The Coating Kitchen

Maintaining Microbial Control through Preservation and Good Housekeeping

By Janet H. Woodward, Ph.D.

The consequences of allowing microbial growth to go unchecked are many and can be detrimental to the coating color. Therefore, microbicides are typically applied to pigments, coating additives, and coating colors to minimize microbial contamination. Additionally, good housekeeping practices can improve overall performance of the biological control program. The synergistic combination of appropriate biocides(s) and good housekeeping can improve performance, reduce coating color losses or upsets, and potentially reduce operating and chemical costs.

MICROBIOLOGY “101”

Some form of microbial growth can occur in most coating pigments, binders, additives, and coating colors. Microorganisms use diverse carbon and energy sources. Components in the pigments, binders, and additives serve as energy or carbon sources as well as provide other nutrients needed for microbial growth.

The type of microbial contamination will be dependent upon several parameters: 1) the source of water; 2) pH; 3) temperature; and 4) the oxidation-reduction potential (ORP) of the solution. Aerobic, iron-oxidizing bacteria are commonly found in ground water whereas fungi, filamentous bacteria, encapsulated bacteria, algae, and other higher life forms are found in surface waters. Fungi typically flourish at an acid pH although many can tolerate a pH as high as 10. The optimum pH for bacterial growth is 7; however, bacteria can be found in a pH range of 0.5-12.

The majority of microorganisms are classified as mesophilic; they grow in a temperature range of 10-50° C. Thermophilic organisms survive temperatures between 40-70° C. Endospores produced by thermophiles can survive the elevated temperatures of jet cookers. Aerobic microorganisms grow readily at ORPs above 100mV. Strict anaerobes tolerate an ORP of -
50mV or lower. Facultative bacteria can be the most troublesome because they can switch metabolic processes and grow in either highly aerobic or strict anaerobic environments.

**WHY CONTROL MICROBIAL CONTAMINATION?**
Unchecked microbial growth causes a variety of problems. Viscosity increases are observed in pigment slurries as the dispersant is degraded. The pH can be depressed. Severe anaerobic growth can cause brightness losses and odors such as hydrogen sulfide. Starches and protein lose viscosity as they are degraded. Low level contamination in a coating color can depress pH, affect viscosity, and ultimately lead to coating defects.

**MICROBICIDES**
Microbicides are generally classified as biocides or preservatives. Biocides are chemicals used to kill microorganisms. Preservatives, also known as biostats, inhibit reproduction and may not necessarily kill microorganisms. Some microbicides have properties of both a preservative and a biocide.

The microbicide(s) of choice will be dependent upon several factors. These include pH and temperature of the coating component or coating color, type of problem-causing microorganisms, water quality, contact time needed for maximum efficacy, FDA requirements, other environmental restrictions, and compatibility with other biocides used in the coating kitchen. Properties of the microbicides used in the coating kitchen are listed in Table 1.

Oxidants are not used to preserve pigments, binders, additives, or coating colors for several reasons. Oxidants work by removing electrons from other molecules and, thus, they would have a negative impact on many components of a coating color. Also, oxidants are considered to be quick-killers; they do not have any preservation qualities that are needed in the coating kitchen.

In the United States, any chemical applied as a microbicide must be registered through the Environmental Protection Agency (EPA). The microbicide may also have a US Food and Drug Administration (FDA) allowance through the Code of Federal Regulation (CFR) 21. There are several FDA allowances that affect the dry-end applications of microbicides used in the manufacturing of paper and paperboard for food contact.

The strictest regulation is 21 CFR § 176.170. It covers microbicides used on the dry end of a machine producing paper or paperboard that may contact fatty or aqueous food, such as liquid packaging. Some of the microbicides commonly used in coating applications included in the 176.170 allowance are isothiazolin (a combination of 5-Chloro-2-methyl-4-

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Chemical Name</th>
<th>FDA Allowance</th>
<th>Mode of Action</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thione</td>
<td>Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione</td>
<td>176.230</td>
<td>Reacts with thiol containing compounds</td>
<td>1) Effective at alkaline pH 2) One end-product is also biocidal</td>
<td>1) Potential lacrimation and odor issues</td>
</tr>
<tr>
<td>Bronopol</td>
<td>2- Bromo-2-nitro-propane-1,3-diol</td>
<td>176.170</td>
<td>Reacts with thiol containing compounds in the cytoplasmic membrane</td>
<td>1) Good preservative 2) Synergistic effects with isothiazolin</td>
<td>1) Requires contact time 2) Loses efficacy at pH above 8-8.5</td>
</tr>
<tr>
<td>Isothiazolin</td>
<td>5-Chloro-2-methyl-4-isothiazolin-3-one and 2-Methyl-4-isothiazolin-3-one</td>
<td>176.170</td>
<td>Reacts with thiol containing enzymes in the Krebs Cycle as well as other protein thiols</td>
<td>1) Combination of a quick-kill and preservative</td>
<td>1) Loses efficacy at pH above 8.5 2) Inactivated by amines and some thiols</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Pentane-1, 5-dial</td>
<td>176.170</td>
<td>Cross-link with primary amines in bacterial cell walls and reacts with amino containing compounds</td>
<td>1) Broad range bactericide 2) Effective sporocide</td>
<td>1) Inactivated by ammonia, primary amines, and protein</td>
</tr>
<tr>
<td>DBNPA</td>
<td>2,2-Dibromo-3-nitrilopropionamide</td>
<td>176.170</td>
<td>Reacts with thiol containing groups in the cytoplasmic membrane</td>
<td>1) Effective against slime formers</td>
<td>1) Is a quick killer – not a preservative</td>
</tr>
<tr>
<td>BIT</td>
<td>Benzoisothiazolin-3-one</td>
<td>176.170</td>
<td>Reacts with thiol containing compounds in the cytoplasmic membrane</td>
<td>1) Is compatible with amines</td>
<td>1) Inactivated by thiols</td>
</tr>
</tbody>
</table>
isothiazolin-3-one and 2-Methyl-4-isothiazolin-3-one, BIT (Benzoisothiazolin-3-one), glutaraldehyde (Pentane-1,5-dial), DBNPA (2,2-Dibromo-3-nitrilopropionamide) and bronopol (2-Bromo-2-nitropropane-1,3-diol). The 21 CFR§176.180 regulates biocides used in the production of paper or paperboard that may contact dry food, e.g. cereal boxes. For both regulations, application limitations typically apply and will vary for each active.

The biocide commonly known as thione (Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione) has its own regulation, 21 CFR§176.230. For preservation, most manufacturers of pigments use a microbicide that has the 176.170 or 176.230 allowance. Other environmental regulations that have to be considered when choosing the appropriate biocide include volatile organic compounds (VOC) and Superfund Amendments and Reauthorization, Title 3, section 313 restrictions (commonly called SARA 313).

The half-life of a microbicide is affected by the pH and temperature of the coating component or coating color. Generally, acidic biocides will lose effectiveness at high alkaline pH due to a reduction in their half-life. The reverse is true of alkaline biocides. As with any chemical reaction, elevated temperatures will increase a microbicide’s reaction rate and potentially reduce its half-life by increasing the rate of hydrolysis.

Knowledge of all raw materials and the overall process is crucial in implementing a successful microbicide program. To varying degrees, all biocides are impacted by reducing environments and reducing agents such as sulfite. Thione and its breakdown products are known to be incompatible with isothiazolin. There have been reports that bronopol and glutaraldehyde are also incompatible with thione.

Choice of application points and dosing schemes play an integral part in an effective biocide program. Most pigments and additives are treated during the manufacturing process. Dependent upon turnover rates, tank configurations, or final end products produced, mills may choose to treat specific pigment, additives, and coating colors or just the coating colors. In either case, microbicides should be fed intermittently. This allows the biocides to achieve an effective concentration which is needed to control microbial contamination. The turnover rate of the chests, the pH, temperature, and actual microbial problem will be used to determine the feed cycles.

Appropriate monitoring procedures are also important to trend the effectiveness of a microbiological control program in the coating kitchen. Most mills use the planktonic aerobic (bacterial) plate counts as a way to monitor the success of a biocide program. Widely used in the industry for this enumeration is the aerobic count plate Petrifilm™ from 3M™. There are numerous enumeration methods for specific types of microorganisms, such as slime formers, filamentous bacteria, sulfate-reducing bacteria, fungi, etc. Other useful data to trend are the pH and viscosity of pigments, starches, and coating colors. As the microbial population increases, the pH will be depressed and the viscosity will change from the “norm.” Adenosine Triphosphate (ATP) testing is also commonly used to monitor biocide programs on the wet end of the paper machine. It is a rapid method to measures the overall level of ATP, the energy molecule, in a given sample. However, the procedures for ATP testing of pigments and coating colors are somewhat cumbersome and results are not consistent.

**IMPLEMENTING GOOD HOUSEKEEPING PROCEDURES**

Without the implementation of good housekeeping practices, even the best biocide program will be stressed to maintain microbial control of the process. Many coating kitchens have standard operating procedures (SOPs) in place to address boilouts. However, other housekeeping practices can be ignored.

Basic housekeeping does start with the classic “first in, first out” rule. Well-preserved pigment slurries are highly susceptible to contamination if a railcar stays in the rail yard for many weeks at high summer temperatures. Off-loading procedures should include dedicated hoses for each pigment or bulk additive and thorough washing of hoses with adequately treated water. Storage tanks and chests should have sufficient agitation and recirculation. Any water used on the coating kitchen should be of the highest quality, especially with regards to microbial contamination. Flushing chests or lines with clarified white water will simply re-contaminate the process.

Even the best tank configuration will not prevent buildup or deposition. Therefore, if swing tanks are available, coating kitchen tanks need to be cleaned on some routine basis. Most pigment and coating storage tanks should be hydroblasted with a bleach solution and then thoroughly rinsed.
with good quality water. This will help remove any biofilm or spoiled product that has built up on the sides or bottom.

If dual tanks are used for coating components, special attention must be given to the tank that is not in use. Is there product still in the tank and/or lines? Is the product being treated with a microbicidal? Is the product being agitated or recirculated? If these questions are not addressed, there is the likelihood that the product will become contaminated to the point of going anaerobic. When the tank is put back into service, the “spoiled” contents will contaminate fresh, prepared product with microorganisms and odors. Coating reclaim tanks are often ignored in a similar manner and cause similar problems to the coating color.

Boilout procedures should also be reviewed on a regular basis. The main item to address is determining or recon- firming the “success” criteria of the boilout. Is an annual system-wide boilout needed? If time and temperature are restricted, would an enzymatic boilout be useful? Attention to these details will help minimize the potential for problems associated with microbial contamination.

The most effective microbiological control program for the coating kitchen will employ both the most effective biocide program and a good housekeeping program. The synergistic combination of appropriate biocides(s) and good housekeeping can improve performance, reduce coating color losses or upsets, and potentially reduce operating and chemical costs.

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