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Recent Study Evaluates Potential For Biofilm And Bacteria Formation In Various Plumbing Products

Copper and PEX Pose Greatest Risk; CPVC Shows Lowest Concentrations

Biofilm formation has become a topic of widespread interest, not only from a consumer standpoint as it affects the quality of household drinking water, but also because of its impact on a number of industries, including petroleum, specialty chemicals, mining and utilities. You may not be familiar with the term “biofilm”, but you have certainly encountered it on a regular basis. The plaque that forms on your teeth and causes tooth decay is a type of bacterial biofilm. The “gunk” that clogs your drains is also biofilm. If you have ever walked in a stream or river, you may have slipped on the biofilm-coated rocks.

Biofilm forms where bacteria adhere to surfaces in aqueous environments and begin to excrete a slimy, glue-like substance that can anchor them to all kinds of materials, such as metals and plastics. Essentially, biofilm may form on any surface exposed to bacteria and some amount of water.

Some biofilms cause serious problems when they establish colonies inside metal piping and hasten corrosion.

With regard to drinking water, biofilm is an especially critical issue, since once anchored to a surface (such as plumbing pipe), biofilm microorganisms can carry out a variety of detrimental reactions and actually interfere with the water treatment process. According to The Center for Biofilm Engineering in Montana, conventional methods of killing bacteria (such as antibiotics and disinfection) are often ineffective with biofilm bacteria. Or, in the best situation, much higher concentrations of antibiotics are needed to kill bacteria in biofilms, compared to free-living bacteria. In essence, biofilm provides a safe haven for bacteria to grow and recycle.

Researchers at Stanford University have shown, for example, that by forming itself into a biofilm, the organism responsible for outbreaks of cholera can survive chlorine concentrates 10 to 20 times higher than are normally used to treat drinking water. In 1996, biofilms repeatedly caused the water supply of Washington, D.C., to violate federal standards for bacterial contamination. Common waterborne diseases found in biofilm include: E. coli, Legionella pneumophila, Pseudomonas, Flavobacterium, Arthrobacter, Acinetobacter, Sarcina, Micrococcus, Porteus, Bacillus, Klebsiella and Enterobacter.

In addition to contamination concerns, biofilm can also affect water pressure. Once attached to a pipeline wall, biofilm begins building upon itself, adding layer upon layer, forming a plaque-like coating. The bacterial community traps nutrients, microbes, worms and viruses to form an almost impenetrable material. Such growth can clog water lines to the point of insufficient water pressure. This becomes a hazard for homes, businesses and even firefighters. In 1996, for example, a home that caught fire in Ontario was completely burned because the water-supply pipes were blocked with biofilm buildup which caused insufficient water pressure to extinguish the fire.

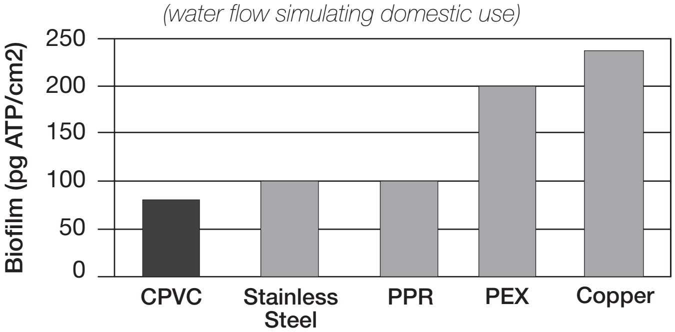
Performance of Plumbing Materials Vary Widely

Evaluating the potential for biofilm formation in various plumbing products offers yet one more comparison between copper and plastic plumbing materials. Critics in the plumbing industry have raised the concern that certain plastics could release biodegradable compounds that could promote the growth of microorganisms in the water supply. These critics assumed that the increased risk was caused by the compounds that are added to the plastic to help improve the material’s properties, e.g. stabilizers, anti-oxidants, dyes, etc. In this line of thinking, it was assumed that all plastics performed similarly and should be classified in one group.

To separate perception from reality and to objectively evaluate the potential for biofilm formation in various plumbing products, in mid 1999, the Ministry of Public Housing, Urban Planning and Environment (VROM) for The Netherlands commissioned a study to be completed by KIWA, the approvals agency for potable water piping systems. As part of the study, 13 different pipe products commonly used in drinking water, including metals and plastics, were tested for their promotion of the growth of microorganisms in the water.

The results demonstrated the basis for several interesting comparisons. First, it was proven that not all plastics are the same. Some show a tremendous affinity for biofilm formation, while others actually show lower concentrations than for the metal samples tested. In the end, it was shown that biofilm concentration was actually lowest on CPVC (Figure 1). The highest biofilm concentration was actually found for copper at a level three times that of CPVC. Copper was followed closely by PEX (cross-linked polyethylene), which demonstrated biofilm concentrations two-and-a-half times greater than CPVC. Similarly, the growth of Legionella bacteria was extremely low in the presence of the CPVC materials.

Figure 1: Average biofilm concentration on the pipe wall
(water flow simulating domestic use)



How were the results determined?
Thirteen different pipe samples, representing six material types, were tested in both static (no water flowing) and dynamic (continuous flowing water) test conditions for biofilm formation potential (BFP) and for bacteria colony formation. The BFP of a material is defined as the average biofilm concentration (expressed in pg ATP/cm2) after 8 weeks, 12 weeks and 16 weeks of exposure. The ATP, adenosine triphosphate, is measured on both the pipe sample and on the water sample and compared after the various incubation periods.

Among the material types tested were PEX, composite PEX, Polypropylene Polybutylene, Copper and CPVC. Stainless steel and glass were used as control samples.

For the static test, pipe samples were submerged in two different water samples. One water sample was biologically stable and representative of drinking water in the Netherlands. The second sample was comprised of the same biologically stable water with microorganisms from river water added. The pipe samples submerged in the water samples were incubated at 25 $\pm$ 1°C (maximum temperature allowed for drinking water) during a 16 week period.

Additional static tests were conducted where specific microorganisms were implanted into the BFP testing scenario to further test whether the pipe samples were able to promote the growth of bacteria colonies. Specifically, cultures of Legionella pheumophila, Pseudomonas aeruginosa, Mycobacerium and Coliform bacteria were added to the water samples.

The tested pipe samples differed widely from one another in the static test. A relatively strong biofilm formation was observed on the two tested copper samples, which was assumed to be the result of the presence of mineral oil on these samples or possibly due to corrosion. Of the plastics, the CPVC and Polybutylene samples displayed the lowest BFP values.

The Polyethylene-based samples (PEX and composite PEX) displayed the strongest biofilm formation and the strongest promotion of the growth of Legionella bacteria.

Each material type (CPVC, Copper, PEX, etc.) tested in the static test was then re-examined in a test with flowing water (dynamic). Among each material type, the sample was selected that had exhibited the highest BFP value and the highest growth of Legionella bacteria. The test set up was designed to simulate the last five meters of a domestic plumbing system. Water was circulated through the pipe of the set up according to a typical domestic pattern. The test set up was supplied with drinking water coming from a water treatment plant and was representative of many types of drinking water in the Netherlands.

The test set up was sampled after 4, 8, 12, 16 and 20 weeks of continuous circulation. Both water samples and pipe samples removed from the test set up were tested for ATP and bacteria growth.

In general the biofilm formation on the samples in the test with flowing water was lower than in the test where the water was stagnant. The highest biofilm concentration was observed on copper. The biofilm concentration was lowest on CPVC. The quantity of biofilm that was formed on the PEX and the composite PEX pipes was also substantially higher than the quantity of biofilm that formed on the CPVC.

In general, the bacteria colony numbers on the samples were low. The highest colony numbers were observed on the composite PEX sample.

Conclusions
Although there are still many questions to answer with regard to the level of risk posed by various piping materials, the KIWA study confirms that some materials are better than others for plumbing applications. In the case of biofilm and bacteria formation, it was clearly shown that CPVC outperformed both copper and PEX, which contrary to industry perceptions, proves that not all plastics are the same.

Further, the study confirmed that “a highly significant positive relationship exists between the BFP value of a material and the number of Legionella bacteria on the material.” So even if the biofilm formation by itself is determined to be harmless, the related increase in micro-organism activity should be a critical consideration. Of all the plastics tested, CPVC displayed the lowest BFP values.

Finally, KIWA concluded that preventive measures, including the design of the installation and choice of materials, are of great importance in limiting the increase of micro-organisms.

To receive a copy of the entire KIWA study, contact the FlowGuard Gold® Marketing Department at 888/234-2436, Ext. 7393.