International Journal of Engineering, Management and Humanities (IJEMH)
Volume 5, Issue 2, Mar.-Apr., 2024 pp: 114-116 ISSN: 2584-2145
www.ijemh.com

Bio-fouling- a concept, it's deleterious impacts and prevention

Aditi Vishwanath

Date of Submission: 15-03-2024 Date of Acceptance: 30-03-2024

Bio-fouling, a biological-mechanical phenomenon.
Also known as "biological fouling", bio-fouling is the amassment and growth of organic matter in undesirable places, such as submarine hulls or water inlets. The organic matter mainly constitutes of micro-organisms, such as algae and microscale animals.
Bio-fouling can lead to a steady degradation of mechanical accessories. This further results in the complete destruction (or deterioration) of the same.
Bio-fouling can affect;
i) grates and pipes/pipework,
ii) ship surfaces and
iii) water bodies (lakes, rivers and ponds)

Epibiosis.
Epibiosis is the alternate, biological term for bio-accumulation. The relationship shared between the host organism and the micro-organism dwelling in or on it may not necessarily be parasitic. In fact, it is not parasitic at all.
The primary requirement for epibiosis to take place is the presence of water. Shipyards and other construction companies, over the years, have faced tremendous losses under this circumstance.

Prevention.
- The concept of "*anti-fouling*".
The synthesis of specialized paints, which may be toxic or non-toxic, are usually used to eradicate bio-fouling. These materials may either retard the growth of the organic matter or result in the complete, premature death of it.

The consequences.
- Hydrodynamic vessels
Biofoulers are known to cause or have the following effects on the hull* and the propulsion system present in ships;
i) An increase in the volume of the shipping vessel
ii) An increment in the hydrodynamic resistance which directly influences the drag
[hydrodynamic friction (or resistance) α drag force]
iii) [drag force α 1/speed of the shipping vessel] (inverse proportionality)
iv) A decrease in the speed also brings down the fuel efficacy, that is, the consumption of the fuel is even more than before.
➢ The excess usage of fuel contributes to the phenomenon of global warming as it promotes carbon dioxide (CO_2) emissions alongside sulphur dioxide (SO_2).

*__Note__: The hull is also the most prominent part of a ship. It is impervious to water and other fluids. The hull is an enclosure where the cargo of the vessel is stored along with its' various other machineries. They are present in boats as well.

Bio-fouling; types.
- Micro-fouling
The formation of a biofilm by the organic matter falls under micro-fouling. It even houses the process of bacterial adhesion.
- Macro-fouling
Macro-organisms or larger organisms belong to this category. The resultant effect remains the same, ultimately leading to the unmitigated spoliation of the mechanical accessory in picture.
The biological and chemical mechanisms of the organisms further divide them into;
i) hard-fouling type and
ii) soft-fouling type
➢ The hard-fouling type of organisms are majorly calcareous. Their bodies consist of a calcium carbonate-based ($CaCO_3$) exoskeleton. A brilliant example of this type are the barnacles and mollusks. On the other hand, the soft-fouling type comprises of non-calcareous organisms, like the hydroids (Hydrozoans, Cnidarians) and seaweed (macroalgae).

Marine fouling; the mechanism.
Marine fouling takes place in four, different steps.
➢ The commencement of the process begins with the formation of a conditioning, organic film on the surface of the article which is in contact with water. The polymers adhere with the aid of van der Waals' interactive forces.

- The organic film now poses or serves as a *substratum* on which the bacteria can establish their colony (colonies). Diatomaceous matter also start attaching themselves on to the organic film.
- After the micro-organisms settle down, firming their residences, a secondary film forms. This one is referred to as the *biofilm*.
- The nutrient-rich biofilm now becomes a housing complex, where the next set of occupants (macroalgae and the sporozoans) can claim their abode. This takes approximately seven days.
- The cnidarians and mollusks are the tertiary colonizers. They occupy the topmost part of the hierarchy. These macrofoulers take around fourteen to twenty days to adhere themselves to the biofilm.

The ecosystem has now advanced towards completion.

How can bio-fouling be detected?

LED equipments

Ultraviolet C (UVC) radiation which has a wavelength ranging from 100 to 280 nanometres (nm) can help detect the build-up of the biological colonies. During operation, the limit is set from 250 nanometres onwards.

The property of fluorescence is what drives the process of detection. Micro-organisms contain intracellular fluorophores, which occur naturally in them. When excited, they emit radiations which fall within the spectral range of ultraviolet rays. Fluorescence relies on the following amino acids;

- Phenylalanine
- Tryptophan and
- Tyrosine

As a matter of fact, these amino acids also happen to be aromatic. If we talk about the ease of detection, fluorophores consisting of tryptophan are (relatively) the easiest to detect. Its' radiation is of the order of 350 nanometres (when bombarded or irradiated with a ray of 280 nanometres). Shipping industries also schedule biofouler removal sessions to keep a constant check on the biological activity caused by such infestations.

Preventive measures

A dispersant is a surfactant, which is added to a suspension consisting of solid or liquid particles in a liquid (a colloid or an emulsion), to improve dissociation of the particles. Dispersing agents help prevent their settling or "*clumping*". Such biodispersants are used by industries to keep a check on bio-fouling.

- Zwitterions are made to create an ultra-low, fouling interface which offer poor or weak points of anchorage (or coupling). Such a surface topology makes the organisms incapacitated, depriving them of building a strong base or film for their accumulation and growth.

Coatings, which occupy a major portion of the anti-fouling scheme, are sub-divided into;

- toxic and
- non-toxic coatings

i) Toxic, anti-fouling coatings

Copper oxide and organic tin (stannanes) were traditionally used to kill biofoulers. The contamination and obliteration of marine life then led to their discontinuation.

ii) Non-toxic coatings

- Hydrophobic-type: The organic polymers falling under this class possess low friction and *lowered surface energies*, which result in a surface that is hydrophobic. They are ecologically inert (fairly unreactive), but, short-lived. An example of a non-toxic polymer are silicone-based coatings.
- Hydrophilic-type: Coatings that are hydrophilic rely on the power (intensity) of hydration. They increase the energetic penalty of removing water for proteins and the organic matter to affix themselves. Zwitterions, such as *sulfobetaine*, are used as low-friction, hydrophilic coatings. The hydrophilic-type coatings are currently being synthesized by the *Office of Naval Research*.

Biocides.

Biocides are chemical paints, which are applied on top of mechanical surfaces, to preclude the formation of biofilms wholly. But, biocides also come with a lot of stumbling blocks as they are a grave peril to marine organisms.

An example of a biocide is the organotin-based paint, dichlorooctylisothiazolinone (DCOIT/DCOI).

Ultrasonic transducers.

These devices send ultrasonic waves through the hull to the surrounding water (the fluid medium). This helps denature or kill the potential organic matter dispersed in the latter.

Pulsed laser irradiation | Plasma pulse technology.

Diatoms and mussels are stunned with high-voltage electric current which lasts for around a microsecond, killing them within the shortest time period plausible. Acoustic pulses which carry high

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 5, Issue 2, Mar.-Apr., 2024 pp: 114-116 ISSN: 2584-2145
www.ijemh.com

energy are passed down pipes to do away with any build-ups which might have formed there.

Bio-mineralization fouling

Bio-mineralization fouling also falls under the concept of bio-fouling, and thus, I found the need to address about it in my review paper. Bio-mineralization fouling branches into two more sub-categories, namely;
i) bio-corrosion and
ii) scaling
In a nutshell, bio-mineralization refers to the conversion of organic compounds or molecules to inorganic derivatives, by micro-organisms. These micro-organisms produce minerals, which augment over time to produce mineralized tissues that are rigid and unyielding in nature.

Bio-corrosion.
[alternate names: microbial corrosion | microbiologically influenced corrosion (MIC) | microbially induced corrosion (MIC)]
The process in which a group of microbes transmute the electrochemical configuration of the environment of the surface that they are on, is referred to as bio-corrosion. The biofilm produced by them corrodes the surface, and these biofilms are often made up of the by-products formed from the microbe's cellular pathways.
A few examples of these corrosive derivatives include the oxides of iron, such as;
i) Iron (II) carbonate or Ferrous carbonate | $FeCO_3$
ii) Iron (III) oxide | Fe_2O_3 (red iron oxide or "rust")
iii) Iron (II) sulphide or Ferrous sulphide | FeS (a water-insoluble solid)

Scaling.
The accretion of (inorganic) particles on a surface (or membrane) is known as scaling. The membrane concentrates promptly absorb inorganic salts, which form water-insoluble precipitates if they surpass their saturation point(s). This occurs during nanofiltration (NF) or reverse osmosis procedures. Since chlorine (Cl) cannot be used to disinfect the membranous systems and make them devoid of any bacterial growth, scaling becomes inevitable sometimes.
The particles deposited are mainly carbonate salts ($CaCO_3$, for instance) and sulphides of lead (Pb) or zinc (Zn).

References

[1]. What is biofouling and how can we stop it? (n.d.). https://www.sofarocean.com/posts/what-is-biofouling-and-how-can-we-stop-it
[2]. Vuong, P., McKinley, A. J., & Kaur, P. (2023). Understanding biofouling and contaminant accretion on submerged marine structures. Npj Materials Degradation, 7(1). https://doi.org/10.1038/s41529-023-00370-5
[3]. Callow, J. A., & Callow, M. E. (2011). Trends in the development of environmentally friendly fouling-resistant marine coatings. Nature Communications, 2(1). https://doi.org/10.1038/ncomms1251
[4]. Beech, I. B., & Sunner, J. (2004). Biocorrosion: towards understanding interactions between biofilms and metals. Current Opinion in Biotechnology, 15(3), 181–186. https://doi.org/10.1016/j.copbio.2004.05.001
[5]. Hoek, E., Weigand, T. M., & Edalat, A. (2022). Reverse osmosis membrane biofouling: causes, consequences and countermeasures. Npj Clean Water, 5(1). https://doi.org/10.1038/s41545-022-00183-0
[6]. Idais, R. H., Abuhabib, A. A., & Hamzah, S. (2022). Recent Advances in Measuring and Controlling Biofouling of Seawater Reverse Osmosis SWRO: A review. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.95782