The use of Silver Compounds in Water Treatment and Prevention of Biofilm Formation in Water Distribution Channels.

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Abstract: This paper revealed biofilm as an aggregation of microorganisms that grows on solid surfaces or substrates. The surface can be living (body of animals and plants) or non living (rocks and water pipes), they are characterized by structural interactions and cellular matrix of polymer substances which may be specific or non-specific. Biofilms affect many part of everyday life, which include contamination of water, blocking of water channels and causing infections. Biofilm can be prevented by adequate cleaning of water storage systems and use of antimicrobial agents also known as disinfectants. The paper also highlight notable disinfectants such as silver compounds, which when impregnated into water filters, robbins device, diffusion gel and coatings of inner surface of water channels can inhibit a lot of cellular activity of the microorganism and can also kill the organism. The paper concluded by recommending the use of silver compounds in water treatment and prevention of biofilm formation in water channels.

[Erena, N B., Mu'azu, N K. and Musah, M. **The use of Silver Compounds in Water Treatment and Prevention of Biofilm Formation in Water Distribution Channels.** *Academ Arena* 2015;7(11):1-4]. (ISSN 1553-992X). http://www.sciencepub.net/academia. 1

Keywords: Biofilm, Water Channel, Silver, Compounds, Microorganisms.

Introduction

Biofilm is a complex aggregation of microorganisms growing on a solid substrates (surfaces). The surfaces can be living or non-living, example of such living surfaces include teeth, gums, and cells that line the intestinal tracks, while example of non-living surfaces include rocks in water courses, water pipes and implemented medical devices such as catheters. Biofilms are characterized by structural interactions and extracellular matrix of polymeric substances (exopolysaccharide) (Nardai *et al.,* 2008).

Biofilms have been described in many systems, since when Anton Van Leeuwenhock examined the 'animalcules' in the plague on his own teeth, in the seventeenth century. But the general theory of biofilms predominance was not promulgated until 1978. This theory states that, the majority of bacteria grow in matrix-enclosed biofilms, adherent to surfaces in all nutrient-sufficient aquatic ecosystems and that, these sessile bacterial cells differ profoundly from their planktonic (floating) counterparts (Donlan and William, 2002).

Formation of biofilm begins with the attachment of free floating microorganism to a surface molecules by another molecule on the surface. The attachment can occur specifically or non-specifically (Hilary and Costerton, 1997). Specific attachment involves the recognition of surface molecules by another molecule on the surface of the microorganism. Bacterial attachment can be aided by appendages, such as flagella and cilia.

Microorganisms first adhere to surface as initial colonist through weak reversible Vander-Waals forces and later if not separated from the surface, they permanently anchor themselves using cell adhesion structures such as Pilli. This attachment is followed by a more long-lasting association with the surface. For bacteria, these associations involves structural and genetic changes, genes are expressed following surface attachment, which result to production of a large amount of glycocalyx (Hilary *et al.,* 1992). The first colonist facilitate the arrival of other cells by providing more diverse adhesion sites and beginning to build the matrix that holds the biofilm together.

The non-specifically biofilm formation involves species that able to attach to a surface on their own or oftenly able to anchor themselves to the matrix or directly to earlier colonists. Once colonization has begun, the biofilm grows through a combination of cell division and recruitment.

Effect of Biofilms

Biofilms affect many parts of everyday life and cost nations billions of dollars yearly, in equipment damage, products contamination, energy losses and cause various infections, which is why biofilms research is becoming so important and gaining popularity. The microbial biofilm involves the secretion of metabolites that damage the surface or the production of organic or inorganic deposits upon the surface, a process known as biofouling. The consequences of biofouling are; the physical damage of the surfaces as a result of microbial growth and

metabolic activity, reduction in proper function of the surfaces and creation of potential pathogens within the biofilms (Hilary *et al.,* 1992).

In water industries, biofouling is difficult to monitor and control, because, the supply systems are made up of an extensive network of treatment plant and delivery pipes. The use of cupper pipes in distribution does not lessen the chances of biofouling. For example, a study of drinking water utility shows that bacterial counts were above permitted levels, when samples of biofilms were taken as pipes scrapings from various part of the systems, an unacceptable levels were found in biofilms in the distribution systems and along the way to the consumer (Hilary and Costerton, 1997).

Bacterial biofilms cause very serious problems in industrial water systems. The biofilms in water distribution channels reduces fluid flow and can harbor water born potential pathogens (Hilary *et al.,* 1992). The presence of the microorganisms in the water channels affect the use of water by animals and humans, either for drinking or recreational activities, example can be seen in algal bloom in water bodies. Infect the existence of biofilms in water channels have deleterious effect on drinking water quality and may harbor pathogens (Kim, 2001).

Prevention of Biofilms in Water Distributing Channels

The only specific antibiofilms presently in used is based on the incorporation of antibiotics into the materials (surfaces) and the combination of antibiotics. The approach decreases the probability of colonization (Fred, 2008). This conventional method of killing microorganism (use of antibiotics and disinfection) are often ineffective with bacterial biofilm. Because the huge doses of antimicrobial substances, required to rid systems of bacterial biofilms are environmentally undesirable, perhaps not allowed by environmental regulations and medically impractical. So new strategies based on a better understanding of how bacteria attach, grow and detach are urgently needed (Nardai *et al.,* 2008).

Inadequate cleaning of storage tank oftenly cause biofilm formation in water channels and also the treatment to break down undesirable compounds, thereby purifying the water from biofilm, has lead to occurrence of resistant microorganisms, that have become resistance to some antimicrobial agents (Jeffrey, 2005).

In water treatment, the best method employed, is disinfection by the use of chemicals. One of the commonest disinfectant used is chorine, for the treatment of municipal water, to kill all other possible bacteria present in the water. Other chemicals use include soda ash, hydrated lime, alluminium sulphate e.t.c (Laguna, 1997).

In developed countries the use of secondary disinfectant following the use of chlorine as a primary disinfectant, has been recognized and the administration of the secondary disinfectant produce a dramatic reductions in disinfection by products (DBPs) (Kim, 2001).

Silver compounds use in water treatment and preventing biofilm formation in water channels.

Silver has long been acknowledged as having antibacterial properties (Kelly, 2002). Its affinity as a bactericide has been documented since the late 1800s, its use in purification has been known throughout the ages. Early records indicate that, the Phoenicians used silver vessels to keep water, wine and vinegar pure during their long voyages. In America, pioneers moving west put silver and copper coins in their water barrels to keep the water clean (The Silver Research letter, 1997).

Infact, a statement 'born with a silver spoon in his mouth' is not a reference to wealth, but to health. In the early 18th century, babies who were fed with silver spoon were healthier than those fed with spoons made from other metals, and silver pacifiers found wide use in America because of their beneficial health effects (The Silver Research letter, 1997).

Silver and its compounds or in combination with other substances are used in disinfection of water bodies for drinking and recreational activities. The most important silver compound currently in use, is silver sulfadiazine (AgSD), although silver metal, silver acetate, silver cyanide, silver zeolite, silver nitrate (Gerald and Devera, 1999). Other notable silver compounds in use are, silver chloride, silver oxide and combined copper and silver (Stuart, 2008).

Silver and copper are the best antibiofilm agents. Copper prevented algal colonization for 14 days post-deployment and the response was unaffected by the antibiofilm agent, throughout the period silver was even better and prevent biofilm formation of up to 21 days post-deployment (Jeffery, 2005).

Methodology of using silver compounds in water treatment and biofilm prevention on water channels

In using silver compounds for disinfections, different systems, techniques and device are used.

- Water filters are often impregnated with silver compounds to treat domestic waters and to prevent biofilms formation in water storage tanks.
- Robbins device with polyvinyl chloride and stainless steel surface used with 100µg/litre of silver compound is found to be effective in preventing biofilm formation (Stuart, 2008).
- Diffusion Gel Techniques (DGT) is use as a potential tool for monitoring reactive phosphorus in fresh water aquaculture effluents, because, those waters have high concentrations of suspend matter and

nutrients, biofilms may form on the surface of the DGT device. Those biofilms may hinder the movement of reactive phosphorus and hence interfere with the DGT measurement. Copper and silver filter, nucleopore membrane and silver based filters are use to evaluate their respective potential to prevent the formation of algae biofilm (Catherine *et al.,* 2007).

- Silver ion generators are used for municipal water supplies, the silver ionization is being developed for main stream water systems. Machines used to clean primary water must be large, powerful and require accurate control mechanisms to ensure that low level of silver are maintained and kept within drinking water standards. Its clearly shown that silver promptly kills bacteria in the water and maintain water purity over long periods of time. For swimming pools, silver in filters keeps water crystal clear as well as clean (The Silver Institute Letter, 1975).
- A filter of activated carbon impregnated with metallic silver was found to show long enduring efficiency of silver purification of water (The Silver Institute Letter, 1997).
- Fungi and bacteria are killed by using alternating silver and copper screens in water circulation systems, the process produce sparkling bacteria and algae free water (Klans, 1975).
- Coating the inner surface of water channels (pipes) with silver compounds, before burying them into the ground can prevent biofilm formation in the channels as well as help in water treatment (The Silver Institute Letter, 1975).

Action of Sliver Compounds on Microbial cells.

Silver Nitrate: This compound causes inhibition of microbial growth, such as *Cryptococcus neoformans* and is deposited in the vacuole and cell wall as granules. Silver nitrate inhibit cell division and damages the cell envelope and content of bacteria. Bacteria cells increase in size, while the cytoplasmic membrane which is outer organ, exhibit structural abnormalities, although without any blebs (protuberances). Finally silver nitrate interacts with nucleic acids; it react preferentially with the bases of DNA rather than the phosphate groups there by inhibiting bacterial cell division (Gerald and Devera, 1999).

Silver sulfadiazine: The compound of silver is essentially a combination of two antibacterial agents silver (Ag^+) and sulfadiazine (SD). Silver sulfadiazine has a broad spectrum of activity and unlike silver nitrate , it produces surface and membrane blebs in susceptible bacteria. AgSD binds to cell components including DNA (Gerald and Devera, 1999).

Colloidal Silver: Modern electrolytic colloidal silver is an oligodynamic, naturally microbiocidal element, by virtue of disabling only the metabolic enzymes of anaerobic unicellular microorganism (Stuart, 2008).

WHO and USEPA reported that, Colloidal silver, especially in combination with hydrogen peroxide exhibit significant microbial inactivation at a concentration that pose no health risk (Stuart, 2008). Several countries; Switzerland, Germany and Australia have given approval for the use of colloidal silver in combination with hydrogen peroxide for drinking water disinfection and biofilm prevention.

Silver zeolite: This silver compound is known to inhibit several functions in the cell of microorganism and consequently damage the cells of organism (Yohashnobu *et al,*. 2003).

Conclusion.

Due to the antimicrobial affinity of silver and its compounds, it has become one the best antibacterial agent in use today, for the prevention of biofilms in water channels, storage tanks and swimming pools, also for domestic and municipal water treatment. Silver and its compounds can be equal to chlorine in maintaining essential coliform-free water, and is some what better than chlorine in killing and destroying microbial cells.\

Silver plays no known natural biological role in human and possible health effects of silver are subject of dispute. Silver salts are known to be toxic and some may be carcinogenic. Silver and compounds containing silver (like colloidal silver) can be absorbed into the circulatory system and become deposited in various body tissues leading to a condition called argyria, which results in a blue-grayish pigmentation of the skin, eyes and mucous membrane. Although this condition does not harm a person's health, its disfiguring are usually not permanent. Argyria is rare and mild forms are sometimes mistaken for cyanosis (Stuart, 2008).

The USEPA has declared that 'silver does not cause adverse health effects' and set silver at 100mg/litre for disinfection of drinking water. Recently an EU drinking water standard, proposed removing any upper limit (due to it non health risk) for silver in drinking water treatment following WHO's guidelines for drinking water quality, which states that, 'it is not necessary to recommend a health based guidelines for silver as its not hazardous to human health' (Stuart, 2008).

According to Catherine *et al*., (2007) it is believed that:

- Silver is an effective bactericidal for municipal and swimming pool water treatment.
- Silver disinfection is easier and safer than other purifying agents.
- Silver does not produce changes in pH, and does not require any addition of pH adjustment chemicals.

- Silver is prescribed dosage of 100mg/litre is non toxic to humans.

Silver and its compounds are becoming a universal disinfectant to water bodies in prevention of biofilm formation and in drinking water treatment (Kelly, 2002).

Recommendations.

- Government should embark on the use of silver compounds for municipal water treatment and for the prevention of biofilm in water channels.
- Water channels (pipes) should be coated with silver compounds to prevent biofilm formation as well as help in water purification for domestic purposes.
- Water channels (pipes) should also be subjected to replacement, at least every decade.
- Municipal water works, should use silver compounds for post or secondary disinfectant, in water treatment, instead of post chlorination.

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11/2/2015