IJETIR
ISSN (Online) 2583-0554
IJETIR
Impact Factor: 5.731
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Volume 4, Issue 10, October 2024

Effect of Thermo-Physical and Bio- Chemical Properties of Soil on Corrosion Morphology

Monika Sharma[1] and Prof. (Dr.) Rekha Israni[2]
Research Scholar, Chemistry Department, Bhagwant University, Ajmer, India[1]
Professor, Chemistry Department, Bhagwant University, Ajmer, India[2]

Abstract: *Soil composition and its properties have an impact on corrosion from a thermophysical and biochemical perspective. Soil composition consists of sand, clay, and gravel, which affect its thermophysical properties. For example, changes in water and air flow, changes in soil potential, and thermal equilibrium can affect the soil corrosion process. Biochemically, the presence of various bacteria, fungi, and other biological organisms in soil can affect corrosion activity. This study explores the influence of thermophysical and biochemical properties of soil on corrosion morphology. Thermophysical properties such as moisture content, thermal conductivity and soil structure significantly affect soil temperature distribution and moisture retention, which in turn affect the rate and pattern of corrosion in buried metals. Additionally, biochemical properties including the presence of microorganisms, organic content and pH levels play an important role in corrosion processes by altering the electrochemical environment. Understanding these interactions is essential for predicting corrosion behaviour and developing effective strategies to mitigate soil-induced corrosion in various engineering applications*

Keywords: Air, Flow, Properties, pH, Soil, Corrosion etc

I. INTRODUCTION

Soil represents one of the most active and complex natural systems on the Earth's surface and is composed of six components namely inorganic matter, organic matter, soil organisms, soil moisture, soil solution and soil air.

In natural ecosystems there is the development of soil layers and the accumulation of humus. A portion of the annual accretion of minerals from atmospheric inputs, including substrate weathering and N-fixation, becomes stabilized by colloids and biota. This builds up the available nutrients in the soil, which increases the fertility of the soil. In assessing soil fertility status and in nutrient cycling studies, the determination of nutrient content in forest soils is important. At higher altitudes, soil is formed by the process of volatilization. Soils on slopes above a 30°C angle are generally shallow, usually very thin-surfaced due to erosion and mass-wasting processes such as skeletal soils with a medium to coarse texture, depending on the materials they contain from whom they have been obtained. The interdependence of soil, plant and animal has deeply entered human life. Braun-Blanquet (1934) has pointed out a close relationship between the natural assessment of vegetation and soil development. Various studies have been done regarding their correlation with soil and plant growth in the deciduous forests of the country (Singhal et al., 1980). Therefore the present study was undertaken to analyze the physical and chemical properties of soils along the disturbance gradient in Ajmer region.

Failures of buried pipeline systems (water, sewage, oil and gas) due to corrosion are an inevitable concern for owners and asset managers in any country, as they reduce the service life of pipelines. The direct cost of replacing drinking water and sewage systems is approximately US$36 billion each year in the United States (Koch et al. 2002). In Australia, more than 70% of water utilities are made of ferrous metal pipes (Worthington 2011). Failure of these water utilities leads to financial losses and sometimes even accidents leading to loss of human lives. According to the Australian Corrosion Association's official website (under Cost of failure of urban water infrastructure), the cost of corrosion failures associated with water services in Australia is $91 million per year. In Australia, the failure rate averages 20 breaks per 100 km per year, and replacement costs have increased by 10% annually since 2006 (National

IJETIR
ISSN (Online) 2583-0554
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Volume 4, Issue 10, October 2024
Impact Factor: 5.731

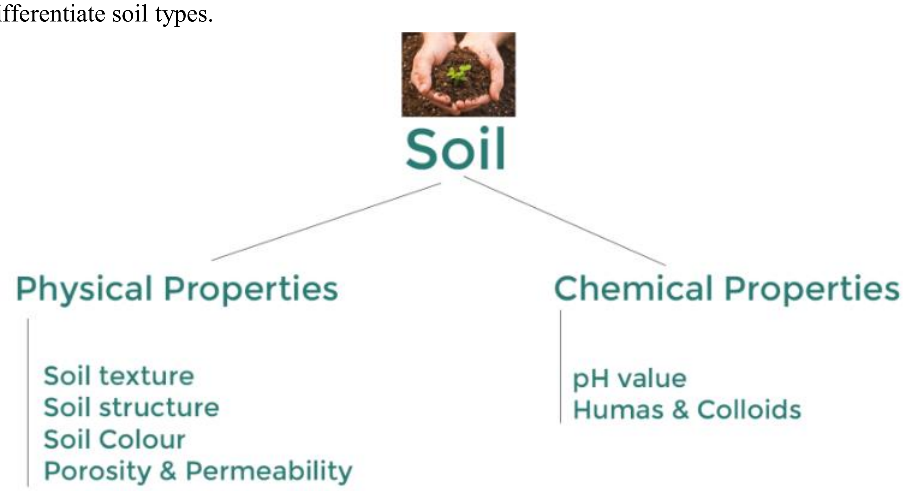
Water Commission Australia 2010). The failure rate of buried pipelines in the UK and Canada has been recorded as 39 breaks per 100 km annually (Li and Yang 2012).

On 19 July 2017, a water main line in the Adelaide Central Business District (CBD) suddenly burst during peak traffic hours, resulting in massive traffic disruptions and significant financial losses (News Channel South Australia). Similarly, sudden bursting of pipes and resulting significant losses in the United States and Britain have been reported in news channels and newspapers (CNN and BBC). These pipes are buried underground, making them difficult to inspect and maintain at any specific location, in addition to field conditions and environmental changes. The high frequency of pipe failures, as explained above, is due to the lack of understanding and inaccuracy of the current theories used to predict the failure of buried pipes. Although extensive research related to corrosion failure of cast iron pipes has been conducted in different parts of the world funded by local research councils, such as the Australian Research Council (ARC) (Australia), National Science Foundation (NSF) (USA).), the Engineering and Physical Sciences Research Council (EPSRC) (UK), and the National Research Council (NRC) (Canada), these failures are still inevitable.

1.1 Properties of Soil

All soils contain mineral particles, organic matter, water, and air. The combinations of these determine the soil's properties – its texture, structure, porosity, chemistry, and colour.

Knowing a soil's water, mineral, and organic components and their proportions can help us determine its productivity and what the best use for that soil may be. Several soil properties that can be readily tested or examined are used to describe and differentiate soil types.



1.1.1 Effects on Bio-chemical properties of the soil

Cation exchange capacity (CEC)

Increase in soil temperature decreases organic matter Ubeda et al. through combustion. This decrease in organic matter and reduction in clay size clay fraction as a result of high temperature leads to a decrease in the cation exchange capacity of the soil Certini.34 Increase in soil temperature leads to a decrease in the cation exchange capacity of the soil.

Available phosphorus

Yilvaiaio et al., observed that water-soluble phosphorus increased with soil temperature from 50c-250c due to the increase in the movement of phosphorus in the soil controlled by diffusion. Soils with low temperature have low availability of phosphorus because the release of phosphorus from organic material is hindered by low temperature.

Soil pH

At a soil temperature ranges of 25°C- 39°C the soil pH increases as a result of organic acid denaturation which increases at high temperature.

Inorganic matter present in the Soil: The mineral content of the soil is the major factor that differentiates various types of soil. It is so because of its abundance in the soil.
Organic matter present in Soil: Though these matters present in very small quantities but they play important role in deciding the fertility of the soil.
Colloidal properties of Soil: Colloids are mainly of two types:
Clay Colloids: they are important for the adsorption of a large quantity of water.
Organic Colloids: these help in increasing the moisture and nutrient retention capacity of the soil.
The pH of Soil: The measure of the chemical reaction which a soil shows is expressed by its pH value. The pH value of soil determines its acidic or basic nature.

1.1.2 Effects on soil Thermo-physical properties

Soil structure

Increase in soil temperature causes temperature induced dehydration of 2:1 clay minerals in the soil leading to strong interactions among the clay particles which in turn yield less clay and more silt-sized particles in the soil. High soil temperature also leads to heat-induced cracks in the sand-sized particles that eventually lead to breakdown and consequently a reduced amount of sand-sized particles in the soil. Increase in soil temperature lowers the clay sand contents and increases the silt content.

Aggregate stability

At soil temperature above 30oc, the aggregate stability of the soil increases Fox et al. This is as a result of thermal transformation of iron and aluminium oxides, causing them to act as cementing agents for clay particles that then form strong silt-sized particles in the soil.

Soil moisture content

Reductions in soil moisture occur when increased soil temperatures decrease water viscosity, thus allowing more water to percolate through the soil profile Broadbent. In addition, reduced shade combined with increased soil temperatures also results in higher evaporation rates which in turn restrict the movement of water into the soil profile.

Soil aeration

Temperature influences the carbon dioxide content in the soil air. High temperature encourages micro-organism activity which results in higher production of carbon dioxide in the soil Allison.

Soil Texture

Soil texture defines the proportion in which the soil separates to make the mineral component of the soil. These separates can be classified as sand, clay, and silt. Sand and silt are of no importance to the soil as they don't contribute to the soil's ability to restore water or nutrients. Clay is an active part of soil texture as clay has a small size and it has a large amount of surface area per unit mass and it helps in storing ions and water.
The soil texture refers to the coarseness/fineness of the mineral matter in the soil. It is determined by the proportion of the sand, silt, and clay particles. The equal proportion of all three of them is known as loam. Soil texture affects the water holding capacity, nutrient retention, nutrient fixation, drainage, compressibility, and aeration of the soil.
Clay: Particle Size – diameters **less than 0.002** millimeter
Silt: Particle Size – diameters between 0.002 millimeters to 0.05 millimeters.
Sand: Particle Size – diameters between 0.05 and 2 millimeters.

1.2 Result Analysis

The chemical properties of soil can influence the corrosion of buried pipes. The chemical elements that are responsible for causing corrosion are sodium, potassium, calcium and magnesium, and other are acid-forming elements, such as carbonates, bicarbonates, sulfates, and nitrates. The conductivity of electric current (corrosion) largely depends on the soluble salts and the moisture content of the soil. There is a voluminous literature on the chemical analysis of soil and methods to analyze it which can be referred to for more details (Head and Epps 1986, Peverill et al. 1999). pH is the measure of the soil's alkalinity or acidity, which is the logarithm of the reciprocal of hydrogen concentration. The neutrality of a soil is indicated by a pH of 7, while soil below this pH level is acidic and above it is alkaline. The pH of soil can be determined by using pH sensors or ASTM D4972 (2013). The following levels of pH define the nature of the soil (Soil Survey Manual 1951):

- Extremely acidic below 4.5 pH
- Very strongly acidic--------4.5-5.0 pH
- Strongly acidic--------------- 5.1-5.5 pH
- Medium acidic---------------5.6-6.0 pH
- Slightly acidic------------------6.1-6.5 pH
- Neutral---------------------- 6.6-7.3 pH
- Mildly alkaline-------------- 7.4-7.8 pH
- Moderately alkaline-------- 7.9-8.4 pH
- Strongly alkaline------------ 8.5-9.0 pH
- Very alkaline---------------- 9.1 and higher pH

Clarification with reference to previous studies on how various factors like soil pH, moisture, temperature and SRB in soil etc. affect the corrosion behavior of buried pipes is necessary to review them for the present project.

Over 70% of existing buried pipes in Australia are ferrous metal pipes including cast iron, ductile and steel pipes (Kennaway et al 2008). The manufacturing method of these ferrous metal pipes plays an important role in understanding the corrosion mechanism of these pipes in soil to predict corrosion and develop materials and techniques for corrosion resistance. It has been observed that pipes with different types of construction and metallurgical characteristics fail differently due to corrosion (Nicholas and Moore 2009). The reason for this behavior is not well understood, but it can have a significant impact on the failure mechanisms of buried pipes. Since the objective of the present research is to understand the corrosion mechanisms of buried pipes made of three types of ferrous metal pipes, it is essential to know about pipe manufacturing in Australia. This section briefly covers pipe manufacturing processes for cast iron, ductile and steel pipes.

Table 1.1 Chemical composition of mild steel

C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Al	Ti	Fe
0.22	0.55	1.70	0.04	0.03	0.25	0.5	0.4	0.35	0.1	0.04	95.82

Comparison of corrosion behavior of ferrous metal pipes

There is disagreement among researchers regarding the corrosion behavior of ferrous metal pipes i.e. cast iron, ductile iron and mild steel pipes in soil. Some researchers have examined the corrosion behavior of these pipes for comparison purposes. Pennington (1967) analyzed the experimental data of Romanoff (1957) and found that the corrosion resistance of steel pipes was greater than that of cast and ductile iron pipes. Furthermore, Pennington stated that cast iron pipes were more resistant to corrosion than ductile iron pipes.

Sears (1968) conducted extensive research on the corrosion of ductile and cast iron pipes and buried specimens in various soils over 14 years. They found similar corrosion penetration and mass loss in both cast iron and ductile iron samples. In contrast, Fuggerson and Nichols (1984) stated that cast iron pipes tend to pit more deeply than ductile iron pipes when exposed to the same environmental conditions due to the morphology of cast iron pipes. However, Cox (1998) and others postulated that the layered graphite matrix of gray cast iron is a diffusion barrier that not only hinders easy access of the corrosant to the ferrite phase, but also traps corrosion products within its matrix. The presence of the graphite matrix was thought to be a factor in increasing the service life of cast iron compared to uncoated steel or ductile iron pipe exposed to the same soil environment. Other research found no difference in the corrosion resistance of ductile and gray cast iron (Cast Iron Pipe Research Association 1964; Rose and Parkinson 1985; NACE 1992). Similarly, Lack (1995) found from field testing on samples buried in corrosive clay soils in Europe that ductile iron and gray cast iron had similar corrosion resistance. Nevertheless, the corrosion susceptibility of cast iron compared to ductile iron has been well recognized by previous studies, such as Romanoff (1964), Rosa and Parkinson (1985), Pelletier et al. (2003), Kleiner (2003), Berardi et al. (2008) and Paradkar (2013).

IJETIR
ISSN (Online) 2583-0554
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Volume 4, Issue 10, October 2024
Impact Factor: 5.731

According to this recent research, it is clear that cast iron corrodes faster than steel.

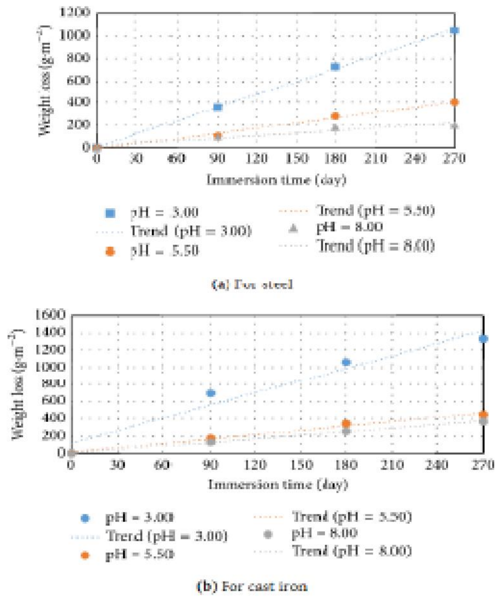


Figure 1.1 Comparison of corrosion in steel and cast iron (Hou et al. 2016)

A comparison of the corrosion of ductile and steel pipes in the context of previous research has shown that ductile iron has greater corrosion resistance than steel pipes (Gerhold 1976). Failure in cast iron occurs more suddenly than in steel and ductile pipe. Failure of steel and ductile pipe occurs in the form of leakage, with no catastrophic failure. Corrosion protection technologies, such as, but not limited to, coatings and cathodic protection, provide resistance to corrosion. However, despite all corrosion protection technologies, pipe failure in the form of leaks and ruptures is common in almost every part of the world. Interestingly, in rare situations, it has also been observed that some buried pipes have been in operation for more than 120 years and no failures have been reported (Nicholls 2009).

In a recent study, Song et al. (2017) investigated the corrosion behavior of ductile iron and carbon steel in solutions of different chloride concentrations. They analyzed corrosion products, corrosion rates and corrosion depths of ductile and steel samples. In their analysis of corrosion rates and corrosion depth, they found that steel samples corrode more than ductile samples in the same corrosive environment. A comparison of the corrosion rates of ductile and steel specimens in solutions of different chloride concentrations is shown in Figure 1.2.

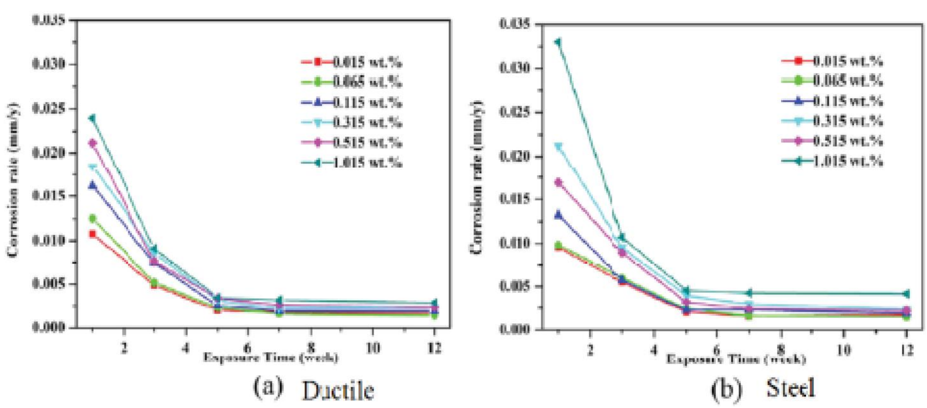


Figure 1.2 Comparison of corrosion in ductile iron and steel (Song et al. 2017)

Based on the above discussion, it can be inferred that although there is disagreement among researchers regarding the corrosion resistance of cast iron, ductile and steel, many studies show that cast iron is more corrosion prone than ductile and steel. It happens. steel. In recent studies, ductile iron has been found to be more corrosion resistant than steel, and steel is more corrosion resistant than cast iron in the same corrosive environment.

1.3 Conclusion

Corrosion is a serious concern for owners and managers of buried ferrous metal pipelines because it can cause structural deterioration, which adversely affects the service life of the pipes. Leakage or cracking due to corrosion are commonly recognized problems in buried metal pipes that can lead to catastrophic failures, causing significant socio-economic losses to consumers and water utilities. Despite the periodic inspection of these buried pipelines and the development of corrosion-protection techniques, corrosion-induced deterioration of pipes remains a major problem globally, and billions are spent each year on repair and maintenance of corroded buried pipes. Corrosion can change the mechanical properties of metals due to chemical and microstructural changes at the macro, micro or nano levels which affects their service life. To date it has not been widely explored for buried pipes by other researchers. Therefore, an understanding of the corrosion mechanism, its contributing factors and its effect on thermo-physical and bio-chemical properties is essential for corrosion protection of newly installed pipes and maintenance of existing pipes. In the research reported here, various laboratory-controlled experiments were conducted to observe the variation in the mechanical properties of metal pipes in different corrosive soil and simulated soil environments to investigate the major factors affecting the corrosion of pipes in soils, including anaerobic bacteria. Will be done The coupled effects of varying acidity and saturation on corrosion of gray cast iron samples will be explored by conducting laboratory experiments simulating underground corrosion. A correlation between soil corrosion and cast iron simulated soil was demonstrated in comparison with previous studies. Most of the experiments were carried out on cast iron and selected ductile iron, and mild steel samples were also used in simulated soil solutions for comparison of corrosion severity. Next, the effect of corrosion on their fracture toughness induced by different corrosive environments will be investigated. In addition, the hydrogen emission of steel pipelines to the soil environment due to the release of hydrogen during the corrosion process will also be investigated. Furthermore, the variation in thermo-physical and bio-chemical properties due to corrosion at the micro- and nano-scales will be assessed. Based on the analysis of the various test results, it is concluded that corrosion has a substantial effect on the thermo-physical and bio-chemical properties of metals, thus forming an integral part of the current approach to the design of new pipes and the assessment of the condition of old pipes.

REFERENCES

[1]. Aiyer KS, Vijayakumar BS, Vishwanathan AS. 2018. The enigma of biofilms. Curr Sci. 115:204–205. doi:10.18520/ cs/v115/i2/204-205.

[2]. AlAbbas FM, Williamson C, Bhola SM, Spear JR, Olson DL, Mishra B, Kakpovbia AE. 2013. Influence of sulfate reducing bacterial biofilm on corrosion behavior of lowalloy, high-strength steel (API-5L X80). Int Biodeterior Biodegradation. 78:34–42. doi:10.1016/j.ibiod.2012.10.014.

[3]. Al-Darbi MM, Agha K, Islam MR. 2008. Comprehensive modelling of the pitting biocorrosion of steel. Can J Chem Eng. 83:872–881. doi:10.1002/cjce.5450830509.

[4]. Almeida PF, Almeida RC, Carvalho EB, Ramos-de-Souza E, Carvalho AS, Silva CHTP, Taft CA. 2006. Overview of sulfate-reducing bacteria and strategies to control biosulfide generation in oil waters. In: Taft CA, editor. Modern biotechnology in medicinal chemistry and industry. Research Signpost. pp. 183–195.

[5]. Anandkumar B, George RP, Maruthamuthu S, Parvathavarthini N, Mudali UK. 2016. Corrosion characteristics of sulfate-reducing bacteria (SRB) and the role of molecular biology in SRB studies: an overview. Corr Rev. 34:41–63. doi:10.1515/CORRREV-2015-0055/ASSET/ GRAPHIC/J_CORRREV-2015-0055_CV_005.JPG.

[6]. Anguita J, Pizarro G, Vargas IT. 2022. Mathematical modelling of microbial corrosion in carbon steel due to earlybiofilm formation of sulfate-reducing bacteria via extracellular electron transfer. Bioelectrochemistry. 145: 108058. doi:10.1016/J.BIOELECHEM.2022.108058.

[7]. Antony PJ, Chongdar S, Kumar P, Raman R. 2007. Corrosion of 2205 duplex stainless steel in chloride medium containing sulfate-reducing bacteria. Electrochim Acta. 52:3985– 3994. doi:10.1016/j.electacta.2006.11.016.

[8]. Beech IB, Sunner JA, Arciola CR, Cristiani P. 2006. Microbially-influenced corrosion: damage to prostheses, delight for bacteria. Int J Artif Organs. 29:443–452. doi: 10.1177/039139880602900415.

[9]. Bernt K, Uffe S, Thomsen S, Juhler S, Larsen J. 2012. Cost efficient MIC management system based on molecular microbiological methods. /NACECORR/proceedingsabstract/CORR12/All-CORR12/119789.

[10]. Bowman E, Thompson N, Gl D, Moghissi O, Gould M, Payer J. 2016. International measure of prevention, application, and economics of corrosion technologies study. http://impact.nace.org/economic-impact.aspx.

[11]. Cai Z, Xu J, Wei B, Sun C. 2022. A comparative study of sulfate-reducing Desulfovibrio desulfuricans induced corrosion behaviours in Q235, X65, X70, and X80 pipeline steels. Int J Press Vessels Pip. 195:104599. doi:10.1016/j. ijpvp.2021.104599.

[12]. Chang HY, Park YS, Hwang WS. 2000. Initiation modeling of crevice corrosion in 316L stainless steels. J Mater Process Technol. 103:206–217. doi:10.1016/S0924-0136(00)00462-3.

[13]. Chen L, Wei B, Xu X. 2021. Effect of Sulfate-Reducing Bacteria (SRB) on the corrosion of buried pipe steel in acidic soil solution. Coatings 2021, Vol 11, Page 625. 11: 625. doi:10.3390/coatings11060625.

[14]. Chesnokova MG, Shalaj VV, Kraus JA, Mironov AJ. 2015. Assessment of soil biocorrosion severeness on the pipeline locations. Procedia Eng. 113:57–61. doi:10.1016/j. proeng.2015.07.289.

[15]. Chesnokova MG, Shalaj VV, Kraus YA, Cherkashina NV, Mironov AY. 2016. Analysis of corrosion defects on oil pipeline surface using scanning electron microscopy and soil thionic and sulfate-reducing bacteria quantification. Procedia Eng. 152:247–250. doi:10.1016/j.proeng.2016.07. 698.

[16]. Costello JA. 1974. Cathodic depolarization by sulphatereducing bacteria. S Afr J Sci. doi:10.10520/EJC15B61CD63D. Dawuda AW, Taleb-Berrouane M, Khan F. 2021. A probabilistic model to estimate microbiologically influenced corrosion rate. Process Saf Environ Protec. 148:908–926. doi:10.1016/j.psep.2021.02.006.

[17]. De Andrade JS, Vieira MRS, Oliveira SH, de Melo Santos SK, Urtiga Filho SL. 2020. Study of microbiologically induced corrosion of 5052 aluminum alloy by sulfatereducing bacteria in seawater. Mater Chem Phys. 241: 122296. doi:10.1016/j.matchemphys.2019.122296