Table 1: Data for the Evaluation of Soils

No.	Characteristic and Measurand	Unit	Measuring range	Rating value
a) Evaluation of soil samples				
1	Type of soil			Z_1
	a) Cohesiveness: Content of settleable solids	% of weight	≤ 10 > 10 to 30 > 30 to 50 > 50 to 80 > 80	$+4$ $+2$ 0 -2 -4
	b) Peat, moor, warp, and marshy soils, organic carbon	% of weight	> 5	-12
	c) Severely polluted soils			-12
2	Specific soil resistance	Ohm cm	 > 50000 > 20000 to 50000 > 5000 to 20000 > 2000 to 5000 1000 to 2000 < 1000	Z_2 $+4$ $+2$ 0 -2 -4 -6
3	Water content	% of weight	 ≤ 20 > 20	Z_3 0 -1
4	PH value		 > 9 > 5.5 to 9 4 to 5.5 < 4	Z_4 $+2$ 0 -1 -3
5	Buffer capacity	mmol/kg		Z_5
	Acid capacity up to pH 4.3 (alkalinity $K_{A\,4.3}$)		< 200 200 to 1000 > 1000	0 $+1$ $+3$
	Base capacity up to pH 7.0 (acidity $K_{B\,7.0}$)		< 2.5 2.5 to 5 > 5 to 10 > 10 to 20 > 20 to 30 > 30	0 -2 -4 -6 -8 -10
6	Sulfides (S^{2-})	mg/kg	 < 5 5 to 10 > 10	Z_6 0 -3 -6
7	Neutral salts in aqueous extract $c(Cl^-) + 2\,c(SO_4^{2-})$	mmol/kg	 < 3 3 to 10 > 10 to 30 > 30 to 100 > 100	Z_7 0 -1 -2 -3 -4
8	Sulfates (SO_4^{2-}, hydrochloric acid extract)	mmol/kg	 < 2 2 to 5 > 5 to 10 > 10	Z_8 0 -1 -2 -3
b) On-site evaluation				
9	Location of object relative to groundwater		 No groundwater present Groundwater present Groundwater changes over time	Z_9 0 -1 -2
10	Soil homogeneity, horizontal			Z_{10}
	Soil resistance profile: The variation of Z_2(see line 2) above across neighboring soil areas is determined: ΔZ_2 (All positive values of Z_2 are set to equal "+1.")		$\lvert\Delta Z_2\rvert < 2$ $2 \leq \lvert\Delta Z_2\rvert \leq 3$ $\lvert\Delta Z_2\rvert > 3$	0 -2 -4
11	Soil homogeneity, vertical			Z_{11}
	a) Soil in the immediate surroundings		Homogeneous embedding with soil of the same type, sand Inhomogeneous embedding containing extraneous material such as wood, roots etc. or including more strongly corrosive soils of different types	0 −6
	b) Z_2[1] values varying across soil layers; $\lvert\Delta Z_2\rvert$ is determined in analogy to line 10		$2 \leq \lvert\Delta Z_2\rvert \leq 3$ $\lvert\Delta Z_2\rvert > 3$	-1 -2
12	Potential between object and soil $U_{Cu/CuSO_4}$ (used to detect extraneous cathodes) If it is impossible to measure the potential, e.g. in the absence of the object from the soil, Z_{12} must be set to equal -10 if pieces of coal or coke are present.	V	 -0.5 to -0.4 > -0.4 to -0.3 > -0.3	Z_{12} -3 -8 -10

Note on Table 1: For evaluations of soil type (line 1) and vertical soil homogeneity (line 11), the rating values are set to the most negative alternatives.

Rating values nos. 9 to 12 and, whenever possible, rating value no. 2 are determined on site. Rating values nos. 1 to 8 are determined on the basis of soil samples through lab analyses. It is important to make sure that the soil samples are sufficiently representative of the object to be evaluated and for the question to be answered. It is advisable to analyze several soil samples taken as suggested by the specific features of the object to be evaluated. The overall evaluation should then be based on the results of all the analyses.

The table contain general designations of the various soil types. Anaerobic soils containing active sulfate-reducing microorganisms often play an important role for the evaluation of corrosion risks. The following rating values characterize such soils: $Z_1 < -2$, $Z_7 \leq -2$, and in particular $Z_6 = -6$.

$B_D = Z_2 + Z_4 + Z_5 + Z_6$	Table 5.
B_D-, W_D-, W_L values	Quality of the coating
≥ 0	Very good
-1 to -4	Good
-5 to -8	Satisfactory
< -8	Insufficient

$B_0 = Z_1 + Z_2 + Z_3 + Z_4 + Z_5 + Z_6 + Z_7 + Z_8 + Z_9$

Soil Classes, Soil Aggressiveness and Probability of Corrosion in Soils for Unalloyed and Low-Alloy Iron Materials				
B_0 or B_1 values respectively	Soil class	Soil aggressiveness	Probability of corrosion based on the values of B_1	
	based on the values of B_0		Pitting	General corrosion
> 0	Ia	In practice not aggressive	Very low	Very low
-1 to -4	Ib	Weakly aggressive	Low	Very low
-6 to -10	II	Aggressive	Medium	Low
< -10	III	Highly aggressive	High	Medium

[1] In the original, the index 3 is given as 3, which is an obvious typo.

<u>In well-aerated to very well-aerated soils</u>, with a specific soil resistance of more than 10,000 Ohm x cm, having a content of settleable solids (< 0.063 mm) of less than 30 percent of weight and a water content from 3 to 14 percent of weight, the protective zinc coating is subject to an initial rate of corrosion (up to 2 years) of 2 µm/a. Once a covering layer has formed, the corrosion rate is 0.5 µm/a.

<u>In moderately aerated to well-aerated soils</u>, with a specific soil resistance of more than 5,000 Ohm x cm, having a content of settleable solids (< 0.063 mm) from 30 to 70 percent of weight and a water content from 20 to 35 percent of weight, the protective zinc coating is subject to an initial rate of corrosion (up to 2 years) of 5 to 9 µm/a. Once a covering layer has formed, the corrosion rate is 2 µm/a.

<u>In poorly areated to moderately aerated soils</u>, with a specific soil resistance from 1,300 to 1,500 Ohm x cm, having a content of settleable solids (< 0.063 mm) of more than 70 percent of weight and a water content from 20 to 38 percent of weight, the protective zinc coating is subject to an initial rate of corrosion (up to 2 years) of 8 to 32 µm/a. Once a covering layer has formed, the corrosion rate is 2 µm/a.

If an elevated content of salts is present in such soils and the specific soil resistance ranges from 60 to 150 Ohm x cm, the initial rate of corrosion (up to 2 years) reaches 22 to 30 µm/a. Once a covering layer has formed, the rate of corrosion lies between 2 and 9 µm/a in these cases.

<u>In very poorly aerated soils</u>, with a specific soil resistance of 406 Ohm x cm, having a content of settleable solids (< 0.063 mm) of more than 70 percent of weight and a water content of 29 percent of weight, the protective zinc coating is subject to an initial rate of corrosion (up to 2 years) of 48 µm/a. Even after a covering layer has formed, the corrosion rate remains at 48 µm/a.

Source: Reports of KIWA MPA Bautest GmbH.

The probability of corrosion of metallic materials in soils has so far been evaluated on the basis of

1) the assessment of the quality of covering layers on hot-dip galvanized steels as indicated by the value of B_D.

Note: This approach does not take into account a number of factors including the value of Z_1, which is important for assessing the soil type.
Peat soil e.g. (share of weight $> 5\%$) may be highly corrosive even if the quality of the protective zinc layer has been rated "good."

It is therefore advisable to determine at least the value of B_0. In this case, all rating values $Z_1$to Z_9 are determined, which has the additional advantage of allowing a lab such as "Kiwa Bautest GmbH" to estimate the average annual degradation of the zinc layer* as well as the maximum period of time during which it provides protection.

[* Translator's note: The word „degradation" is missing in the original, an obvious error.]

<u>**Information**</u>
8.3 Hot-Dipped Galvanized Steels
The points made in section 8.1 regarding ungalvanized steels essentially obtain here, too. Hot-dipped galvanized steels should only be used if the zinc layer offers sufficient protection as indicated by table 5. An additional protective layer does not provide synergistic protection for objects in soil or water, in contrast with cases in which the objects are exposed to the atmosphere.

Source: DIN 50 929 – Part 3 (1985)

<u>**Information**</u>

Hot-dipped galvanized construction elements such reinforced earth may be used only in soils of classes I or II.

Source: Stahl-Informations-Zentrum, Merkblatt 400 (Corrosion properties of hot-dipped galvanized steel)