Research Journal of Agriculture and Biological Sciences, 5(5): 680-688, 2009

Investigation of Soil Corrosivity in Thane Region of Maharashtra, India.

[1]Dr. Mirgane S.R. [2]Bhagure Ganesh Ramdas

[1]Reader in Chemistry, P.G. Department of Chemistry, J.E.S. College Jalna- 431203. Maharashtra, India
[2]Sr. Lecturer in Chemistry, Dnyanasadhana College, Thane. 400604. Maharashtra, India.

Abstract: Heavy industrialization and increasing urbanization are responsible for the rapidly increasing stress on water and soil environment of the Thane area. This increasing stress is responsible for corrosion of metal structures buried in soil. Twenty soil samples were investigated for corrosivity by analyzing the physical, mechanical and chemical characteristics of the soil environment. The concentrations of the soil parameters examined in the study are; Temperature(29-34.5^{0}c); Redox potential (175-346mv),electrical conductivity (217—948 micro simens cm1$^-$), Salt content (141-616 mg/lit.), moisture content (13.50-36.90%) organic matter (0.095-1.286%), resitivity (619-6993 ohm.cm), pH (6.25- 8.59) Chloride (273-907mg/kg), Total alkalinity (300- 1500 mg/kg) Sulphate (48.4 – 681 mg/kg), nitrate (0.06 – 9.75 mg/kg) phosphate (6.68 – 205 mg/kg), Calcium (1082-6813 mg/kg.), magnesium (1094 -3403 mg /kg), Sodium (81-1161 mg/kg) and potassium (8-485 mg/kg) Except two soil samples all soil samples are basic in nature .High amount of chlorides, sulphates, and water soluble cations increases conductivity and decreases soil resitivity and hence soils of Thane region are classified as highly aggressive soil.

Key word: Physico-chemical, Soil texture, Resistivity, Soil corrosivity,

INTRODUCTION

Corrosion of underground metallic structures is world wide problem. The 2004 global direct cost experience by the owners & operators of manufactured equipments &systems was estimated to be $ 990 billion U.S.dollars annually or 2% of the $ 50 trillions (USD) world gross domestic product (G.D.P) [1].

The 2004 global indirect cost of corrosion representing cost assumed by the end users and overall economy was estimated to be $ 940 billions (USD) annually [1]. On this basis ,the total cost of corrosion to the global economy in 2004 was estimated to be approximately $1.9 trillion (USD) annually or 3.8% of the world (GDP) the largest contribution to their cost comes United States at 31% [1]. Where as in India, the direct cost of corrosion in all sectors has been estimated to be 3% 0f its G.D.P. that is 30 billion [2].

The important sector affects significantly is the corrosion of defense establishment. Corrosion of military equipment and facilities has been ,for many years ,a significant problem [47]. The corrosion related problems are becoming more prominent as the acquisition of new equipment is decreasing and the reliability required ageing of system is increasing .The data provided by the military services (Army, Air Force, Navy and Marine Corps) indicate that corrosion is potentially the number one cost driver in life cycle cost. The total annual direct of cost corrosion incurred by the military services in USA for systems and infrastructure is approximately$20 billion.[3,45,47]. Soils are known to promote corrosion of buried metallic structures such as underground oils & gas pipelines, hazardous liquid transmission pipelines, crude oil gathering pipelines, natural gas transmission pipelines, natural gas gathering pipelines .etc [4,5,6,46]. When a gas or crude oils pipelines fails there is a high degrees of environmental, human and economic consequences. In August 19-2000, A 30 inch diameter natural gas transmission pipeline ruptured adjacent to picas river near Carlsbad New Mexico .EPNG. In its incident report to the research & special program administration (RASP) stated the cause of incident was$ 998.296 [7]. Failure of water means can be equally destructive because people depend on it for various purposes [8].

The fundamental cause of the deterioration of metal structures buried underground is soil corrosion [9]. Soil is a complex material, a pores heterogeneous and discontinuous environment constituted by mineral or organic solid phase, water liquid phase and air and

Corresponding Author: Dr. Mirgane S.R., Reader in Chemistry, P.G. Department of Chemistry, J.E.S. College Jalna-431203. Maharashtra, India.
Contact. No. 09869286796 (M), 02225824567 (R), Fax No. 0222580 1999
E-mail: gnshbhagure @ yahoo.co.in

other gas phase. Metal structures corrode in soil by complex electrochemical processes because of the presence of different soil electrolytes. In particular, the corrosivity of soil is based largely upon the interaction of electrical resistivity, dissolved salts, moisture contents, total acidity, bacterial activity, and concentration of oxygen. In addition soil environments are generally stationary electrolyte exposure conditions [10,11,12]. Corrosion is also caused by the formation of differential aeration and concentration cells due to soil of different compositions and textures present along the metal structures [13,14]. Normally in the absence of air, there should be no corrosion under neutral conditions as the oxidant–cum–cathodic depolarizer oxygen is absent [15]. However, extensive corrosion has been reported under such conditions due to anaerobic sulphate reducing bacteria and other microbiologically influenced corrosion [16,17].

Thane district is one of the most industrialized districts in the Maharashtra state. The heavy industrialization and increasing urbanization are responsible for the rapidly increasing stress on the water and soil environment of the area [18]. This increasing stress not only affect the aquatic and micro-organisms but also destructive to the metal structures especially water pipelines buried in soil, and civil constructions. Therefore an attempt has been made through comprehensive physical, chemical and mechanical analysis of soils to assess the corrosivity towards various required metal structures.

MATERIALS AND METHODS

Geographic Location and Physiographic Description: Thane, the northern most district of konkan, lies adjoins to the Arabian Sea in the northwest of Maharashtra state. It extends between 20^0 20‘north latitude and 73 ^{0}, 45’ east longitudes. Thane city and its suburb Kalwa, Mumbra, Diva junction, Dombivali, Kalyan, Ulhasnagar, & Ambernath are located in Thane districts. The above area that includes a portion of Thane district is called as Thane region in the present study. Thane is the most industrialized districts in the state. the district is blessed with abundant natural resources in the form of perennial rivers, extensive seashore and high mountainous range. Thane region is also marked with coastal line and rapidly growing residential areas of thane Dombivali, Ambernath and Mirabhayander. As per the records of MPCB there are about 5449 industries in Thane region [18]. Previous study of the metrology of the area reveals that atmosphere temperature to be 26-28^{0}c in the rainy season and 32 to 40^{0}c in the dry season. The daily humidity values ranged from 62 to 68 percent in the dry season to 77to 78 percent in the rainy season.

Soil Sample Collections: Soil samples for the study were collected from 20 sites from residential, commercial, industrial, and agriculture area in the month of Dec-2008 to Feb -2009.At each of the selected site, samples were collected in special quality polythene bags and taken to the laboratory immediately for analysis.

Soil Corrosivity Parameters: In the investigation of soil corrosivity the following parameters were analyzed for physical, mechanical and chemical analysis of soil samples. For physical and mechanical analysis; the parameters like temperature, redox potential, electrical conductivity ,total salt content ,moisture, organic matter ,resistivity and texture were determined. Similarly for chemical analysis pH, chlorides, sulphate, total exchangeable cations, nitrates and phosphates were determined. Temperatures of the soil are determined by the thermometer buried in the soil. Redox potential was determined using potentiometer [Model Elico-178] combined with platinum electrode along with saturated calomel electrode immersed directly in the soil samples saturated with distilled water {1:5} and value of the potential was noted after stabilization. Electrical conductivity was determined in [1:5] soil water suspension by conductivity meter. Total salt content was determined as per the standard procedure [19]. Moisture content of the soil samples was determined using the weight loss technique [20]. 5 gram of each samples were dried in a oven at 105^{o}c for 24 hours, the weight difference between the samples before and after evaporation was regarded as the moisture content. Organic matter in the soil was determined by the standard method [21]. Resistivity of the soil samples was determined by using multi-combination ohm- meter [22]. The soil samples were placed in the different rectangular boxes with an open top. The boxes were filled to the top with the soil. The value of the resistivity was evaluated using equation.

$$P= \frac{R \times W \times D}{L}$$

p (Resistivity) = of the soil samples in ohm-cm.
R (Resistance) = resistance of the soil samples in ohms.
W = width of the soil box in cm.
L = Length of the soil box in cm.
D = depth of the soil box in cm.

Texture (mechanical analysis) of the soil was determined by International pipette method [23]. While textural class has determined by Soil Texture software [37]. pH of the soil samples was determined in (1:5) soil water suspension by pH meter (Model Elico-178).Chloride content of the soil samples was determined by argentometric method [25]. Total alkalinity, sulphate, nitrate, phosphates and total exchangeable cations of the soil samples were determined by standard procedures [15,25,26].

RESULTS AND DISCUSSION

Soil corrosivity values in terms of the temperature, redox potential, electrical conductivity, salt content, moisture content, organic matter, resistivity, texture, pH, alkalinity, chloride, sulphate, nitrate, phosphate, and total exchangeable cations obtained from soil investigation are presented in (Table1-3).

Temperature: Temperature is an important parameter in the investigation of soil corrosivity, because it can modify the interaction between the metal and soil conditions [27]. Temperature of the soil sample was within Found the range of 29^0c to 34.5^0c degrees. Temperature values were high because study samples were collected during the month of Dec.2008 to Feb 2009. It is reported that the mass-transfer of dissolved oxygen plays an essential role in carbon steel corrosion, and the whole corrosion process is mix-controlled by both activation and mass-transfer steps. Passivity can be developed on carbon steel in the soil at low temperatures. With the increase of temperature, the passive current density increases and the passive potential range decreases. When temperature is elevated passivity cannot be maintained and the steel is dominated by an active dissolution status [28].

Redox Pccapital: Redox potential refers to the relative potential of an electrochemical reaction under equilibrium conditions .It is an affinity of a medium for electrons and its electronegativity compared with hydrogen. The potential of a soil indicates whether or not a soil is capable of sustaining sulphate reducing bacteria (SRB) which contribute greatly to the corrosion problem [29-32]. A low potential indicates that oxygen of the soil is low and consequently the conditions are ideal for the proliferation of SRB. Experimental results showed soil samples with a very high redox potential values 175-346 mv. Hamilton [33,34] reported that with in the redox potential range of 100-400 mv. Biologically catalyzed reaction process such as sulphate reduction, iron (II) reduction, manganese reduction, and nitrate reduction processes are favorable.

Electrical Conductivity and Resistivity: Electrical conductivity values was measured in (1:5) soil water suspension and found to be in the range of 217-948 micro siemens cm-1. Salt content was found in the range of 141 -616 mg/lit. High value of conductivity and salt content are susceptible for electrochemical corrosion. Soil resistivity is a measure of the ability to conduct a current. The lower the resistivity of the soil, the better is the soil's electrical properties and higher is the rate at which corrosion can proceed. Soil investigation results show that soil resistivity values decreases according to increase in moisture and salt content. Resistivity values to be between 619-6993 ohm.cm. A general accepted corrosivity index for soil according to resistivity is [10,35], Very corrosive under 1000 ohm-cm; aggressive from 1000 to 5000 ohm- cm; mildly aggressive from 5000to 10,000 ohm- cm; slightly aggressive from 10000 to 20000 ohm-cm; progressively less corrosive over 20,000 ohm's. Not corrosive from 30,000 to 100,000 ohm-cm. Soil samples number:, SL-2 & SL-5, and SL-6 having resistivity less than 1000 ohm.cm, and then it is classified as a very corrosive soil, while remaining soil samples having resistivity 1000 to 5000 ohmcm. are classified as aggressive, while soil sample No.SL-18 having a resistivity in between 5000 to 10,000 ohm-cm. can be classified as mildly aggressive.

Moisture Content: The moisture content of the soil samples ranged between 13.15 to 36.90 percent. The high moisture content of the samples can be attributed to the influence of the ground water table, tidal situation and hydraulic connection of the underground soil of the area. The presence of the moisture in the soil is the key requirement for corrosion. The position of the water table also influences the nature of the corrosion process as it can determine the rate of oxygen transport in the soil. The position of the water table may very seasonally and this in turn may influence the nature of corrosion process occurring in the buried structure. There are essentially three sources of water in the soil. Gravitational water is derived from the sources of precipitation (rainfall or snow); capillary water is held with the capillaries of the soil particles and ground water, which is the result of accumulation of gravitational water at the water table. In terms of corrosion Booth *et al.* [29] determined that a soil moisture content of >20% can be potentially aggressive towards corrosion of carbon steel and was likely to result in general corrosion. Moisture content of <20% would often result in pitting corrosion, while dry soils were not concern with respect to corrosion. Moisture content and the position of water table will influence the diffusion of oxygen into the soil .In saturated stagnant soils , anaerobic conditions may established , oxygen transport will be low and corrosion rate of buried material (in absence of microbial influence) will be low.

Organic Matter: Organic matter in the soil comes from the remains of plants & animals and increases the water holding capacity and serves as a reservoir of chemical elements in the soil the organic matter after decomposition produces organic acids and carbon dioxide which helps to dissolve the minerals present. Further it also reduces evaporation losses of water and helps in reduction of alkalinity of soils. The organic matter in the present investigation was found in the range of 0.095%to 1.286%. The observed range of organic matter suggests that all the soils have low water holding capacity. Many previous studies suggest that organic matter in the soil is the most important component concerning the metal retention [36] retention of metal in the soil accelerates the corrosion rate.

Soil texture: In general, the soil structure and particle size distribution determine the physical properties of matrix such as its permeability. Permeability in turns controls the rate of movement of fluids or gases through the matrix. Mineral composition is a key to understanding how a soil can influence the corrosion of buried metal structure.The soil separates are grouped in to textural classes determined by U.S. department of Agriculture [37] .Soil texture of the samples in the study area shows six out of twenty samples are loamy,three are sandy loam, two are silty loam, three are clayey, and one is is sandy clay loam.

Clays are the most common minerals on earth. Most clay has notable plasticity when wet and marked ability to adhere to surfaces. Physically, clays of the montmorillonite group such as bentonite can radically change volume through dehydration, redehydration or ion exchange .This shrinking and swelling can exert forced on structures buried in montmorillonite rich soils leading to potentially detrimental consequences [27]. Coarse silica sand tend to be relatively permeable, well drained, and inert but responsible for the development of aeration cells which create corrosion problems to the metallic constructions buried in the soil [38-42].

Chemical Analysis of Soil and Corrosivity: pH of the soil samples were within the range 6.25-8.59.soil sample Nos. SL-1, SL-8, and SL-9 are slightly acidic .while remaining soil samples are basic in nature. The acidic nature of the soil medium may have resulted from humic acid formed from organic matter. It has been observed that soil can become acidic due to leaching of basic cations (Ca+2, Mg+2, Na+, and K+) [23]. The alkaline nature of soil is due to the exchangeable cations Ca+2, Mg+ Na+& K+. These exchangeable cations also contribute towards a reduction in acidity and an increase in alkalinity. Soils usually have a pH 4.5 to 8 is generally not considered to be a problem for stainless steel. However recent research results have suggested that in the pH range 4.5 to 8 underground natural gas transmission pipeline ruptured in Carlsbad, New Mexico [7].

Total Alkalinity: The total alkalinity of soil samples are observed in the range at 300 to 1500 mg/kg. This is due to presence at salts, especially due to carbonates of calcium, magnesium and sodium giving preponderance of OH^- ions over H+ ions in the soil solution.

Chloride and Sulphate: The contribution of chloride (Cl^-) to the soil corrosivity is very significant in corrosion process. They not only promote corrosion because they are conductive by nature, but also inhibits passivity of the metal i.e. they inhibit the formation of on anodic layer on the surface which protects the metal from corrosion [30]. In addition the presence of Chloride tends to decrease soil resistivity [33,48]. Result showed that chloride levels to range between 273 and 907 mg/kg. Chloride ions are harmful, as they participate directly in pitting initiation of stainless steel and their presence tends to decrease the soil resistivity. In the present study most of the soil samples are sandy, aeration is possible .Stress corrosion cracking are possible in water mains due to aeration and chloride content. It was also reported that presence of significant quantities of chloride ions at the reinforcement level in concrete break down the passive film and initiate corrosion of steel embedded in concrete. The most important cause of initiation of corrosion of the steel bar is the ingress of chloride ions in to steel surface Chlorides may depassivate steel even at high pH [24,35,43]. Compared to the aggressivity of chloride ion levels, sulphate ions are generally considered to be less aggressive. The presence of sulphate may pose a major risk for metallic materials in the sense that sulphate can be converted to highly corrosive sulphides by anaerobic sulphate reducing bacteria [32,37]. Result showed that sulphate levels to range between 48.4 and 681 mg/kg.

Nitrate and Phosphate: Both inorganic and organic forms of nitrogen and phosphorous occur in soil. The relative amounts of the two forms vary greatly form soil to soil. Under favorable condition (i.e. moisture and temperature etc.) the organic matter decomposes to nitrates and phosphate in the form of $Hpo4^{2}{}_{-}$. In alkaline medium. In the present study, nitrate and phosphate are observed in the range of 0.06 to 9.75 mg/kg and 6.68 to 205 mg/kg-1 respectively in the soil samples under study.

Besides the energy and carbon sources, micro organisms also need the so called supplementary materials. These are bound nitrogen, phosphoric and sulphuric compounds [34]. Nitrogen compounds are absorbed by most organisms as ammonium salts. Nitrates are also important. Phosphorus is usually used as inorganic and organic phosphates.

Soluble Cations: soluble cations such as calcium, magnesium, sodium and potassium are present in the saturation extracts of the soils. The alkaline nature of the soil solution confirms the occurrence of montmorillonite mineral. This mineral undergoes slow and complicated hydrolysis reaction in which cations and part of silica are removed in the solution. While aluminum and clay stay behind as clay mineral. The concentration of Ca^{2+}, Mg^{2+}, Na+ and K+ are present in the soil samples are presented in Table – 3. All the soils are dominated by Ca^{2+} and $Mg2^{+}$ concentrations a careful examination of data presented in Table – 3 reveals that sodium availability is more as compared to potassium. Recent research results have suggested that some minimum concentration of soluble cations in the soil, such as sodium or potassium ,must be present for high pH stress corrosion cracking to occur [44].

Conclusion: A twenty soil samples were studied to identify a link between the different soil properties and its corrosivity to the underground metallic structures. Soils of Thane region shows that soil samples are alkaline in nature, highly conductive due to excess of chloride, sulphate and water soluble cations. Soil samples show High electrical conductivity and low resistivity. Thane region can be categorized in to highly aggressive.

The present study will be useful to find out the corrosion problem and future solutions for all the underground structures in the defense department such as permanent and temporary establishment. In the permanent establishment the study will be useful for selection of sites such as peace, civil constructions, housing, offices and all type of stores i.e. is supply depot and ammunition depot.

Ammunition depots are always underground where the bombs, missiles, weapons, explosive materials such as RDX, dynamite, granites etc, are stored. Selection of safe place for underground structure and its future consequence can be investigated from the present study. The study will be also useful in arsenals.

It was reported that installations with underground ammunition storage facilities on islands have large volume of water slippery through concrete walls, floors and joints of magazines. The moisture contribute the corrosion.

Head quarters of commands, hospitals, mess, residentitial quarters, foundations of establishment in these case, certain portions remain underground to firm positions. When underground portions comes the study is useful. The study is also useful in the permanent establishment of underground pipelines for gas, water distribution, underground foundations of telecommunication systems, nuclear waste storage tanks, etc. In such establishment soil corrosivity survey, selection of materials, possible protection of underground metallic structures can be investigated through the present study.

Table 1: Physical Analysis of Soils of Thane region

Soil Sample	Temp. 0^{0}c	Redox potential (mv)	Elec.Cond. micro Scm-^{1}	Salt content (1:5)	Moisture (%)	Organic matter %	Resistivity ohm- cm
SL -1	29	346	280	182	26. 57	0.327	1335
SL -2	32	245	870	566	30.98	0.479	619
SL -3	32	175	420	273	25.39	0.52	1259
SL -4	32	185	383	249	30.30	0.385	2015
SL –5	32	290	400	260	22.50	0.268	935
SL -6	32	308	420	273	27.17	0.317	616
SL -7	32.5	304	307	200	23.35	0.483	1046
SL -8	32.5	312	301	196	24.53	0.30	1049
SL -9	32.5	329	625	407	20.60	0.096	1229
SL -10	32.5	310	501	326	19.10	0.326	1253
SL -11	32.5	340	518	337	26.84	0.095	1134
SL -12	34.5	343	948	616	20.50	0.58	1158

Table 1: Continue

SL -13	34.5	322	437	284	36.90	1.286	1495
SL -14	34.5	336	896	582	23.78	0.862	1398
SL -15	32	283	304	198	28.19	0.216	1767
SL -16	32	291	310	202	26.61	0.334	3176
SL -17	32	311	312	203	20.61	0.225	2358
SL -18	32	301	217	141	13.50	0.379	6993
SL -19	32	311	596	388	21.43	0.610	2053
SL -20	32	323	322	209	18.95	0.659	3555
Range	29	175	217	141	13.50	0.095	619

(Salt content in mg/lit.)

Table 2: Mechanical Analysis of Soils of Thane Region of Maharashtra

Soil Sample.	Location	Habitat	Sand (%)	Silt (%)	Clay (%)	Class of soil.
SL-1	Thane	Comm. area.	39.6	50	9.85	Silt loam
SL-2	Thane	R.A.	22.4	22.5	53.85	Clay
SL-3	Thane	I.A.	58.63	19.95	18.85	Sandy loam
SL-4	Thane	I.A.	49.09	41.0	8.85	Loam
SL-5	Thane	R.A.	20.0	24.0	55.5	Clay
SL-6	Airoli	C.A.+I.A.	24.0	27.2	48.0	Clay
SL -7	Thane	R.A.	49.08	30.5	18.85	Loam
SL-8	Kharegaon	M.L.	41.0	30.0	28.85	Clay loam
SL-9	Thane	R.A.	51.94	29.0	17.85	Loam
SL-10	Mumbra	C.A.	35.57	39.0	24.85	Loam
SL-11	Dombivili	I.A.	29.45	33.0	35.85	Clay loam
SL-12	Dombivili	I.A.	44.24	27.5	27.85	Clay loam
SL-13	Kalyan	A.I.	22.8	43.5	32.85	Clay loam
SL-14	Kalyan	I.A.	48.99	27.0	22.85	Loam
SL-15	Kalyan	R.A.	76.15	15.0	6.85	Sandy loam
SL-16	Ambernath	F.L.	34.2	51.0	13.85	Silt loam
SL-17	Ambernath	M.L.	36.76	43.5	18.85	Loam
SL-18	Ulhasnagar-No.2	R.A.	68.85	22.0	7.35	Sandy loam
SL-19	Kalyan	A.L.	40.50	25.5	32.85	Clay loam
SL-20	Diva junction	R.A.	61.88	14.5	23.35	Sandy Clay loam

I.A. - Industrial area; M.L – marshy land; R.A.-Residential area; C.A.- Commercial area.
A.L – Agriculture land; F.L - forest land.

Table 3: Chemical analysis of Soils of Thane region of Maharashtra

Soil sample	pH	Cl^-	T.A.	So42-	No3-	Po_4^{3-}	Ca^2+	Mg^{2+}	Na+	K^+
SL-1	6.55	592	502	48.4	0.06	6.68	2445	1726	81	8
SL -2	8.034	455	750	101	0.708	20.32	6813	1532	248	131
SL-3	7.58	319	500	84	0.50	19.10	2926	2236	164	52
SL-4	8.08	364	750	116	0.659	18.60	3367	2455	113	9
SL-5	8.52	546	500	93	0.544	19.0	2204	2358	264	19
SL-6	7.52	346	500	129	3.55	7.52	3206	1459	296	89
SL -7	7.51	273	1500	27	2.5	10.32	4409	2431	146	42
SL-8	6.62	410	450	35	2.65	11.30	3207	3403	440	146
SL -9	6.25	319	300	681	1.64	104	2285	924	120	192
SL-10	8.59	410	700	438	9.75	205	5010	1095	403	251
SL-11	8.34	621	500	110	2.88	71	5611	1508	232	48
SL-12	8.34	683	500	263	0.659	94.52	2805	1945	1161	266
SL-13	8.01	364	700	149	3.24	164.33	2405	1094	216	485
SL-14	7.55	546	450	313	3.38	191.08	3928	2042	200	159
SL-15	8.18	819	500	76	0.164	58	3807	2309	138	187
SL-16	7.07	683	500	139	0.753	92.73	4008	1824	129	61.0
SL-17	7.17	1088	500	436	4.076	48.15	3006	2188	85	91.0
SL-18	8.27	635	750	127	0.896	82.16	1082	2625	126	135
SL-19	7.03	907	500	224	0.609	95.28	2004	2407	89	62
SL-20	7.26	680	500	221	0.824	188	2605	1823	176	46

The study will be helpful in the Air force for selection of place of underground hangers before construction. If resistivity is higher soil formation is hard cohesive and compact, whereas if the resistivity is low soil formation is loose, moist and soft. This concept may be useful in the constructions of wire rope bridges, hanging bridges and suspension bridges. Entire strata classification can be obtained, number of trials bores can be reduced and labour cost can be reduced and large number of sites can be investigated within a short period of time. Study is also useful in navy, docs and naval equipments such as buoys.

There are the wide areas of application of the present study however if certain application, example, problem is reported or suggested further study for that particular problem can be taken up. The data presented may be at great help for further studies.

ACKNOWLEDGEMENTS

Authors are thankful to Principal Dr. G.B. Vishe, Dnyanasadhana college, Thane, Mr. N. Kalyan M.D; Elca Laboratories Thane, Mr. D.S. Patil Insecticides Testing Laboratory, Thane for providing Laboratory facility.

Authors are also thankful to Mr.M.P. Kulkarni, M.D. Ashida electronics, Thane and Mr. Shirish Pathak for valuable suggestions and guidance to carry out resistivity measurement of soil samples.

REFERENCES

1. R.Bhaskaran, Palaniswamy, N.S. Rangaswamy and M.J. Jayachandran, 2005 Global cost of corrosion –A Historical Review corrosion: Materials, 13-B, ASM Hand book, ASM international materials.

2. Tushar Jhaveri, cost of corrosion- Degenerated effects in India, Indocating Summit august 12-14. 2008. JAKARTA.
3. Koch, G.H., M.P.H. Brangers, N.G. Thompson, Y.P Virmani and J.H. Payer, 2002. Corrosion cost and preventive strategies in the United States ," FHWA- RD01-156,Federal highway. Administration.
4. Palmer, J.D., 1989. Environments Characteristics controlling the soil corrosion of Iron in soil ferrous piping I n: V Chaker and Palmer, J.D. (Eds.) Effects of Soil characteristics on Corrosion A S T M S T P 1013, American Society for Testing and Materials, Phil., 5-17.
5. Starkey, R.L. and K.M. Weight, 1983. Anaerobic Corrosion of Iran in soil American Gas Associations, Bulletin,17: 11-13.
6. Kulman , F.E., 1955. American Gas Association, 37: 467.
7. Corrosion .doctors.org/pipeline/carl
8. Financial Express,sept.27,2006. BMC Water pipeline bursts, Thane flooded.
9. Romanoff, M., 1957. Underground Corrosion, NBS Circular, 579, U.S. Government printing office, Washington, D. C.
10. Booth, G.H., A.W. Cooper and A.K. Tillers, 1967. Criteria of soil aggressiveness towards buried metals, III Verification of Predicated behavior at selected soils. British corrosion J; 2(3): 116-118.
11. Escalante, E. Concept of underground corrosion In: V Chaker and J. D. palmer (Eds) 1989. Effects of Soil characteristics on Corrosion, ASTM STP1013, American Society for Testing and Materials Phil, pp: 81-94.
12. Dayal, H.M., B.K. Gupta, K.C. Tiwar,Kamlesh Mehta, Chandrashekhar, and S.K. Gupta, April, 1988. Underground corrosion by organisms. part-I. Analytical studies of some Indian soils. Def.Sci. J; l-38(2): 209- 216.
13. Applegate, L.M: 1960. Cathodic protection, (MC Graw-Hhill,NewYork).
14. Levlin, E., 1991. British Corrosion journal 1: 36-66.
15. Corrosion Advisory Bureau, 1973.Code of procedure for conducting studies on underground corrosion of metals –Report (C.S.I.R. Jamshedpur).
16. Zbigniew Jan Mudryk, Beata Podgorska, Jerzy Bolalek, 2000. The occurrence and activity of sulphate reducing bacteria in the bottom sediments of Gulf of Gdansk. Oceanlogia, 42(1): 105-117.
17. Ramesh babu, B., S. Maruthamuthu, A. Rajasekar, N. Muthu kumar and N. Palani swamy, 2006. Int. J. Environment science, tech.Spring 3(2): 159-166.
18. MPCB Report, 2005. Environmental Status of Thane Region of Maharashtra.
19. Rhoades, J.D., 1996. Salinity, Electrical conductivity and Total Dissolved solids .Methods of Soil analysis .Soil science of America ser.5 part -3, Chemical methods .SSSA & ASA. Madison wis., 417-435.
20. ASTM Standard D2216-98, 2006. Standard Test Method for Laboratory Determination of Moisture Content, 04: 09, Phil.
21. Standard Test Method for Determination of Organic matter in soil, IS 2720, part (22), 2001.
22. ASTM Standard G187-05, 2006. Standard Test Method for Measurement of Soil Resitivity using Two Electrode Soil Box Method, 04. 09. Phil.
23. Hesse, P.R., 1971. A Textbook of soil chemical analysis; John Murray, London, p: 520.
24. Kapat, Chetan, Balu pradhan, B . Bhattchajee, 2006 Corrosion in reinforced steel. Corrosion science, 48: 1757.
25. ALPHA AWWA, 1998.Standard Methods for Examination of water and waste water 20th(edi) see. 3120.
26. Piper, C.S., 1966. A Text book of soil and plant analysis , (Hans Publisher)
27. Benmoussat, A. and M. Hadjel, 2005. Corrision Behavior of low carbon line pipe steel in Soil environment. Eurasion Chemico-Technological Journal, 7(2): 16-22.
28. Nie, H., X.G. Li, C.W. Du and Y.F. Cheng, feb. 2009. Temperature Dependence of the electrochemical corrosion characteristics of carbon steel in a salty soil. J .Applied Electrochemistry, pp: 39.
29. Booth, G.H., 1971. Microbiological Corrosion London mills and Boon Ltd., pp: 29.
30. Uhling, H.H. and R.W. Revie,1985. Corrosion and Corrosion Control, Newyork; Jhon Wiley and sons.
31. Hakkarainen, T.J., 2003. Microbiologically Influenced corrosion of stainless steels. J. Materials and Corrosion., 54(7): 503-509.
32. Demet Cetin and Mehmet Levent Aksku, 2009. Corrosion behaviour of low alloy steel in the presence of Desulfotomaculum sp. J.Corrosion Science, 51(8):1584-1588.
33. Hamilton, W.A., 1990. Ann. Rev. Microbial.39,1958
34. Enrlich, H.L., 1990. Geomicrobiology.New York; Marcel Deker.
35. AWWA Soil Corrosivity Scale-105.
36. Harter, R.D., R. Naidu,1995. Role of metal organic complexation in metals sorption by soils. Advan. Agron, 55: 219-263.
37. USDA Natural Resources Conservation Service (NRCS) Soil Survey Staff, 2009. Soil Hand Book.
38. Glazov, N.P.and K.L. Shamshedinov, 2002. Protection of steel pipes against corrosion, J. Protection of metals, 38(2): 172-175.

39. Glazov, N.P., S.M. Ukhlovtser, I.I. Reformatskaya, A.N. Podabaer and I.I. Asheulova, may 2006. Soil corrosion of differential aeration cells and conditions of their operations. J. Protection of metals 42(3): 238-243.
40. Joseph, R. Devis, 2000. Aeration cells corrosion understanding the basics, ASM. International. Park, Ohio.
41. John O'M Bockris, Amulya K.N. Reddy, 2000. aeration cells, concentration cell, Corrosion In: Modern Electrochemistry-2b Kluwer Academic/Plenum publishers.
42. Concrete Repair Bulletin sept. oct 2005. Corrosion in concrete Due to aeration cells.
43. Marianna Kay Adler Fliten, INL, Idoho Falls, ID Peter, K., Nagata, Retired Idoho Falls, Timothy S. Yoder, the underground corrosion of selected Type 300 Stainless steel After 34 year,. NACE corrosion 2009, conference and EXPO. Atlanta. Georgia USA.
44. Beavers, J.A., C.L. Durr and K.C. Garrity, 2002. the influence of soil Chemistry on SCC of pipelines and Application of 100 mv Polarization criterian, paper No.02426, corrosion /2002NACE International.
45. The NACE ADVOCATE, 2008. NACE and DOD Extend Partnership to Combat Corrosion., 3: 4.
46. John a. Beavers and Niel G. Thompson, C.C. Tecnologies, 2006. External orrosion of oil and Natural gas pipelines .ASM Handbook.
47. Kay Winkelmann, 2005. The conversion of liquid rocket fuels: In NATO Science series, 162, Location of liquid missile propellant depot in Azerbijn, Recent storage situation and Risk assessment, 2005, springer Link publication. 53-72.
48. Beckman, W., 1965. Factors affecting electrical soil resistance and it's importance in corrosion prevention, Gas-U Wasser Fact, P101.