

Review of Literature

2. REVIEW OF LITERATURE

One important trend in modern civilization is to effect gradual replacement of natural materials especially made of wood with either all synthetic materials or modified natural materials. The rapid industrialization of many countries indicates the shrinkage in metal resources. It is obvious that metals are extremely important in modern engineering yet many can be badly affected by corrosion since they are associated with high energy. In the modern age, it is essential to modify the properties of a metal and/or alloys according to tailor-made specifications designed for target applications. But after the modifications the major problems associated with the metallic materials is its corrosive nature. The extent of corrosion depends on the material composition and the nature of the environment to which it is exposed.

The major problems of corrosion involve loss of economy, natural resources and human lives in case of infrastructural collapses. So it is very vital to step into new developments in corrosion mitigation. Prevention of corrosion of materials in corrosive environment is a challenging one. There are several corrosion control methods to modify the materials under consideration, which includes cathodic protection, **Subasria et al., (2005)** and **Kim et al. (2006)**; anodic protection, **Cecchetto et al. (2007)**, coating **Praveen et al. (2007)** and alloying. The use of chemical inhibitors, **Zhao et al. (2005)** and **Jevremovic et al. (2012)** was the main corrosion prevention technique in which modification of the environment was considered. This method is often considered as the most effective and practical method of corrosion prevention due to its ease of usage.

Several works have been reported on the corrosion inhibition of different metals in various corrosive environments. Initially attention was centered on organic compounds. **Sanyal (1981)** has reviewed the number of reported organic compounds while **Kuznetsov (2012)** has discussed the various heterocyclic compounds used as corrosion inhibitors. Global awareness on the environmental impact of the organic compounds laid the foundation for the development of environmentally benign compounds as green inhibitors. Green inhibitors include natural plant materials and non toxic, eco friendly polymers. **Raja and Sethuraman (2008)** and **Rajalakshmi et al. (2012)** in their review articles covered the different reported plant materials for corrosion inhibition of metals.

In the past years, there has been increased emphasis on applications of polymers, copolymers, grafted polymers and polymer composites as green corrosion inhibitors. **Umoren (2009a) and Arthur et al. (2013)** in their articles reviewed the polymers for corrosion prevention applications. The prime controlling factors influencing the corrosion inhibitive performance of polymeric compounds on the corrosion of metals in various corrosive environments have been discussed in this chapter.

The high performance of the polymeric corrosion inhibitors is due to its larger size and numerous functional anchoring groups. Through the anchoring groups the polymers easily get adsorbed on the metal surface and protect considerably more surface than the corresponding monomers. The main factors influencing the corrosion mitigating properties of the polymers are molecular size, weight, composition and nature of the anchoring groups. The solution pH, concentration, exposure time and temperature also find their role in influencing the inhibition performance. The various types of polymeric corrosion inhibitors were grouped according to their monomer nature and discussed separately for ferrous and non ferrous alloys.

The polymeric compounds were tested for their potential to control the corrosion process using conventional and electrochemical techniques. The major research work in this pioneer area involved weight loss or coupon measurements, thermometric or calorimetric measurements and gasometric or hydrogen evolution techniques. The electrochemical methods such as potentiodynamic polarization, potentiostatic polarization, linear polarization and electrochemical impedance spectroscopy techniques were used to study the effectiveness of the inhibitors. Any other special techniques used for the evaluation of polymeric corrosion inhibitors were discussed in detail.

2.1 POLYMERIC CORROSION INHIBITORS FOR FERROUS AND ITS ALLOYS

Generally iron and its alloys were used for the fabrication of reaction tanks, boilers, pipes etc., Despite of their advantages, they experienced series drawback owing to corrosion especially under aggressive environments in processes such as acid pickling, acid cleaning, oil well oxidizing, etc., which

results in awful degradation. The polymeric inhibitors for ferrous and its alloys were classified into four major types i) Amines-Imines and Amides based polymers ii) Vinyl based polymers iii) Bio polymers and iv) other polymer systems.

2.1.1. AMINES, IMINES AND AMIDE BASED POLYMERS

2.1.1.1. Alkyl and Alkoxy Aniline Based Polymers

Polyanilines are conducting polymers and their electronic properties can be modified by varying either the number of protons or the number of electrons or both. Protonation of polyaniline and its derivatives at nitrogen below pH 4 increased their conductivity. The structures of polyaniline in acidic and alkaline medium are represented in **Figure 2.1**.

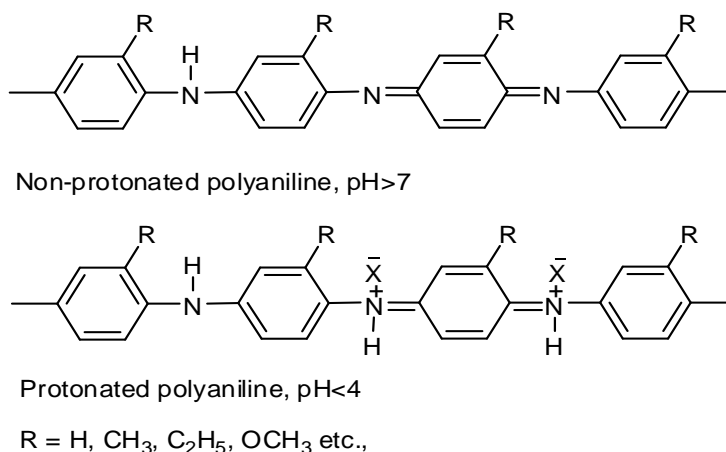


Figure 2.1. Structures of polyaniline in different pH values

The protonated species get easily adsorbed on the metal surface forming an effective barrier for the diffusion of aggressive ions. Therefore polyaniline have been recognized as an excellent acid corrosion inhibitors for metals from twentieth century. Many authors have reported polyanilines for anticorrosive coatings.

Polyaniline was synthesized from its monomer by persulphate oxidation and was used as corrosion inhibitor for iron in 0.5M H₂SO₄ by **Jeyaprabha et al. (2006a)**. The authors had also reported the effect of cerium ions on the inhibition performance of polyaniline, **Jeyaprabha et al. (2006b)**. The processability of

polyaniline is still an unexplored one due to its insoluble nature in water and in common organic solvents.

In recent years, researches are moving towards doping, blending, compositing or grafting of polyaniline with some other materials to achieve the desired properties with high processability. Though there are several articles reporting polyaniline and its derivatives, copolymer, composites and blends for corrosion protection application, here only those used as inhibitors are discussed. Most of the polyaniline based substances showed about 90 percent inhibition efficiencies and are tabulated in **Table 2.1**.

Table 2.1. Polyaniline based polymers used as corrosion inhibitor for iron and its alloys

S.No	System	IE _{max} (%)-Medium
1.	Poly(o-methoxy aniline), Cl ⁻ and sulphamic acid doped poly(o-methoxy aniline), Sathiyarayanan et al. (1994)	88% IE in HCl
2.	Poly(o-ethoxy aniline), Cl ⁻ and sulphamic acid doped poly(o-ethoxy aniline), Sathiyarayanan et al. (1992)	89% IE in HCl
3.	Dodecyl benzene sulphonic acid doped polyaniline/2-alkyl polyaniline/its copolymer, Bhandari et al. (2009a)	76% IE in HCl
4.	5-lithiosulphoisophthalic acid doped poly(aniline-co-2-isopropylaniline), Bhandari et al. (2009b)	80% IE in HCl
5.	Low molecular weight poly(o-ethoxyaniline) ie. Pernigraniline, Daouadji and Chelali (2004)	96% IE in HCl
6.	poly(aniline-formaldehyde), Quraishi and Shukla (2009)	94.5 % IE in HCl
7.	poly(vinyl pyrrolidone-aniline), Karthikaiselvi et al. (2010)	93.3% IE in HCl

Table. 2.1. Cont'd...

S.No	System	IE _{max} (%)-Medium
8.	poly(vinyl pyrrolidone-methyl aniline), Karthikaiselvi and Subhashini (2012a)	87% IE in HCl
9.	poly(vinyl pyrrolidone- <i>o</i> -methoxy aniline), Karthikaiselvi and Subhashini (2012b)	97% IE in HCl
10.	poly(aniline-co-4-amino-3-hydroxy-naphthalene-1-sulfonic acid), Bhandari et al. (2011)	90% IE in HCl
11.	Polyanthranilic acid, Shukla et al. (2008)	92.3% IE in HCl
12.	Polyaniline & poly(dially dimethyl ammonium chloride) blends, Prakash et al. (2008)	80% IE in H ₂ SO ₄
13.	Poly(styrene sulphonic acid) doped polyaniline, Manickavasagam et al. (2002)	86% IE in HCl
14.	Poly(aniline-formaldehyde), poly(<i>o</i> -toluidene-formaldehyde) and poly(<i>p</i> -chloroaniline-formaldehyde), Shukla and Quraishi (2012)	97-98% IE in HCl
15.	poly(aniline-co-ortho toluidine), Benchikh et al. (2009)	70% IE in NaCl
16.	Magnetite-containing polyaniline-polyacrylamide, Geethanjali and Subhashini (2013)	91% IE in HCl

Among these most of them were used in acid medium. The influence of H⁺ ion and Cl⁻ ion concentrations on the inhibition effect of poly(aniline) on the corrosion of high-purity iron was investigated by **Manivel et al. (2007)**. The higher inhibition efficiency at higher H⁺ and Cl⁻ ion concentration was due to the enhanced adsorption of the cationic form of polyaniline. The higher protection efficiencies of polyaniline based compounds in acid medium are due to the adsorption of the protonated species on the metal surface. **Gomez et al. (2010)** have composited polyaniline with nanodiamonds (ND) by oxidative polymerization of aniline using ammonium peroxydisulphate under controlled conditions. The ND-PANI proved to be an excellent corrosion inhibitor for steel and aluminum due to the electronic properties.

Poly(vinyl alcohol-aniline)-(PVAA) and poly(vinyl alcohol-anthranilic acid)-(PVAAA) composites were evaluated for their corrosion inhibition performance for MS in 1M HCl by **Karthikaiselvi et al. (2011)** and **Srimathi et al. (2011)** respectively. **Banumathi et al. (2010a and 2010b)** have evaluated the corrosion inhibition properties of polyethylene glycol-aniline and polyethylene glycol-anthranilic acid composites (PEGA and PEGAA). The inhibition efficiencies of PEG composites were low compared to that of PVA composites. The inhibition efficiencies of about 90% was reached only at very high concentrations above 10000 ppm. The results obtained in the impedance measurements are presented in **Figure 2.2**.

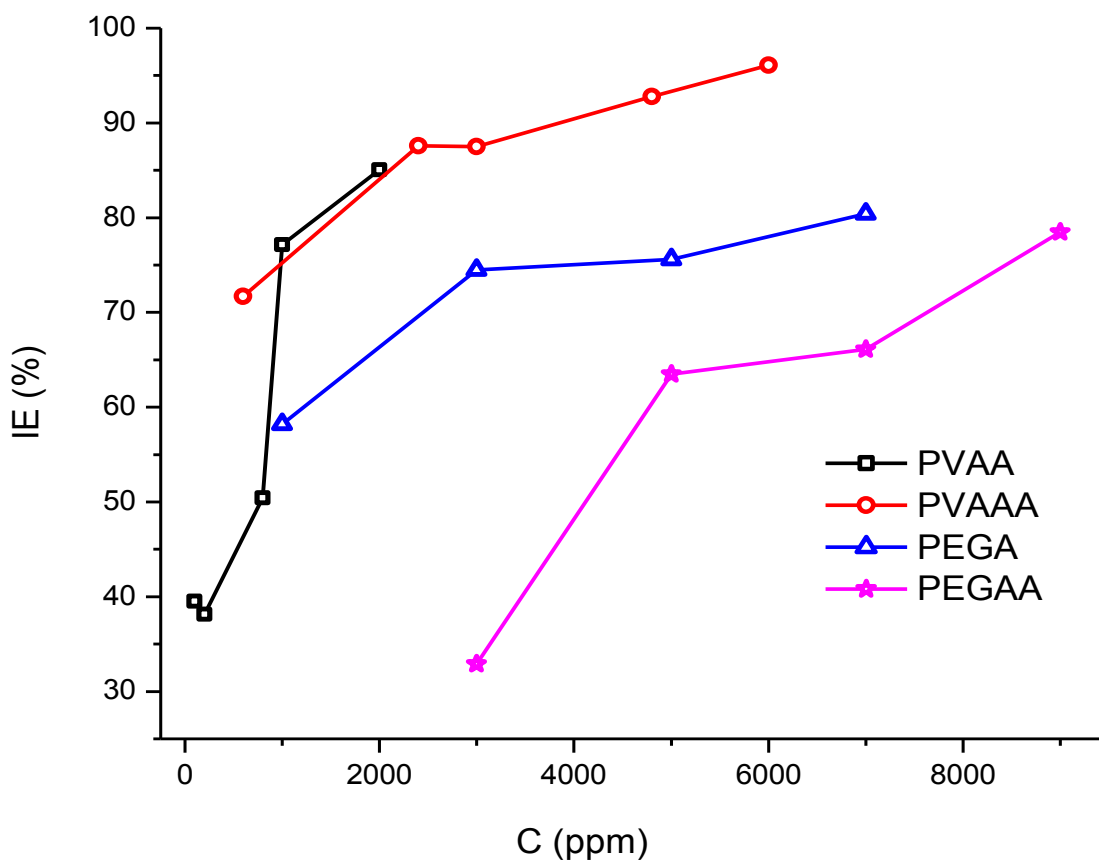


Figure 2.2. Inhibition efficiencies of polyvinyl alcohol and polyethylene glycol composites with aniline and anthranilic acid

2.1.1.2. Amines and Diamines (other than anilines)

Polymer amines are excellent corrosion inhibitors for iron in acid solutions. **Jeyaprabha et al. (2005a and 2005b)** have reported the corrosion inhibition performance of poly(diphenylamine) and poly(aminoquinone) on iron in

0.5 M H₂SO₄. FTIR and UV-reflectance studies were performed to prove the adsorption of inhibitors on the iron surface. Poly(*p*-amino benzoic acid) was synthesized using chemical oxidation method and its inhibitive effect on iron in 1M HCl was studied by **Manivel and Venkatachari (2006)**. The effectiveness of poly(*p*-amino benzoic acid) is very high in comparison with its monomer. The inhibiting effect of *p*-toluidine and poly(*p*-toluidine) on corrosion of iron in 1M HCl was reported by **Manivel and Venkatachari (2007)**. Poly(*p*-toluidine) provided much higher protection efficiency than the *p*-toluidine. Triethanol amine was polymerized by condensation at 245 °C for 4, 6 and 8 hours to yield three different polymeric amines (P4, P6, and P8). P8 was ethoxylated and then esterified with oleic acid at different molar ratio. The esterified products were tested for its inhibition efficiency on carbon steel corrosion in 1M HCl, **Al-Sabagh et al. (2010)**.

The effect of different polymethylene diamines on the corrosion of iron in deaerated 6N HCl at room temperature has been investigated using polarization measurements and colorimetric analysis of the solution. The adsorption of these inhibitors at the metal/solution interface was monitored by measuring the double layer capacitance using the single pulse method. The inhibition efficiency increased with increase in number of methylene groups [NH₂-(CH₂)_n-NH₂] upto n=8, **McCafferty and Hackerman (1972a)**. The inhibition properties of the electro-polymerized poly(*o*-phenylenediamine), on the corrosion of mild steel in 1M HCl solution have been evaluated by **Abd El Rehim et al. (2010)**.

2.1.1.3. Imines

Quaternized polyethyleneimine was prepared by tertiary amination, quaternization, and its corrosion inhibition property was tested on low carbon steel in H₂SO₄ solution. The polymeric quaternary ammonium salt provided excellent corrosion inhibition. The inhibition efficiency increased with cationic degree. **Gao et al. (2008)** reported polymeric quaternary ammonium salt as a mixed type inhibitor with anodic predominance. **Sekine et al. (1992)** have studied the corrosion inhibition behaviour of cationic polymers such as polyethyleneimine, its derivative, polyarylamide and polydicyanodiamide derivative and anionic polymers such as polymaleic acid derivative, polyacrylic acid derivative and polyacrylic acid on mild steel in low and high concentrate

solutions of CaCl_2 . Anionic polymers acted as a scale forming corrosion inhibitors for mild steel while the cationic polymers were lack in inhibition abilities. A cationic polyelectrolyte (quaternary polyethyleneimine) has been reported as a corrosion inhibitor for iron in sulphuric acid medium, **Song et al. (2009)**. Polyethyleneimines with different mean molar mass (from 1300 to 750,000 g mol^{-1}) were used as potential corrosion inhibitors for AISI 430 stainless steel in a 3 percent NaCl solution, **Finšgar et al. (2009a)**. The polymer with a mean molar mass of 2000 g mol^{-1} provided best protection against localized corrosion, as demonstrated by cyclic polarization measurements.

Finšgar et al. (2009b) have reported the effect of polyethyleneimine on the corrosion of ASTM 420 stainless steel in 3 percent aqueous NaCl solution. Cyclic polarization deduced the inhibitive performance of polyethyleneimine against pitting corrosion. Film persistency immersion test revealed the stability of the film in a non-inhibited NaCl solution. The inhibition efficiency of polyethyleneimine and quaternary polyethyleneimine self-adsorbed films were tested for low carbon steel in different acid baths, **Zhang et al. (2011)**. Diatomite particles were surface-modified with the inhibitors, and zeta potentials were measured. The morphologies and composition of the polymer film on the steel surface were examined with SEM and XPS.

2.1.1.4. Amides

Polyurea derivatives were synthesized by solution polycondensation of 4,4'-bis(2''-aminothiazol-4''-yl)diphenyl ether monomer with diisocyanate compounds in pyridine. An aminothiazol-4''-yl diphenyl ether model compound was synthesized from the monomer and phenyl isocyanate in pyridine. The structure was confirmed by elemental and spectral analyses. The resulted polyurea derivatives were evaluated for their inhibition performance on steel corrosion in 0.5 M H_2SO_4 at 40 °C, **Aly et al. (2009a)**. A class of polyamides containing diarylidene cyclopentanone moiety were synthesized by polycondensation reaction of the new diaminoarylidene monomer with different aliphatic and aromatic diacid chlorides. The resulting polymers were used as corrosion inhibitor for carbon-steel in 0.5 M H_2SO_4 at 40 °C, **Aly et al. (2009b)**. Bis (2-aminothiazol-4-yl-benzylidene) cycloalkanones and diisocyanate compounds on polycondensation yielded a class of interesting polyurea derivatives in pyridine

The authors, **Akbarzadeh et al. (2011)** have evaluated the inhibition efficiencies of Kraft lignin and Soda lignin on the corrosion of mild steel in 3.5% (w/v) sodium chloride at two levels of pH. Kraft lignin gave maximum inhibition efficiencies of 95 and 92% for pH 6 and 8, respectively, whereas soda lignin gave 97 and 95%. The corrosion inhibition of some sulphated water soluble natural polymeric (carrageenan) compounds on the corrosion of iron in 1M HCl was studied using different techniques. The inhibition efficiency was found to increase with increasing concentration and number of sulfur atoms per molecules, **Khairou and Zaafarany (2006)** and **Zaafarany (2006)**.

The dextran was partially oxidized using sodium hypochlorite under basic conditions and used as an organic corrosion inhibitor for mild steel in cooling water system, **Oyaizu et al. (2006)**. The polymer showed moderate corrosion inhibition activity and biodegradability under conditions for cooling water systems. Acetyl thiourea chitosan polymer (ATUCS) was synthesized and evaluated as corrosion inhibitor for mild steel in 1M H₂SO₄, **Fekry and Mohamed (2010)**.

2.1.2. OTHER POLYMER SYSTEMS

Ali and Saeed (2001) and **Ali et al. (2012)** have synthesized a variety of N,N-diallyl compounds from 1,6-hexanediamine and 1,12-dodecanediamine, capable of undergoing cyclopolymerization. The synthesized monomers were subjected to homo and copolymerization with sulphur dioxide to produce polyelectrolytes. The polymers thus obtained were used as corrosion inhibitors for MS in different molar concentrations of HCl, H₂SO₄ and NaCl media providing efficiency of more than 95%. **Li et al. (2002)** have studied the corrosion behavior of carbon steel in presence phosphor-polymaleic acid-ZnSO₄ in borate buffer solution of pH 8.4 using cyclic voltammetry. The voltammograms of carbon steel electrode in presence of the inhibitor displayed a smaller oxidation peak current, and a larger photocurrent response than in the reference solution. Auger electron spectroscopy technique was used to confirm the passive film formation on the carbon steel surface. **Migahed et al. (2004)** have reported the effect of gamma-ray pre-irradiation on the corrosion inhibition efficiency of polymeric surfactants (maleic anhydride and polyoxy ethylene-polyoxy propylene) on 304 stainless steel corrosion in 2M HCl. The gamma ray pre-irradiation decreased the inhibition efficiency of the aromatic inhibitors.

Some new macrocyclic polyether compounds containing 1,3,4-thiadiazole moiety was synthesized and their inhibition behaviour was studied by weight loss and impedance spectroscopy. The difference in their inhibition efficiencies (**Table 2.3.**) was attributed to the number of oxygen atoms present in the polyether ring which contribute to the strength of chemisorption bond between the non-bonding electron pair and the vacant orbital of the metal surface, **Lebrini et al. (2007)**.

Table. 2.3. Macrocyclic polyethers used as corrosion inhibitor for mild steel

Macrocyclic polyether compounds	IE(%)
(2,3,8,9-dibenzo-4,7-dioxa-13-thia-11,12-diazabicyclo[8.2.1]trideca-10,12-diene (1-MCTH)	97.7
2,3,11,12-dibenzo-4,7,10-trioxa-16-thia-14,15-diazabicyclo[11.2.1]hexadeca-13,15-diene (2-MCTH)	99
2,3,14,15-dibenzo-4,7,10,13-tetraoxa-19-thia-17,18-diazabicyclo[14.2.1]nona deca-16,18-diene (3-MCTH)	99
2,3,17,18-dibenzo-4,7,10,13,16-pentaoxa-22-thia-20,21-diazabicyclo[17.2.1]docosa-19,21-diene (4-MCTH)	99.2
2,3,20,21-dibenzo-4,7,10,13,16,19-hexaoxa-25-thia-23,24-diazabicyclo[20.2.1] pentacoza-21,24-diene (5- MCTH)	99.5

Ashassi-Sorkhabi et al. (2006) have evaluated the inhibition efficiency of polyethylene glycol (PEG) having different molecular weights (400, 1000, 4000, and 10,000 g mol⁻¹) for mild steel in 0.5 N HCl. The concentration and molecular weight of the PEG gave a direct proportional effect on the inhibition efficiency. The corrosion inhibition of mild steel in the presence of a poly sorbate 20, poly ethylene glycol nonyl phenyl ether, poly ethylene glycol tetra octyl phenyl ether etc., has been studied in sulfuric acid medium by **Khandpur and Singh (2005)**. Polyaspartic acid grafted melamine copolymer was synthesized by **Xu et al. (2013)** and its anti-scale behaviour in artificial cooling water system was reported by conducting static scale inhibition test.

The statistical count of the polymeric inhibitors discussed for the ferrous alloys was presented in the form of pie chart in **Figure 2.3**. Amines, imines and

amides contributed about 41% out of the reviewed polymeric materials. The next mostly studied inhibitors were vinyl based polymers (36.84%). Around 13.68% of the reviewed polymeric inhibitors were bio-polymers and the remaining, special polymeric systems.

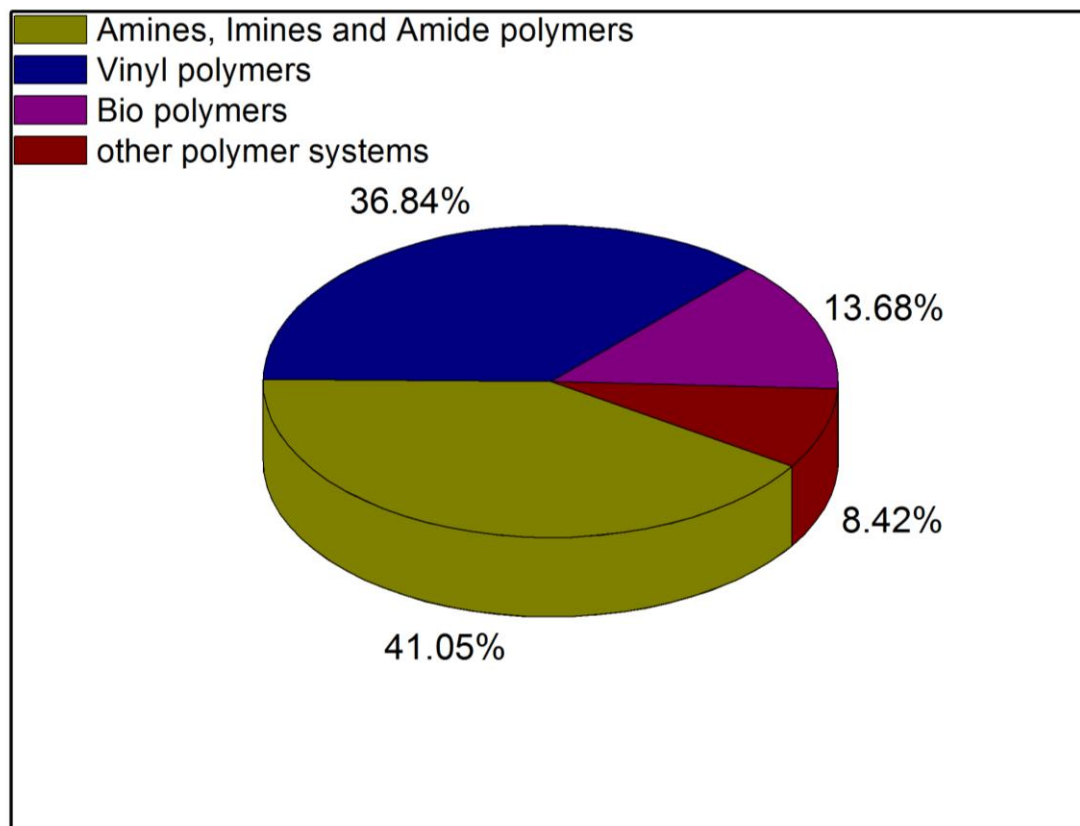


Figure 2.3. Percentage of various types of polymers used for corrosion inhibition of iron and its alloys

2.2. CORROSION INHIBITION OF NON FERROUS ALLOYS IN DIFFERENT CORROSIVE ENVIRONMENT

Non ferrous metals and alloys include aluminium, copper, brass, zinc, cadmium pigments etc., among them aluminum is highly susceptible to corrosion in alkaline environment. A wide variety of polymeric compounds were used as corrosion inhibitors for non ferrous materials. The polymeric compounds are grouped on the basis of the repeating units.

2.2.1. ANILINE BASED POLYMERS

The effect of polyaniline incorporated with ZnO in 2 M NaOH solution on the corrosion of commercial aluminum alloys was studied by **Elango et al. (2009)**. The inhibition of corrosion by polyaniline was found to be under anodic control. The inhibitory effect of 3-(10-sodium sulfonate decyloxy) aniline monomeric surfactant and the analog polymeric surfactant poly[3-(decyloxy sulfonic acid) aniline] on the corrosion of aluminum in 0.5M HCl was studied by **EI-Deeb and Mohamed (2011)**. The results showed the anodic predominance character of the polymers.

2.2.2. VINYL BASED POLYMERS

2.2.2.1. Polyvinyl pyridines/pyrrolidones/imidazoles

Poly(4-vinyl pyridine) and poly(4-vinyl pyridine poly-3-oxide ethylene) were used as the corrosion inhibitor for Cu60-Zn40 in 0.5 M nitric acid by **Abed et al. (2001b)**. The predominant cathodic nature of poly(4-vinylpyridine poly-3-oxide ethylene) was confirmed by the potentiodynamic studies. The inhibitive performance of polyvinylpyrrolidone (PVP) and polyacrylamide (PAAm) on the corrosion behavior of aluminum alloy 3SR in HCl solution has been investigated by **Umoren (2009b)**. PVP was reported as a better corrosion inhibitor than PAAm. The copolymer of 4-vinylpyridine and acrylamide was synthesized by radical copolymerization in solution and quaternarized using dimethyl sulfate to produce cationic polyacrylamide containing quaternary pyridine salt (**Gao et al. 2003**). The effects of cationic degree and molecular weight on the flocculation and corrosion inhibition properties were studied and the results confirmed their excellence. **Patachia et al. (2001)** have evaluated the corrosion inhibitive properties of some polyelectrolytes such as poly(1-vinyl imidazole) and some of its partially quaternized derivatives. The partially quaternized poly(1-vinyl imidazole) provided higher inhibition efficiency than the other studied polymers.

2.2.2.2. Polyvinyl alcohols

Khairou and EI-Sayed (2003) have used different polymers such as poly vinyl alcohol, poly acrylic acid, its sodium salt, poly ethylene glycol, pectin and carboxy methyl cellulose as corrosion inhibitors for cadmium in 0.5M HCl. PVA had much greater adsorbability on the surface than PEG at the anodic potential.

The corrosion inhibition of aluminum in H_2SO_4 by polyethylene glycol and polyvinyl alcohol at 30–60°C was reported by **Umoren et al. (2007a)**. PEG was found to be a better inhibitor for aluminum than PVA. The effect of halides (KCl, KBr, KI) on polyvinyl alcohol and polyethylene glycol on the corrosion inhibition of aluminum in H_2SO_4 were studied at 303 and 313 K by **Ebenso et al. (2005 and 2006)**. The values of synergism parameter were greater than unity indicating the enhanced inhibition efficiency in presence of halides. The effect of halide ions on the better corrosion inhibition performance of aluminium using PVA was also studied by **Umoren et al. (2007b)** in NaOH solution. The calculated synergism parameter revealed the role of ionic radii and electro negativity of halides on the corrosion inhibition process.

2.2.2.3. Polyacrylic acids/acrylate

Hazzazi (2006) has tested polyacrylic acid for corrosion inhibition of aluminum in weakly alkaline solution of pH 8. **Amin et al. (2009)** have studied the aluminium corrosion inhibition performance of polyacrylic acids with different molecular weights (PAA1 = 1800, PAA2 = 11,000 and PAA3 = 14,000 $g\ mol^{-1}$) in weakly alkaline solutions (pH 8 and 10) at 30 °C. The isoelectric point of aluminium oxide (pH 9) controlled the corrosion inhibition and adsorption of the polymers. Corrosion inhibition of sodium polyacrylate and polyethylene glycol on aluminium foil in 2M HCl solution has been evaluated at room temperature by **Yang and Liu (2010)**.

2.2.2.4. Polystyrenes

The low molecular weight styrene-maleic acid copolymers have been reported as a corrosion inhibitors for zinc pigments, **Müller and Imblo (1996)**; Cu and brass pigments, **Müller and Triantafillidis (2001)** in an alkaline medium . Maleic acid copolymers with styrene and acrylic esters (ethyl-, n-butyl-, n-hexyl-, n-dodecyl-, and n-octadecyl acrylate) were studied as corrosion inhibitors for aluminium pigments in alkaline medium by **Müller et al. (1998)**. The results established some correlations between the content of carboxyl groups of the copolymers and the corrosion rate. The copolymers with lower acid number were established as good inhibitors. The corrosion-inhibiting effect of heat-hardening phenolic resins and styrene-maleic anhydride (SMA) copolymers on Al pigments

in alkaline medium (pH 8 and 10) has been investigated by **Müller (2002)**. Surface of the aluminum metal was analyzed through XPS technique. No adsorption of SMA copolymers was detected at pH 10 but a significant adsorption at pH 8, while phenolic resins were found to adsorb significantly at both pH values. The pH-dependent adsorption behavior of the SMA copolymers was explained by the isoelectric point of Al_2O_3 . Phenolic resins exhibited a more effective corrosion inhibition than SMA copolymers.

2.2.3. POLYETHYLENE GLYCOLS

Shukla et al. (2003) have evaluated the effect of polyethylene glycol (PEG) on the corrosion of aluminum in acidic medium. Differential pulse polarogram (DPP) and differential pulse anodic stripping voltammetry were used to study the corrosion rates of Al in acidic medium for short time intervals. The corrosion inhibition of aluminium in alkaline medium was studied at 30 and 40 °C in the presence of polyethylene glycol by **Umoren et al. 2009**. The effect of halides (KCl, KBr, and KI) on the inhibitory action of PEG was also studied. Corrosion inhibition of zinc metal in alkaline solution containing poly ethylene glycol and poly oxy ethylene alkyl phosphate were reported by **Ein-Eli and Auinat (2003)**. Effects of molecular weight, concentration and storage time on inhibition efficiencies were studied. The corrosion of tin in various concentrations (0.05-0.7M) of succinic acid involved anodic active dissolution process; addition of polyethylene glycol decreased the anodic peak current and shifted the peak potential in the negative direction, **El-Sherbini et al. (2007)**. The ratio of the anodic charge/cathodic charge was more than unity indicating that the passive layer was very thin and the dissolution products were mainly soluble species. The effect of molecular weight of the polyethylene glycol on the inhibition efficiency followed the order (PEG)6000 > (PEG)4000 > (PEG)1200.

2.2.4. OTHER POLYMER SYSTEMS

Abdallah et al. (2004) have reported the effect of two polyamide compounds on the corrosion behavior of high-purity aluminum in oxalic acid solution. The addition of polyamides shifted the pitting potential of the aluminum electrode to more positive potential which indicated the increased resistance of aluminium to pitting attack. Some natural polymers (carrageenans) were tested

as corrosion inhibitors for pure aluminum and pure tin in hydrochloric and nitric acid solutions respectively, **Khairou et al. (2007)**. Molecular orbital treatment was used to rationalize the electronic structure and the ground state properties of the studied carrageenan compounds.

New possibilities of corrosion inhibition using different polymers, copolymers, terpolymers, polymer blends, composites, doped polymers and polymers extracted from natural products have been discussed so far. Though research on polymeric corrosion inhibitors bloomed in late nineteenth century, they were not successfully taken to onsite applications. The high performance of organic corrosion inhibitors suppressed the potentials of polymeric inhibitors. Global awareness on the environmental impact of the organic compounds laid the foundation for the development of environmentally benign polymeric compounds. The overview of the available literatures also revealed the high inhibition performance of the polymers compared to its monomer against corrosion of ferrous and non ferrous alloys in acid and neutral media. So, polymeric compounds can be appreciated for opening up new frontiers in the corrosion research.