1.0. Biofouling

The marine environment is composed of an intricate web of diverse habitats. Life in the marine realm ranges from the miniature microbes to the giant whales. Over the years, marine organisms have developed varied characteristics depending on their dwelling habitat. They mainly include free-swimming, bottom-dwelling, floating and sedentary forms. Among these, the sedentary or sessile beings contribute to a major issue concerning all the maritime nations of the world, i.e., Biofouling. The term "Biofouling" was defined by Characklis (1990) as “An undesirable accumulation of a biotic deposit on a surface” and by Kerr et al. (1998) as "The process in which biological organisms attach to surfaces in an aqueous environment". Attachment is a way of life for the sedentary marine life. With man's progress in trade and industry, he began to introduce structures such as ships and platforms into the marine environment. The sedentary beings, quite naturally, started to develop a niche on these surfaces. Since the surfaces involved are of interest to man, biofouling has become a major cause of concern.

Biofouling can be classified into two categories, micro and macrofouling. Macrofouling occurs when macroscopic organisms such as algae and invertebrates attach to the surface of substratum, which is often preceded by microfouling or biofilm formation, where microorganisms colonise a surface (O'Connor and Richardson, 1998). The representatives of fouling organisms vary based on their size and diversity (Fig.1). Based on morphology of the fouling organisms it can be distinguished into three types i. microfoulers (unicellular microorganisms such as bacteria, diatoms and protozoa) ii. soft macrofoulers (such as algae, soft corals,
sponges, anemones and tunicates) and iii. hard macrofoulers (such as barnacles, mussels and tubeworms).

![Image: Fouling representatives based on size and diversity (Thome, 2013)](image)

**Figure: 1. Fouling representatives based on size and diversity (Thome, 2013)**

### 1.1. Microfouling

Biofilms are the oldest and most successful form of life on Earth with fossils dating back to 3.5 billion years and represent the first signs of life on Earth (Schopf *et al.*, 1983). Biofilm is an assemblage of microbial cells that is irreversibly associated with a surface and enclosed in a matrix of primarily polysaccharide material (Donlan, 2002). “Biofilm” includes a wide variety of manifestations of microbial aggregates (Flemming, 2011). Clusters of different microbial populations are found in almost all moist environments where nutrient flow is available and surface attachment is possible. In aqueous environments the majority of microbes grow as biofilms. These biofilms can be pathogenic, releasing harmful products and toxins, which become encased within the biofilm matrix. In marine environment biofilm is a surface accumulation which is not necessarily uniform in time or space and comprises of cells...
immobilised at a substratum, frequently embebbed in an organic polymer matrix of microbial origin (Characklis et al., 1990). Of all the life forms, microbial biofilms are ubiquitous and most successful with highest survival potential.

In natural conditions, monospecies biofilms are relatively rare; thus most biofilms are composed of mixtures of micro-organisms. The exact structure of any biofilm is probably a unique feature of the environment in which it develops. Biofilm formation protects and enables single-cell organisms to assume a multicellular lifestyle, in which “group behaviour” facilitates survival in adverse environments (Maria, 2014). Since biofilms form under diverse conditions, and may be composed of single or multiple species, the structures of various biofilms will necessarily have distinct features. Nevertheless, biophysical, structural and chemical studies have led to a useful basic concept of a “biofilm model” (Costerton et al., 1995). In this model, microorganisms form microcolonies surrounded by copious amounts of exopolysaccharide. Between the microcolonies are water-filled channels, and it has been proposed that these promote the influx of nutrients and the efflux of waste products. The major component in the biofilm matrix is water – up to 97% (Zhang et al., 1998).

In the ecological perspective, biofilms are involved in the biogeochemical cycles of virtually all elements and are carriers of the environmental “self-purification” processes. The process is always the same: microorganisms on surfaces convert dissolved or particulate nutrients from the water phase and/or from their support into metabolites and new biomass. The study of biofilms has grown markedly in recent years due to increased awareness of the pervasiveness and impact of biofilms on natural and industrial systems, as well as human health. Understanding the mechanism of biofilm formation will be a significant approach to solve the problem of biofilm formation.
1.1.1. A brief history of biofilm

The concept of biofilm starts from the microorganism. Hence it is considered that discovery of microorganism or bacteria must be the steppingstone for the development of biofilm.

1684 Antonie van Leeuwenhoek was the first to display the animalcule (bacteria) found in the plaque of teeth.

1922 Angst reported that slime on the bottom of ships was caused to a large extent by bacteria, when biofouling occurred on surfaces.

1933 Henrici used direct microscopy to study biofouling in freshwater and he observed that ‘it is quite evident that for the most part water bacteria are not free floating organisms, but grow attached upon submerged surfaces.

1935 ZoBell and Allen studied the adherence and growth of bacteria on submerged glass slides in seawater.

1940 Heukelekian and Heller observed the “bottle effect” for marine microorganisms and wrote about the development of bacterial slime and colonial growth attached to surfaces.

1969 Jones et al. used scanning and transmission electron microscopy to examine biofilms on trickling filters in a wastewater treatment plant and showed them to be composed of a variety of organisms.

1973 Characklis investigated microbial slimes in industrial water and revealed that biofilms were both tenacious and highly resistant to the antimicrobial effects of chlorine.

1978 Costerton et al. published a theory of biofilms that explained the mechanisms whereby microorganisms adhere to living and non-living materials and the benefits accrued by this ecological niche.
After 1978 the study of biofilm became renowned to the scientific, medical, industrial and marine researchers. Hence many researchers focused to understand the mechanism of biofilm formation followed by the antifouling strategies being developed.

1.1.2. Biofilm formation

Biofilm formation is a cycle of events; it varies from place to place based on the availability of nutrients and suitability of the environment. Biofilm formation occurs in a sequential manner, involving formation of conditioning layer or film, initial attachment of microorganisms and biofilm maturation followed by dispersal of biofilm.

1.1.2.1 Conditioning film

An important phenomenon in the initial adhesion of bacteria to non-living substrate is surface conditioning (Carpentier and Cerf, 1993; Korber et al., 1995). Generally, water contains a large number of organic (micro and macro) molecules such as polysaccharides, proteins, lipids, humic acids, nucleic acids and amino acids resulting from the breakdown of dead organisms and animals (Fig. 2). When a clean solid surface is immersed in water, it is quickly coated by a thin film of organic molecules. This is known as the conditioning film (Siboni et al., 2007). Loeb and Neihof (1975) were the first to report the formation of these conditioning films on surfaces exposed in seawater. These researchers found that films were organic in nature, formed within minutes of exposure, and continued to grow for several hours. The conditioning film is formed rapidly, as significant organic deposits have been detected after even 15 min of submergence. Film thicknesses ranging from 30 to 80 nm have been measured (Korber et al., 1995; Siboni et al., 2007). The composition of the conditioning film
differs depending on the environment. In order to understand the fouling process it is necessary to study the kinetics and composition of conditioning film, based on the composition of organic molecules the bacterial consortia may vary. Also based on the property of substrate, adsorption of organic molecules may differ. For example, proteins were the first compounds followed by carbohydrates to adsorb onto the stainless steel panels immersed in seawater (Compere et al., 2001; Poleunis et al., 2002). Sometimes these organic molecules may react with the substratum and the chemical composition may be modified (Garg et al., 2009). A study by Jain and Bhosle (2009) showed that without the conditioning film, the number of bacterial cells that attach to a surface is significantly reduced. They also found that depending on the composition of the conditioning film, different species were more successful at attachment. For example, the concentration of carbohydrates in a marine conditioning film was positively correlated to *Pseudomonas* species attachment, but negatively correlated to *Bacillus* species attachment. This may have been a result of the differences in cell hydrophobicity between the different species (Jain and Bhosle, 2009) or due to chemical attraction or repulsion (Chet et al., 1975). Helke et al. (1993) found that proteins forming part of the conditioning film can competitively inhibit attachment of bacterial cells by occupying suitable binding sites on the attachment surface. However, many molecules (especially proteins) present in a conditioning film are made up of long chains of monomers which themselves may provide additional binding sites for microorganisms (Lappin-Scott and Costerton, 1995). As well as providing attachment sites for microorganisms, the conditioning film may increase attachment by altering the physical properties of the attachment surface like surface tension, surface free energy and surface roughness (Schneider, 1996; Callow and Callow, 2002).
1.1.2.2. Initial attachment

Biofilm formation is thought to begin when bacteria sense environmental conditions like physico-chemical properties and nutrients that trigger the transition to life on a surface (Fletcher and Pringle, 1986; Wimpenny and Colasanti, 1997). Microbial adhesion to surfaces is initially reversible, but even in the absence of metabolic processes becomes essentially irreversible shortly after first contact. Initial attachment may be single microbial species or multiple microbial species and can form on a range of biotic and abiotic surfaces. Initial adhesion between bacteria and non-living surfaces is usually mediated by non-specific (e.g. hydrophobic) interactions, whereas adhesion to living surfaces is usually accomplished through specific molecular docking mechanisms (Dunne 2002). Korber et al. (1995) explained the interaction between the cell and the conditioned surface by two different theories (Wetting theory and DLVO theory). The “wetting” theory is based on surface thermodynamics, relies on determining critical surface tension of the bacteria and substratum. DLVO theory...
(named after Derjaguin and Landau, Verwey and Overbeek) equates repulsive and attractive forces acting on an adhering particle.

Microbial aggregation is an important initial phenomenon, which further leads to mature biofilm formation (Basson et al., 2008). Higher incidence of microcolonies, formed by autoaggregation as well as coaggregation, leads to enhanced biofilm formation (Windt et al., 2006). Autoaggregation is the term used to describe the adhesion of genetically identical cells (Elliot et al., 2006), while coaggregation is the highly specific recognition and adhesion of different bacterial species to one another (Min and Rickard, 2009). Macroscopically, the phenomenon can usually be detected as clumping when the different cell types are mixed. Microscopically, the clumps of cells formed consist of a network of interacting cell types (Kolenbrander et al., 1993). Coaggregation facilitates structural and metabolic co-dependences, subsequently resulting in the development of complex biofilm communities (Elliott et al., 2006).

The environmental signals vary among organisms. For example, P. aeruginosa and P. fluorescens will form biofilms under almost any conditions that allow growth (O’Toole and Kolter, 1998). On the other hand, Escherichia coli K-12 (Kolter and Pratt, 1998) will not form biofilms in minimal medium unless supplemented with amino acids. Further, Freter and O’Brien (1981) proved that Vibrio cholerae has been shown to be chemotactic toward all amino acids, suggesting that proteins, peptides, or amino acids may be important nutrient sources in the aquatic environment. In contrast, E. coli O517:H7 is reported that needs low-nutrient media to make a biofilm (Dewanti and Wong 1995).
Many studies have shown that sometimes the seasonal changes affecting the chemical composition of the conditioning film will impact the initial adhering of microbial community in the marine environment (Bakker et al., 2003; Bhosle et al., 2005). Initial interaction being established, stable connection between bacteria and substrate surface is maintained by specific cell membrane proteins and adhesins. If adhesion activity is inhibited, there will be no biofilm formation, which was proved by studies carried out by Kolter and Pratt (1998) on *E. coli* and Kolter and Watnick (1999) on *V. cholerae*.

### 1.1.2.3. Biofilm Development or Maturation

Continued growth of bacterial cells on a surface leads to the development of mature biofilm colonies containing millions of tightly packed cells gathered into pillar and mushroom shaped masses that project outward into the surrounding medium for hundreds of microns (Hall-Stoodley et al., 2004). The maturation of a biofilm, resulting in the complex architecture with water channels, is influenced by a number of biological factors and by hydrodynamic features (Stoodley et al., 2002). The biological factors include cell-to-cell signaling between the biofilm bacteria, growth rates of the bacteria, extent of Extracellular Polymeric Substances (EPS) production, motility of the biofilm bacteria as well as possible competition or cooperation between the bacteria. Once in initial contact with a surface, microbes develop different types of attachment behaviours such as motile attachment, reversible attachment and irreversible attachment. Bacterial mobility is enabled by two types of protein growths on the cell surface, flagella and fimbriae. Bacterial mobility enabled by flagella is necessary for establishing the connection between the bacteria and the surface, while the mobility enabled by fimbriae is necessary for the formation of...
microcolonies. Flagella are long, spiral growths that enable bacteria to float in liquid medium, and fimbriae are short, straight growths that enable limited, twitching movements of bacteria on substrate surface. Many studies have been conducted to look at the role of flagella on the development of bacterial biofilms (Hossain and Tsuyumu, 2006; Kim et al., 2008; Lemon et al., 2007). For example *Pseudomonas fluorescence* uses the motile attachment of flagellated cells to move along surfaces in a semi-attached condition within the hydrodynamic boundary layer, independent of the flow direction (Korber et al., 1995). The reversible adhesion of *E. coli* cells with residence time of over 2 min on a surface has been described as “near-surface swimming” (Vigeant and Ford, 1997). “Irreversible attachment” is exhibited when microbes can no longer move perpendicularly away from the surface (Busscher et al., 1998). Microbes can attach irreversibly, while retaining active motility by mechanisms known as gliding, swarming, twitching, swimming, darting and sliding. *Vibrio cholerae* and *E. coli* first utilize the flagella to spread across the surface, and then anchor onto the surface with pili and possibly outer membrane proteins. *P. aeruginosa* requires type IV pili for twitching motion on a surface and for the subsequent build-up of stagnant microcolonies (O’Toole et al., 2000).

Once cells have adhered to the surface by any one of the kind of motility mentioned above, bacteria undergo further adaptation to life in a biofilm. They often proliferate by binary division to form clusters of microcolonies which spread over the surface (Lappin-Scott and Costerton, 1995). As the initial colonisers grow and divide, two properties are often associated with surface-attached bacteria, increased synthesis of EPS and the development of antibiotic resistance. Generally polysaccharides mediate cell-to-surface and cell-to-cell interactions that are critical for biofilm formation and
stabilisation. The EPS matrix of a biofilm community can also contain microzones with different charge and hydrophobicity (Wolfaardt et al., 1998).

A mature biofilm with its complex architecture provides niches with distinct physicochemical conditions, differing e.g. in oxygen availability, concentration of diffusible substrates, metabolic byproducts, pH and cell density. Consequently, cells in different regions of a biofilm can exhibit different patterns of gene expression (Costerton et al., 1999). The development of a biofilm is a highly regulated process, for which communication between cells is essential. Many bacteria possess ability to communicate with one another and to organize into communal groups with characteristics not exhibited by individual cells (Greenberg, 1999). Bacteria produce diffusible extracellular signaling molecules, e.g., Acylated homoserine lactones (AHLs; gram-negative bacteria), cyclic oligopeptides (gram-positive bacteria) to monitor their own population density and to coordinate expression of specific sets of genes in response to the cell density (Waters and Bassler, 2005). This type of cell-density-dependent gene regulation is termed as quorum sensing. Watnick and Kolter (2000) summarised that a mixed species biofilm is a dynamic community harboring bacteria that stay and leave with purpose, compete and cooperate, share their genetic material, and fill distinct niches within the biofilm. Further they stated that the natural biofilm is a complex, highly differentiated, multicultural community much like a city.

1.1.2.4. Biofilm dispersal

Dispersal of biofilm denotes the disassociation of bacteria from the matured biofilm to colonise a new surface. The bacterial biofilm dispersal can be divided in to three distinct phases:

(i) Detachment of cells from the biofilm colony
(ii) Translocation of the cells to a new location and

(iii) Attachment of the cells to a substrate in the new location.

Various factors are responsible for the dispersal of bacteria in biofilm, including physical, environmental and extracellular secretion. Additionally cell death often becomes the reason for dispersal of biofilm. In general, mechanisms of biofilm dispersal can be divided into two broad categories: active and passive. Active dispersal refers to mechanisms that are initiated by the bacteria themselves, whereas passive dispersal refers to biofilm cell detachment that is mediated by external forces (Lawrence et al., 2002; Choi and Morgenroth, 2003). The two type of biofilm dispersal mechanism is successfully carried out by following the three distinct mode of dispersion such as erosion, sloughing and seeding. Erosion refers to the continuous release of single cells or small clusters of cells from a biofilm at low levels over the course of biofilm formation. Sloughing refers to the sudden detachment of large portions of the biofilm, usually during the later stages of biofilm formation. The process of dispersal (Fig. 3) from the interior of microcolonies has been termed “seeding dispersal” which is the passive removal of cells from the biofilm by fluid shear (Kaplan, 2010). Seeding dispersal has been well extensively studied in oral bacterium *Aggregatibacter actinomycetemcomitans* (Kaplan et al., 2003) and in *P. aeruginosa* biofilms (Sauer et al., 2002; Hunt et al., 2004; Schooling et al., 2004). Erosion and sloughing can be either active or passive processes, whereas seeding dispersal is always an active process. The physical processes such as shearing result in sloughing or erosion of clusters of cells. Environmental cues are also sometimes responsible for the dispersal of biofilm; for example nutrient starvation can induce dispersal in *P. aeruginosa* biofilms (Gjermansen et al., 2005; Hunt et al., 2004).
On the contrary, Sauer and colleagues (2004) showed that rapidly increasing nutrient availability can also induce dispersal in *P. aeruginosa*. Some of the dispersal events are regulated by the several inter- or intra-cellular signalling mechanisms including quorum sensing systems. Increased levels of the intracellular messenger cyclic-di-GMP determine the transition from planktonic to biofilm growth, while a reduction causes biofilm dispersal (Chua *et al.*, 2014). Extracellular secretion of polysaccharides, enzymes, antimicrobial peptides, anti-adhesion agents, and chelating agents play a vital role in the culmination of biofilm processes. Extracellular polysaccharides secreted by the bacteria exhibit anti-biofilm properties by a) altering the physical characteristics of bacterial cells or abiotic surfaces, b) acting as signalling molecules that impact the gene expression patterns of susceptible bacteria or c) competitively inhibit multivalent carbohydrate–protein interactions, thereby interfering with adhesion (Aziz and Aeron, 2014). Enzymes that degrade biofilm extracellular matrix may play a role in biofilm dispersal and may also be useful as anti-biofilm agents. For example, Dispersin-B is a glycoside hydrolase that cleaves β 1–6 N-acetyl glucosamine polymer in the bacterial peptidoglycan layer. Dispersin-B treatment has been shown to be effective against *S. aureus* and *S.*
*epidermidis* biofilms and bacteria (Kaplan, 2010). Chelating agents, such as sodium citrate, tetrasodium-EDTA and lytic peptides of antimicrobial peptides have been shown to destabilize biofilm architecture besides interfering with bacterial membrane stability. A pattern of cell lysis within biofilms has now been observed as a normal feature of development across a broad range of biofilm forming bacteria. In biofilms, cell death commonly occurs with spatial organization inside mature microcolony structures, and kills only a proportion of cells within the biofilm which facilitates conversion of surviving cells to the motile dispersal phenotype. It was believed that cells dispersed from biofilms, immediately go into the planktonic growth phase. Recently, Chua *et al.* (2014) proved that when expression of the small regulatory RNAs RsmY and RsmZ is down regulated, secretion genes are induced in dispersed cells. In connection with this they found that the physiology of dispersed cells from *Pseudomonas aeruginosa* biofilms is highly different from those of planktonic and biofilm cells using single nucleotide resolution transcriptomic analysis (Fig. 4).

![Figure: 4. The stage-wise processes of biofilm-dispersal (Chua et al., 2014).](image)
1.2. Macrofouling

Macrofouling has been defined as the attachment and subsequent growth of a community of visible plants and animals on structures and vessels exposed to water. Macrofoulers settle on biofilms for many reasons. For example, the presence of a biofilm can increase the stability of attachment for macro-foulers in comparison to a clean surface (Zardus et al., 2008). Also, biofilms may alter the physical properties of a surface, making it easier to colonise (Gray et al., 2002).

About 5000 biological species have been listed as involved in the fouling of structures exposed to or immersed in water, the composition and community assemblages showing wide variations from site to site. Animals involved in macrofouling consist largely of barnacles, mussels, bryozoans, hydroids, tunicates and serpulid worms. Corals, sea anemones, sponges, echinoderms, amphipods, isopods, nemertean and platyhelminthes are also found to colonise surfaces (Fig. 5). These organisms adhere themselves to the substrate, developing a fast growth rate and great reproductive potential.

Additionally, it has been speculated that the settlement of invertebrate larvae and algal spores is mediated in part by the production of settlement signals by microbial biofilms. Harder et al. (2002) showed that extracts of metabolites from marine bacterial species increased the settlement of the tubeworm *Hydroides elegans* larvae and a study by Joint et al. (2002) showed that bacterial quorum sensing molecules act as a cue for the settlement of the spores of the green alga *Enteromorpha* sp.
Calcareous shell-shaped hard skeleton is a distinguishing characteristic feature of hard fouling organisms and is designed to protect the organism's body from invasions or aggressive waves and water streams. Barnacles are one of the most frequently observed calcareous biofouling organisms that attach to submersed surfaces by secreting a special, still obscure in composition, adhesive material, usually called "cement".

All biofouling communities vary temporally and spatially. Major temporal changes are driven by seasonality in marine invertebrate populations. The arrival of new recruits, periods of intense growth, or times of dormancy and regression, all impact on community development at different times of the year. Spatial variability in marine invertebrate communities varies on both the small and large scale (Fraschetti et al., 2005) and between temperate and tropical waters.
1.3. Structures prone to fouling

Generally fouling problems are observed in various places like paper industry, reverse osmosis membrane in water treatment systems, some household instruments and marine environment. In marine ecosystem, biofilm-formation and subsequent macrofouling assemblage leads to corrosion, efficiency-reduction and subsequent economic loss to submerged structures such as ship hulls, Ocean Thermal Energy Conversion (OTEC) plants, desalination plants, moored instruments, buoys, jetties, piers, aquaculture infrastructure, etc.

Biofouling has long been considered as a limiting factor in ocean monitoring requiring the placement of any materials under water. Ship hulls are one of the most affected structures by the fouling organisms. Huge amount of money is spent every year by the shipping industry due to increased fuel consumption due to the drag caused by biofouling. Moored optical oceanographic instruments like current meter, fluorometer, transmissometer, and echosounder being in contact with water for long time is susceptible to fouling, which in turn affects the sensitivity of the instrument. Three type of sampling methods followed by these instruments are open, closed or semi enclosed and shuttered. The sensing elements of these instruments are freely exposed to the water of surrounding environment or water is pumped though the instruments hence the instruments are prone to fouling (Delauney et al., 2010; Manov et al., 2003). The floating objects of data buoys and Fish Aggregating Devices (FAD) in ocean are easily fouled by various macroorganisms, like barnacles, mussels, sea weeds and polychaetes. These fouled organisms affect the buoyancy of the buoy by increasing the weight and subsequently leads to corrosion (Tao et al., 2004). Desalination and OTEC plants are functioning by the pumping of seawater. Hence,
pipelines are severely fouled and corroded by macroorganisms (Thirupathi et al., 2014). The aquaculture infrastructures like pens and cages are often fouled by the micro and macroorganisms since these cages are located very close to the shore. The cage environment is either nutrient rich or polluted, resulting in frequent fouling of the associated structures, like rope, mesh, plastic structures, anchors and chains (Fitridge, 2012). Biofouling of aquaculture nets causes serious maintenance and operational problems. The direct economic cost to the aquaculture industry for controlling biofouling has been estimated to be 5–10% of production cost.

1.4. Fouling control measures

The problem of biofouling was noticed in concurrence with man's venture into the sea. Our ancestors were using the copper sheathing and woods in the ships (Omae, 2003). Based on the application and environment, different kinds of fouling control measures were followed. Based on the nature of control measure, it can be classified into three types:

1. Physical
2. Chemical / material and
3. Biological.

Physical treatment includes heat treatment, pulse power, radiation, scrubbing, pressure washing, cathodic protection, water jetting, magnetic devices, sonication, UV and nuclear measures. Chemical/material treatment includes chlorine, chlorine dioxide, hydrogen peroxide, bromine, iodine, potassium, chloramine, polymers, elastomers, copper, copper-nickel, copper-manganese, cerium, gallium and titanium. Biological control measures involve bioactive compounds isolated from organisms,
such as bacteria, fungi, eel grass, ascidians, marine sponges, nudibranch, holothurians and corals (Abdul Aziz et al., 2003; Raveendran and Limna Mol, 2009).

Engineers and scientists have put up efforts to control the fouling complications through technical and biological sources for quite a long time. Biocide is still the most effective method of fouling control, however, there are concerns with respect to the accumulation of biocides in the environment. Chlorine and TBT were used as effective antifouling agents in many industries for many decades, but after the treatment, effluents were found to be harmful to the environment (Vinitha et al., 2010; Murthy et al., 2005; Petrucci and Rosellini, 2005; Heral et al., 1989). As a consequence, TBT as an antifoulant has been banned worldwide since January 2008 (Raveendran and Limna Mol, 2010). Hence the eco-friendly approaches began to control the fouling. Many kind of bioactive compounds have been extracted from various groups of flora and fauna to arrest the biofouling without disturbing the environment. For example the natural product antifoulant sesquiterpene (1'E,5'E)-2-(2',6'-dimethylocta-1',5',7'-triyl)-4-furoic acid isolated from soft coral Sinularia kavarattiensis was showing activity against the settlement of barnacle larvae (Limna Mol et al., 2010). Similarly the marine surface associated Pseudoalteromonas species produces bioactive compounds against settlement of algal spores, invertebrate larvae, bacteria and fungi (Holmstrom et al., 2002). Particularly in aquaculture industry, the chemicals cannot be applied, because it may have adverse effect on the cultured organisms. Therefore, mostly physical methods of scrubbing, cleaning and water jetting have been used in cage culture systems in particular.