

# Corrosive and aggressive phenomena associated to wastewater sanitation

Rafael Marín Galvín, José Miguel Rodríguez Mellado

**Abstract**— The origin of corrosive and aggressive phenomena acting in wastewaters are electrochemical actions, chemical processes and microbial sources usually preceded by the two first ones. The biofilms (composed by microorganisms and inorganic compounds) developed in the collectors and other elements of sanitation has also an important contribution. The combination of all these dynamics provokes premature degradation of all the materials in the entire sewer system. The starting agents of above situations are located in either wastewater, in solids contained by this one and in the atmosphere in contact with wastewater, solids and materials of the system infrastructures. Negative action of corrosive and aggressive phenomena with respect to networks and support systems as well as their own sewage treatment plants, causes annual losses of more than 30,000 million euro/year in Spain, as well as non-economic costs social, health and environmental. The mechanisms to minimize the negative impacts of corrosion and aggression in sanitation systems and urban wastewater treatment undergo several complementary ways: efficient implementation of control industrial discharges adapt them to the provisions of the normative about the item; election of the most suitable materials for each facility prioritizing not only the economic aspect; use of paints and coatings materials that are appropriate to each particular material depending on the practical use of it; implementation of cathode protection systems; finally, establishment in each case of contrasted and effective routine of maintenance of sanitation equipment and facilities.

**Index Terms**—Corrosion. Sanitation. Wastewater. Corrosion protection.

## I. INTRODUCTION

Wastewater is a complex fluid, rich in a variety of substances more or less degraded, either organic or inorganic, as well as in significant amounts of microorganisms that have a remarkable potential of interaction with the environment. There is a continuous change in their physicochemical and microbiological characteristics along the sewage system: from its generation (households, industries, commercial centers), through its conduction by collectors and emissaries, until its arrival at the treatment plants (WWTP) where they constitute a highly deoxygenated and reducing medium.

Faced with all these elements, wastewater sanitations are able to carry out significant degradation in the full sanitation

facilities, with several associated problems whose have their origins in three types of interacting mechanisms: electrochemical, chemical and microbial [1]-[3] which will be discussed below.

## II. MECHANISMS OF CORROSION AND AGGRESSIVENESS

### A. Electrochemical corrosion

A metal immersed in a solution tends to originate positive ions, which pass to the solution, and remaining negatively charged. The electrode potential for the process is governed by the well-known Nernst equation (equation 1) [3]-[5]:

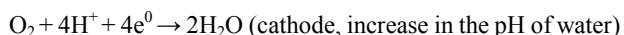
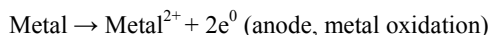
$$E = \frac{RT}{nF} \ln \frac{P}{\pi} \ln \frac{C}{a_m} \quad (1)$$

Where, “n” is the ion charge, “am” the ion activity in the dissolution, “ $\pi$ ” the ion osmotic pressure, “P” the ion partial pressure in dissolution, “T” the temperature, “F” the Farady number, and “R” the perfect gas constant.

By solving the above equation for T=25 °C (298 K), it could be obtained the so-called standard electrode potentials, whose define the possibility of interaction between substances with oxidation-reduction action. In the practice, the value of the standard electrode at a partial pressure of H<sub>2</sub> equal to 760 mm Hg at 25°C, immersed in a solution having an activity of the H<sup>+</sup> ions equal to 1 M, is taken equal to zero; this is the basis for comparing arrangement for the electrode potentials and the possible interaction between different redox couples [4], [5].

Electroactive species can contact either directly or through a medium (i.e. wastewater) for the electron transfer, and the metal having oxidation potential more negative (or less positive) is dissolved slowly. This phenomenon is the electrochemical corrosion which can develop in both aerated and non-aerated (more common in wastewater) media.

Electrochemical corrosion in aerated media responds to the processes (e.g., divalent metal) [6]:



The oxidation potential of the redox coupled Me/Me<sup>2+</sup> must be lower than that of the pair O<sub>2</sub>/H<sub>2</sub>O (+1.23 V) to provoke the metal oxidation, which generally will be favored with increases in pH and O<sub>2</sub> partial pressure (or its concentration in the medium). In the case of Fe, there are generated hydroxides (Fe(OH)<sub>2</sub> and Fe(OH)<sub>3</sub>, in particular) as the main products of corrosion found in the practice in

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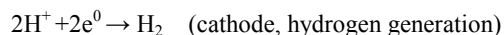
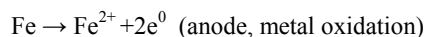
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pipelines, manifolds and facilities, originating collaterally the increase of the pH of water by the consumption of  $H^+$  ions.

Additionally, deposition over the metal of the hydroxides generated by the electrochemical process acts slowing the  $O_2$  diffusion from the water, which leads to the phenomena of the feedback anodic and the extent of corrosion.

Otherwise, in oxygen deficient media, as frequently in wastewater, corrosion phenomena also occur. Redox reactions would be now (e.g. for Fe) [6]:



In practice, the dissolution of Fe shall continue until  $pH < 10.5$  or when there is a sufficient amount of  $Fe^{2+}$  to coat the exposed metal areas to the access of  $O_2$  in these media, whereby the  $Fe^{2+}$  would have a tendency to rust later. In general, the corrosion in non aerated medium only ceases in stagnant or without circulatory flow there be no entrainment of deposited  $Fe(OH)_2$  formed. Finally, this mechanism causes widespread fairly uniform corrosion throughout the extent of the metal, with the coexistence of several anodic areas, which constitutes new points of future metal alteration [3] (see Figure 1).



**Figure 1:** External and internal corrosion in iron pipelines (authors).

The action of the two above discussed corrosion types provokes corrosion of the metal areas without direct contact with  $O_2$  (turns, thread holes, cracks, etc.), i.e., anodic the dissolution of metal. The areas in contact with  $O_2$  are protected from the cathodic corrosion: also, between the two zones a difference of potential appears, this originating an associated corrosion, which leads to the process named differential aeration [3], [6].

Summarizing, all the metals with oxidation potential lower than 1.23 V will be oxidized by  $O_2$ , if present, while those with  $E < 0.00$  V will be oxidized by  $H_2O$ . Consequently, except the noble metals (e.g., Au, Ag, Pt and Rb) all the rest of metals will be oxidized in greater or lesser extent in water.

#### 1. Corrosion and aggressiveness induced by chemical processes

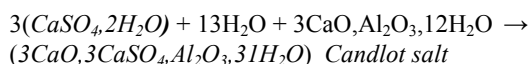
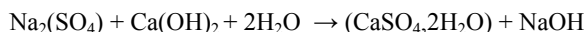
Water carbon balance would be the first mechanism considered here. Thus, in waters which Langelier index  $i_L < 0$  or Ryznar index  $i_R > 6.8$ , it would be observed the gradual dissolution of carbonates from concrete and construction materials of collectors and other non-metallic facilities, which

further promote corrosive attack or enhancing microbial degradation of the element in question. Meanwhile, for Langelier index  $i_L > 0$ , or Ryznar index  $i_R < 6.2$ , water would experience fouling associated with deposition of solid carbonates [3], [6], [7].

Other chemical aggressive agents in wastewater can be the inorganic salts that increase the conductivity of the medium and diminish the resistance to the flow of corrosion currents: thus the presence of  $Cl^-$ ,  $SO_4^{2-}$ , and  $Br^-$  and  $NO_3^-$ , even in low concentration [1], [3].

$Cl^-$  ions are accumulated in the anodic zone, while an increase of  $H^+$  ions by precipitation of iron hydroxides, and the subsequent generation of traces of HCl, is produced; that is, the presence of HCl together with  $O_2$  provoke pitting on the metal areas. This effect is found most commonly in salted waters up to concentrations of 104 g/L of NaCl. At higher concentrations there was observed a decrease in the aggressiveness by the decrease in the solubility of  $O_2$  in the water, associated to the increase in salinity [1], [3].

$SO_4^{2-}$  ions can also cause aggressiveness by means the increasing of salinity of the water through a specific process of degradation of concrete and construction materials that runs in the two steps:



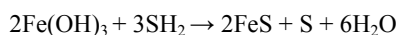
This process generates the so-named Candlot salt, which is a complex compound with a high capacity of subsequent decomposition and disintegration [6]. Alternatively,  $SO_4^{2-}$  ions can be also converted into  $S^{2-}$  ions by microbial pathway as will be commented below.

On the other hand, temperature has also influence over aggressiveness: so, a difference of  $15^\circ C$  between distinct areas of a material implies differences of potential around 40-50 mV and, consequently, serious corrosive effects [3].

Almost, inorganic ( $HCl$ ,  $HNO_3$ ,  $H_3PO_4$ ,  $H_2SO_4$ ,  $HF$ ) as well as organic acids (citric acid) promote alterations in concrete, cement and metals, while alkalis ( $NaOH$ ,  $KOH$  and  $Na_2CO_3$ ) cause induced dissolution of aluminates and alumina present in cements and other construction materials [1], [3], [6], [7].

At the same time, the presence of  $NH_3$ , especially with the presence of  $Mg^{2+}$ , affects to concretes and cements through nitrifying microbial processes that generate  $NO_3^-/HNO_3$  in aerated media. In addition, their ability to react with the lime accelerate the degradation of the cement [1], [3], [6].

Finally, the known system  $H_2S/HS^-/S^{2-}$ , present in wastewater or in interphases water-air, can generate metal sulfides including dissolving metals (Figure 2) or  $H_2S$  gas (which could then be oxidized to  $H_2SO_4$ , highly corrosive) according to the process:



Almost, the  $S^{2-}$  ion could evolve in two opposite ways depending on the medium conditions: (1) oxidation to  $H_2SO_4$ , highly corrosive, and (2) reduction of the  $Fe^{3+}$  present in  $Fe(OH)_3$  to generate  $FeS$ . This last species has a lower volume than the first one and promote the decomposition of tubers hydroxides existing previously in the materials, especially in acidic media with  $pH < 6$ ,

and where are experienced increases of the system temperature [3].



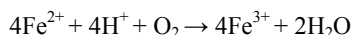
**Figure 2:** Corrosion by sulfurs in internal walls of wastewater collector (authors).

#### C. Microbial processes of corrosion

Microbiological action is often developed after the electrochemical and chemical corrosion, generating concretions, tubers, holes and cracks in the materials. The following organisms should be considered [2], [3], [8], [9].

#### Bacteria involved in the Fe and Mn cycle

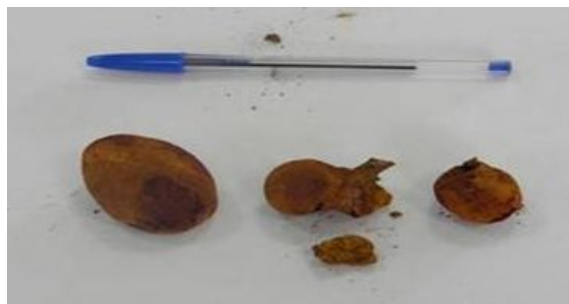
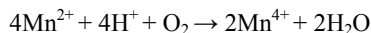
The bacteria involved in the Fe and Mn cycle are quimiotrophic and aerobic microorganisms, and they can oxidize  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  in acidic medium (pH=4-6). The chemical process responds to the reaction:



Typical bacteria of this type are *Leptothrix ochracea*, *Crenothrix polyspora*, *Siderocapsa geminata*, *Ferrobacillus* and *Gallionella ferruginea*. The  $\text{Fe}(\text{OH})_3$  formed by such organisms is stored in secretions mucilaginous shaped hollow pods, capsules and tubers (Figure 3) further containing  $\text{CaCO}_3$  and  $\text{FeS}$  in very many cases.

The Fe and Mn bacteria act by increasing both the extent and speed of the electrochemical process which generates the  $\text{Fe}^{2+}$  necessary for their life.

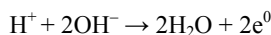
All these above cited microorganisms oxidize  $\text{Mn}^{2+}$  to  $\text{Mn}^{4+}$ , whether Mn predominates against Fe in the medium, being favored the process by nitrification phenomena. Nevertheless, there are specific Mn bacteria (some *Pseudomonas*, *Metallogenium*, and *Hyphomicrobium*) that do not attack Fe in any situation and for which the chemical reaction could express as,



**Figure 3:** Tubers and capsules generates by the Fe and Mn bacteria (authors).

#### Oxidizing hydrogen bacteria

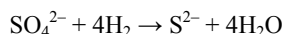
These microorganisms are chemotrophic and aerobic, being able to carry out their growth in the presence of  $\text{H}_2$ , although they can employ other easily oxidizable substrates. This process is developed by the genre *Hydrogenomonas* and by some *Pseudomonas* (*P. facilis*, *P. delafieldii*) and is conducted by the oxidation of the hydrogen to  $\text{H}_2\text{O}$ , a process promoted by the presence of  $\text{NO}_3^-$  ions and  $\text{O}_2$ , in alkaline media [3]. The chemical reaction responds to,



#### Sulfate reducing bacteria

These ones are facultative anaerobic autotrophic microorganisms that can operate under two metabolic pathways: assimilatory and dissimilatory reduction. The first one is shared by many bacteria, aerobic and facultative anaerobic which employ the S generated internally (e.g., *Escherichia coli*).

However, the more important process in bacterial corrosion is the dissimilatory reduction, process conducted by strictly anaerobic bacteria (e.g., *Desulfatamaculum*, *Desulfovibrio* and *Clostridium nigrificans*). In both cases, the  $\text{S}^{2-}$  produced (see reaction below) can generate black deposits of  $\text{FeS}$ , additionally rich in  $\text{Fe}(\text{OH})_2$ .

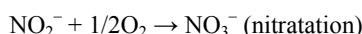
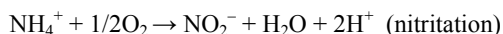


#### Bacteria involved in the nitrogen cycle

Several bacteria fix atmospheric  $\text{N}_2$  from soil, water, and even from aquatic organic sediments degraded present in wastewater collectors (well, a few species of *Azotobacter*). Similarly, other bacteria may perform the ammonification (or  $\text{NH}_3$  production) by increasing the rate of the process in the presence of protein substrates and having an optimum yield at temperatures in the range 25-35°C.

Once the  $\text{NH}_3$  is generated it is after used as a source of N by the so-named nitrosobacteria that produce  $\text{NO}_2^-$  (process known as nitritation, and carried out by *Nitrosomonas* and *Nitrosococcus*); this last product is subsequently oxidized to  $\text{NO}_3^-$  by the so-called nitrobacteria (process known as nitratation, and carried out by *Nitrobacter* and *Arthrobacter*).

However, the activity of nitrobacteria can be inhibited by the presence of high content of  $\text{NH}_3$  in water [3], [6]-[9]. The above processes respond to the following reactions:



Furthermore, in anaerobic media rich in organic matter occurs the process named denitrification, i.e., the microbial reduction of  $\text{NO}_3^-$  to  $\text{NO}_2^-$  followed by subsequent reductions of this last one to nitrogen oxides and  $\text{N}_2$ . This complex process is carried out by certain facultative anaerobic bacteria, which use  $\text{NO}_3^-$  as reducing substrate during episodes of lack of  $\text{O}_2$  in the medium.

Finally, the turning of ammonia to nitrates is developed by bacterial species of the genera *Clostridium* and *Bacillus*, and by a few strains of *Escherichia coli* [9].



### Fungi

On the other hand, hydrocarbon utilizing microorganisms such as *Cladosporium resinae* are commonly present in jet fuel. They live in the water-fuel interface of the water droplets, form dark black/brown/green, gel-like mats, and cause microbial corrosion to plastic and rubber parts of the aircraft fuel system by consuming them, and to the metal parts by the means of their acidic metabolic products. Specially, these microorganisms are able to attack aluminum, copper as compounds in medium with pH value of 3-7 [1], [3].

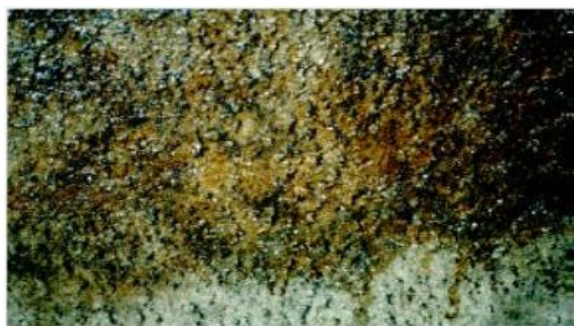
### III. IMPORTANCE OF BIOFILM FORMATION ON THE CORROSION AND AGGRESSION PHENOMENA IN SANITATION

As a necessary complement to the far collected on materials degradation mechanisms in sanitation it should be mentioned the formation of biofilm as a phenomenon developed in the interior parts of the water collectors. Although this phenomenon has been treated more extensively in drinking water distribution [10] the evidences there obtained are largely applicable to wastewater.

Biofilms are initiated by microorganisms called "pioneers" present in the wastewater, which are located in low velocity zones associated to solid accumulation and deposits (especially clays and limes) and other sediments remain there "anchored".

Fixing action is produced through two ways: chemical, involving Van der Waals forces, and physical, by emission of extracellular appendages excreted by the microorganism which forms a matrix that serves as support and protection for both, pioneer microorganisms as well as other opportunistic microorganisms.

In wastewater systems, some habitual initiator bacterial microorganisms are *Pseudomonas*, *Flavobacterium*, *Sphaerotilus*, *Thiodendrum* and typical enterobacteria, *Escherichia coli*, *Citrobacter sp.*, *Hafnia*, *Klebsiella* and *Salmonella*. Moreover, also fungi and yeasts wastewater are typical common initiator microorganisms. (Figure 4).



**Figure 4:** Typical biofilm in the inner part of a water piperline (J.L. De Victorica Almeida)

Once formed the jelly mass, it is capable of chemically adsorbing cations such as Ca, Fe, Mn or Zn with its associated anions (carbonates, sulfates, nitrates, oxalates, acetates, lactates...) as well as fine particulate materials and novel microorganisms. Metabolic waste products excreted by microorganisms (initiators and opportunistic) act as a feedback mechanism for the further development of the biofilm, initially slow, but whose speed increases significantly with time.

Typical biofilm sanitation usually contain various bacteria, fungi (especially actinomycetes) yeasts, protozoans and nematodes, plus the chemicals that are progressively adsorbed or fixed (depending on the size) for the same organisms.

### IV. LOCATION OF CORROSIVE AGENTS IN SANITATION FACILITIES

All the aggressive and corrosive agents for sanitation systems can be found in the three recipes: (a) in the liquid phase as wastewater; (b) in the gas phase as wastewater escaping gases; (c) in solid phase as higher or slower solids included in the wastewater which are deposited naturally or artificially either in collector either in pump station or finally in the Wastewater Treatment Plants [2]-[3], [8]-[9].

Following the process line in a WWTP, cleanings and periodic maintenance of water elevation elements, purges of degreasing-sandblasting systems, purges of the primary settlement or, if applicable, water from sludge drying or spin side, and even sewage and internal wastewater generated by washing and cleaning elements, all of them will constitute focuses of potential corrosion, while they can be conducted by treatment in the WWTP itself [6],[8].

The remains of diluted chemical treatments used in the plant, while must be managed as hazardous waste by an authorized agent, may in emergency or accident reach the WWTP process and become as other potential sources aggressive and corrosive vs. materials.

Moreover, the presence in wastewater of many volatile compounds, either in the sources or generated through chemical and microbiological mechanisms outlined above ( $H_2S$ , mercaptans or amines) results very evident. For example, benzene or chloroform present in wastewater can be partially incorporated into the gas phase in equilibrium with the liquid phase depending on several variables: temperature, volatility, partial pressures of the components, chemical reactions experienced by the compounds, etc.

A significant fraction of the above cited compounds will be in the atmosphere of sewage collectors, and also in the environment of the WWTP when they come there. Then, they can carry out their activity against materials and facilities in touch with them. In relation to primary and secondary sludge, the elements of sludge dewatering and drying, fresh or digested, or temporary storage facilities, they often generate gaseous environments with high corrosive power and aggressive atmospheres.

To finish this summary about this item, in wastewater collectors it will be produced solid deposition as a function of tracing network, low slope areas, fornix, low flow rate, etc... Solids are accumulate in the bottom and sides thereof. We also must consider the pumping wells and solids elevations as well as the purging systems and pretreatment of storm tanks and similar networks collectors, without forgetting the overflows elements that, when operating tend to accumulate large amount of solid residues rich in chemical with potential chemical or microbial aggressiveness [6]-[8].

### V. COSTS ASSOCIATED TO CORROSIVE PHENOMENA

The materials affected by corrosion and aggression processes in sanitation systems include:

Metals (especially iron materials, steel, and other metals –i.e., Cu-):

- Collectors, armatures, pumps, lifting screws.
- Indoor facilities WWTP.
- Rush domestic and industrial.

Concrete, construction materials and similar:

- Collectors and outfalls.
- Deposits and storm tanks, spillways.
- Decanters, grit chambers.
- Rush domestic and industrial.

Plastics materials:

- Manifolds.
- Auxiliary elements in networks and WWTP.

Costs arising from the effects of corrosion and aggression are of two types: non-economic and specifically economic. With regard to purely economic costs, breaks, cracks, fractures and damage of varying lengths in collectors and equipment as well as equipment items and WWTP (see Figures 5, 6, 7 and 8) are a major outlay for the sector [1], [11].

Almost it is very important that we also must include as other significant economic costs which would be derived from the statement of administrative proceedings caused for discharges of deficient treated wastewater from the sanitation systems to aquatic public environment.



**Figure 5:** Chemical corrosion on two high diameter wastewater collectors (authors).



**Figure 6:** (left) chemical acidic corrosion and (right) chemical alkaline corrosion in industrial wastewater rush to general network (authors).



**Figure 7:** (left) pitting in decanter (stell surface) and (right) electrochemical corrosion in metallic elements (authors).



**Figure 8:** Pitting and metallic corrosion observed in pipeline to dose ferric chloride (authors).

In short, although the economic costs always will depend on the starting parameters, the sector evaluates the total or partial replacement of materials and equipment sanitation and sewage, between 2% and 4% of GDP of industrialized countries, what it reaches in Spain amount to 30,000 million of euro per year [1], [3].

With regard to not specifically economic, we can comment the following: Evacuation undesirable of non-treated effluent into the environment, both sewage and harmful gases and atmospheres there existing. If the above occur in populated areas or in its proximity, there it would create health problems for rich microbial contamination active vectors of various diseases which should be contained in the wastewater [7]-[9].

The output of the medium, especially in urban areas, of gaseous effluents could also bring problems linked to unpleasant odors and atmospheres.

The output to the water table or even to the urban environment of wastewater deficiently treated could be a major focus of undesirable contamination of water resources (in both surface and groundwater).

Generation of urban mobility problems and discomfort linked to episodes of repairing damaged facilities: road closures, heavy machinery noises, disturbance by machinery combustion gases (e.g., cutting or to generate electricity) and even, the restriction access to the house itself depending on the specific location of the problem to solve.

Finally, the social perception of the citizen to pay little attention to their city to environmental issues related to the collection, sanitation and treatment of wastewater.

## VI. MECHANISMS TO LED REDUCTION OF CORROSION AND AGGRESSIVENESS IN WASTEWATER SANITATION

It may apply four types of measures, other than in any case, periodic maintenance of equipment and facilities.

### *Effluent control by applying normative about the subject*

The normative about effluent is usually named as Ordinances at Spain [11]-[14]. These ones establish as main objectives to protect our urban environment and our urban drainage and treatment systems, as well as to the personnel responsible for maintenance and operation of those, against the aggressions of wastewater cited above. It is wanted to reduce episodes of physical attack manifolds and obstructions in them, as well as the incidences of harmful and toxic substances for both collectors and WWTP and for people who work in them.

Thus, in all Ordinances are restricted pollutant emissions linked to the problems of corrosion and aggression reviewed



in this paper: discharges with extreme pH, presence of high salinity, high temperature metals, toxic compounds, etc... In this sense, the first mechanism to be applied against corrosion and aggression in the sanitation systems will be effective control of industrial discharges as a way of protecting it.

However, we must be aware that control does not always guarantee the absence of problematic discharges, or in many cases, identification of the causative agent.

Finally, application of pre-treatment systems for industrial effluents (prior to be discharged to network) is also required by all the Ordinances, and it shows its usefulness against corrosive and aggressive problems especially in the wastewater collectors [11]-[14].

#### *Suitability of materials*

The choice and implementation of materials in the sanitation system must try to use those for durability, strength and chemical inertness are most appropriate with abstraction of its cost, which nevertheless does not always apply.

With respect to the metallic materials, high-quality stainless steels are more suitable (see Figure 9) and it should be avoided whenever assemblies with direct contact between dissimilar metals and using, for example, O-rings or rims inert between them [1]-[3], [15].

From the above said, there is no doubt the plastics are the most inert materials to electrochemical, chemical and microbiological phenomena, and within them, PVC, polyethylene, polypropylene and polyesters reinforced with fiberglass are widely used to date in collecting, wells, connections and other accessories. While their main problem is that of high economic costs, this question is being quickly less important because these materials are decreasing your economic value.



**Figure 9:** Application of non-suitable and suitable materials in WWTP elements (authors).

#### *Use of paints & coatings*

Paints and coatings applied over collectors, fittings and holding tanks must be extended in both outside the element and on the inside in contact with the wastewater [1]-[3], [16].

In selecting paint system it should be considered the expected lifetime of the item to a degree of oxidation and to the allowable initial, surface preparation, priming, finish and thickness. The practical painted includes proper cleaning of the surface, a former cathode protection to achieve passivation of material and the final application of paint coatings or paints suitable.

All the paint system must meet the following requirements: electrical and chemical resistance, impact resistance and abrasion resistance, and resistance to cathode de-cohesion. Best results, with high durability's are achieved with epoxy coatings and polyurethanes, the use involves the use of

organic solvents or not depending on the particular type of item to be preserved [16].

#### *Cathode protection*

This system is based on translating the corrosion (that is, the anodic reactions) from the material of interest to another additional system which contact with the first one; it will reduce the rate of corrosion thickness at rates of less than 10  $\mu\text{m}$  per year [1]-[3], [17].

Cathode protection can be internal or external, and in both cases may be performed by installing sacrificial anodes or impressed current application system to protect, by an adjustment system DC, typically with a voltage of 50 V.

Sacrificial anodes exploit the potential difference between the metal in the material to be protected (including metal reinforced concrete) and that of the anode or material which is corrodes to receive the oxidation current: for example, the most useful materials against Fe, are Al, Zn and Mg.

The best results are achieved with the application together of subsequent coatings and cathode protection systems and by applying buried and buried pipelines, and complex items and accessories (flanges, valves).

#### *General actions*

Establishment in each specific situation of the contrasted and effective routine of maintenance of equipments and facilities more suitable after evaluation.

### CONCLUSIONS

Wastewater systems can experience corrosive and aggressive phenomena which have tree origins: electrochemical actions, chemical processes and, finally, microbial sources, preceding usually the two first ones the microbiological action.

Active microorganisms in microbial corrosion are majority bacteria such as that involved in the Fe and Mn cycle, oxidizing hydrogen bacteria, sulfate reducing bacteria, and that involved in the nitrogen cycle. Almost, a few specific fungi are also involved in microbial corrosion phenomena. Moreover, the action of the biofilm (composed by microorganisms and inorganic compounds) developed in the collectors and other elements of sanitation has also a important contribution.

The starting agents of above situations are located in: wastewater, solids contained by this one and atmosphere in contact with wastewater, solids and materials of the system infrastructures.

Negative action of corrosive and aggressive phenomena with respect to networks and support systems causes annual losses of more than 30,000 million euro/year in Spain, as well as various non-economic costs of type social, health and environmental.

Five mechanisms can be applicable to minimize the negative impacts of corrosion and aggression in sanitation systems: (1) efficient implementation of control industrial discharges adapt always them to the provisions of the normative; (2) election of the most suitable materials for each facility prioritizing not only the economic aspect; (3) use of paints and coatings materials appropriate to each particular material depending on the practical use of it; (4) implementation of cathode protection systems; (5) and

finally, establishment in each case of contrasted and effective routine of maintenance of equipment and facilities.

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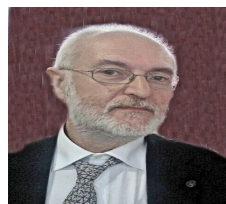
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