



Effect of Quality Parameters of Krishna River Water, Krishna District, Andhra Pradesh, India, on Corrosion Behaviour of Some Commercially Important Metals

S. Srinivasa Rao^{*1}, A. Ratnakar¹, A. Venu Gopala Krishna², Ch. Kavitha¹ & M. Sri Lakshmi¹

1. Department of Chemistry, V. R. Siddhartha Engineering College (Autonomous), Vijayawada, Andhra Pradesh.

2. Department of Chemistry, Dhanekula Institute of Engineering & Technology, Vijayawada, Andhra Pradesh.

Email: ssrnitw@gmail.com

Received on 13th December and finalized on 28th December 2012

ABSTRACT

Various water quality parameters of Krishna river water in Andhra Pradesh, India, were determined by using different analytical methods and the results were correlated to evaluate the corrosion rates of commercially important metals like carbon steel, copper and aluminium in the river water samples. The study was performed for the river water collected at seven different sites along the river. The analyzed parameters are chlorides, dissolved oxygen, conductivity, pH, total dissolved solids, total suspended solids, alkalinity and hardness. The trends of these physical and chemical parameters are analyzed. An attempt is made to evaluate corrosion rates of the metals, determined by gravimetric measurements, in terms of variations in the physical and chemical parameters.

Keywords: Corrosion rate, Gravimetric studies, Water quality parameters, Krishna River and Commercially important metals

INTRODUCTION

Application of various commercially important metals and alloys in engineering and construction fields is mainly due to their better physical, mechanical and electrical properties. But, they have a major drawback of susceptibility to corrosion in environments in which they are expected to work. Metallic objects and structures in contact with natural waters can easily undergo corrosion due to presence of aggressive chemical species like chlorides in natural waters. Water quality parameters strongly influence rate of corrosion of metals. Hence, it is essential to determine water quality parameters in predicting the rate of corrosion of a particular metal in specific aqueous environment. These parameters include particularly pH, dissolved oxygen, conductivity, alkalinity, chlorides, total dissolved solids, etc. When rivers flow from one place to the other, they carry all types of impurities both suspended and dissolved, and hence the quality parameters of river water differ from place to place. In general, it is expected that the quantity of dissolved salts increases in water collected at different places along the river in the flow direction. Consequently, other quality parameters like conductivity, chlorides, hardness, etc. also follow the same trend. When river water comes in contact with metallic structures like underground pipelines, motors, metallic objects 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 [1-3].

Krishna (Krishnaveni) river is the third longest and famous river in India that flows in central-southern India. It originates at Mahabaleswar near the Jor village in the extreme north of Wai Taluka, Satara district, Maharashtra state in the west and meets the Bay of Bengal at Hamsaladevi near Avanigadda in Andhra Pradesh on the east coast. It flows through Karnataka state before entering Andhra Pradesh. It covers a total distance of about 1400 km in the three states. The main objective of the present study is to determine water quality parameters of Krishna river at different sites, 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.

MATERIALS AND METHODS

Sampling sites: The study area and sampling locations are shown in Fig.1. All the sampling sites are restricted to Krishna district of Andhra Pradesh state, a state of South India. The first sampling site is Muktyala and the last being Prakasam barrage, which are separated by a distance of about 90 km along the river. The samples were collected at seven different sites. The geographical position of each site is mentioned in Table 1 including the allotted sample number.

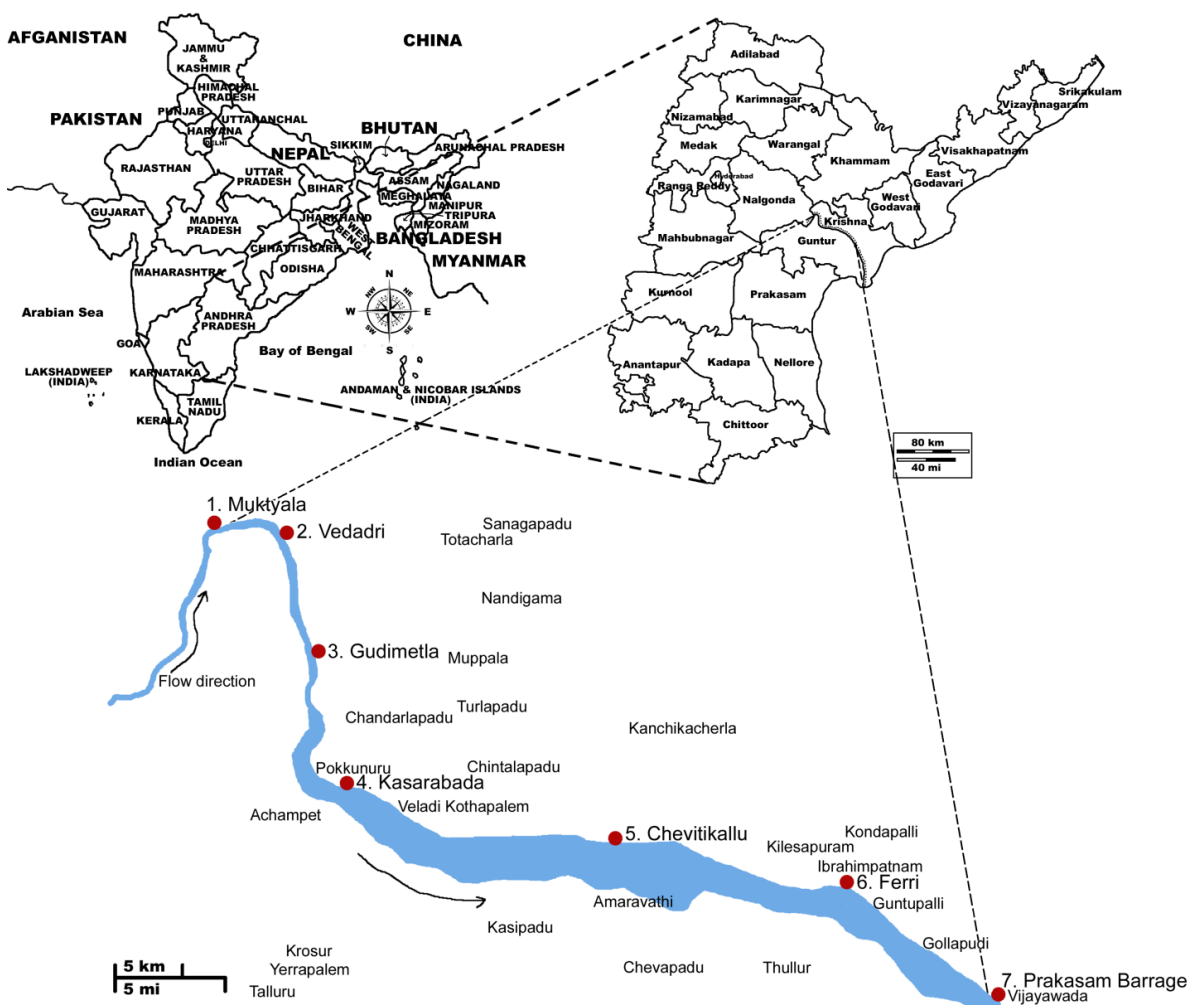


Fig. 1: Study area and sampling locations.

Analytical methods and Procedures: The river 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 basic and well-known to the researchers in chemistry, particularly 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, calcium hardness, dissolved oxygen, chlorides and alkalinity due to individual ions, viz., carbonate, bicarbonate and hydroxide ions were determined by conventional volumetric method. Total suspended solids and total dissolved solids were determined by gravimetric method. Total hardness, calcium hardness and alkalinity are expressed in terms of milligrams of CaCO₃.

Table 1: Names of the sampling sites, locations and the corresponding sample numbers.

Sampling site	Location	Sample number
Muktyala Temple	Mukteswarapuram, Jaggaiahpet Mandal, Andhra Pradesh (16°49'10" N 80°04'08" E)	1
Vedadri Temple	Vedadri, Jaggaiahpet Mandal, Andhra Pradesh (16°48'52" N 80°07'24" E)	2
Gudimetla	Chandarlapadu Mandal, Andhra Pradesh (16°45'45" N 80°08'11" E)	3
Kasarabada	Near Pokkunuru, Chandarlapadu Mandal, Andhra Pradesh (16°39'08" N 80°09'31" E)	4
Chevitikallu	Kanchikacherla Mandal, Andhra Pradesh (16°36'42" N 80°21'34" E)	5
Ferri	Ibrahimpattanam Mandal, Andhra Pradesh (16°34'47" N 80°30'52" E)	6
Prakasam Barrage	Vijayawada, Andhra Pradesh (16°30'43" N 80°36'16" E)	7

For studies on corrosion, the specimens taken from single sheets of carbon steel, aluminium and copper were used. Prior to the tests, the specimens of carbon steel and 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 [4]. 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 [5].

Table 2: Volumetric and instrumental methods used for chemical analysis of river water in Krishna district, Andhra Pradesh, India.

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)
Calcium hardness (CaH)	mg/L	Volumetric method (EDTA method)
Carbonate alkalinity (CA)	mg/L	Volumetric method (Neutralization titration)
Bicarbonate alkalinity (BA)	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

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

$$\text{Corrosion rate (mdd)} = \frac{\text{Loss in weight (mg)}}{\text{surface area of specimen (dm}^2\text{) x 7 (period of immersion in days)}}$$

where mdd is milligram per dm² per day.

Corrosion rate expressed in mdd above is then converted in to mmpy (millimeter per year) using the following equation.

Corrosion rate (mmpy) = (Corrosion rate in mdd x 0.0365) / D, where D = density of metal.

RESULTS AND DISCUSSION

Water quality parameters: Water quality parameters of Krishna river water in Krishna district, Andhra Pradesh, India are listed in Table 3. From the table, it can be observed that pH is varied between 7.5 and 7.8 for all the seven samples. The electrolytic conductivity values of the samples were increased from 432 $\mu\text{S/cm}$ to 498 $\mu\text{S/cm}$. The content of chloride ions is gradually increased from 47.3 ppm for the sample 1 to 67.1 ppm for the sample 7, except that the sample 3 has slightly less chloride content than that of the sample 2. The dissolved oxygen of the samples is varied between 6.2 ppm and 7.3 ppm, but without following a specific trend. Table 3 also shows that carbonate alkalinity is very less when compared with the bicarbonate alkalinity in case of all the samples. Hydroxide alkalinity is found to be zero for all the samples. Total hardness of the samples ranges between 111 ppm and 139 ppm. Total suspended solids are found to decrease gradually reaching 145 ppm for the sample 7. All these results indicate that there are no much significant changes in almost all the water quality parameters for the samples at different places. The slight variations in the parameters infer that the composition of river water in the studied range is almost constant.

Table 3: Water quality parameters of Krishna river water in Krishna district, Andhra Pradesh, India.

Parameter	Sample number						
	1	2	3	4	5	6	7
pH	7.5	7.8	7.6	7.5	7.8	7.8	7.6
Conductivity	432	440	456	466	464	475	498
Chlorides	47.3	50.6	47.8	52.3	57.5	60.3	67.1
TDS	346	391	471	484	473	508	521
TSS	494	431	387	346	369	212	145
DO	6.9	6.2	7.3	6.6	7.3	6.5	6.9
TH	120	125	116	120	139	125	111
CaH	76	75	71	64	85	75	61
CA	11	10	16	32	21	10	7
BA	118	131	115	104	129	126	126

Corrosion rates of metals: Corrosion rates of carbon steel, aluminium and copper in the water samples of Krishna river are shown in Fig. 2. The figure shows that corrosion rates of all the three metals increase from sample 1 to sample 7. In case of aluminium and copper, the increase in corrosion rate is gradual, while in case of carbon steel the gradual increase in corrosion rate is observed, except for the specimens immersed in sample 5. Corrosion rate of carbon steel is found to be highest and that of copper is lowest in case of any sample. The extent of increase in corrosion rate from sample 1 to sample 7 is also found to be in the same order. Effects of water quality parameters viz., conductivity, chloride content and total dissolved solids on corrosion rates of the metals are shown in Figs. 3 to 5 respectively. These three parameters play significant role in deciding the corrosion rate of a metal. The electrolytic conductivity of a solution in contact with a metal surface is essential for any metal to initiate and continue corrosion.

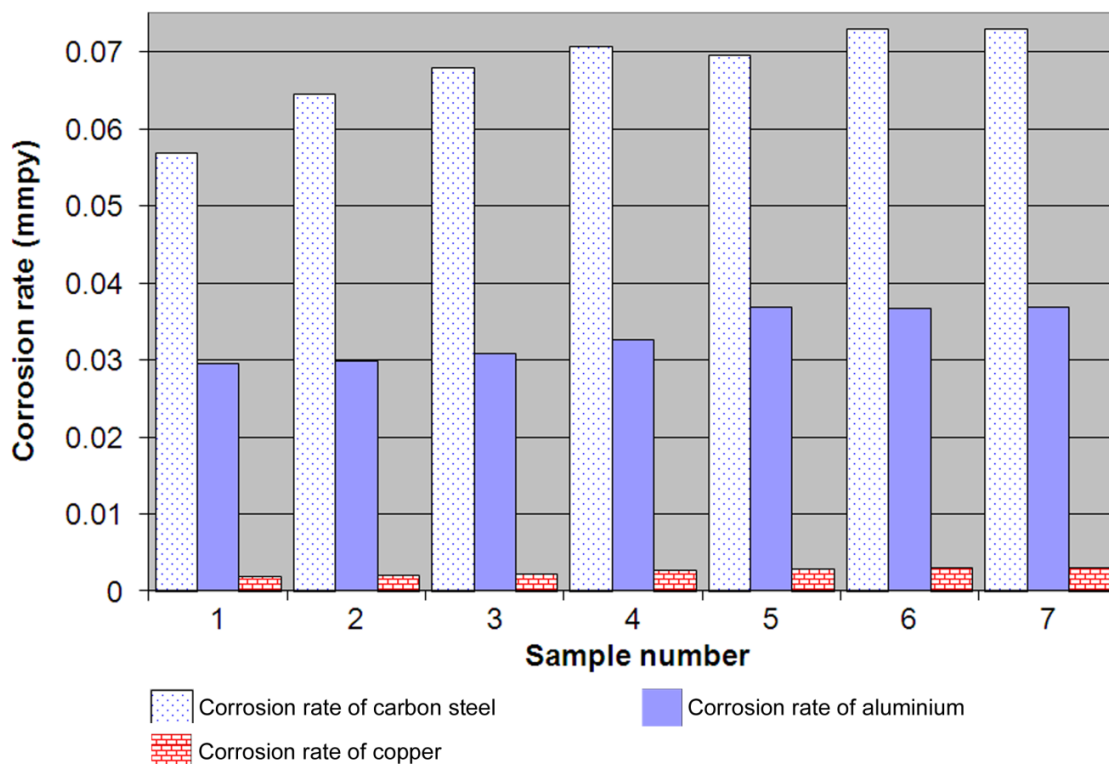


Fig. 2: Corrosion rates of carbon steel, aluminium and copper in the water samples of Krishna river, Andhra Pradesh, India.

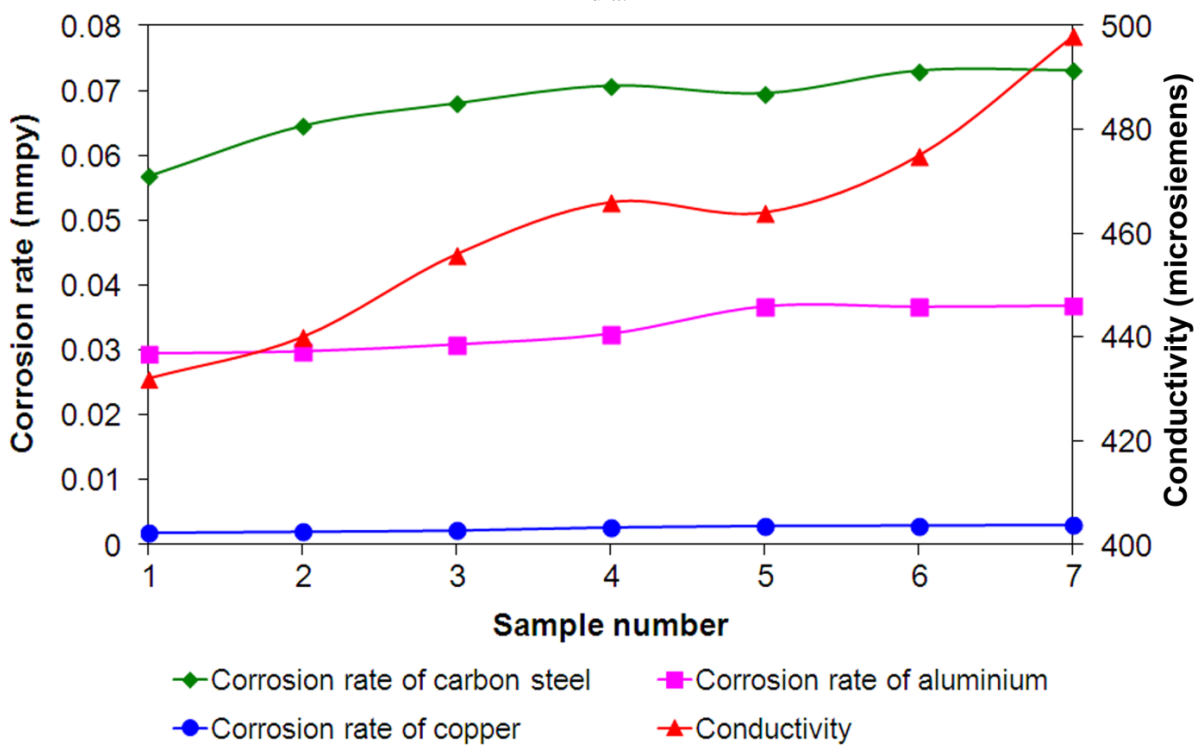


Fig. 3: Effect of conductivity of water samples on corrosion rates of metals.

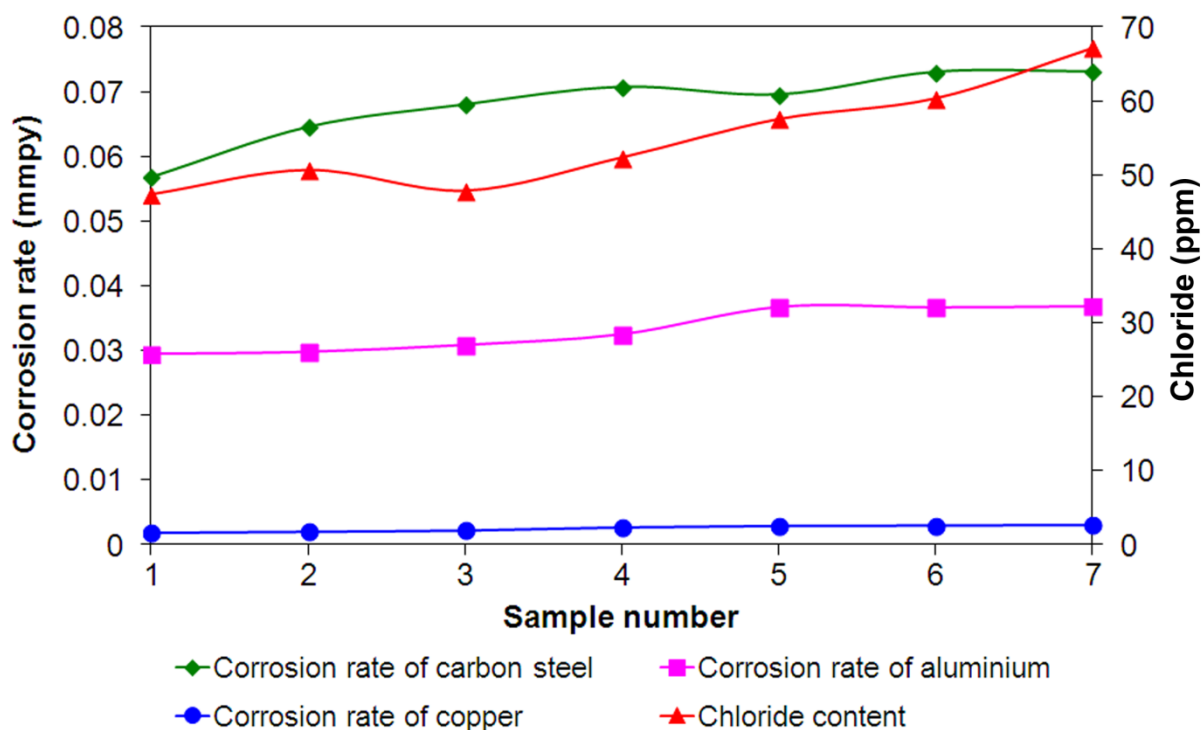


Fig. 4: Effect of chloride content present in water samples on corrosion rates of metals..

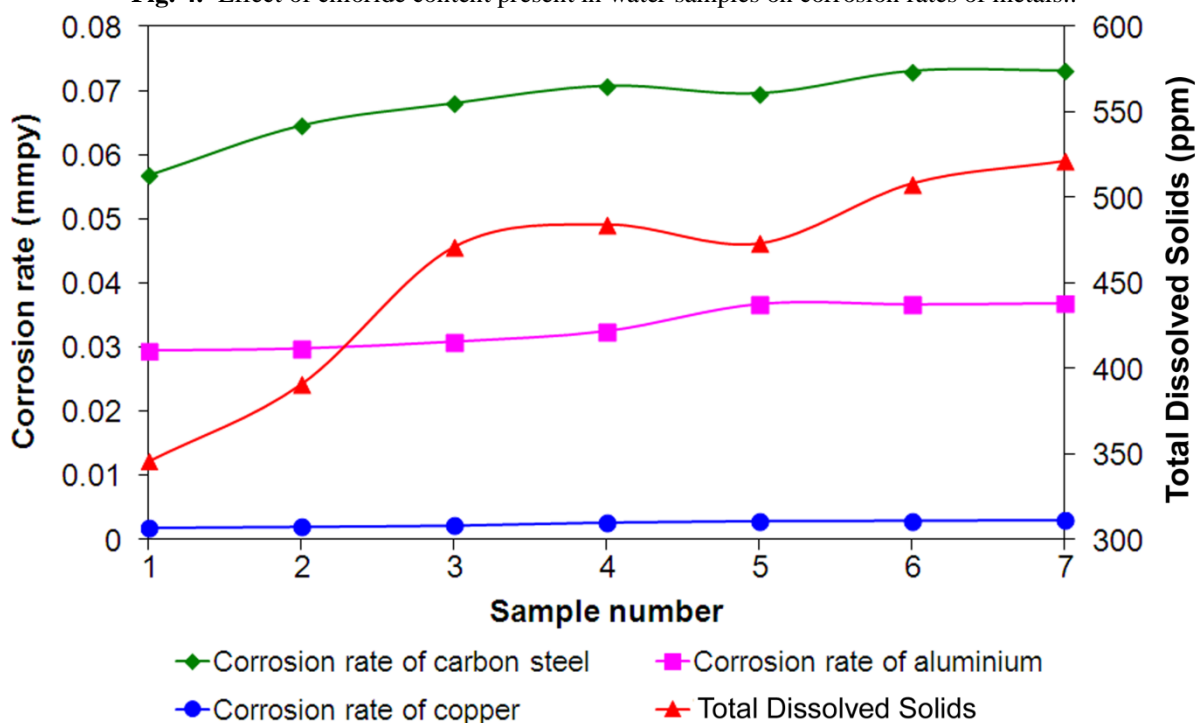


Fig. 5: Effect of total dissolved salts present in water samples on corrosion rates of metals

Figure 3 shows that electrolytic conductivity of water samples 1 to 4 increased, slightly decreased for sample 5 and then rapidly increased for samples 6 and 7. It is interesting to note that the corrosion rate of carbon steel also followed the same trend of conductivity. Fig. 4 shows the effect of chloride concentration on corrosion rates of metals in contact with different water samples. Concentration of chloride increased

from sample 1 to sample 2, decreased from sample 2 to sample 3 and from sample 4 onwards, the free chloride concentration increased. It is well-known that corrosion rate of metal increases with increase in free chloride concentration of the electrolyte [6]. Concentration of chloride, total dissolved solids and conductivity are the significant parameters to be considered while dealing with the corrosion aspects.

APPLICATION

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.

CONCLUSION

Variation of water quality parameters like chlorides, conductivity and total dissolved solids for Krishna river water followed the usual expected trend; however, the extent of variation of all the quality parameters is very low. Slight differences in these parameters indicate almost constant composition of river water along the river in the study region. From this observation, it can be inferred that significant variation in quality parameters may be observed by extending the study region of the river. The extent of corrosion of different metals in the collected samples is found to be in the order: carbon steel > aluminium > copper. Rate of corrosion of all the metals increases with increase in the water quality parameters like chloride content, total dissolved solids as well as conductivity, inferring that these parameters significantly influence rate of corrosion of the selected metals. The order of the metals in the extent of increase in corrosion rate due to water quality parameters is carbon steel > aluminium > copper. The present study can be useful in predicting the rate of corrosion of metals based on water quality parameters.

ACKNOWLEDGMENTS

The authors affiliated to V. R. Siddhartha Engineering College, are thankful to the Principal of the College for continuous encouragement and facilities provided for the experimental work.

REFERENCES

- [1] R. E. Melchers, *Corros. Sci.*, **2007**, 49, 3149-3167.
- [2] S. B. Lyon, In: Tony J. A. Richardson, (Ed.), Shreir's Corrosion, 2nd volume **2010** 1094-1106.
- [3] R. E. Melchers, *Corros. Sci.*, **2006**, 48, 4174-4201.
- [4] ASTM Standard G31-72, "Standard Practice for Laboratory Immersion Corrosion Testing of Materials," (Reapproved **1990**), *Annual Book of ASTM Standards*, (ASTM International, Philadelphia, **2004**).
- [5] R. A. Freeman, D. C. Silverman, *Corrosion*, **1992**, 48, 463-466.
- [6] R. Winston Revie, Herbert H. Uhlig, *Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering*, John Wiley & Sons, Inc., Publication, USA, **2008**, 4th Edition.