ORIGINAL RESEARCH PAPER

Chemistry

REVIEW OF IRON CORROSION STUDIES USING THE WEIGHT LOSS TECHNIQUE IN DIFFERENT ENVIRONMENTS

KEY WORDS: Iron, Corrosion, weight loss method, concentration, metals, time

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ABSTRACT

The corrosion behaviour of iron metal was studied using the weight loss method, a simple and widely used technique for evaluating corrosion rates. Cleaned and weighed iron specimens were immersed in a corrosive medium for a specified period. After exposure, the specimens were removed, cleaned to eliminate corrosion products, dried, and reweighed. The difference in initial and final weight was used to determine the weight loss due to corrosion. The corrosion rate was calculated from the observed weight loss, exposure time, and surface area of the specimen. Results showed that the corrosion rate increased with longer exposure periods and more aggressive environments. The weight loss method provided reliable information about the extent of metal deterioration. This study demonstrates the usefulness of the weight loss technique for assessing the corrosion resistance of iron and for comparing the effectiveness of corrosion control measures.

INTRODUCTION:

Corrosion is a natural, progressive and often irreversible degradation of metals and alloys driven by chemical and electrochemical interactions with their environments. When a metallic surface encounters oxygen, moisture, salts, acids, or industrial pollutants, it tends to transform into more thermodynamically stable compounds most commonly oxides, hydroxides, carbonates, or sulphides thereby diminishing structural integrity, aesthetics and service life [1]. A familiar example is rusting, the corrosion of iron and steels, which produces a reddish-brown, flaky layer of hydrated iron (III) oxide (Fe O xH O). Rusting is fundamentally an electrochemical process: iron dissolves anodically while dissolved oxygen is reduced cathodically on adjacent sites, establishing a galvanic microcell that perpetuates material loss. Although some metals spontaneously form thin, adherent oxide films that slow further attack by limiting access of oxygen and electrolytes, this passive protection is fragile. It can be disrupted by chloride ions, mechanical abrasion, cyclic wet–dry exposure, or elevated temperatures, after which corrosion accelerates until a new, sometimes less protective, film re-forms.

Corrosion of iron has been extensively investigated using the weight loss method because it provides a simple and reliable means of determining corrosion rates under different environmental conditions[2]. Early studies demonstrated that iron corrosion in acidic and neutral media is strongly influenced by oxygen diffusion and mass transfer phenomena. Weight loss measurements have been widely employed to evaluate atmospheric corrosion, iron pipe deterioration, microbial corrosion, and the effectiveness of corrosion inhibitors[3-6]. Studies on iron and steel exposed to atmospheric environments showed that pollutants such as sulphur compounds and chlorides significantly accelerate metal loss. Investigations on water distribution systems reported that weight loss techniques effectively quantify long-term iron pipe degradation and support corrosion-control strategies[7-12]. Research on sulphate-reducing bacteria confirmed that microbial activity enhances iron dissolution, resulting in measurable weight reduction. Recent studies have combined weight loss analysis with electrochemical and surface characterization techniques to evaluate corrosion inhibitors and monitor corrosion processes more accurately[13-16]. Weight loss measurements remain an important benchmark for validating electrochemical corrosion-rate determinations and assessing corrosion behaviour under practical service conditions[17-21]. Overall, the literature confirms that the weight loss method is a dependable and widely accepted technique for studying iron corrosion kinetics, inhibitor performance, and environmental effects on metal degradation.

One of the pioneering contributions in corrosion inhibition was made by M. A. Quraishi and co-workers[22], who investigated environmentally benign compounds as corrosion inhibitors for cooling water systems. Their study demonstrated that green compounds could effectively reduce corrosion and scaling in industrial cooling systems while minimizing environmental hazards. Subsequent research by M. A. Quraishi and D. Jamal[23] focused on the synthesis and evaluation of organic vapour phase corrosion inhibitors for mild steel, brass, and copper. Suriyaprabha, Rajendran and Sathiyabama investigated the corrosion resistance of mild steel in a simulated concrete pore solution, which is essentially a saturated solution of calcium hydroxide, in both the absence and presence of 4000 ppm chloride ions. The corrosion behaviour was evaluated using the weight loss method[24]. Saxena et al. assessed how substrate preparation determines the protective efficacy of an organo-silane coating on AZ91D, linking interfacial chemistry to durability[25]. Surfaces received distinct pre treatments before silanization and were characterized by wettability and FTIR (Si–O–Si network formation), then tested by polarization, EIS, and salt exposure in NaCl. Khan et al. aimed to determine whether cerium-based conversion coatings can enhance the electrochemical corrosion resistance of aluminium alloy substrates in alkaline media relevant to cleaning or processing lines[26]. Tiwari et al. aimed to establish whether selective laser melting (SLM) intrinsically improves the corrosion resistance of AlSi10Mg compared with conventionally cast material[27]. Radhika et al. investigated electrochemical and hot-corrosion behaviour of annealed high-entropy alloy (HEA) coatings to couple room-temperature passivity with high-temperature resilience[28]. Parashar et al. reported on the significance of metal and alloy membranes in industrial hydrogen separation and recovery processes, with particular emphasis on their application in bio-jet fuel production, where hydrogen serves as a key reactant[29].

Materials and methods: Corrosion Study of Iron by Weight Loss Method

The weight loss method is one of the simplest and most widely

used techniques for studying the corrosion behaviour of iron. In this method, a clean and accurately weighed iron specimen is immersed in a corrosive medium, such as acidic, alkaline, or saline solution, for a specified period. Before immersion, the surface of the iron specimen is polished, degreased, washed with distilled water, dried and weighed accurately. After exposure to the corrosive environment, the specimen is removed, cleaned to remove corrosion products, washed, dried and reweighed. The difference between the initial and final weight represents the amount of metal lost due to corrosion. The corrosion rate is calculated using the weight loss data and is generally expressed in mils per year (mpy). The corrosion rate can be determined using the formula:

$$\text{Corrosion Rate} = \frac{87.6 \times W}{D \times A \times T}$$

Where: W = Weight loss (mg) D = Density of iron (g/cm³)
A = Surface area exposed (cm²) T = Exposure time (hours)

Commercial iron plates (6 × 5 × 0.3 cm) were used to study corrosion in various environments: acids, bases, neutral solutions, seawater, and organic acids. Solutions of 0.1, 0.5, 1 and 4 N concentrations were prepared and standardized. Corrosion was measured using the weight loss method over 1–5 hours, and results were compared with literature. Electrochemical potential measurements were also performed, with the iron plate as anode and a calomel electrode as cathode. Results are summarized in Tables 1–2 and figures 1-8 respectively.

The weight loss method provides valuable information about the effect of factors such as concentration of corrosive medium, temperature, pH, immersion time, and corrosion inhibitors on the corrosion behaviour of iron. It is inexpensive, easy to perform, and suitable for long-term corrosion studies. The weight loss method remains a standard and reliable technique for evaluating the corrosion resistance of iron and other metals.

Result and discussion

The following acids were used: hydrochloric, sulphuric, nitric, phosphoric and acetic acid and the bases included sodium hydroxide, potassium hydroxide and ammonium hydroxide, at concentrations of 0.1N, 0.5N, 1N, and 4N.

From the results, the following conclusions were drawn:
1. The rate of corrosion increases with increasing acid concentration.
2. The rate of corrosion increases with time.

The bases, such as sodium hydroxide and potassium hydroxide, produce much lower corrosion rates compared to the acids. Electrochemical potential studies on iron indicate the following trend:
Bases > Neutral solutions > Organic acids > Inorganic acids

For inorganic acids, which show higher corrosion rates, the measured e.m.f is lower. Conversely, for less corrosive bases, the e.m.f is higher. This behaviour aligns with the electrochemical characteristics of iron. Weight loss (in mg) and Potential study of Iron in different medium (in terms of Volt) are represented in table 1-2 and figure 1-8. In general, corrosion in water decreases with increasing purity of water. This is because higher purity water contains fewer dissolved solids and gases, resulting in higher electrical resistance and lower corrosion rates.

Table-1 Weight loss (in mg) study of Iron in Different medium

Sr. No.	Medium	0.1N	0.5N	1N	4N	Saturated solution	Natural solution
1.	HCl	510	461	459	368	....	.....
2.	H2SO4	511	500	384	487	....	....
3.	HNO3	524	475	2183	3419	....	....
4.	H3PO4	177	279	375	497	.....	.....
5.	CH3COOH	589	525	520	500	.....	.....
6.	NaOH	370	199	895	790	....	....
7.	KOH	240	365	810	710	.....	....
8.	NH4OH	315	270	490	377	.....	.....
9.	NaCl	....	.....	.....	.....	642	.....
10.	KCl	....	....	.....	.....	647	.....
11.	Sea Water	....	.....	.....	.....	....	609
12.	Water	....	....	.....	.....	.....	315

Table-2 Potential study of Iron in different medium in terms of EMF (V)

Sr. No.	Medium	0.1 N	0.5 N	1N	4N	Saturated Solution	Natural solution
1.	HCl	25	110	190	213	....	....
2.	H2SO4	48	492	553	589	....	....
3.	HNO3	53	559	2182	3419	....	....
4.	H3PO4	78	431	774	824	....	....
5.	CH3COO	18	45	57	85	....	....
6.	NaOH	05	09	08	18	....	....
7.	KOH	06	07	19	24	.....	.....
8.	NH4OH	05	29	37	43	....	....
9.	NaCl	....	....	.....	.....	18	....
10.	KCl	....	....	.....	....	58	.....
11.	Sea water	....	.....	.....	.....	....	146
12.	Water	....	....	....	.....	.....	23

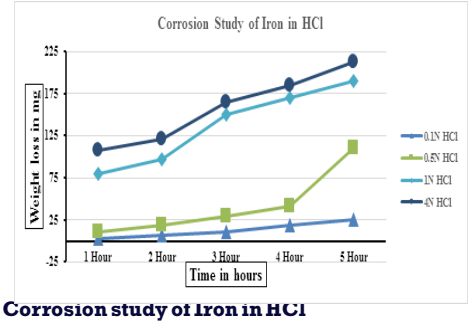

Fig.1 Corrosion study of Iron in HCl

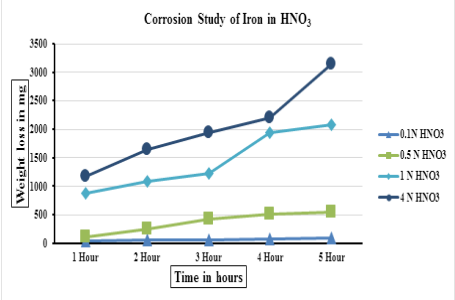

Fig 2. Corrosion study of Iron in H_2SO_4

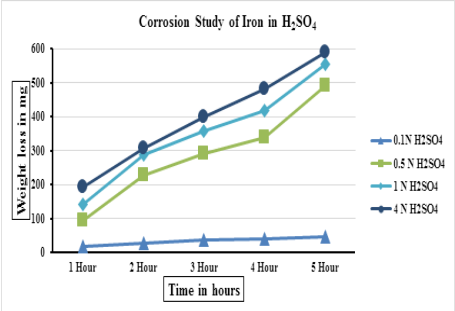

Fig. 3 Corrosion study of Iron in HNO_3

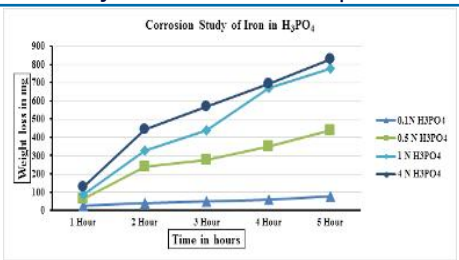

Fig 4 Corrosion study of Iron in H_3PO_4

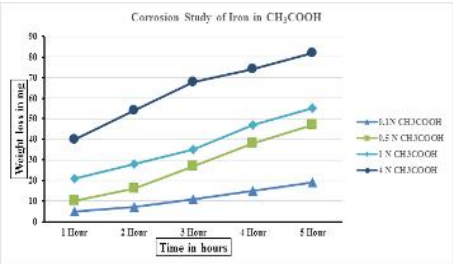

Fig 5. Corrosion study of Iron in Acetic Acid

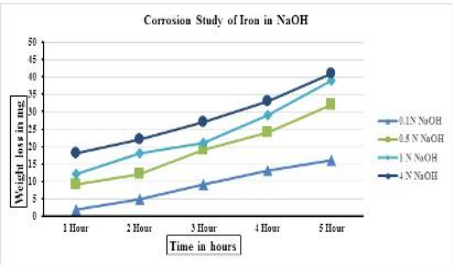

Fig. 6 Corrosion study of Iron in NaOH

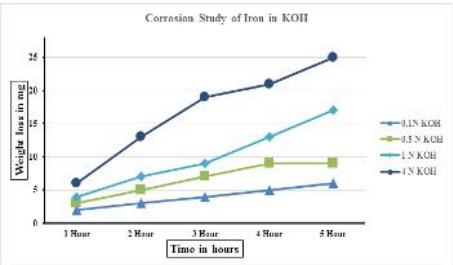

Fig. 7 Corrosion study of Iron in KOH

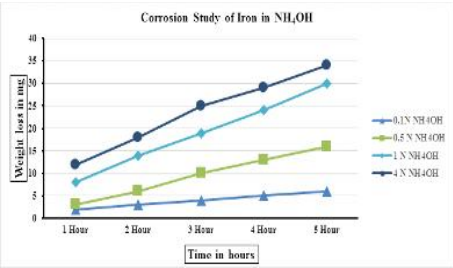

Fig. 8 Corrosion study of Iron in NH_4OH

CONCLUSIONS

As the concentration of an acid increases, the corrosion rate of iron generally increases because a higher concentration provides more hydrogen ions (H) that participate in the electrochemical corrosion process. The increased availability of these ions accelerates the dissolution of iron from the metal surface, leading to greater weight loss over time. Concentrated acidic solutions also enhance the electrical conductivity of the medium, facilitating faster electron transfer and promoting corrosion reactions. As a result, iron exposed to highly concentrated acids undergoes more rapid degradation compared to iron in dilute acid solutions. This effect is commonly observed in acids such as hydrochloric acid, sulfuric acid, and nitric acid, although the extent of corrosion depends on the nature of the acid and experimental conditions such as temperature and exposure time. Therefore, acid concentration is one of the most important factors influencing the corrosion behaviour of iron. The rate of corrosion also increases as the time of exposure increases.

Order of Corrosion in Different Solutions
The order of corrosion activity in the given solutions is:

$$HNO_3 > H_3PO_4 > H_2SO_4 > HCl > CH_3COOH > KOH > NaOH$$

Strong inorganic acids cause more corrosion. Organic acids cause moderate corrosion. The bases such as NaOH and KOH show less corrosion compared to acids.

Electrochemical (EMF) Studies

Electrochemical potential (EMF) measurements were carried out using iron as the working electrode and the Calomel electrode as the reference electrode.

The order of EMF values observed is:
Bases > Neutral solution > Organic acids > Inorganic acids

Inorganic acids, which cause more corrosion, show lower EMF values. Bases, which cause less corrosion, show higher EMF values. This behaviour depends on the electrochemical nature of the metal in different solutions and concentrations.

Similar weight-loss and potential studies were carried out for copper and brass.

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