Galvanic corrosion in waste water installations

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1. Introduction

In Switzerland, about 50 % of corrosion damages in waste water installations are caused by the presence of galvanic couples. Under such conditions corrosion is often 5 to 40 times faster compared to the „natural" corrosion velocity (without galvanic couples) in water, so that corrosion damages occur far before the expected life time of an installation, in many cases already after3 to 5 years of service life.

2. Mechanism of corrosion in galvanic couples

The mean condition for the formation of galvanic couples is the presence of a potential difference between different parts of a metallic structure. **Table 1** indicates typical corrosion potentials E_c of different materials. Those are also determined by the composition of the corrosive environment.

Metal		**E_c [mV_{CSE}]**		
steel, cast iron in aerated waste water		-650	to	-450
steel, cast iron in non aerated waste water (anaerobic conditions)		-900	to	-700
stainless steel in aerated waste water		-200	to	+100 *
rebars of reinforced concrete	in air, soil	-200	to	+100
	in water	-500	to	-200
Zinc/galvanised steel in aerated waste water		-1.000	to	-800
Aluminium compounds in aerated waste water		-600	to	-50

* in presence of micro-organisms the potential can reach values up to 500 mV
E_c [mV_{CSE}] : potential difference between the considered metal and a reference electrode (copper/copper-sulphate) in the same electrolyte

Table 1: Corrosion potentials in different media

When two metals with different corrosion potentials are in contact with an electrolyte (water, soil) a galvanic couple (galvanic cell) is formed. At the moment where the electrical circuit between the two metals is closed, the metal with the more negative corrosion potential becomes the anode, the metal with the more positive corrosion potential the cathode (**fig. 1**). Because the anodic and cathodic areas are separated clearly, such cells are also named macrocells.

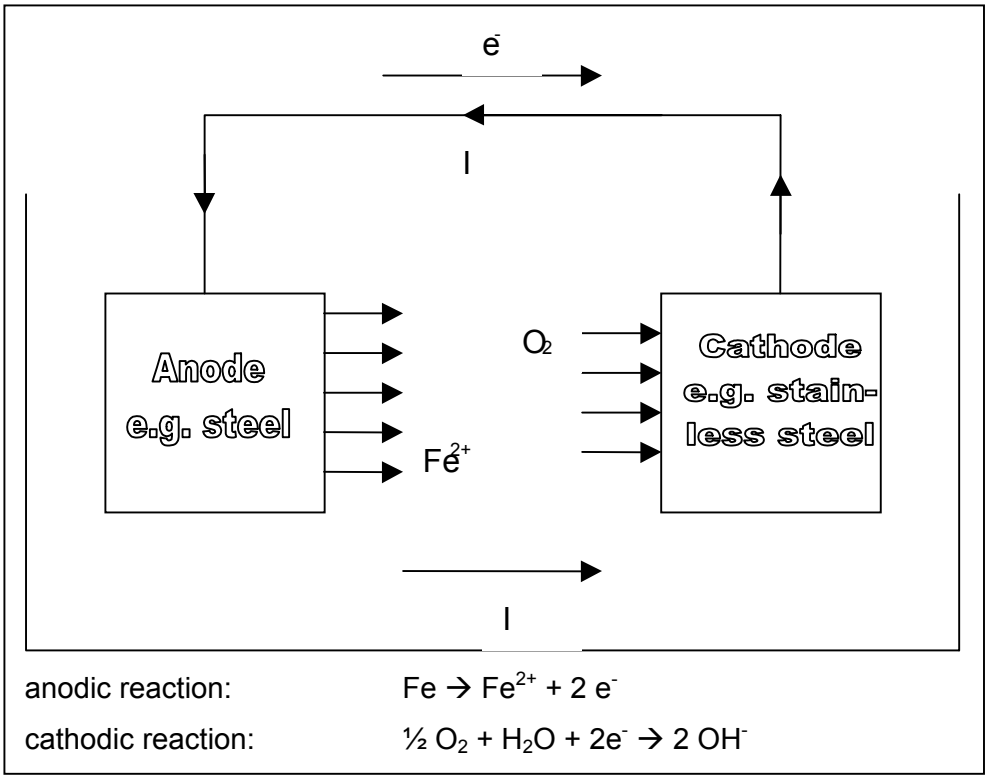

Fig. 1: Corrosion mechanism in macrocells

3. Corrosion veolocity

In galvanic couples there is always a D.C. current flow. The macrocell current depends on the potential difference (difference between the corrosion potentials) and the electric resistance between anode and cathode as well as on the polarisation behaviour (electrochemical resistances) of the electrodes.

The corrosion of the anode is composed by the natural corrosion (without galvanic couples) and the loss of material caused by the current flow in the galvanic couple as indicated in table 2.

Metal	**Loss of material per mA**	
	g/year	cm^3/year
Aluminium	2.90	1.08
Steel, cast iron	9.13	1.16
Zinc	10.69	0.98

Table 2: Loss of material in macrocells

In waste water installations corrosion losses of several hundred grams per year may be caused by galvanic couples. High macrocell currents have to be expected in couples with large cathodes and small anodes, the corrosion concentrates to the interface anode/cathode. Local corrosion rates between 0.5 and 2 mm/year are observed frequently in waste water plants.

4. Materials susceptible to damages in galvanic couples, typical situations

Two types of galvanic couples are predominant :

a) aeration cells

Corrosion by formation of aeration cells is observed, when the oxygen concentration varies along a structure (e.g. basins with large variations in oxygen content) or if the structure is partly covered by

deposits (cakes and residues of mud, non adhering corrosion products, ...) which hinder the oxygen to reach the metal surface. A local anode with metal dissolution is formed in the area with low oxygen content (e.g. below a deposit). This type of corrosion is observed generally on steel, galvanised steel and cast iron.

b) Macrocells with foreign cathodes

Macrocells with foreign cathodes are formed when there is an electrical connection between the structure and a foreign installation with a more positive corrosion potential than the structure. From table 1 it can be seen, that the most important foreign cathodes are stainless steel and the reinforcement of concrete structures. The last has nearly almost a very large surface which leads to high corrosion velocities. Grounding systems made of copper or stainless steel can also present important foreign cathodes.

The materials susceptible to galvanic corrosion are those with negative corrosion potentials as steel, cast iron, galvanised steel, zinc and aluminium. If such components are « protected » by a coating, the corrosion attack will concentrate on areas where the coating has defects (pores, mechanical damages, degradation). In this case the unfavourable ratio of surfaces (small anode, large cathode) leads generally to high corrosion rates.

Typical examples of galvanic couples in waste water installations are :
- mixed constructions made of carbon steel and stainless steel
- under water pumps, ladders and aeration systems in reinforced concrete basins, when they are in contact with the rebars
- metallic pipes in soil, which are in contact with copper grounding systems or reinforced concrete structures

The electrical connections between the metals with different corrosion potentials can be intended or accidental. They may result e.g. from :
- metallic fasteners which are in contact with the rebars
- equipotential bondings, earthing, measuring and steering devices

Contacts between the rebars of reinforced concrete structures and stainless steels normally do not lead to corrosion problems due to macrocells even though the corrosion potentials can differ notably in some cases. In fact, due to the electrochemical behaviour (low polarisation resistance of passive materials) the currents in such macrocells are small and do not cause notable corrosion on the structure with the more negative corrosion potential.

5. Preventive measures

The preventive measures to avoid damages by galvanic corrosion is to avoid the formation of galvanic couples or to limit the macrocell current to acceptable values. This may be reached

a) in the case of aeration cells
- by use of materials with low susceptibility for this type of corrosion (stainless steels ..) or by use of non conductive materials
- by application of coatings with a minimal thickness of 300 μm
- by application of cathodic protection to avoid or reduce potential differences in areas with different oxygen concentrations
- by building structures, installations without longitudinal electrical continuity (non conductive connection of pipes) to limit active cathodic surfaces
- by prevention of the formation of deposits to reduce variations of oxygen concentration on the surface along the structure
- by levelling the oxygen concentration in the electrolyte

b) in the case of galvanic couples with foreign cathodes

- by use of non conductive (non metallic) materials
- by avoiding the combination of different materials (of materials with different corrosion potentials)

If this is not possible :

- by galvanic separation (isolation for d.c. currents) of the different materials
- by avoiding permanent contact with the electrolyte of devices which are in use only temporarily, e.g. take out under water pumps which are not in use
- by increasing the resistance in the electrical current circuit (e.g. installation of isolating pieces between tubes made of different materials)
- by avoiding unfavourable surface ratios cathode/anode (e.g. by painting the cathodic surface or the application of an isolating coating
- by application of cathodic protection (galvanic anodes or preferably imposed current systems.

It is important to harmonise the electrical and corrosion protection concepts already in an early stage of the project study of waste water plants.

Remark :
The corrosion protection measures have to be in accordance with the regulations concerning electrical safety (grounding, equipotential bonds, lightening protection). Galvanic separation between structures with different corrosion potentials often need special electrical measures to guarantee security of persons and corrosion protection at the same time. Such measures may be the connection of lightening protection to the earthing system through spark gaps, the current supply of components without direct connection between the protective conductor of the component and the general earthing system, e.g. by use of separating transformers and so on. The detailed application possibilities of such protective measures depend on the national regulations.

6. Curative measures

The curative corrosion protection measures consist in the interruption of the electrical circuit of galvanic couples (galvanic separation of structures with different corrosion potentials) or in the reduction of macrocell currents to an extent, that they will not lead to damages or to a reduction of the service life of the installation.

Such measures may be :

a) in case of aeration cells

- Replacement of corroded structures by materials which are not or less susceptible to this type of corrosion (stainless steel, plastics, ..)
- Application of a coating with an minimal thickness of 300 μm on a sand blasted (at least Sa 21/2 in accordance to ISO 8501) and proper surface (free of salts as chlorides, sulphates, ...)
- Cathodic protection
- Prevent formation of deposits to avoid formation of anaerobic areas
- Agitation of the electrolyte (water) to reach homogeneous oxygen concentration

b) In case of macrocells with foreign cathodes

- Replacement of constructions with different materials (materials with different corrosion potentials)
- Galvanic separation (isolation for low D.C. currents)
- Avoid permanent contact with electrolyte of installations which are in use only temporarily (e.g. take out under water pumps out of the electrolyte when not in use)
- Increase the resistance in the electrical current circuit (e.g. installation of isolating pieces between tubes made of different materials)
- Reduction of the ratio of area cathode/anode (e.g. reduction of the cathodic surface by application of a paint or an isolating coating
- Cathodic protection with active anodes or with impressed current system

Note: For the application of the recommendations in this paper, above all the combination of different protective measures, a corrosion expert should be consulted.