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Der Pharma Chemica, 2013, 5(1):125-130
(http://derpharmachemica.com/archive.html)

ISSN 0975-413X
CODEN (USA): PCHHAX

Atmospheric corrosion study of metals in an urban environment

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ABSTRACT

The present study concentrates on the atmospheric corrosion on metals after one year atmospheric exposure in urban environment. Monthly and Yearly Corrosion rate of Mild-steel (MS), Zinc and Aluminum as well as the Sulphation rate was determined during 2010-2012 under outdoor exposure in an urban environment at Ahmedabad (Dist. Ahmedabad) situated in Gujarat, India. Monthly corrosion rate vary from ***93*** *to* ***787****,* ***09*** *to* ***95*** *and* ***1.1*** *to* ***9.1*** *mg/sq.dm correspond to Mild Steel, Zinc and Aluminium respectively, whereas the Yearly corrosion rate vary from* ***1137*** *to* ***2438****,* ***72*** *to* ***506*** *and* ***8.1*** *to* ***29.8*** *mg/sq.dm for Mild-steel, Zinc and Aluminium respectively. Monthly corrosion rate was found in the decreasing order: Mild steel < Zinc < Aluminium. Corrosion rate of these three metals was found more in rainy seasons than the rate of winter and summer season.*

Keywords: Monthly and Yearly atmospheric Corrosion, Ahmedabad urban Environment, mild-steel, zinc and aluminium.

INTRODUCTION

The term "Atmospheric corrosion" comprises the attack on metal exposed to the air as opposed to metal immersed in a liquid. Atmospheric corrosion is the most prevalent type of corrosion for common metals [1]**.** The atmospheric corrosion of mild steel is an extensive topic that has been studied by many authors. Useful reviews have been performed by several researchers [2].

Urban atmosphere is similar to rural atmosphere where there is little industrial activity, characterized by pollution composed mainly of SO_x and NO_x variety, from motor vehicles and domestic fuel emissions which, with the addition of dew or fog. Generate a highly corrosive wet acid film on exposed surfaces (deposition rate of SO_2 higher than 15 mg m^{-2} day^{-1}) and that of NaCl lower than this value. In developed countries, the national annual cost of corrosion varies 1% to 3.5% of the Gross National Product (GNP) [3]**.**

D. D. N. Singh et al. reported [4]corrosion rate of steel exposed for two years at different locations of India found that, Chennai (urban) 19.0 µm/y, 12.9 µm/y and Delhi (dry, urban polluted) 13.9 µm/y.

H. K. Kadiya et al. reported [5] corrosion rate of mild steel exposed for one year at Valsad (South Gujarat) of India was found in the range of 2575 to 3667 mg/sq.dm.

In India, data regarding the relative corrosivity of atmospheres at Ahmedabad [6] (urban) are available.

MATERIAL AND METHODS

Test plates of Mild steel, Zinc and Aluminium have the following chemical composition:
a)Mild-steel : C (0.062%), Mn (0.291%), S (0.007%), P (0.011%), Si (0.006%), Cr (0.010%), Al (0.047%), Cu (0.002%), Mo (0.001%), Ni (0.004%) and Fe-rest.

b)Zinc : 99.41 % purity, Pb (0.02% Max), Cd (0.01% Max.) and Fe (0.015% Max.)
c) Aluminium : 99.19 % purity and Si (0.55%).

Test plates are individually mounted on a wooden rack. Special care should be taken that they were electrically insulated from surrounding metallic stand. The frame was placed in parallel outdoor fully exposed condition on the ground level making an angle of 45° towards the horizontal plane. Two types of time duration viz., monthly and yearly were considered for calculation of corrosion rate with time. All tests were carried out in duplicate and mean of the two values were taken. After exposure period test plates were wrapped in plastic bags and brought to the laboratory for cleaning. Different cleaning solutions are to clean different metals. Hudson used Clark's solution [7-8] to remove rust from **Mild-Steel** made by 2% Sb_2O_3 (antimony Oxide), 5% $SnCl_2$ (stannous chloride) in concentrated HCl (100 ml) at room temperature with constant stirring about 15-20 minutes. **Zinc** plates are derusted by 10% CrO_3 and about 0.2 gm $BaCO_3$ in distilled water (100 ml) at 25°C for about 2 minutes [9]**.** Corrosion products on **Aluminum** plates were removed by using the solution of concentrated HNO_3 containing CrO_3 (chromic acid, 50 mg/lit) at a room temperature for about 10 minutes [10]**.**

Control specimen was used to determine the loss of metal in a cleaning solution and the final figures of the loss in weight of exposed specimens were corrected accordingly.

Sulphur dioxide is considered as a major air pollutant causing the corrosion of most metals. The **lead peroxide method** used for monitoring SO_2 content in air [11-12] essentially, the technique depends upon the measurement of Sulphation caused by gaseous SO_2 on an exposed lead peroxide (PbO_2) paste. Lead dioxide in paste form was painted as a thin layer on a gauze cylinder (candle method) and allowed to dry. This PbO_2 reacts with SO_2 of air to form $PbSO_4$. After exposure, the lead peroxide layer was removed and the sulphate content was determined by a gravimetric method. These candles were exposed at the ground level on a rack with the panels.

RESULTS AND DISCUSSION

Meteorological and pollution data:-
The average maximum and minimum temperature was noted as **314** K and **284** K corresponds to the year 2010 to 2011 respectively. There is a considerable variation in temperature during all months. The data of rainfall (in mm) and number of rainy days of the year 2011 are mentioned in Fig.1. Relative humidity (minimum and maximum) in percentage is shown in Fig.2. The relative humidity at urban station was found to be higher than the critical relative humidity value (70%).

Sulphation rate (in mg SO_3/sq.dm/month) of the study area is shown in Fig.3. The prominent direction of wind is South-West (SW) during summer and monsoon season, with comparatively higher speed (9.0 km/hr). A Sulphation rate was measured at Ahmedabad urban environment shows an appreciable value ranging from 11.5 to 29.5 mg SO_3/sq.dm/month Fig.3.

A mean Sulphation rate was measured 34.6 mg/m^2.d SO_2 (average 6 months) at Cuba [13]**,** 0.3 to 9.0 mg/SO_2/m^2.d^{-1} of 22 urban atmospheric in the Ibero-American region [14]**,** 0.98 mg SO_3/sq.dm/day at Jamshedpur [4]**,** 10.2 to 20.2 mg SO_3/sq.dm/month at Valsad [5] and 0.85 mg SO_3/sq.dm/day at Chennai [4]**.** In Urban atmosphere, however the SO_2 deposition rate was measured between 10 to 100 mg $m^{-2}d^{-1}$ [15]**.**

(1) Mild-Steel (MS):
The corrosion suffered by MS was mainly of a general type. Approximately 1.3 mm thick corrosion product was found deposited on a panel of a twelve months exposure period. Corrosion rate of MS varied from month to month and from season to season.

Monthly corrosion rate of MS was found in the range of **93** to **787** mg/sq.dm/month. These values are higher than that measured at 46 to 324 mg/sq.dm at Kanpur [16]**,** 20 to 286 mg/sq.dm at Jodhpur [17] and 83 to 635 mg/sq.dm at Tezpur [18]**.**

The yearly corrosion rate was found in the range of **1137** to **2438** mg/sq.dm Fig. 4. These values are higher than the value of 312 to 529 mg/sq.dm at Jodhpur [17], 1473 to 3409 mg/sq.dm at Tezpur [18] and lower than the value of 2575 to 3667 mg/sq.dm at Valsad [5].

Panels exposed in winter months (November to February) indicate lower initial corrosion loss than the panels exposed to rainy months (June to September). This suggests that a protective film is formed on metal surface which can resist attack during subsequent exposure. Whereas higher corrosion rate in rainy months are attributed to the corrosion product which is washed regularly by rain keeping fresh metal surface exposed to further corrosion. Lower corrosion rate in summer months (March to May) are due to the removal of gaseous and particulate pollutants from the atmosphere by higher wind velocity.

(2) Zinc:
The corrosion suffered by a zinc plate is of the general type (uniform attack). Corrosion rate of zinc varied from month to month.

Monthly corrosion rate of zinc varied from **09** to **95** mg/sq.dm. This value are higher than the value of 2.1 to 40 mg/sq.dm at Kolkatta [19]**,** 12 to 40 mg/sq.dm at Bombay [20]**,** 10.7 to 42.5 mg/sq.dm at Baroda [21]**,** 17 to 59 mg/sq.dm at Surat [22] and lower than the value of 19 to 109 mg/sq.dm at Valsad [5]**.**

Yearly corrosion rate of zinc at an urban station was varied from **72** to **506** mg/sq.dm (Fig.-5). This value is higher than the value of 41 to 115 mg/sq.dm at Surat [22] and lower than the value of 181 to 459 mg/sq.dm at Valsad [5]**.** Average corrosion rate was obtained in the rainy months (**272** mg/sq.dm) is higher compared to the values obtained in summer months (**152** mg/sq.dm) and winter months (**94** mg/sq.dm)

(3) Aluminum:
No significant attack was observed on aluminum panels. The corrosion rate of aluminum was found very low compared to Mild Steel and Zinc.

Monthly corrosion rate for aluminum was found in the range of **1.1** to **9.1** mg/sq.dm. This value was higher than the value of 5.0 to 16 mg/sq.dm at Surat [22] and lower than the value of 1.5 to 17.8 mg/sq.dm at Valsad [5]**.**

Yearly corrosion rate of aluminium was found in the range of **8.1** to **29.8** mg/sq.dm (Fig.-6). This value is lower than the value of 25 to 37 mg/sq.dm at Baroda [21] and lower than the value of 8.3 to 37.2 mg/sq.dm at Valsad [5]**.**

Average seasonal corrosion rate of aluminium was obtained in the rainy months (**21.8** mg/sq.dm) is higher compared to the values obtained in winter months (**6.9** mg/sq.dm) and summer months (**9.7** mg/sq.dm)

Low corrosion rate of aluminum in outdoor exposure is attributed with the formation of a more protective oxide film on the metal surface which might have offered protection to the metal from reacting with the surrounding environment.

Fig. 1: Rainfall (in mm) and number of rainy days at Ahmedabad Urban Environment.

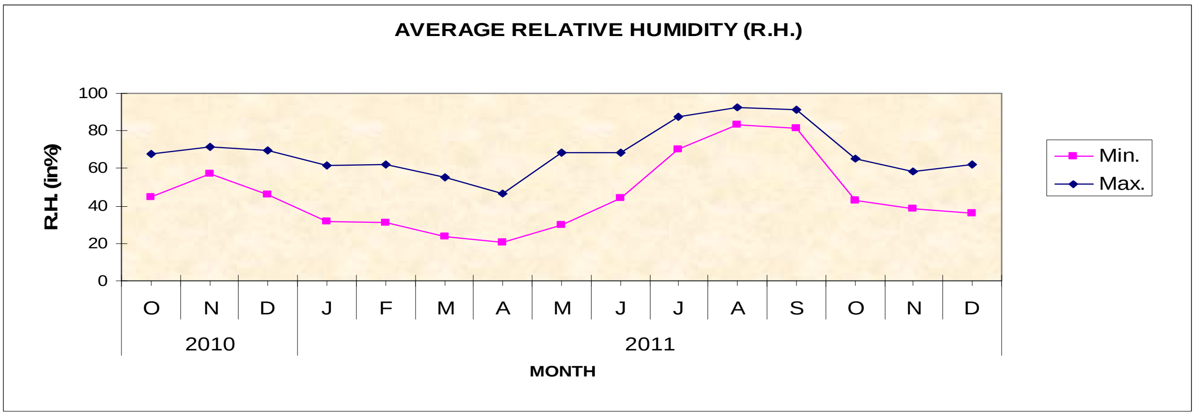


Fig. 2: Relative Humidity (in %) at Ahmedabad urban Environment.

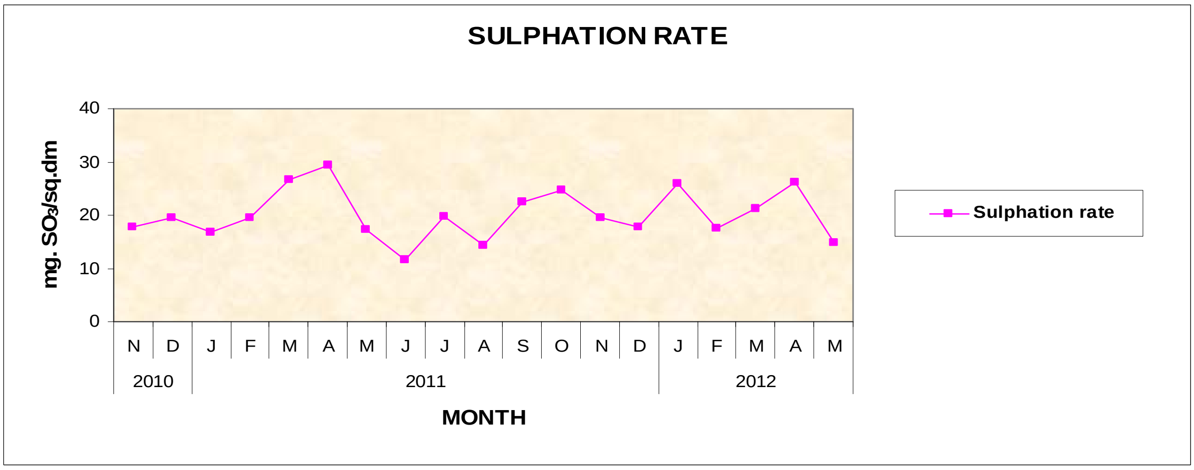


Fig.3: Sulphation rate (in mg. SO_3/sq.dm/month) at Ahmedabad Urban Environment.

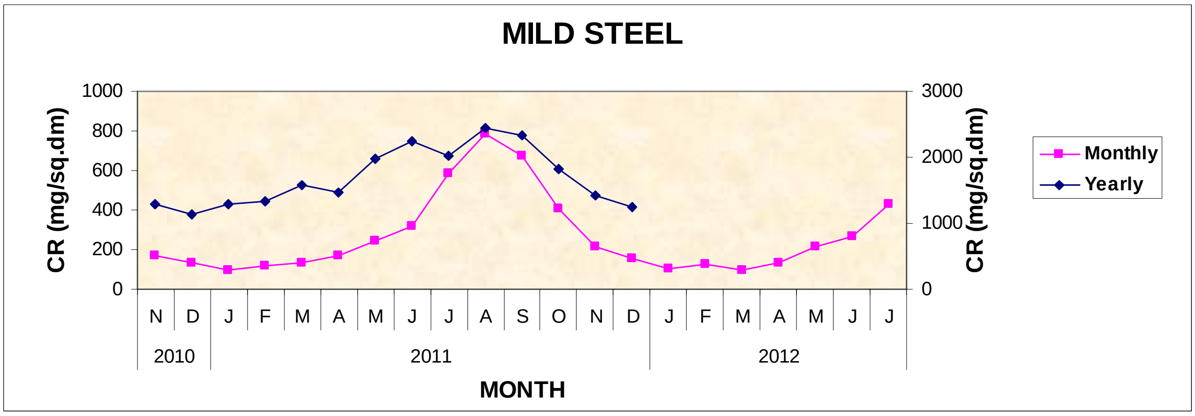


Fig. 4: Monthly and yearly corrosion rate of mild steel under outdoor exposure during different months.

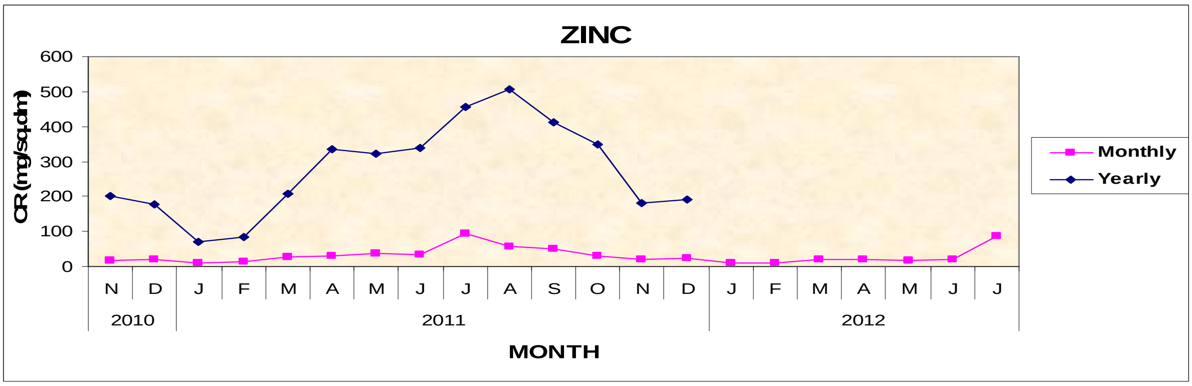


Fig. 5: Monthly and yearly corrosion rate of zinc under outdoor exposure during different months.

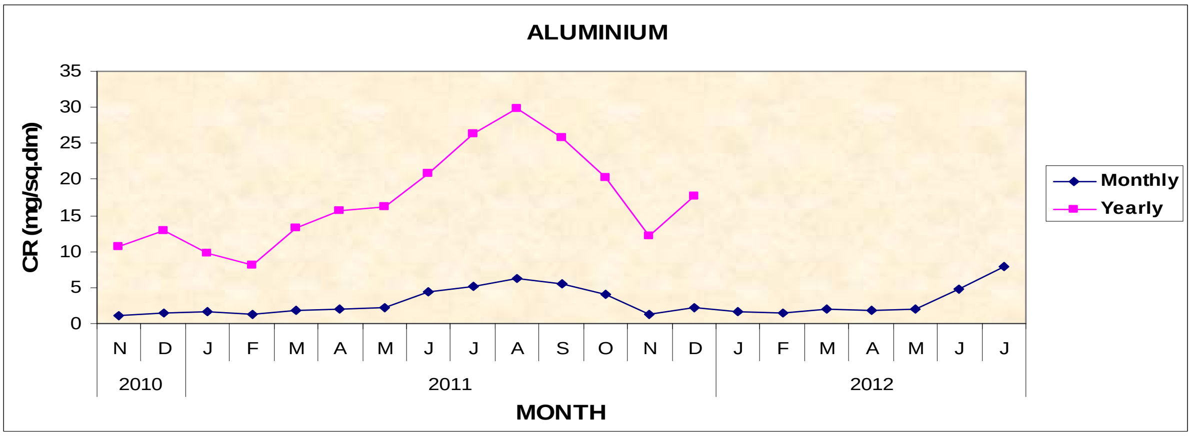
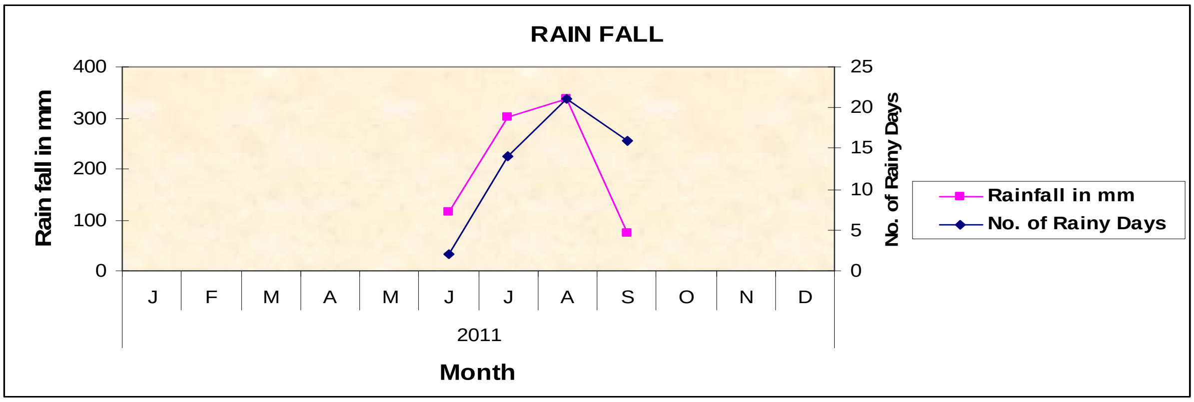


Fig. 6: Monthly and yearly corrosion rate of aluminium under outdoor exposure during different months.



CONCLUSION

Monthly corrosion rate of MS was **5** to **14** times higher compared to Zinc. Similar results obtained at different cities are as follows: 12 at Bombay [14] and 6 to 41 at Baroda [21]. The yearly corrosion rate of MS was **4** to **1 8** times higher than Zinc.

Monthly corrosion rate of MS of urban Environment was **54** to **153** times higher compared to Aluminium. Similar results obtained at 27 to 200 at Surat [22]**;** whereas Yearly corrosion rate ratio of MS:Al varies from **70** to **164**.

Monthly corrosion rate of Zinc of urban Environment was **4** to **17** times higher compared to Aluminium. Similar results obtained at Surat [22] (7 to 15 times), whereas yearly corrosion rate of Zinc was **7** to **22** times higher compared to Aluminium.

Acknowledgements
The authors are thankful to Kadisarvavishwavidhyalaya, Gandhinagar, Department of Chemistry and Biochemistry, C. U. Shah Science College Ahmedabad for providing laboratory facilities.

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