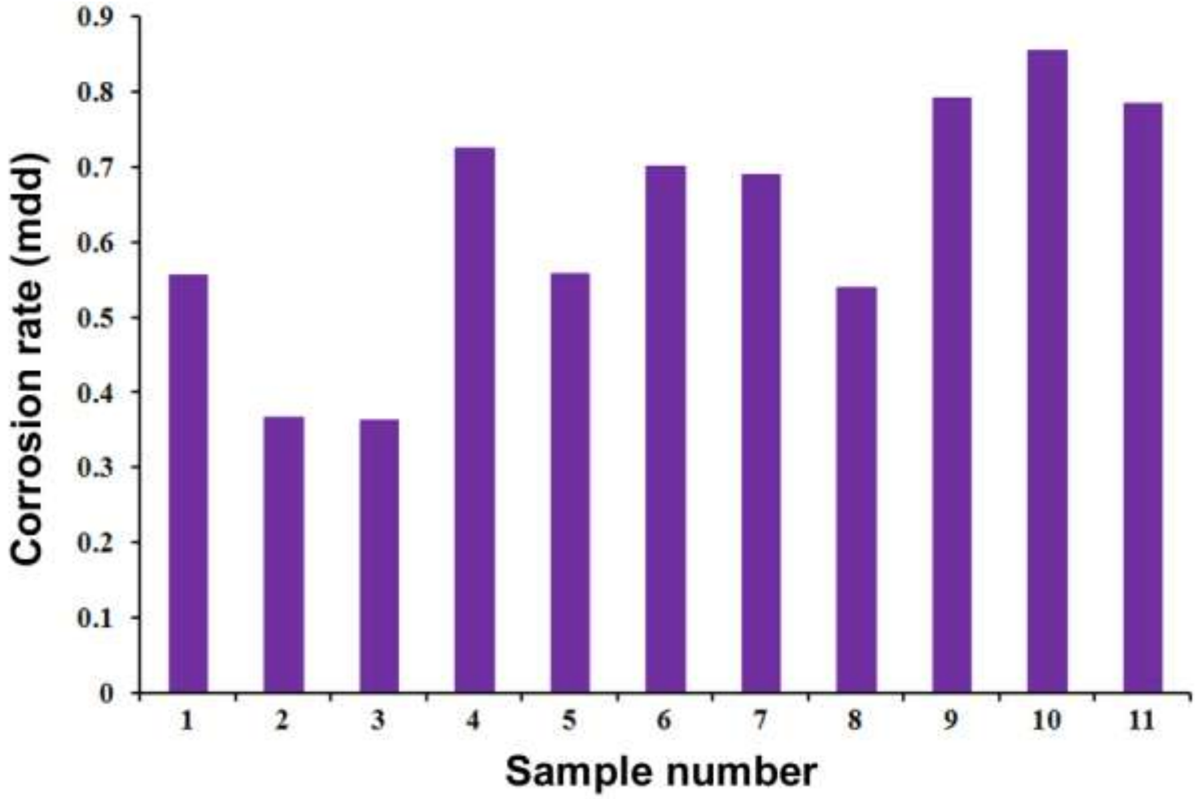

Fig. 3 Corrosion Rates Of Aluminum in the Underground Water Samples

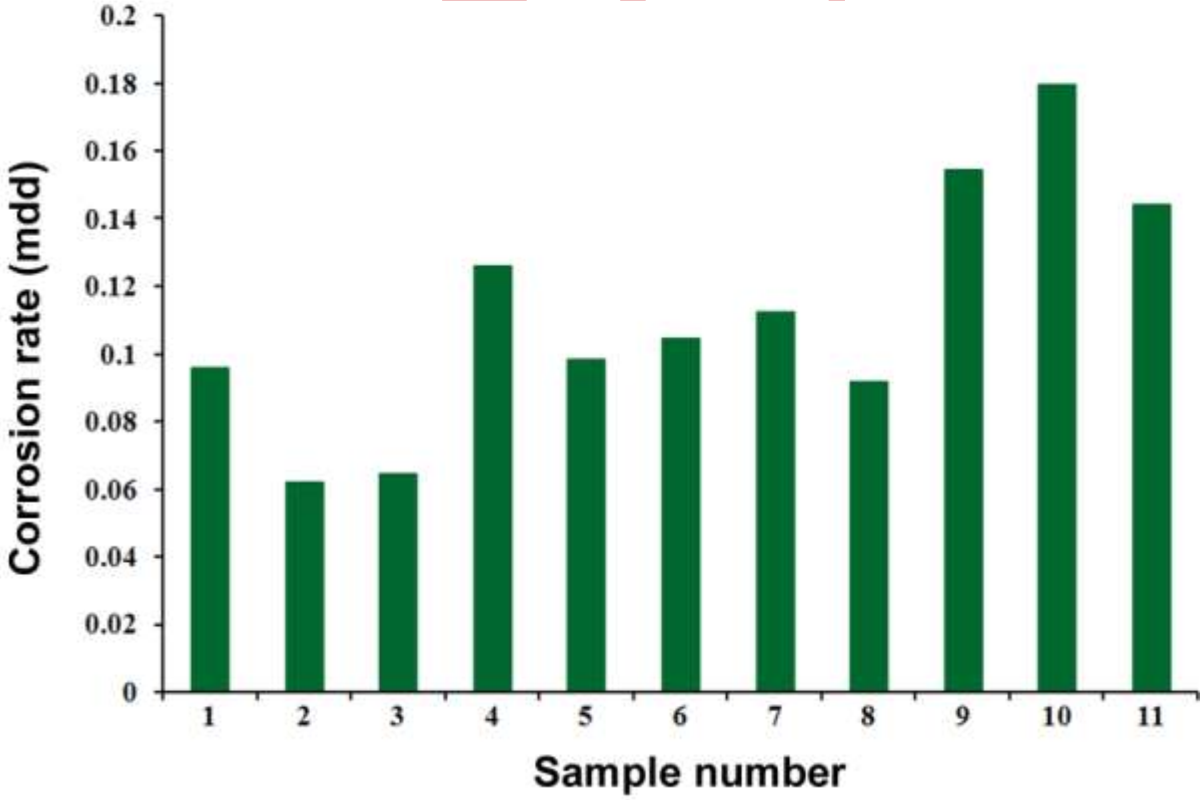

Fig. 4 Corrosion Rates Of Copper in the Underground Water Samples

Interestingly, corrosion rates of all the three metals are found to be highest in sample 10. It indicates that the corrosion rates of the metals are directly proportional to electrolytic conductivity, chlorides and total dissolved solids. The minimum corrosion rates of the metals in case of the samples collected at Madduru and

Vallurupalem infer that there is possibility of application of this water after treatment for industrial and domestic purposes as far as corrosion aspects are concerned.

IV. CONCLUSION

Water quality parameters like chlorides, electrolytic conductivity, total dissolved solids, dissolved oxygen, etc. are found to be different for underground water samples collected at the selected mandals of Krishna district. These parameters reported highest values in case of the sample at Avanigadda when compared with the rest of the samples. The general observation from the results is that the rate of corrosion is directly proportional to concentration of free chlorides, electrolytic conductivity and total dissolved solids. The extent of corrosion of different metals in the collected samples is found to be in the order: carbon steel > aluminium > copper. Minimum corrosion rates are recorded for the samples collected at Madduru and Vallurupalem. This observation facilitates the use of such water samples after mild treatment process for industrial and domestic purposes as far as corrosion of metals is concerned. The present study can be useful in predicting the rate of corrosion of metals based on water quality parameters. The inferences of the present study can be applied in various industrial processes involving metallic structures to assess behaviour of these metals towards corrosion in aqueous environments with different qualities.

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