

Kinetics of Atmospheric Corrosion of Mild Steel in Marine and Rural Environments

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Abstract: In continuation of the extensive studies carried out to update the corrosion map of India, in this study, the degradation of mild steel by air pollutants was studied at 16 different locations from Nagore to Ammanichatram along the east coast of Tamilnadu, India over a period of two years. The weight loss study showed that the mild steel corrosion was more at Nagapattinam site, when compared to Ammanichatram and Maravakadu sites. A linear regression analysis of the experimental data was attempted to predict the mechanism of the corrosion. The composition of the corrosion products formed on the mild steel surfaces was identified by XRD technique. The corrosion rate values obtained are discussed in the light of the weathering parameters, atmospheric pollutants such as salt content & SO₂ levels in the atmosphere, corrosion products formed on the mild steel surfaces.

Keywords: Kinetics; atmospheric corrosion; mild steel; XRD; weight loss

Article ID: 1671-9433(2015)01-0105-08

1 Introduction

Atmospheric corrosion may cause serious damage to metallic structures and equipments. The effect is so serious that the annual cost of atmospheric corrosion is approximately half the total annual cost of all types of corrosion of metals (Ke, 2003). The atmospheric corrosion of metals is an electrochemical reaction, involving the anodic dissolution of the metal, the cathodic reduction of an oxidant, such as oxygen or γ -FeOOH, and the transport of reactants and products to and from the surface (Evans, 1969; Misawa *et al.*, 1974; Keiser *et al.*, 1983; Raman *et al.*, 1986; Suzuki *et al.*, 1979). Numerous investigations on atmospheric corrosion have been attempted world wide (Cao, 2005; Uhlig, 1950; Barton, 1976; Rozenfeld, 1972). It is well established that the phenomenon of atmospheric corrosion is greatly influenced by many environmental factors viz, temperature (T), relative humidity (RH), sunshine, duration and frequency of rain, dew and fog, speed and direction of wind, *etc.* In addition, pollutants present in the atmosphere including salinity, SO₂, NO_x, O₃, NH₃, and wind-blown soils and sands *etc.* may enhance the

rate of the corrosion processes (Philip and Schweitaer, 1999; ISO, 1992a; Tran *et al.*, 2006; Marco *et al.*, 2000; Santana Rodrigues *et al.*, 2002). Added to this, they can also cause a decrease in the critical relative humidity and increase their aggressiveness. Many research groups have attempted and obtained empirical relationships between corrosion rate and environmental parameters. Effects of meteorological variables and contaminants such as SO₂, Cl⁻ on atmospheric corrosion were taken into account in these studies (Mendoza and Corvo, 1999; Oh *et al.*, 1999; Feliu *et al.*, 1993; Lan *et al.*, 2005) has analyzed the corrosion rate of mild steel, zinc, galvanized iron and aluminium for five years in 57 exposure sites (Rao and Lahiri, 1970; Natesan *et al.*, 2005a; 2005b; 2006a; 2006b; 2006c). In the present work, atmospheric corrosion of mild steel was studied at 16 locations from Nagore to Ammanichatram in the east coast areas of Tamil Nadu, a southern state of Indian peninsula by weight loss method over a period of two years. Atmospheric pollutants such as salinity and sulfur dioxide were estimated in those 16 sites and they were correlated with corrosion rates. The nature and rate of atmospheric corrosion of a metal or alloy depend on the level and type of gaseous pollutants present in the atmosphere and duration of their action on the metal surface. Corrosivity data are essential for the development and specification of optimized corrosion resistant for manufactured products. The environmental characteristics and corrosivity categories in these sites are discussed.

2 Experimental procedure

The exposure test was conducted at 16 different locations from Nagore to Ammanichatram (120km) in the east coast road (ECR) of Tamilnadu. The sites are situated at the latitude of 13°06' North and longitude of 80°18' East and its locations are shown in Fig. 1. The details of the exposure stations are given in Table 1. The ECR is surrounded by sea, aquaculture and agricultural lands. The sea water spray and deposition of wind driven salt during transportation and storage at building sites for a long period prior to their installation in concrete structures leads to the formation of corrosion products on the surface of reinforcement steel. Commercially available mild steel plates of compositions (C-0.18%, Mn-0.73%, P-0.007%, S-0.017%, Si-<0.01%, Ni-<0.01%.) and size 150 mm×50 mm with thickness of

Received date: 2014-06-12.

Accepted date: 2014-09-22.

Foundation item: M/s IRCON International Pvt, Ltd, Muthupettai, Tamilnadu, Sponsored project No: SSP09/06.

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6 mm, supplied by M/s IRCON International Private Ltd, New Delhi were used in this study. The samples were exposed for the period of 2 years. Specimens were cleaned to remove scale and other products by pickling (ASTM G1-90.,1990), polished manually using 120 emery wheel

(ASTM Committee G02) to mirror finish, degreased with trichloro ethylene and weighed before exposure. The metal specimens in triplicate were then positioned on the exposure stands in outdoor conditions at an angle of 45° to the horizontal facing seacoast as shown in Fig. 2.



Fig. 1 Location of the test site



Fig. 2 Atmospheric exposure stand

Table 1 Exposure site details along with average pollutants

Site No.	Site	Prominent features	Average yearly chloride content/ (mg/m ² /day)	Average yearly SO ₂ content/ (mg/m ² /day)
1	Nagore	A residential area site at the top of single story building and 100 m away from sea	19.45	Traces
2	Puthur	A residential area site at the top of single story building and 1 km meters away from sea	23.40	Nil
3	Nagapattinam 1	A residential area site at the top of single story building and 1 km away from sea	17.03	Traces
4	Nagapattinam 2	A fish cultivation land site surrounded by salt water and 1 km away from sea	24.52	Traces
5	Karunganni	Site at the top of a single story building surrounded by agriculture land and 5 km away from sea	18.07	Nil
6	Keelayur	Site at the top of a single story building surrounded by agriculture land and 8 km away from sea	16.03	Nil
7	Alangudi	Site at the top of a single story building surrounded by agriculture land and 10 km away from sea	16.47	Traces
8	Odachery	Site at the top of a single story building surrounded by agriculture land and 10 km away from sea	19.58	Nil
9	Neermulai	site at the top of a single story building surrounded by agriculture land and 10 km away from sea	16.54	Nil
10	Thiruthuraiipoondi	site at the top of a single story building surrounded by agriculture land and 15 km away from sea	16.75	Traces
11	Nachikulam	Site at the top of a single story building surrounded by agriculture land and 15 km away from sea	14.81	Nil
12	Alangadu	Site at the top of a single story building surrounded by agriculture land and 5 km away from sea	17.17	Traces
13	Muthupet	Site at the top of a single story building surrounded by agriculture land and 3 km away from sea	19.84	Traces
14	Thambikottai	Site at the top of a single story building surrounded by agriculture land and 3 km away from sea.	13.95	Nil
15	Maravakkadu	Site was surrounded by agriculture land and 5km away from sea the exposure stands were erected in the ground level	20.11	Nil
16	Ammanichatram	Site at the top of a single story building surrounded by agriculture land and 3 km away from sea	17.89	Nil

The tests were carried out during the years 2006–2008. After the exposure of 1, 3, 6, 9, 12, 15, 18, 21 and 24 months, the metal specimens were removed from the test site. They were cleaned in the pickling solutions described in the ASTM norms G1-90 (ASTM International, 1990) dried and reweighed. The corrosion loss of the specimens was determined by the gravimetric method according to ISO 9226 (ISO, 1992c) and the average corrosion rate values of three specimens for each exposure period was reported. Pollution by SO₂ and airborne salinity represented by chloride, were evaluated continuously on every month by deposition methods (by lead peroxide candle and wet candle methods, respectively) (ISO, 1992b). The corrosivity category may be determined from corrosion rates for first year exposure of standard specimens. The pollution level is the main characteristic of the corrosivity of atmosphere (ISO, 1992a). At all 16 exposure sites, the pollution by SO₂ was classified as P₀ (the lowest possible category) and chloride was S₁ (medium) and all the sites were designated as the S₁ P₀ environment. The composition of the corrosion products of the exposed samples was determined by X-ray diffraction analysis (XRD) (JEOL-JDX-8030). The time of wetness was calculated as per ISO (1992a).

3 Results and discussion

3.1 Climatic conditions of exposure sites

All the exposure sites are located within town/urban areas of Nagapattinam (Nagore, Nagapattinam1, Nagapattinam 2, Karunganni and Keelayur), Thiruthuraiipoondi (Alangudi, Odachery, Neermulai Thiruthuraiipoondi and Nachikulam) and Muthupet (Alangadu, Muthupet, Thambikottai, Maravakadu and Ammanichatram) mean annual variations of temperature, relative humidity (RH), and the rain fall at these three locations are given in Table 2.

Table 2 Climatic data observed at three major cities

City	Temp/°C	Rainfall/mm	RH/%
Nagapattinam	24.7–32.4	1 400–1 800	70–77
Thiruthuraiipoondi	23–27	700	45–55
Muthupet	28–30	1 200	65–75

Average annual temperature in Nagapattinam, Thiruthuraiipoondi and Muthupet are in the range of 24.7–32.4 °C, 23–27 °C, 28–30 °C, the average RH varied from 70% to 77%, 45%–55% and 65%–75%, annual rainfall varied between 1 400–1 800, 700 and 1 200 mm respectively. Most of the rainfall is received from October to December under the influence of northeast monsoon and during June and July in the southwest monsoon period. Rainfall is higher in the coastal area and progressively decreased towards inland. Air pollutants such as salinity and SO₂ were also monitored at 16 locations during the study period and the

results are reported in Table 1. The salinity content in the atmospheres varies from location to location. No industry is there in the studied area and the major source of air pollution is due to domestic activities and rural conditions. Due to this, the SO₂ was estimated and found to be traced. The results of the monitoring data indicate that the ambient air quality of these locations in general is in line with traditional values. During nighttime, the specimen temperature lowers to the dew point, a thin moisture film is formed on the specimen surface which evaporates during the day. The data of meteorological parameters were obtained from the meteorological observatory, Chennai, for the entire study period. Up to 1 year, the levels of sulphur dioxide and chloride were monitored on a monthly basis and after that once in 3 months, till the end of the study period.

3.2 Time of wetness

A quantitative relation was obtained in order to calculate the time of wetness (TOW) as a function of average annual temperature (T) and relative air humidity (RH), where (P) represents a probability distribution function. The time of wetness, TOW (h/year) can be calculated by the equation (Tidblad *et al.*, 2000):

$$TOW=8\ 766\times P(T)\times P(RH)$$

TOW can vary from nearly zero to 8 766 h/year or from zero to unity in parts of the year. As per the equation the time of wetness was calculated for 3 different sites, namely Nagapattinam, Thiruthuraiipoondi and Muthupettai and the corresponding values are 5 031 h/year, 1 474 h/year and 4 615 h/year respectively. It is due to climatic conditions prevailing at the test sites.

3.3. Corrosivity classification

The nature and rate of atmospheric corrosion of a metal or alloy depend on the level and type of gaseous pollutants present in the atmosphere and duration of their action on the metal surface. Corrosivity data are essential for the development and specification of optimized corrosion resistant for manufactured products.

The corrosivity category may be determined from corrosion rates for first year exposure of standard specimens. The pollution level is the main characteristic of the corrosivity of atmosphere (ISO, 1992a). At all 16 exposure sites, the pollution by SO₂ was classified as P₀ (the lowest possible category) and chloride was S₁ (medium) and all the sites were designated as the S₁ P₀ environment. Table 3 shows the classification of corrosion rate as per ISO 9223 norms. The levels of chloride are the annual average of 1st & 2nd year. It is evident that, the corrosion rate of steel plate for the first and second year exposure are in range of 25–50 μm/y and 1.6–25 μm/y which is due to high salinity, moderate temperature and humidity during the first year, with duration of exposure extends up to 24 months, the corrosion rate is minimized due to protective corrosion products formed on the metal surface.

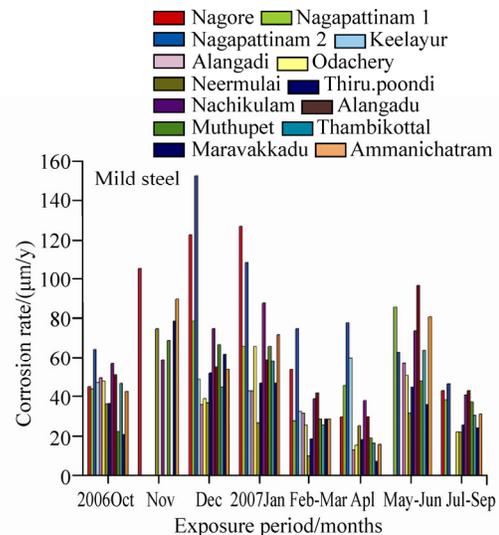
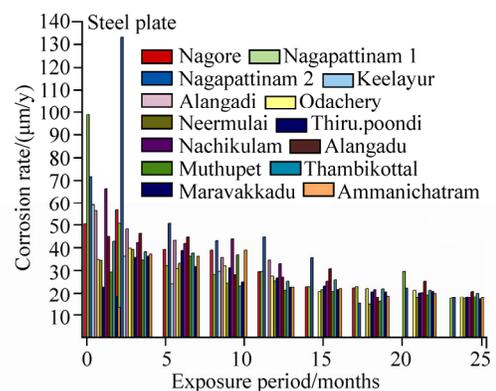
Table 3 Classification of corrosion rate as per ISO 9223 norms

Name of the exposure site	First year		Second year		Average yearly chloride content	
	$\mu\text{m}/\text{y}$	Corr.Cat.	$\mu\text{m}/\text{y}$	Corr.Cat.	$\text{mg}/\text{m}^2/\text{day}$	Cl ⁻ Cat.
Nagore	29.2	C3	missing		19.45	S1
Nagapattinam 1	29.5	C3	17.3	C2	17.03	S1
Nagapattinam 2	44.4	C3	17.7	C2	24.52	S1
Keelayur	missing	—	missing	—	16.03	S1
Alangudi	34.5	C3	missing	—	16.47	S1
Odachery	27.3	C3	18.0	C2	19.58	S1
Neermulai	25.2	C3	17.1	C2	16.54	S1
Thiruthuraiipoondi	26.5	C3	18.0	C2	16.75	S1
Nachikulam	32.9	C3	17.7	C2	14.81	S1
Alangadu	26.9	C3	20.5	C2	17.17	S1
Muthupet	21.0	C2	18.1	C2	19.84	S1
Thambikottai	25.1	C3	19.7	C2	13.95	S1
Maravakkadu	22.4	C2	17.0	C2	20.11	S1
Ammanichatram	22.4	C2	17.4	C2	17.89	S1

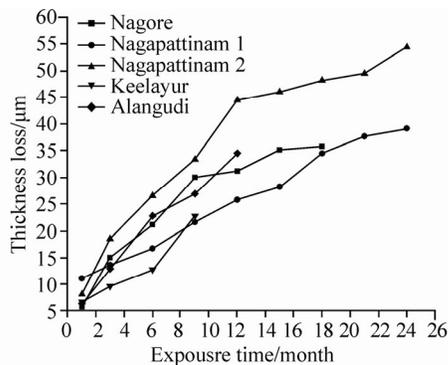
3.4 Seasonal variation of corrosion rate

The seasonal variation of monthly corrosion rate of mild steel as a function of exposure time at 16 different locations from Nagore to Ammanichatram is shown in Fig. 3. It is observed from the figure that the corrosion rate values are higher at Nagapattinam 2 exposure site during Dec'2006. The values corresponding to mild steel are $153 \mu\text{m}/\text{y}$. Lower values ($21.3 \mu\text{m}/\text{y}$) are observed at Maravakkadu and Ammanichatram sites during Oct' 2006. The higher values could be attributed to high humidity, moderate wind velocity and high salt content prevailing at the test site owing to storage of sea water for fish culture farm in the vicinity of exposure stand. The lower values are due to low levels of salt content, temperature, moderate humidity, and wind velocity.

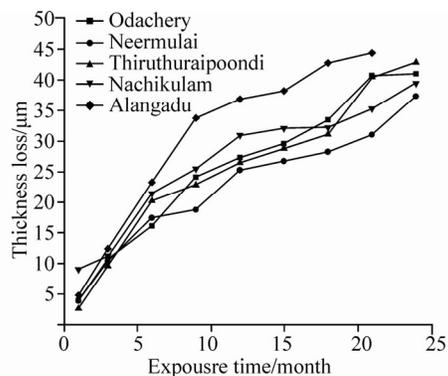
Fig. 4 shows the cumulative exposure study of mild steel at 16 different locations between Niagara and Ammanichatram. During 3 months exposure, the higher corrosion rate values for steel plates were observed at Nagapattinam 2 sites when compared to Nagore site. This could be attributed to high salinity content, moderate wind velocity, high humidity and temperature prevailing at this test site. As the duration of exposure increases, the corrosion rate value decreases to a considerable extent due to the formation of protective corrosion products onto the metal surface. The corresponding corrosion rate values for 6, 12, and 15 months are $50.5 \mu\text{m}/\text{y}$, $44.0 \mu\text{m}/\text{y}$ and $35.35 \mu\text{m}/\text{y}$ respectively. The decreasing trend was observed up to 24 months. The trend may be due to the protective character of the mild steel corrosion product layers, which once sufficiently developed, attenuate the effects of meteorological and pollution variables.

**Fig. 3 Seasonal variation of corrosion rate of mild steel****Fig. 4 Corrosion rate (3 months intervals) of steel plate**

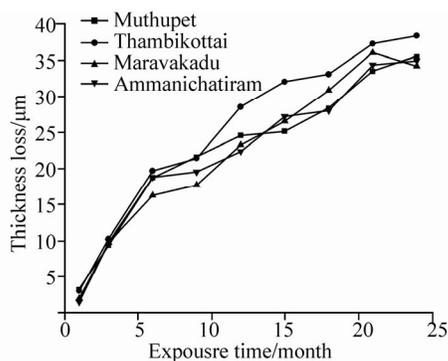
The cumulative corrosion rate of metals (steel plates, rods) lies in the range between 15–50 μm/y which corresponds to the corrosivity category of C2 and C3. The category C2 is low corrosivity and C3 is medium corrosivity. From the monthly corrosion rate values the corrosivity is under the category of C3, whereas the cumulative corrosion value it is under the category of C2 and C3. The corrosivity is medium for monthly, whereas it is low and medium for cumulative exposure specimens.



(a) Nagore, Nagapattinam 1, Nagapattinam 2, Keelayur and Alangudi



(b) Odachery, Neermulai, Thiruthuraiipoondi, Nachikulam and Alangadu



(c) Muthupet, Thambikottai, Maravakadu and Ammanichathiram

Fig. 5 Thickness loss of mild steel in different environment as a function of exposure

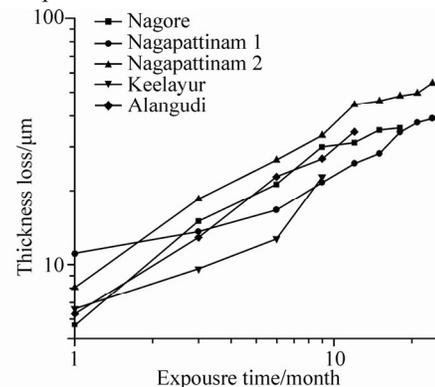
In general, the corrosion behavior of steel shows remarkable similarities in all the exposure sites. However, the reduction in the thickness of mild steel specimens was more pronounced in the Nagapattinam 2 and Nagore exposure sites. Figs. 6a–6c reproduces the results in Fig. 5 by plotting the thickness loss against the exposure time in

3.5 Kinetics of corrosion process

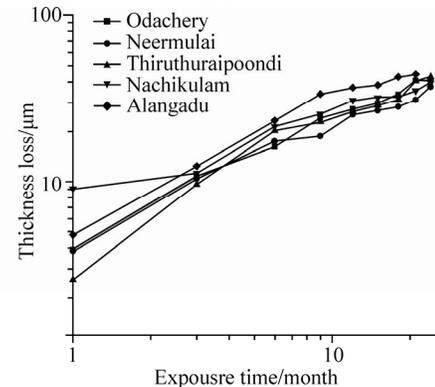
Figs. 5(a)–5(c) compare the reduction in thickness of the mild steel specimens at the different sites. The thickness reduction was calculated by the formula:

$$d = \frac{w \times 10^4}{\rho A} \tag{1}$$

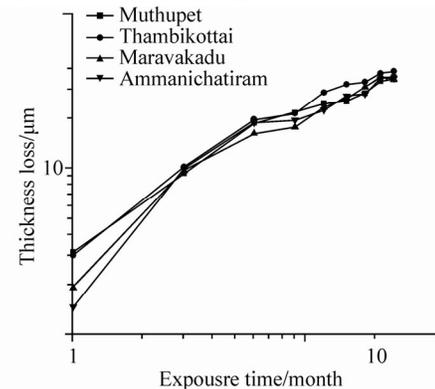
where d is the depth loss in μm, w is the weight loss in g, ρ the density of the steel (7.86 g·cm⁻³) and A is the surface area of the specimen in cm².



(a) Nagore, Nagapattinam 1, Nagapattinam 2, Keelayur and Alangudi



(b) Odachery, Neermulai, Thiruthuraiipoondi, Nachikulam and Alangadu



(c) Muthupet, Thambikottai, Maravakadu and Ammanichathiram

Fig. 6 Log-log plots of data points from Fig. 5

log-log coordinates. Various mathematical models have been used to describe the mechanism of corrosion and the most frequently employed is the power law that relates the weight (thickness) loss and the exposure time as follows (Natesan *et al.*, 2006b; 2006c)

$$C = A \times t^N \quad (2)$$

where C is the weight loss represented in terms of thickness reduction in μm , t is the period of exposure in months, A is the loss in thickness of the material in the first month of the exposure and N is a constant (If N is <1.0 , the corrosion products show protective, passivating characteristics, otherwise N is >1.0). In the present study, the corrosion kinetics of mild steel exposed in these sites are found to deviate from Eq. (2). The corrosivity data presented as the material thickness loss against the exposure time is shown in Figs. 6(a)–6(c). It is evident from these figures that the curves show a discontinuous line consisting of two linear segments. These experimental observations have been fitted to the Eq. (2) and the corresponding results are presented in Table 4.

Fig. 7 shows the schematic thickness loss versus time for mild steel for exposure sites, Nagapattinam 1 and Keelayur, in log-log coordinates. The representative equation for this irregular corrosion behavior can be described as (Ma *et al.*, 2009):

$$C = A \times t_1^{N_1 - N_2} \times t^{N_2} \quad t \geq t_1 \quad (3)$$

where C is the thickness loss, A is that in the first month, t_1 is the number of months of the first period of slope N_1 , and N_2 is the slope in the second period. The slope of the second segment is obviously smaller than that of the initial segment except Nagapattinam 1 and Keelayur exposure sites. Furthermore, the turning point of these linear segments differs with exposure sites. For the exposure sites Nagore, Nagapattinam, Alangudi, Odachery, Neermulai, Thiruthuraiipoondi, Nachikulam, Alangadu, Muthupet,

Thambikottai, Maravakadu and Ammanichathiram the value of slope of the first segment N_1 was greater than 0.5 indicating the acceleration of charge transfer controlled process as a result of the rust removal has been mainly caused either by heavy winds or by rains. This implies that the corrosion product formed on the exposed samples was protective and inhibit further corrosion by blocking the diffusion of corrosive species to the metal surface. In the case of Nagapattinam1 and Keelayur exposure sites, the values of N_1 corresponding to the first segment of exposure are 0.33, 0.36 and 0.54, 1.43 for the second segment respectively, indicating a small variation in the thickness loss in the first segment and then acceleration of corrosion in the second segment. From the atmospheric pollutants values recorded at various sites (Table 1), it is evident that the variations in the amount of chloride ions deposited on the mild steel specimens lead to variations in the corrosion kinetics (Table 4).

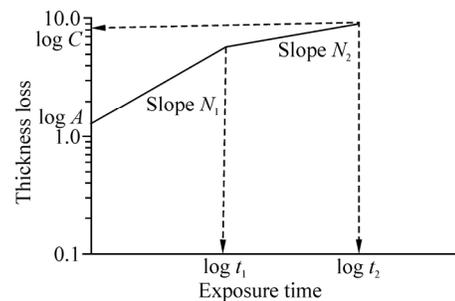


Fig. 7 Schematic diagram of the variation of the thickness loss of mild steel in atmosphere with time in log-log coordinates

Table 4 Corrosion kinetic parameters derived from the power law

No.	Exposure site	Experimental value A	A	Slope N_1	Slope N_2	Deviation month	R_2
1	Nagore	5.63	5.90	0.74	0.28	9	(0.99)
2	Nagapattinam1	11.04	10.26	0.33	0.54	12	0.93
3	Nagapattinam2	8.04	8.28	0.661	0.41	12	0.99
4	Keelayur	6.59	6.54	0.36	1.43	6	1.00
5	Alangudi	6.29	6.17	0.71	0.59	6	0.99
6	Odachery	3.88	3.99	0.81	0.58	9	0.99
7	Neermulai	3.80	3.87	0.86	0.53	6	1.00
8	Thiruthuraiipoondi	2.56	2.59	1.16	0.44	6	1.00
9	Nachikulam	9.02	8.33	0.46	0.40	9	0.84
10	Alangadu	4.75	4.71	0.89	0.33	9	1.00
11	Muthupet	3.14	3.14	0.99	0.42	6	1.00
12	Thambikottai	3.00	3.06	1.06	0.47	6	0.99
13	Maravakadu	1.90	2.06	1.22	0.52	6	0.97
14	Ammanichathiram	1.46	1.59	1.46	0.49	6	0.98

3.6 Corrosion product analysis

The durability of steel in a particular environment is assessed by measuring its corrosion rate or mass-loss after

different exposure times in that particular environment. The corrosion rate values are commonly measured as a function of environmental conditions and steel chemistry. These data

provide no information concerning the oxides or the chemistry of the corrosion product layers formed on the steel. However it is well known that identification of composition of the oxides as well as the corrosion products is very important in understanding the mechanism as well as the loss due to corrosion. XRD patterns recorded for the corrosion products quite often finds useful in identifying the nature of corrosion products. Table 5 provides the 2θ values derived from the XRD peaks and the corresponding nomenclature of the corrosion products collected from the exposed panels from different test sites of Nagore, Nagapattinam 1, Nagapattinam 2, Alangudi, Odachery, Neermulai, Thiruthuraiipoondi, Nachikulam, Alangadu, Muthupet, Thambikottai, Maravakadu and Ammanichatram respectively.

The XRD studies revealed that the corrosion products are lepidocrocite (γ -FeOOH), goethite (α -FeOOH), magnetite (Fe_3O_4) and hydrated maghemite (γ - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$). These forms are typical steel corrosion products exposed to atmosphere and similar results have been reported earlier (Cook, 2005; Yamashita *et al.*, 2000). The XRD pattern also shows that the corrosion products mainly consist of lepidocrocite and a broad diffraction peak at 21.29 shows the presence of very small amount of goethite. It can also be seen from these figures that in some places very little quantities of magnetite (peak at 30.23) and hydrated maghemite (peak at 38.20) corrosion products are conformed. There is no β -FeOOH formation in the corrosion products of steel.

Table 5 XRD data of the corrosion products

Exposure site	2θ value	Nomenclature of the Corrosion products
Alankadu	23, 27, 36, 38	Goethite α -FeOOH, lepidocrocite, γ -FeOOH, γ -FeOOH, γ - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ hydrated maghemite
Alankudi	20, 25, 35, 26	Lepidocrocite γ FeOOH, goethite α FeOOH, Fe_3O_4 magnetite
Ammanichatram	27, 35, 37	Lepidocrocite γ FeOOH, γ FeOOH, magnetite Fe_3O_4
Maravakkadu	28, 35, 38	Lepidocrocite γ FeOOH, γ FeOOH, hydrated maghemite γ - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$
Muthupet	20, 25, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH
Nachikulam	21, 27, 30, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH, γ - Fe_3O_4
Nagapattinam 1	21, 26, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH
Nagapattinam 2	20, 25, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH
Nagore	26, 35, 38, 46	Lepidocrocite γ FeOOH, γ FeOOH, hydrated Maghemite γ - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, Iron sulphide FeS
Neermulai	20, 26, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH
Odachery	20, 26, 29, 35	Goethite α -FeOOH, lepidocrocite γ -FeOOH, γ -FeOOH, magnetite Fe_3O_4
Thambikottai	27.5, 30, 35	Magnetite Fe_3O_4 , goethite α -FeOOH, lepidocrocite γ -FeOOH
Thiruthuraiipoondi	27, 28, 35, 36	Lepidocrocite γ -FeOOH, γ -FeOOH, γ -FeOOH, hydrated maghemite γ - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$

3.7 Comparison with previous data

It is of interest to compare the results of the survey with the previous studies carried out in India. Average corrosion rate of 524, 27.42, 51.3, 109, 83.81 and 15.64 $\mu\text{m}/\text{y}$ were reported for mild steel in East coast of Chennai, Pondicherry, Cuddalore, Mandapam, Tuticorin and Kanyakumari respectively during the year 2004 (Natesan *et al.*, 2005b). In the present study (Table 3), the average corrosion rate of mild steel in east coast area from Nagore to Ammanichatram are found to be in the range of C2–C3 in comparison with that of data obtained above except Kanyakumari (C2). The C2–C3 corrosive categories of the present study may be due

to the presence of S_1 P_0 level of pollutants present in the exposed areas.

4 Conclusions

Of the 16 sites studied for mild steel, the Nagapattinam 2 site, experienced higher corrosion rate for the monthly exposures throughout an year and for cumulative exposures upto 18 months, owing to the proximity of the site to seashore and higher levels of salt content in the air. This is in agreement with the reduction in thickness values for Nagapattinam 2 site, as revealed by the kinetics of corrosion process studied. The corrosivity levels of the sites for the

monthly exposure fall under C3 category, whereas for cumulative exposures, fall under C2 & C3 categories. The corrosion products formed on the cumulative exposures of mild steel are indicative of the protective nature of them, which are reflected in the exponential decrease in the corrosion rate values.

Acknowledgement

The authors are thankful to the Director, CSIR-Central Electrochemical Research Institute, Karaikudi and M/s.IRCON International Ltd., Muthupet for their help and constant encouragement shown in this study.

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