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EFFECTIVE ANTIMICROBIAL TREATMENT AND PLANT SANITIZATION

As environmental regulations increase and tighten allowable plant procedures, water usage, and recycled water, industrial plants are discovering that it is correspondingly more and more difficult to control microorganism contamination and to develop high quality products. Microbial contamination, lack of a technical sanitization program, and poor housekeeping can lead to costly problems such as product biodegradation, decrease in product quality, clogging of pipes, corrosion of equipment, and excessive downtime. These can be prevented by knowing facility contamination sources, how to control contamination, and by maintaining a good housekeeping program.

Because of increasingly tighter governmental regulations, manufacturing plants must recirculate all wash water or must dispose of it through a wastewater plant. However, haphazard compliance or poor housekeeping procedures can often create environments which encourage microbial growth. Before the passing of strict environmental regulations, it was common practice for plants to discharge their untreated water to a waste treatment facility or directly into local rivers. This is unlawful today. Facilities should now add a biocide to their wastewater and adopt an appropriate hygiene program for the plant to prevent microbial contamination.

Without good housekeeping practices, microorganisms can grow and reproduce in many systems resulting in significant problems, such as obstruction of piping, buildup of contaminated product skins in tanks and lids, corrosion of metals, discoloration from pigmented bacteria, loss of viscosity, and precipitation of solids. These can appear in any type of facility, but this brochure will focus on paint, adhesive, slurry, and latex emulsion industries.

Until recently, these industries used non-oxidizing biocides that were more forgiving of poor housekeeping practices to some extent. For example, low levels of biocides used to treat latex emulsions provided sufficient protection to the system because the excess monomer which is used for polymerization also served as a biocide. Similarly, formaldehyde is a preservative that was used in the latex emulsion industry. Paint facilities incorporated mercurial compounds as both in-can preservative and fungicide. Adhesive manufacturers selected products such as phenol, pentachlorophenol, and formaldehyde for preservation.

These methods and products served to control microbial growth for only a short time, but could not substitute for long-term preservation or prevention benefits obtained through good housekeeping practices. Now, these products' materials are obsolete due to tougher environmental laws on toxic chemicals. (Insects and rodents can contaminate systems. Spoiled pieces of food can also lead to an infection of a system. However, this brochure will not go into those details.)

Indicators of Microorganism Invasion

A variety of microorganisms, such as bacteria, yeasts and molds, can contaminate aqueous industrial systems. They can float or swim in aqueous system to reach their destination. They can enter aqueous systems in several ways—microorganisms can enter by water, air, raw materials, people and industrial equipment (such as mixers, piping, etc.). They can also enter by way of other contaminants in the plant due to poor housekeeping, such as flaking paint or wet materials leaking from plastic wraps held above equipment. With contamination comes biodeterioration. The evidence appears only after the microorganisms begin to multiply. Then the pH can shift, viscosity can drop, colors can change, the corrosion process can start, the product can become putrefied, and gases can build up and be released.

Besides invading industrial systems in a free swimming or a floating stage in a fluid, microorganisms can grow up in deposits. We call this biofouling. Biofouling is defined as the adhesion and growth of one or various microscopic organisms on surfaces immersed in a liquid, usually water. The liquid can also be coatings, polymers, adhesives, caulks, ceiling tile, or the interphase between oil and water. When this happens the microorganisms can form a biofilm. Typically, a biofilm involves a growth of over 106 to 109 to even 1012 bacterial cells per cm^3. As the biofilm grows and builds up to a large population, cells are sloughed off. When this happens, a large number of cells travel through a system—or are transferred through the system by a person or plant equipment—and inoculate a different part of the system or environment. When this occurs, acids, produced by the bacterial cells, can be released from under the biofilm, thereby dropping the pH significantly. Gases can also be released. If the anaerobic bacteria are involved, the gases can be hydrogen, hydrogen sulfide, nitrogen or carbon dioxide.

Symptoms of Microbial Contamination

- Shift in pH is one of the first indications of biodeterioration. In cases of contamination, pH falls. Note: chemical interactions can also shift pH, but testing should be conducted to determine the actual cause.
- Viscosity loss starts when the microorganisms grow and produce enzymes. These enzymes degrade product ingredients such as polymers or thickening agents. In most cases the enzyme degrades the larger molecules into simple chemical compounds (e.g., sugars) which they consume as nutrients and energy sources. Once the enzymes initiate degradation, the drop in viscosity follows quickly. At the molecular level this occurs in thousandths of a second, and at the plant level you may see this happen over time.
- Putrefaction is the microbial decomposition of organic matter producing a foul odor. Once the odor is released, it is nearly impossible to eliminate. If the bacteria are killed, the malodorous compounds still linger, making plant environments uncomfortable and capable of fouling other products.
- Color changes from either contamination of pigmented bacteria or product degradation by fermentative bacteria range from slight to dramatic.
- Gassing occurs when microorganisms release CO_2 or other gases. Bulging cans are an indication. In severe cases of population growth, explosions occur and can pop the lids off.

Conditions for Microorganism Growth

Microorganisms can grow across a broad pH range. While most bacteria favor growth environments near neutral pH (that is, ~pH 6–8), they can adapt to a lower pH such as pH 5 or lower, or an alkaline pH. Others specialize in growing in acidic environments, specifically at pH 1–2. *Pseudomonas* species can grow up in biofilms that will resist alkaline pH up to pH 10. Some microorganisms, called *Archaea*, survive in high temperatures as well as high salty conditions. Most yeasts and molds prefer acidic pH from 3.0–6.0.

The average size of a bacterium varies from 0.5 to 1.0 by 0.5 to 2.5 and 0.5 to 1.0 micrometers thick. Many bacteria from salt or brackish water may be only 0.1 µm thick; thus, they easily pass through fine filters. Yeasts may be 3.0 to 20.0 µm long. Molds are even larger.

Bacteria can reproduce every 20–30 minutes. Yeast can reproduce every 1 to 5 hours. Growth of molds is usually every 24 hours. Molds grow on and in the skins (a spongy, moist film that develops in mixing and storage tanks used in manufacturing) or paints, emulsions, or adhesives. Molds can also produce enzymes which they secrete into the environment. These enzymes can rapidly degrade batches of product, frequently dropping viscosity. Some molds can grow on and degrade plastics.

Many factors aid in the growth and reproduction of microorganisms. These include oxygen content, nutrients, time, temperature, pH, and water.

Oxygen — the microorganisms most often found in the paint, adhesive, slurry and latex emulsion industries are classified as aerobic bacteria. This means that they require oxygen to survive. Some are anaerobic bacteria, which require a low concentration (facultative) or a complete absence of oxygen (obligate or strict anaerobes). Anaerobes can be found in all industries, but on a limited basis. Many aerobic bacteria can switch from an aerobic metabolism to a fermentative metabolism, generating acids that have an effect on pH and on the consistency of pigments and thickening agents.

Nutrients — microorganisms need a variety of nutrients to grow and reproduce. These include surfactants (ethoxylated phenol derivatives), thickeners (hydroxyethyl cellulose, carboxymethyl cellulose, and polyvinyl alcohol), defoamers and water. Often, untreated incoming materials, such as surfactants or water, are already contaminated and supply continuous inoculation of coating formulations, for example. It is important that the raw materials be treated with an effective non-oxidizing biocide. It is important that the raw materials be tested to assure that they are uncontaminated.

Temperature — microorganisms and spores can survive in temperatures from 32°F to 194°F. In the paint, adhesive, slurry and latex emulsion industries, the ideal range is 68°F to 98.6°F.

pH — most bacteria prefer a pH range from 3 to 10, but certain types can grow below and above that interval. Most yeasts and molds prefer acidic pH, but both can also be found growing in alkaline conditions. In general, the pH of manufactured product is approximately 7–9.

Water — when untreated, water is a major source of contamination. Incoming water should also be both filtered and treated. Many municipalities do that, but sometimes they do have shutdowns, leading to unexpected microbial problems. Sometimes product quality is affected by poor water due to an unusual change in contamination. This change can be due to plant repairs, cleaning of filters, and changes in an ion exchange column. A change in river water such as during spring turnover frequently allows a different variety of microorganisms to enter a plant leading to a massive inoculation of water and equipment. In other instances, water stored in an industrial plant may harbor a biofilm at the bottom or on the walls of the tank. These slough off millions of organisms at a time, leading to an infection of the water supply there, as well as in equipment and eventually finished product. Water in a storage tank should be treated with an oxidizing biocide such as bleach, bromine, hydrogen peroxide, peracetic acid, or ozone. Since paint or emulsion wash water cannot be discharged to a waste treatment facility sewer, many companies store it for later use in paint makeup. This water contains nutrients needed for microbial growth and is also a medium for incubation of that growth in the storage tank. Likewise, stagnant water from pipelines, filter equipment, tank trucks, rail cars, hoses, floors or puddles becomes contaminated in a similar fashion.

System Considerations—How to Assure Biocide Effectiveness

When selected incorrectly, biocides can contribute to biodeterioration. Two categories of biocides that can be incorporated into a system for preservation in the wet state are:

- Narrow spectrum — controls just one group of microorganisms, e.g., bacteria, but has no effect on others. Some narrow spectrum biocides control only a narrow range of bacteria, and have little effect over time.
- Broad spectrum — kills most members of microorganisms, such as bacteria and yeast. Some may kill even mold.

To clarify, a narrow spectrum preservative, such as a formaldehyde donor, effectively controls bacteria in an acidic environment, but does not control bacteria in an alkaline environment nor kill yeast or mold. Formaldehyde also does not kill bacteria which are formaldehyde resistant.

Temperature

Most biocides decompose at 212°F. Many lose their impact when they are warmed above 120°F (where they lose their potency and, therefore, their antimicrobial activity is only at 80–90% of their nominal value). So, adding them at the right temperature in the process is critical to their effective performance. For adhesives made from starches and dextrins, the biocide should be added during the cool down cycle (typically after the cool down), preferably below 120°F. As a rule, most biocides should be maintained cooled at <100°F.

Redox Systems

During latex polymerization, excess oxidizing and reducing agents are sometimes present in the redox systems and can react with the biocide, nullifying its efficacy. Then, when a contaminant enters the system, the remaining concentration of biocide (if any active is left) would most likely be insufficient to combat the microbial population. This occurs often in the emulsion industry. Most manufacturers remain dissatisfied with methods needed to overcome the problem, namely increasing the dose of the biocide, or adding a chemical to neutralize the residual redox chemicals to eliminate it before introducing the biocide. Both practices cost more money—the former increases biocide costs and the latter ties up production equipment. Not addressing the issue(s), however, results in waste of a batch of product.

Dosage

Biocide dosage depends largely on the susceptibility of a particular formulation. A minimum dosage makes a system vulnerable to degradation. Too low a dosage also leads to antimicrobial resistance, which results in higher dosages later becoming completely ineffective. Biocide suppliers integrate a series of factors to calculate a specific system's dosage requirements. However, changes in the system, or an infection of contaminated raw materials or water, increases biocide demand in the system. Therefore, testing should be done periodically to assure that the proper dosage is being employed. It is common that contaminants, by their demand on the biocide, decrease the available biocide concentration, allowing the microorganisms that are present to increase in population. If this is not corrected, it results in a lack of protection for current and future batches of product(s).

Good Housekeeping and Technical Sanitation

An effective microbiological program depends a lot on a well-defined and faithfully executed technical sanitation. Without it, biodeterioration is inevitable, regardless of the biocide recommended. The following list provides companies with a proven series of practices used to effectively control microbes.

- Start with clean water and clean vessels. Record water test results by date, frequency of cleaning of vessels, as well as maintenance. If anything goes wrong, these records save a lot of time in investigating.
- Clean the equipment and make sure the initial rinse water contains a small residual of oxidizing biocide, for example 1000 ppm of hypochlorite (bleach) solution. If the process involves oil, then wipe off the surfaces and dry them with denatured ethyl alcohol and Kimwipes or other disposable wipes.
- Keep mixing and storage tanks free of skins. Periodically scrape skin buildup to bare metal. (The frequency may be every month or two months depending on the history of use and contamination.) Follow this with a sanitizing dose of steam or a rinse with 1000 ppm hypochlorite solution.
- Remove residual water from tanks or vessels. This water can stagnate by becoming contaminated, and spoil product in the vessel. Drain the water (best), or treat with a quick-killing biocide to prevent contamination.
- Cover any pipes in use. To prevent skin formation, flush inlet or outlet pipes with water and cap them. If you cover pipes with plastic, make sure that the plastic does not collect moisture over time. That would harbor undesirable microbial growth.
- Know the source of the incoming water. River, well, and water from exchange columns are notorious for causing biological problems. Proper use of a chlorinator or ozone generator will eliminate this source of contamination. Filters are effective if they are properly maintained and are kept clean. Drain hoses and store them appropriately. Water remaining in hoses can stagnate, so hang them vertically or in an inverted U position. If hoses are left on the floor, vermin can also gain entrance, increasing the contamination level.
- Cover raw materials when not in use. Uncovered raw materials—surfactants, thickeners, and emulsions—are exposed to contamination sources. Routinely check incoming raw materials for infestation.
- Always use clean equipment to draw samples from raw materials. Over time, pails retain excess raw materials and provide nutrients to organisms. When contaminated substances are added to a fresh batch of product, they often become a serious source of contamination. Change pails frequently.
- Review your biocide program at least quarterly. Follow a regular schedule for reviewing your preservative treatment program and adjust it accordingly. Your system changes over time. Water changes with each season.
- Keep records.

Methods of prevention are more important than methods of eradication. Practicing these recommendations is a prerequisite for excellent biocide performance. An unclean plant overwhelms the biocide concentration and inhibits its effectiveness in controlling microbiological growth. Together, good housekeeping, clean equipment, clean water, and a broad-spectrum preservative are the major defenses against system spoilage and the winning combination for consistent production of high quality products.

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Global Headquarters at 1256 N. McLean Blvd., Memphis, TN 38108, USA