BIOFOULING

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Contents

Summary

Biofouling, or the accumulation of unwanted living matter, may be associated with two categories depending on the size of the organism involved i.e. micro or macrofouling. In order to survive living matter requires a source of nutrients. Attachment to a surface generally assists the opportunity to imbibe nutrients, and also provides protection. In certain examples, the conditioning of the surface by macromolecules assists the attachment process. Detachment from the surface may result from conditions within the aqueous system flowing across the surface. Common microorganisms that prefer to reside or attach to surfaces, include; bacteria, algae and fungi. Macroorganisms that require surfaces for sustained growth and reproduction include; mussels, barnacles, and hydroids.

1. Introduction

The accumulation of living matter on industrial surfaces, generally referred to as biofouling was briefly introduced in chapter An Overview of Fouling, and emphasized two categories depending on the size of the organism involved. Microorganisms, such as bacteria, algae, and fungi, may be found in suitable aqueous environments principally, although not exclusively, in "fresh" water systems. Although macroorganisms such as mussels may be found in "fresh" water, they tend to predominate in seawater and brackish water.

In order to survive all living organisms require nutrients, and suitable temperature conditions. The source of the nutrients is wide ranging but in general, their chemical make up will involve the elements associated with organic chemistry, i.e. carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus; some inorganic chemicals are also

essential for growth. Although CO_2 is plentiful in the natural environment it is only used directly by algae in photosynthesis. The usual source of carbon is in carbohydrates usually in the form of polysaccharides. Organic acids, often the breakdown products of decaying once living matter, are used as a ready source of carbon by many microorganisms. Other sources of carbon may originate in fats, proteins and hydrocarbons, such as methane. Some species of fungi derive carbon from cellulose material. Nitrogen is generally obtained from nitrogen containing compounds often complex, that were originally part of some living creature, e.g. amino acids, uric acid, and ammonia. Sulfur is common in natural environments in the form of hydrogen sulfide or organo-sulfur compounds, and may provide the source of essential sulfur.

Microorganisms require minerals for sustained growth. Essential minerals include potassium, magnesium and iron and trace elements, such as zinc, copper, cobalt, manganese, and molybdenum. Sodium and silicon may be necessary for the growth of some species.

Energy is required in metabolic processes, and the source of the energy is a means of classifying microorganisms:

1. Phototrophs obtain their energy directly from the sun. Chemotrophs obtain energy through oxidation processes of organic or inorganic compounds.

2. Autotrophs can utilize simple compounds such as CO_2 in their metabolism.

3. Heterotrophs require a fixed source of carbon in organic molecules.

4. Littotrophs produce reducing equivalents required for cell synthesis from inorganic substances such as H_2S or ferrous iron.

5. Orgotrophs obtain chemical reduction by oxidizing organic molecules.

The behavior of organisms in an aqueous environment in relation to surfaces is of considerable importance in the fouling process.

Micro and macroorganisms respond to a wide range of physical and chemical stimuli, in order to maximize the opportunities for survival and growth. Reference to bacteria emphasizes the kind of response to different conditions that places individual cells and colonies, in the most acceptable environment. In the presence of oxygen, there will be a tendency for aerobic bacteria to move toward a source of oxgyen, whereas anaerobic bacteria will attempt to move away from it.

Predatory microorganisms will tend to move toward the host, such as other microorganisms and plants, dependent upon their nutritional needs.

Movement in response to the presence of a nutrient or chemitaxis, is common in bacteria but not in fungi or algae. The colonization of surfaces (biofouling) may be in response to the presence of adsorbed nutrients on that surface. Some microorganisms respond to the presence of light either moving toward it to facilitate photosynthesis, or

away from it if light energy is not required in the particular metabolic activity. Algae require light so that some blue green algae have the facility to create gas vacuoles in order that they may float near the surface of the water, thereby ensuring the maximum opportunity for metabolic growth. Many microorganisms show the ability to respond to temperature, i.e. moving along a temperature gradient to locate the most favorable temperature for growth.

In a natural environment, such as that found in a river, lake or the sea there is generally an ecosystem that, for the given conditions, is in equilibrium. There is a balance between all the flora and fauna and the prevailing nutrient supply and the temperature. As the conditions change, due to differences between the seasons, winter and summer, and the availability of nutrients, there will be subtle changes in the biosphere, with a shift in the relative amounts of the living species.

In a biofouling situation where a surface becomes host to micro or macroorganisms, it is the activity in the region of the surface that assumes importance. It would appear that both micro and macroorganisms prefer to reside on a surface. Although there are clearly differences in detail, the general principles apply to both groups of living creatures. The advantages of being on a surface are perhaps, not difficult to visualize. Primarily, they involve the supply of nutrients and protection, and the dispersal of metabolic waste products. Furthermore, the continuous movement of natural waters over the surface will generally ensure that the water is aerated, a further advantage for aerobic species. Heat exchanger surfaces in contact with flowing water, would seem to be an ideal location for the growth of bacteria. Provided the water comes into contact with the environment at some stage it will acquire nutrients from the atmosphere and the surroundings. The temperature conditions too, are often near to the optimum for sustained growth.

The advantages of living on a surface may be compared with free floating or planktonic, microorganisms. The suspended organisms move with the water flow and so the availability of nutrients to an individual cell, or cluster of cells, is by Brownian movement either of the cells themselves, or the nutrient particle or molecule. Some species however, are able to move in response to the presence of nutrients.

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Bibliography and Suggestions for further study

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