Mining Division

AGAT Laboratories

Soil Corrosivity Testing Process

What is Soil Corrosivity?

Soil Corrosivity is a naturally occurring process in which the surface of a metallic pipe or concrete structure is oxidized or reduced by chemical or electrochemical reaction with the soil environment around it [1]causing deterioration of material impacting strength and performance.

Why is it important to determine soil corrosivity?

The inherent properties of soil play a significant role in promoting corrosion impacting reinforced concrete structure and service life of underground metallic pipes[2]. Determining corrosivity potential of soil allows for better assessment of service life and durability of underground assets enabling decisions around material selection, protective coating, inspection frequency and long-term planning to save cost on repair and replacement.

How is soil corrosivity evaluated to help mitigate corrosion?

There are many guidelines and models developed to predict soil corrosivity potential to evaluate the need for additional protection and service life of pipes buried in conventional soil backfill as well as to preserve concrete durability. One of the most commonly used standard for corrosion of metallic pipes in soils is ANSI/AWWA C105/A21.5, American National Standard for Polyethylene Encasement for Ductile Iron Piping for Water and Other Liquids and CSA A23.1-Table 3, Canadian Standard Association for concrete subject to sulphate attack (Please refer to page 4).

[1] Hubell (2003). “Step 7 - corrosion Guide.” Hubbell, Inc, <www.vickars.com>.

[2] Sadiq, R., Rajani, B., and Kleiner, Y. (2004a). “Fuzzybased method to evaluate soil corrosivity for prediction of water main deterioration.” Journal of Infrastructure Systems, 10(4), 149–156.

How is corrosivity potential determine by ANSI/AWWA C105/A21.5 method?

ANSI/AWWA C105/A21.5 (1999) is a 10-point scoring method that uses five major soil characteristics to determine corrosivity potential of a conventional backfill. If the sum of the points from all soil characteristics is equal to or more than 10, then the soil is assumed to be corrosive and the pipe requires additional protection. However, this system does not provide information on the intensity of soil corrosivity except to distinguish the soil as aggressive or non-aggressive to metallic pipes 2.

TABLE 2 10-point soil test evaluation for iron pipe

Soil Characteristics	Points*
Resistivity—*Ωcm*†	
<1,500	10
≥1,500–1,800	8
>1,800–2,100	5
>2,100–2,500	2
>2,500–3,000	1
>3,000	0
pH	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0‡
7.5–8.5	0
>8.5	3
Redox potential—*mV*	
>+100	0
+50 – +100	3.5
0 – +50	4
Negative	5
Sulfides	
Positive	3.5
Trace	2
Negative	0
Moisture	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

*10 points: corrosive to iron pipe; protection is indicated.
†Based on water-saturated soil box. This method is designed to obtain the lowest and most accurate resistivity reading.
‡If sulfides are present and low (<100 mV) or negative redox-potential results are obtained, three points should be given for this range.

What are some of the key indicators of soil corrosivity and how do they influence corrosivity potential?

There are many properties of soil that can contribute to soil corrosivity to metal and concrete that come into contact. Here are some of the key factors in the order of their relative degree of influence - soil electrical resistivity, temperature of soil, redox potential, soil pH, presence of salts, soil sulfides content, groundwater variability, availability of oxygen, degree of soil compaction, presence of sulfate-reducing bacteria, availability of sulfate, moisture content and presence of organic and inorganic acids. The interdependency of these soil properties is highly complex which makes it harder to predict the rate of corrosion for a given site. Based on ANSI/AWWA C105/A21.5(1999) scoring system, there are 5 major contributors to soil corrosivity potential.

(a) Soil Resistivity – resistivity is a key contributing factor with a maximum point of 10 on the ANSI/AWWA scale. It is based on the concentration of ions (e.g. salts) produced due to the action of subsurface water on the chemical mineral make up of soil. The electrical resistivity of soil is influenced by the degree of moisture content, temperature, degree of compaction and concentration of different salts and their movements[3]. The higher concentration of soluble salts with lower compaction of soil combined with higher temperature and higher moisture content decreases soil resistivity[3] creating ideal conditions that promote corrosion.

(b) Soil pH – This is a measure of soil acidity or alkalinity based on ions that carry current. A pH range of 0.0 to 4.0 on the ANSI/AWWA scale indicates a higher corrosion rate and assigned more point values. On the other hand, a soil with pH greater than 8.5 is also assigned more points as they are expected to be high in dissolved salts resulting in lower resistivity and higher corrosion potential[4].

(c) Oxidation-Reduction (Redox) Potential – It is a measure of oxygen availability in soil as an electro-negativity reading in volts (V). A redox potential of more than + 100mV on the ANSI/AWWA scale indicates the presence of oxygen making it not possible for anaerobic sulfate-reducing bacteria to survive thereby impeding corrosion rate[4].

(d) Soil Sulfides Content – A measure of sulfides content in the soil indicate the presence of sulfate and sulfate-reducing bacteria that can convert sulfate to highly corrosive sulfide under anaerobic soil conditions[5]. Soils that are high in sulfates can also produce sulfate attack in some concrete causing deterioration.

(e) Soil Moisture Content – Availability of moisture in the soil can highly influence corrosion reaction with a score of 2 points for continuously wet conditions on the ANSI/AWWA scale. Soil moisture content is also affected by varying groundwater levels which in turn slows down soil aeration promoting anaerobic conditions for sulfate-reducing bacteria to speed up corrosion.

[3] Doyle, G., Seica, M. V., and Grabinsky, M. W. (2003). "The role of soil in the external corrosion of cast iron water mains in Toronto, Canada." Canadian geotechnical journal, 40(2), 225–236.

Romanoff (1957). External Corrosion and corrosion control of buried water mains (Re-Printed in 2004). AWWA Research Foundation, USA.

[4] National Academies of Sciences, Engineering, and Medicine (NASEM) 2008. Corrosion Study and Implementation Plan for NCHRP Report 597. Washington, DC: The National Academies Press. https://doi.org/10.17226/23119

[5] Cunat, P.-J. (2001). "Corrosion resistance of stainless steels in soils and in concrete." CEOCOR: comité d'étude de la corrosion et de la protection des canalisations. Journées plénières.

What are the different test options offered by AGAT Laboratories and their requirements?

Please refer to the chart below for test packages, RDLs, hold times, bottle requirements and other special instructions.

Code	Routine Packages	Method Reference	Instrumentation	RDL	Holding Time (as received)	Bottle type/ Preservation/ Min weight	Book Price
93111	Corrosivity in Soil Package I - pH, EC, Resistivity, Redox Potential, Chloride, Sulphate						$225.00
93110	Corrosivity in Soil Package II - pH, EC, Resistivity, Redox Potential, Chloride, Sulphate, % moisture, sulphide						$325.00
	pH (2:1 DI H2O)	MSA part 3/ SM4500H+B	pH Meter	NA	30 days	250mL Amber Glass Jar None 25g (dried & sieved)	
	Electrical Conductivity (2:1 DI H2O)	modified MSA3 Ch14/ SM2510B	EC Meter	0.005 mS/cm	30 days	250mL Amber Glass Jar None 25g (dried & sieved)	
	Resistivity (calculation)	McKeague 4.12/ SM 2510 B/ SSA #5 Part 3	Calculated based on EC	1 ohm.cm	--	250mL Amber Glass Jar None 25g (dried & sieved)	
	Redox Potential*	modified G200-09/ SM 2580 B	Redox Potential Electrode	NA (mV)	24 hrs (lab testing)	250mL Amber Glass Jar None 100g (as received)	
	Water Soluble Chloride (2:1), Sulphate (2:1)	modified SM 4110 B	Ion Chromatograph	2 µg/g	30 days	250mL Amber Glass Jar None 25g (dried & sieved)	
	% moisture	MOE E3139	Balance	0.10%	20 days	250mL Amber Glass Jar None 20g (as received)	
	Sulphide	ASTM E1915-13/ ASTM E1019-18	Carbon/ Sulphur analyzer/ IR	0.05%	30 days	250mL Amber Glass Jar None 10g (dried & sieved)	

* Recommended field testing immediately following sampling

CSA A23.1 – TABLE 3

Additional requirements for concrete subjected to sulphate attack*

(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, 8.4.1.2 and Tables 1.)

Class of exposure*	Degree of exposure	Water soluble sulphate (SO_4)† in soil sample, %	Sulphate (SO_4) in groundwater sample, mg/L‡	Water soluble sulphate (SO_4) in recycled aggregate sample, % §	Cementing materials to be used**
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS or HSb
S-2	Severe	0.20 – 2.0	1,500 – 10,000	0.60 – 2.0	HS or HSb
S-3	Moderate	0.10 – 0.20	150 – 1,500	0.20 – 0.60	MS, MSb, LH, HS, or HSb

** For sea water exposure, see Clause 4.1.1.5.*
† As per CSA A23.2-3B.
‡ As per CSA A23.2-2B.
§ Cementing material combinations with equivalent performance maybe used (see Clauses 4.2.1.2, 4.2.1.3, and 4.2.1.4). Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates. Refer to Clause 4.1.1.3.

CSA A23.1-Table 3, Canadian Standard Association for concrete subject to sulphate attack