



Received: 15-11-2013

Accepted: 10-12-2013

ISSN: 2321-4902

Volume 1 Issue 4



Online Available at [www.chemijournal.com](http://www.chemijournal.com)

## International Journal of Chemical Studies

### Corrosion Tendencies of Some Metals in Underground Water Samples of Krishna District, Andhra Pradesh, India

S. Srinivasa Rao<sup>1\*</sup>, D. Sarada Kalyani<sup>1</sup>, M. Durga Bhavani<sup>1</sup>, N. Murali Krishna<sup>1</sup>

1. Department of Chemistry, V. R. Siddhartha Engineering College (Autonomous), Vijayawada 520 007, Andhra Pradesh, India..

\*[Email: [ssrnitw@gmail.com](mailto:ssrnitw@gmail.com), Tel: 91-8897557599]

---

Various water quality parameters of underground water at different locations in Krishna district of Andhra Pradesh, India, were determined by using different analytical methods and the results were correlated to evaluate the corrosion rates of some important metals like carbon steel, copper and aluminium in the underground water samples. The study was performed for the underground water collected at seven different sites in the villages of Krishna district along the Krishna 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.

---

*Keyword:* Metals, Corrosion rate, Gravimetric studies, Water quality parameters, Underground water.

---

#### 1. Introduction

Carbon steel, copper, aluminium, etc. are the commercially important metals used in various engineering and construction fields due to their better mechanical, physical and chemical properties. However, these materials 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 essential 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

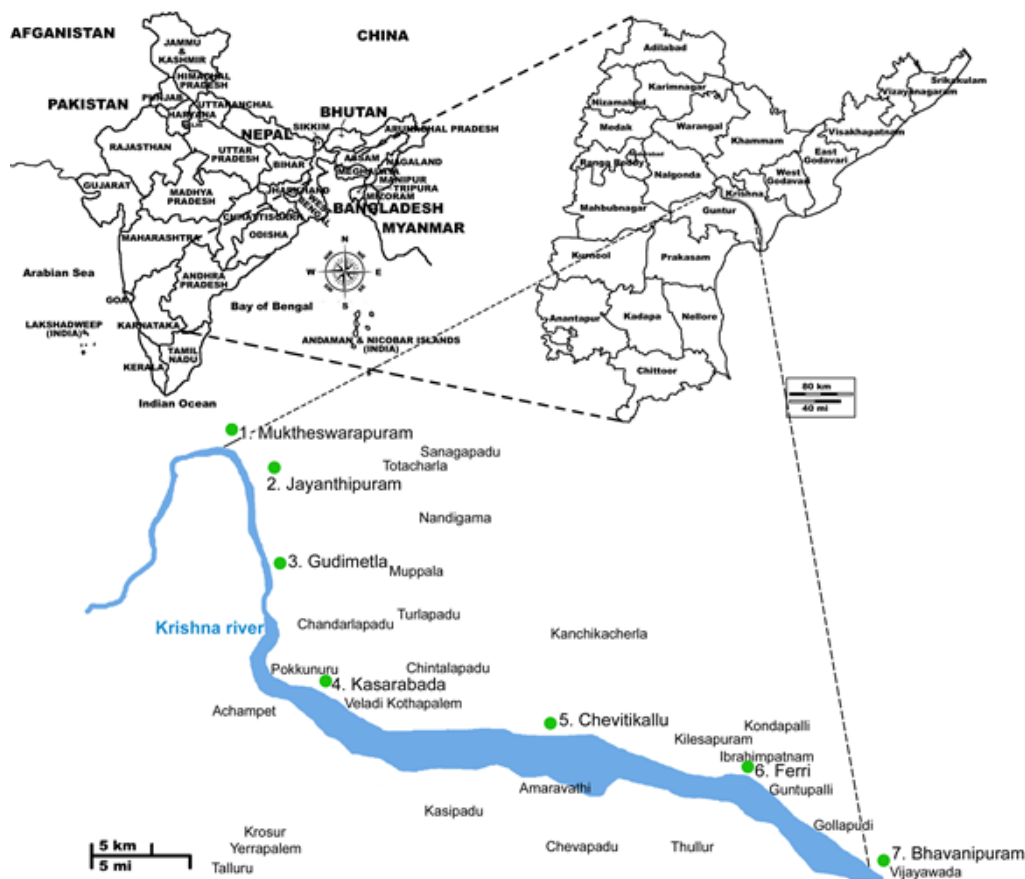
impurities in an underground water sample depend on several factors like nature of soils through which water flows from the earth surface, depth of penetration, influence of nearby surface water sources, etc. Hence, the type of impurity and extent of impurities vary from sample of one place to the sample of another. When underground water comes in contact with metallic structures like underground pipelines, motors, metallic 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 [1,2,3]. The main objective of the present study is to determine water quality parameters of the selected underground samples of water 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.

## 2. Materials and Methods

### 2.1. Sampling sites

The study area and sampling locations are shown in Figure 1. All the sampling sites are restricted to Krishna district of Andhra Pradesh state, a state of South India. The first sampling site is

Muktheswarapuram of Jaggaiahpet mandal and the last being Bhavanipuram of Vijayawada city, 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

### 2.2. Analytical methods and procedures

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 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  $\text{CaCO}_3$ .

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, 3.5x1.5x0.2 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 cm<sup>2</sup>, 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 1** Names of the sampling sites, locations and the corresponding sample numbers

Sampling site	Location	Sample number
Muktheswarapuram	Jaggaiahpet Mandal, Andhra Pradesh (16°49'49" N 80°04'58" E)	1
Jayanthipuram	Jaggaiahpet Mandal, Andhra Pradesh (16°49'43" N 80°09'14" E)	2
Gudimetla	Chandarlpadu Mandal, Andhra Pradesh (16°44'11" N 80°10'34" E)	3
Kasarabada	Chandarlpadu Mandal, Andhra Pradesh (16°40'18" N 80°09'34" E)	4
Chevitikallu	Kanchikacherla Mandal, Andhra Pradesh (16°37'27" N 80°22'57" E)	5
Ferri	Ibrahimpattam Mandal, Andhra Pradesh (16°35'08" N 80°31'04" E)	6
Bhavanipuram	Vijayawada, Andhra Pradesh (16°31'37" N 80°35'53" E)	7

**Table 2** Volumetric and instrumental methods used for chemical analysis of underground water in the selected mandals of Krishna district, Andhra Pradesh, India

Physical/chemical parameter	Unit	Method/Instrument
pH	–	pH meter (Elico Limited)
Electrolytic conductivity (EC)	mS	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 <sup>-</sup> )	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:

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

where mdd is milligram per square decimeter 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.

### 3. 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. From the table, it can be observed that pH is varied between 6.9 and 7.5 for all the seven samples. The electrolytic conductivity, chlorides and total dissolved solids of the sample 4 (at Kasarabada) were found to be highest among all the seven samples. These parameters are found to be surprisingly low in case of the sample 1 (at Muktheswarapuram). This sample is found to be unique among the samples collected as far as underground water

samples are concerned. The obtained water quality parameters of this water sample are highly unexpected as this location is highly polluted with cement manufacturing industries. The dissolved oxygen of the samples is varied between 5.4 ppm and 7.1 ppm. 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 sample 4 is observed to be 501.9 ppm which is highest among the samples while that of the sample 6 (collected at Ferri) is found to be 216.3 ppm the lowest value among all the seven samples.

**Table 3** Water quality parameters of underground water in the selected mandals of Krishna district, Andhra Pradesh, India

Parameter	Sample number						
	1	2	3	4	5	6	7
pH	6.9	7.0	7.1	6.9	7.1	7.5	6.9
Conductivity	0.65	1.24	1.91	3.02	2.59	1.93	1.35
Chlorides	24.2	303.5	211.2	365.2	352.9	231.0	202.4
TDS	325	2514	2230	3200	2907	1532	1188
TSS	75	205	157	107	128	117	102
DO	6.9	5.4	7.1	6.1	6.9	5.9	5.6
TH	334.8	423.2	460.4	501.9	485.6	216.3	346.4
CaH	301.5	320.3	308.9	299.1	374.0	118.3	254.1
CA	53.6	59.0	32.2	71.7	75.8	159.6	21.4
BA	161.0	142.2	252.9	205.9	152.9	254.1	246.6

#### 3.2. Corrosion rates of metals

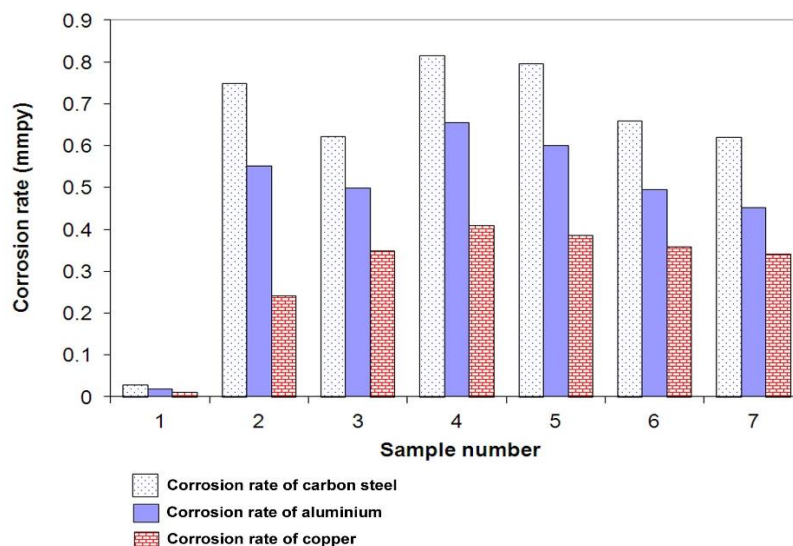
Corrosion rates of carbon steel, aluminium and copper in the collected underground water samples of Krishna district are shown in Figure 2. The figure shows that the corrosion rates of all the three metals are highest in case of the sample 4 (Kasarabada) and lowest in case of the Muktheswarapuram sample. 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 behavior of metals. The effects of conductivity, amount of chlorides and total dissolved solids on corrosion rates of the metals are shown in Figures 3 to 5 respectively.

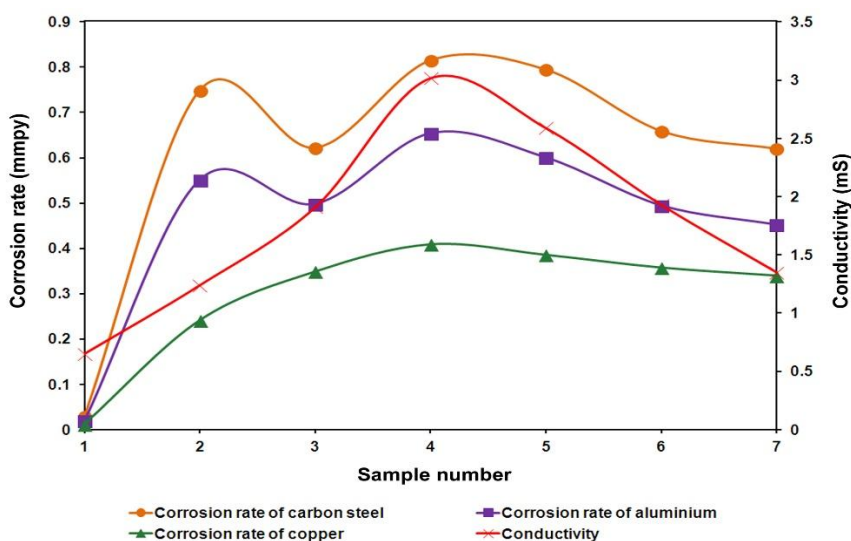
Electrolytic conductivity of a solution in contact with a metal surface is essential for any metal to undergo corrosion. It is well-known that corrosion rate of metal increases with increase in free chloride concentration of the electrolyte [6], due to high penetrating power of these ions.

Figures 3 to 5 show that electrolytic conductivity, chloride content and total dissolved solids are maximum for sample 4 and minimum for sample 1. Interestingly, corrosion rates of all the three metals are found to be highest in sample 4 and lowest in sample 1.

It indicates that the corrosion rates of the metals are directly proportional to the extent of conductivity, chlorides and total dissolved solids. It infers that the possibility is more for the application of underground water nearby Muktheswarapuram for industrial and domestic purposes as far as corrosion aspects are concerned. This is due to better water quality parameters observed in case of Muktheswarapuram sample. This observation is highly significant in view of the fact that underground water is generally more corrosive than surface water.



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



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

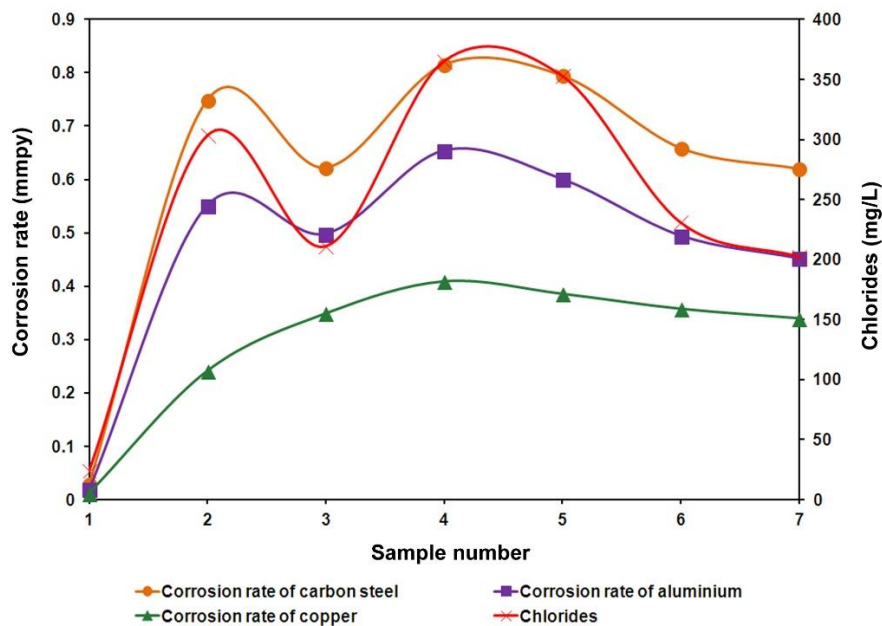


Fig 4: Effect of chloride content present in water samples on corrosion rates of metals

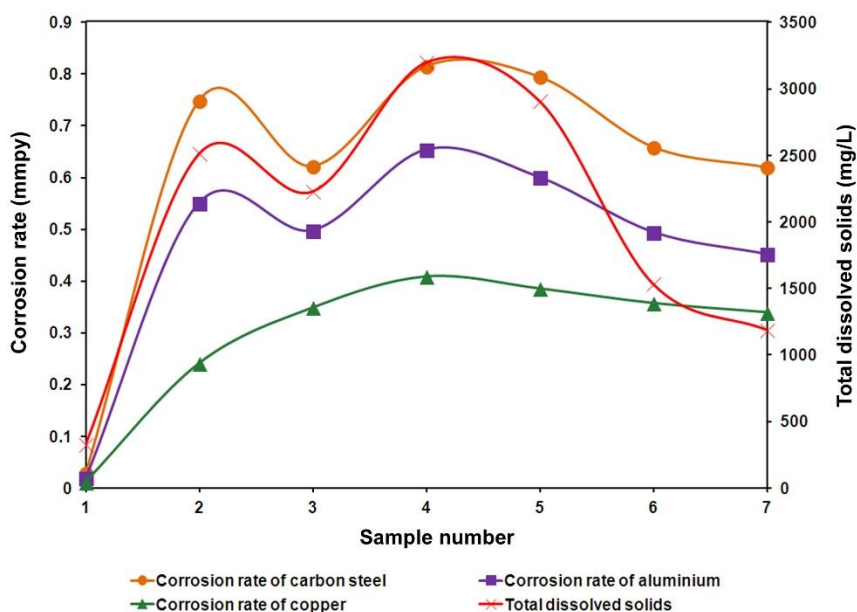


Fig 5: Effect of total dissolved salts present in water samples on corrosion rates of metals

#### 4. Conclusion

Water quality parameters like chlorides, conductivity, total dissolved solids, dissolved oxygen, etc. are found to be different for samples collected at different mandals of Krishna district. These parameters reported extremely low values in case of the sample at Muktheswarapuram 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. The most significant observation from the present study is that corrosion rates of metals are very low in the sample of Muktheswarapuram, probably due to

lower values of conductivity, chlorides and total dissolves solids compared with other samples. This observation facilitates the use of such water samples either directly or 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 behavior of these metals towards corrosion in aqueous environments with different qualities.

### 5. Acknowledgements

The authors are thankful to the Management and Principal of the College and Head of the Department of Chemistry, for their continuous encouragement and facilities provided to carry out experimental work.

### 6. References

1. Melchers RE. The effects of water pollution on the immersion corrosion of mild and low alloy steels. *Corrosion Science* 2007; 49(8):3149-3167.
2. Lyon SB. Shreir's Corrosion: Corrosion in Liquids, Corrosion Evaluation. Edn 3, Vol. 2, Elsevier, 2010, 1094-1106.
3. Melchers RE. Modelling immersion corrosion of structural steels in natural fresh and brackish waters. *Corrosion Science* 2006; 48(12):4174-4201.
4. ASTM Standard G31-72. Standard Practice for Laboratory Immersion Corrosion Testing of Materials: Annual Book of ASTM Standards. ASTM International, Philadelphia, 2004.
5. Freeman RA, Silverman DC. Error propagation in coupon immersion tests. *Corrosion* 1992; 48:463-466.
6. Winston Revie R, Uhlig HH. Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering. Edn 4, Wiley Interscience: John Wiley & Sons, Inc., Publication, USA, 2008, 131-133.