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THE VOICE OF THE WATER TREATMENT INDUSTRY

2001 Spring

The Selection and Application of Nonoxidizing Biocides for Cooling Water Systems

By Colin Frayne, Metro Group, New York, NY

In recent years, there has been a significant resurgence in the use of oxidizing biocides for cooling water application in HVAC and general industrial process. However, oxidizing biocides, per say, seldom provide a complete answer to the universally common and eternal problem of precisely how to ensure that:

1. Microbial populations are properly controlled and kept numerically as low as possible; and

2. The host cooling systems continue to operate in a clean and safe manner.

As a result, many water-treaters design and operate microbiological control programs that combine both oxidizing and nonoxidizing biocides, in order to use more effectively the attributes of each type of chemical. And in many industrial cooling systems, the oxidizer, in fact, plays a dual role of initially destroying infiltrating process contaminants and subsequently acting as a low-level, background biostat, while the nonoxidizer acts as a periodically shock-dosed, microbiological killing agent.

Unfortunately, no foolproof guide is available for the selection and application of microbiocides that can realistically ensure continuous, effective microbiological control in the many different types of cooling systems available (and under a multitude of possible operating conditions). Effective biocide programs are often based on some degree of trial and error by individual field engineers, coupled with previous experience and supported by their technical department.

Part of the reason for the plethora of products is that the problems of fouling, spoilage, health hazard and microbiological induced corrosion in cooling systems remain difficult to control successfully and continuously. As a consequence, there is always a market for new and more effective chemistries, better methods of application, or new inventions.

Some of the factors to be considered by the service engineer when considering biocides include:

- Biocide application rates and frequency.
- Use of bio-dispersants or other cleaners.

• Retention time and water velocity through the system.
• Cooling system pH, chlorides, TDS, or other pertinent analytical parameters, including any process contaminant load or cooling system nutrients.
• Microbiological flora load, including slimes, SRB's, biofilms, etc.
• The compatibility and possible effects on other chemical inhibitors.
• Cost comparisons of a proposed biocide with other possible starting-point biocides.
• Existing corrosion, deposits and other reported problems.

In general, it is not possible to clean up a microbiologically fouled cooling system with only one application of a biocide, as they are never 100% effective at killing or dispersing slimes. Neither is it possible to control consistently biological growth with a haphazard regime of biocide applications, or with inadequate data on loading, or very limited results of previous in-use effectiveness.

A planned, comprehensive, but flexible, microbiological control program that involves an appropriate degree of monitoring is always required. Flexibility is vital, because of the dynamic nature of cooling systems

Good Housekeeping Practice
It is absolutely necessary to control microorganisms and biofouling in cooling systems. Control is achieved by good housekeeping practices and by the monitoring, killing and removal from the system of organisms and foulants detected. It is easier and significantly less expensive to keep a clean system clean, than to stop a dirty system from getting dirtier.

A limitation of oxidizing biocides is that they are generally poor at penetrating and dispersing heavy, anaerobic infestations, unlike some nonoxidizers. They are also completely indifferent as to what they will oxidize, attack or corrode. Therefore, a fundamental need exists for nonoxidizing biocides as a supplement to oxidizing biocides

Basic Questions Before Selecting a Nonoxidizing Biocide
Some key questions that water treatment vendors need to resolve in order to produce a suitable biocide program will include:

• What problems are reported or observed, and which of these problems are treatable?
• What are realistic objectives for a new or modified biocide program?
• Will a new program cost more money than is currently spent?
• What type of nonoxidizing biocide(s) should be used?
• Should the nonoxidizer(s) support or supplant an existing oxidizer chemical currently used?
• How should the new program be applied and monitored?
• What changes to current operating practice will be required?

• Will the site operators and/or the service company be involved in more work? If so, to what extent, and are there any negative aspects of the biocide program?
• What are the tangible benefits of such a program, and when will these benefits be demonstrable to both operators and management.
• Will the program ultimately be cost effective?

The answer to each of the above questions is not immediate. Unfortunately, each cooling system microbiological control program must stand on its own merits. Consequently, there is no instant answer as to the most suitable non-oxidizer and often no guarantee of immediate success.

Primary Microbiological Problem Area
There are a myriad of microorganisms found in cooling water systems. However, the water treatment vendor is primarily concerned with only three problem areas. They include:

• Gram-negative organisms, such as *Pseudomonas sp.*, especially sessile microbes and the biofilm slimes they produce.
• SRBs, and corrosive, anaerobic slimes.
• Algal biomass and the resulting heavy system fouling that can occur.

A Starting Point for Biocide Selection

The following is not an exhaustive list. Also, some products may not be universally available, or are now regarded as environmentally unacceptable

BHAP
2-Bromo-4-hydroxyacetophenone. Organo-bromine group. Good biocide for bacterial slimes. Useful for situations requiring continuous or semi-continuous dosing at low level, such as once-through cooling systems, where dose rate is only 1 to 3 mg/L. Typically supplied as a 30% active biocide. Dose rate for recirculating cooling systems is typically 10 to 20 mg/L, but could possibly require up to 80 mg/L in fouled systems. Considerably higher dose rates are required for algal and fungal slimes. BHAP is not pH dependent, so it is effective at high pH levels. However, BHAP has a relatively long half-life, typically 175 to 250 hours, which may affect the potential for cooling system bleed discharge. Other organo-bromine group products with similar biocidal mechanisms include: bis-bromo acetyl butene (BBAB) and β-bromo-β-nitro-styrene (BNS). Example of BHAP is BRM®10 from Buckman Laboratories, Inc.

Bronopol
2-Bromo-2-nitropropane-1,3-diol. Organo-bromine group. Bronopol is a general-purpose microbiocide, slimicide and aerobic/anaerobic bactericide. A benefit of this biocide is its

good compatibility with most other biocides, such as quats, methylene bis(thiocyanate) and isothiazolinones, and all common cooling water inhibitors. The minimum inhibitory concentration for various strains of *Pseudomonas aeruginosa* (a major cooling system slime former) is 12.5 to 50 mg/L. Typically this product is used at 40 to 150 mg/L, at 20% activity. It is more suitable for cooling waters operating at lower pH levels, (below 8.0). Bronopol is available as a 95% crystalline powder and 40% and 20% solutions. It can be purchased from Boots Company PLC (UK), or ANGUS Chemical Co. in the USA.

Carbamates

Example is mix of sodium dimethyldithiocarbamate (DIBAM) and disodium ethylene bisdithiocarbamate (NIBAM), or single product, such as potassium n-hydroxymethyl-n-methyldithiocarbamate. Organo-sulfur group. Often two carbamates are blended together, typically in 15% DIBAM + 15% NABAM, or 4.5% of each constituent, or alternatively, as 25 to 50% single carbamate. Carbamates are general-purpose anionic, bactericide/fungicide/algaecide. They are effective against fermentation-producing organisms. Carbamates are readily soluble. The kill mechanism is by interrupting cell metabolism, via chelation of essential metallic ions. Carbamates are effective above pH 7.5, but are not particularly effective, at low pH or in the presence of heavy metals. Carbamates react with iron and other metals, but their biocidal properties are not affected, (although care is needed when using with metal corrosion inhibitors). Optimum pH is 7 to 8.5. Dose rate is typically 40 to 60 mg/L for 30% active blend. Contact time often 6 to 8 hours or longer, for good kill rate. They are compatible with neutralized polymers, but not with quats, acids, or other cationic compounds. Winterized formulations are available (contain ethylene glycol), for storage below 39°F (4°C). Examples are AMA®-230 from Vinings Industries, or DNM®-30 from ALCO (National Starch and Chemical Co.). Both are 15% + 15% blends.

Chlorothioether

2,2 Dihydroxy-5,5-dichlorodiphenyl monosulfide. A chlorinated phenolic thioether. It is available as 100% solid or more typically as 40% sodium salt. The chlorothioether is a broad-spectrum bactericide and fungicide. It is a proven biocide for *Legionella sp*. Typical use concentration is 100 to 200 mg/L, with a contact time of 4 to 6 hours, although, in view of high *Legionella sp*. awareness in some markets, it may be dosed at up to 400 mg/L based on volume. Chlorothioethers are often employed in comfort cooling systems, operating within a pH range of 7.5 to 9.5. Example is Nipacide F or Fentichlor (100% active) and Nipacide F40 (40% active) from Nipa Laboratories (U.K.) or Nipa Hardwicke (U.S.)

DBNPA

2-2-Dibromo-3-nitrilopropionamide. Organo-bromine group. Effective, general-purpose bactericide but hydrolyzes rapidly above pH 8.0. DBNPA is suitable for bacterial slime cleanup where high levels of organics and biomass are present. It functions in conjunction with chlorine. DBNPA is suitable for once-through cooling systems, because of its fast acting biocidal action (contact time often less than 1 hour). DBNPA is not particularly effective against algae. The half-life of DBNPA decreases rapidly with increasing pH and temperature. This is not generally a problem due to the short contact time required, and may be a benefit when required to meet strict discharge regulations. DBNPA may be considered an oxidizer, since the bromine component can oxidize bacterial substrates. DBNPA is typically supplied as a 20% or 5% active solution. Dose rate is 25 to 35 mg/L for 5% active material. It is available as a 40% active, slow release tablet (200g). The tablets are suitable for small cooling systems and may take as long as 3 weeks to completely dissolve. The tablets should be placed in bags rather than feeders, as the very slow dissolution rate may lead to clogging. Also, the tablets should be kept out of direct sunlight, as DBNPA is photodegradable. These products are manufactured by Dow Chemical Company, as Dow™ Antimicrobial 7287 (20% solution), Antimicrobial 8536 (5% solution) and Antimicrobial CT (40% tablet).

DTEA, DTEA II

2-(Decylthio)ethanamine. Alkylthioamine group. This is one of the few, genuinely new biocides to enter the market in recent years. DTEA or DTEA II was designed to operate effectively under a wide range of pH levels (pH 6 to10 or greater), but especially for the higher pH's now common with "All Organic" and similar, high alkalinity tolerant inhibitor programs. It was also designed as a specific sessile bactericide, biofilm remover and biofilm growth control agent. DTEA or DTEA II functions by forming reversible chelant complexes with the salts and inorganic ions found in biofilm structures, which severely weakens the biofilm and reduces its adhesiveness. DTEA or DTEA II are highly surface active and can be thought of as a "biocidal soap" to be used for clean-up programs (biofilm debris will quickly be in evidence and foaming may occur), as a biocide component with chlorine (although it is not recommended to be used at the same time as chlorine) and as a maintenance biostat. Application rates are typically 50 to 100 mg/L. It is consumed and decays rapidly in heavily fouled systems (typically in 3 to 4 hours), consequently, it is recommended to slowly add the complete dose over a four-hour period. DTEA or DTEA II is manufactured as a 15% active material. It is distributed primarily through AMSA Corp. in the U.S.

Guanides (Including Guanidine and Biguanides)

Examples are dodecylguanidine hydrochloride and acetate, also polyhexamethylene biguanide hydrochloride, and tetradecylguanidine. The aliphatic guanadines are good, general-purpose algaecides, bactericides and fungicides. These biocides are cationic surfactants with good dispersing properties and readily biodegradable. They act as toxicants by virtue of high surface activity, which disrupts the microorganism's cell wall and cytoplasm. Typically used as a 10 to 20% active solution and often blended with MBT or diamine. Dose rate is 20 to 100 mg/L, at pH 6.0 to 9.5, although foaming may occur at high dose rates. Guanides can be precipitated by strong alkalis, trisodium phosphate (TSP) and sodium hexametaphosphate (SHMP). They are not particularly suitable for fouled cooling systems, but effective in maintaining clean conditions. Example is Vantocil® IB (20% active polymeric biguanide), from ICI PLC.

Glutaraldehyde

Pentane-1,5-dial. Aldehyde group. Glutaraldehyde is a good bactericide, especially with difficult and persistent organisms due to its good penetrating ability. It has limited effectiveness against algae and fungi. The kill mechanism is by cross-linking outer proteins of cell and preventing cell permeability. Glutaraldehyde is a fast-acting biocide (3 to 4 hours, perhaps 4 to 6 hours with difficult slimes), non-ionic, non-foaming, effective over a wide pH range (typically pH 6.5 to 9.0), and compatible with chlorine. It is also effective against SRBs and biofilms. The half-life tends to be short, depending upon the particular cooling system parameters, but typically 4 to 12 hours. Careful evaluation is needed before application on some larger systems, especially as it may not be particularly cost effective. Glutaraldehyde is readily biodegradable. Typical use concentration is 100 to 125 mg/L at 45% active material, although heavily slimed cooling systems may need 200 to 300 mg/L as an initial, cleanup shock dose. It is an effective choice for biological control in air washers. Glutaraldehyde is probably a good biocide where the risk of *Legionella sp.* exists. Although concentrated glutaraldehyde reacts with ammonia, at typical in-use concentrations the rate of reaction is slowed and glutaraldehyde can be suitable for SRB and slime removal in large process systems, where 25 to 50 mg/L or more, of ammonia is present. This biocide is particularly associated with Aquacar® 515, 542, 545 (15, 42, 45% active product), from Union Carbide Corporation, a subsidiary of The Dow Chemical Company.

Isothiazolines

Alkyl isothiazolin-3-ones. Organo-sulfur group. Good, wide-spectrum bactericide and algaecide that is effective over a wide range of pH. Isothiazolines kill by inhibiting microbial respiration and food transport through the cell wall. It is recognized as an industry standard product for cooling systems but can be expensive. Isothiazolines are supplied to some markets as a 13.9% active concentrated blend (10.1% 5-chloro-2-methyl-4-isothiazolin-3-one and 3.8% 2-methyl-4-isothiazolin-3-one). It is always marketed to the end user, as a 1.5% active (1.11% + 0.39% to 1.15% + 0.35%) in-use blend. Isothiazolines are amber to yellow-green liquids that require very careful handling due to severe skin and eye irritant properties. They are effective against both general aerobic and spore-forming bacteria, over a pH range of 6.5 to 9.0. Isothiazolines are very effective algaecides and fungicides, but only at acid to slightly alkaline pH levels. Contact time is typically 5 to 6 hours. Dose rate is typically 50 to 120 mg/L, for 1.5% active isothiazoline. Availability exists as several possible permutations of the product, under the KATHON™ brand from Rohm & Haas Company. Also, AMA®-215 (1.5%) from Vinings Industries, and as 33% aqueous dispersion of 1,2-benzisothiazolin-3-one

(BIT), under the Proxel™ BD brand, from ICI PLC. BIT is also available as XBINX® from PMC Specialties Group, Inc. (U.S.).

MBT

Methylene bis(thiocyanate). Organo-sulfur group. Relatively quick-kill biocide, with a 2 to 4 hours contact time. Excellent biocide for SRBs. The kill mechanism is to block the transfer of electrons in the microorganism, preventing oxidation/reduction mechanisms. MBT is an "enzyme poison." It is non-ionic. The disadvantage is that its pH sensitive and hydrolyses quickly at pH greater than 7.5. High levels of dissolved ferric iron deactivate MBT. Typical product concentration is 10% active, as a beige creamy liquid. Dosage requirements to cleanup a system are 20 to 40 mg/L, with maintenance concentration of 5 to 10 mg/L. MBT is not very soluble in water and is a poor penetrant. The most effective use of MBT is often when blended with a quat. Example of MBT is AMA®-410W water dispersion and AMA®-210 (10%) from Vinings Industries.

Polyquat

There are many polyquat materials and an example is poly[oxyethylene (dimethyliminio)ethylene,dichloride]. They are broad-spectrum, cationic polymers of low molecular weight for cooling systems and air-washers. Polyquats are not a heavy-duty product or effective in dirty or high suspended solids water, but useful for comfort cooling systems. Polyquats are relatively safe, and can be used in swimming pools at lower dose rates (for control of algae). There is minimal risk of harsh skin irritation, (as with isothiazolines). Typically, polyquats are available to end users as 15 or 30% active materials. For 30% product, typical cooling system maintenance dose is 10 to 20 mg/L, with an initial dose of 30 to 50 mg/L. The system needs to be clean prior to use. Contact time may be 6 to 8 hours. The best pH range is 7.5 to 9.0. Biocidal reaction is similar to quats, with fewer tendencies to foam and better fungal activity. Example of polyquat (60% concentrate) is WSCP™, from Buckman Laboratories, Inc.

Quats (ADBACs)

Alkyldimethylbenzylammonium chloride (also known as alkylbenzyldimethyl ammonium chloride or benzalkonium chloride). Quaternary ammonium compound group. There are many popular products in this group that are widely available. The primary amine salts are of limited benefit in cooling systems, but diamine quats are effective. Quats are cationic, surface active products with a tendency to foam, especially above pH 8.0. The kill mechanism is due to the cationic nature, whereby an electrostatic bond is formed with the cell wall, which affects permeability and protein denaturing. Quats are effective algaecide and reasonably good bactericide, and can be applied over a wide range of pH (optimum pH 6.5-8.5). At typical in-use concentrations, diamines will help maintain clean cooling systems, and reduce populations of general algal and bacterial organisms. However, they tend to have only a bacteriostatic effect over *Pseudomonas sp*. and SRBs. An advantage of quats is their relatively low-cost. The disadvantage is that quats are deactivated by high hardness (typically over 500 mg/L), chlorides, oil, dirt, silt and debris. Quats have poor compatibility with polyanionics polymers. Typical end-user product is 10% active strength quat in an alkaline solution, with a dose rate of 50 to 100 mg/L. Contact time is typically 4 to 6 hours. Examples of quat concentrates are Barquat® OJ50 and OJ80 (50 and 80% active ADBAC), from Lonza Inc., Synprolam™ 35DMBQC 50 and 80 (50 and 80% active) from ICI PLC, Arquad™ B-100, from Akzo Nobel B.V. Examples of diamines are Redicote® E9, Duomeen® C and Arquad® DMMCB-50, from Akzo Chemicals BV.

Sulfone

Bis(trichloromethyl) sulfone. Organo-sulfur group. Sulfone is a broad-spectrum biocide, which is particularly effective against algae and fungi. The minimum kill concentration for algae is typically 1 to 3 mg/L and 5 to 10 mg/L for fungi, but 100 to 300 mg/L for bacteria. Optimum pH is 6.5 to 7.5, and possibly up to pH 8.0. Typically, this product is used at 10 to 25 mg/L based on volume, at 34 to 39% active product solutions. Sulfone is a non-foamer. The required contact time is often 6 to 8 hours or longer for good kill rate. Examples are N-1386 HAN (39.2% in heavy aromatic naphtha) and N-1386HG (34.2% in hexylene glycol), from Verichem Inc.

TBTO

Bis(tributyltin) oxide. Organo-tin group. TBTO is a very useful algaecide and fungicide. It tends to act as a bacteriastat, rather than a bacteriacide and is more effective against gram-positive bacteria, rather than gram-negative (which predominate in cooling systems). TBTO is deactivated by low pH, high silt, and organic fibers, such as cooling tower wood. Optimum pH is 7.0 to 8.5. Typical product concentration is available as 18 to 19% active dispersion, blended with a quat. There are solubility problems with TBTO that can be encountered in the cooling system. Also, cationic interfere with TBTO, besides high hardness and organics. There is a risk of foaming with TBTO, due to the presence of quats in the formulation. Dose rate is typically 40 to 100 mg/L. TBTO is less widely used today, due to risk of persistent environmental toxicity.

TBZ (Tertbuthylazine)

2-(tert-butylamino)-4-chloro-6-(ethylamino)-s-triazine. Triazine group. TBZ is an excellent algaecide that is very effective at 1.0 to 1.5 mg/L active triazine. (Triazine inhibits the algal photosynthetic reaction and is thus an algistat, rather than a true algaecide). It is not effective as a fungicide or bactericide. Products are typically available as 4% active dispersion. Shock dosed of 50 to 75 mg/L is required in clean-up programs, or 25 to 30 mg/L for periodic maintenance doses (4% active). TBZ operates at full range of cooling water system pH and is not subject to interference by hardness, organics or metal ions. It is a non-foamer. TBZ is compatible with chlorine and often used with oxidizers in large industrial cooling system programs. Examples are

Bellacide® 325 from BioLabs (Great Lakes Chemical Corp.) and AMA®-204, from Vinings Industries.

TCCBN
Tetrachloro-2,4,6-cyano-3-benzonitrile. TCCBN functions similarly to the chlorophenols. It is a good slime controller, especially algal slimes. TCCBN provides reasonable performance as a general bactericide. It operates within pH range 6.5 to 9.0, although performance tends to decrease at higher pH. Kill mechanism is by destroying the microbial cell wall. Contact time is usually 4 to 6 hours. Typical dose rate is 20 to 50 mg/L. Example is Shercide 97® from PMC Specialties Group Inc.

TCMTB
2(thiocyanomethylthio)benzothiazole. TCMTB is an excellent fungicide for control of wood rot. It is used to prevent fouling and plugging problems caused by filamentous algae and fungi. Long contact time is often required in cooling water systems having high cycles of concentration or long retention time (long half-life). It can be useful for control of SRBs. TCMTB has limited solubility in water, and generally functions better with good biodispersants. Typical biocide product is 30% active TCMTB. Typical use concentration is 20 to 50 mg/L.

Thione
Tetrahydro-3,5,dimethyl-2H-1,3,5-thiadiazine-2-thione. Organo-sulfur group. The optimum pH for thione is 7.0 to 8.5. Typical product concentration is 20 to 24% active, alkaline solution (although 100% active powder is also available), with maintenance dose of 15 to 30 mg/L and cleanup dose of 30 to 60 mg/L. Thione is useful for closed-loop systems. Also, it is very effective for SRBs. Example of thione is DAZ™, from Buckman Laboratories, Inc., DAZOMET™ from Verichem, or AMA®-220 (20%) and AMA®-224 (24%) from Vinings Industries. Also known as Mylone, from Boots Company, PLC, Basamid™ from BASF Corporation, Crag Fungicide® and Crag Nemacide®.

THPS (TKHPS)
Tetrakish(hydroxymethyl)phosphonium sulfate. Alkyl phosphonium group. THPS is promoted as one of the newest biocides on the U.S. market having an EPA registration. It is marketed as a broad-spectrum product, possessing an excellent safety and environmental fate profile. It functions over the entire open and closed cooling system pH range and has proved useful against SRBs. Although compared to some other alkylphosphonium salts, THPS has limited activity in heavily fouled systems against the removal of algal biomass and biofilm slimes, and thus, its suitability as a heavy-duty biocide is questionable. THPS is cationic and if used as high concentrations (for example, during a cleanup program), there is a risk of incompatibility with anionic inhibitors such as polyacrylates, polymaleic acid (PMA) and phosphonates. THPS is less hazardous than many other commonly used biocides, and in view of its excellent environmental fate

profile, it is likely to be entirely suitable for small industrial and comfort cooling systems. Dose rate in the field is high at typically 60 to 80 mg/L (as a 25% active material), although it is likely to be formulated with nonionic biocides for improved heavy-duty performance and to reduce the high in-use expense of the product. THPS is sold as Tollcide® PS71A from Albright & Wilson, a division of Rhodia.

TTPC

Tributyltetradecylphosphonium chloride. Alkylphosphonium group. TTPC is a broad-spectrum microbiocide, with good algaecide properties. It is chlorine-compatible and will enhance ability of chlorine to penetrate polysaccharide slime layer. TTPC is cationic (therefore care required with anionic inhibitors), highly surface active, but with low foaming tendency. It has a high level of hydrolytic stability, and functions over the entire pH range of open and closed cooling water systems. The surface acting properties of TTPC causes severe damage to microbial cell membranes and deactivates cell enzyme processes. Typically used concentration is 20 to 40 mg/L as product (at 50% active material), for periodic cleanup programs, either alone or in combination with other nonoxidizers, such as bronopol, guanadines, DBNPA and isothiazolines. TTPC functions as a synergist for many other biocides, improving their activity. Example is Bellacide® 350, (50% active) from BioLabs (Great Lakes Chemical Corp.).

There are many combinations of biocide blends that are cable of good biofilm penetration, and have effective microbial action against SRBs. One combination is a blend of MBT and TCMBT. One source for this blend is from Buckman Laboratories, Inc., under the proprietary name of MECT™ or MECT 5™.

In order for nonoxidizing biocides to be fully effective under the wide range of operating conditions and environmental demands today, the selected oxidizers and non-oxidizers should be compatible with each other, and also with other chemical inhibitors.

The program should ideally provide equal effectiveness against algae, gram-negative aerobic slime formers and SRBs. Additionally, the program should provide effectiveness against iron bacteria, fungi, legionella, nitrifyers, etc., and have the ability to kill and remove existing sessile organisms/biofilms, and keep surfaces clean, especially in the prevention of re-establishment of biofilms.

About the Author:

Colin Frayne is a water treatment consultant. He has more than 30 years experience in the practice of industrial chemistry and water systems management, and has worked and lectured in over 40 countries. Mr. Frayne currently resides in New York with his wife and two daughters.

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This article was excerpted from Chapter 6 of Colin Frayne's book "Cooling Water Treatment - Principles and Practices." Some of the nonoxidizing biocides discussed in Chapter 6 have not been included in this article due to space limitation. Mr. Frayne's book may be purchased in its entirety from the AWT bookstore.

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QUIZ: Based on "The Selection and Application of Nonoxidizing Biocides for Cooling Water Systems", by Colin Frayne, 2001 Spring

1. **Oxidizing biocides**: Which one of the following statements is not true?
   a. In many cooling systems oxidizers initially destroy infiltrating process contaminants
   b. In many cooling systems oxidizers act as a low-level, background biostats
   c. Oxidizing biocides are generally good at penetrating and dispersing heavy, anaerobic infestations
   d. Oxidizing biocides are completely indifferent as to what they will attack or corrode

2. **DBNPA** 2-2-Dibromo-3-nitrilopropionamide: Which one of the following statements is not true?
   a. DBNPA hydrolyzes rapidly above pH 8.0
   b. DBNPA functions in conjunction with chlorine
   c. The half-life of DBNPA decreases rapidly with increasing pH and temperature
   d. The dose rate for a 5% active DBNPA material is 125 to 135 mg/L

3. For which biocide is the following statement true? - "The required contact time for this biocide is often 6 to 8 hours or longer for good kill rate."
   a. **Glutaraldehyde** Pentane-1,5-dial.
   b. **Isothiazolines** Alkyl isothiazolin-3-ones
   c. **MBT** Methylene bis(thiocyanate)
   d. **Sulfone** Bis(trichloromethyl) sulfone

4. Which biocide is generally the most effective algaecide?
   a. **TBTO** Bis(tributyltin) oxide
   b. **TBZ** Tertbuthylazine
   c. **TCMTB** 2(thiocyanomethylthio)benzothiazole
   d. **THPS (TKHPS)** Tetrakish(hydroxymethyl)phosphonium sulfate

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5. Which of the following biocides is deactivated by low pH?

a. **TBTO** Bis(tributyltin) oxide
b. **TCCBN** Tetrachloro-2,4,6-cyano-3-benzonitrile
c. **Glutaraldehyde** Pentane-1,5-dial
d. **BHAP** 2-Bromo-4-hydroxyacetophenone

6. Which of these biocides typically requires the highest application rate per unit volume of water?

a. **Carbamates** sodium dimethyldithiocarbamate and disodium ethylene bisdithiocarbamate blend (30%)
b. **Glutaraldehyde** Pentane-1,5-dial (45%)
c. **Isothiazolines** Alkyl isothiazolin-3-ones (1.5%)
d. **Polyquat** poly[oxyethylene (dimethyliminio)ethylene,dichloride] (30%)

7. Which one of the following statements in not true?

a. **Glutaraldehyde** is effective against SRBs and biofilms
b. **Isothiazolines** are effective against both general aerobic and spore-forming bacteria
c. **Quats (ADBACs)** Alkyldimethylbenzylammonium chloride tend to have a powerful bacteriacidal effect over *Pseudomonas sp*. and SRBs
d. **Thione** Tetrahydro-3,5,dimethyl-2H-1,3,5-thiadiazine-2-thione. Thione is very effective for SRB's

8. Which is the only one of the following statements that is true?

a. **BHAP** 2-Bromo-4-hydroxyacetophenone. BHAP is pH dependent, so it is not effective at high pH levels
b. **Bronopol** 2-Bromo-2-nitropropane-1,3-diol. The minimum inhibitory concentration of Bronopol for various strains of *Pseudomonas aeruginosa* is 125 to 150 mg/L
c. **MBT** Methylene bis(thiocyanate). High levels of dissolved ferric iron will not deactivate MBT
d. **TTPC** Tributyltetradecylphosphonium chloride. TTPC is chlorine-compatible and will enhance the ability of chlorine to penetrate polysaccharide slime layer.

9. Which one of the following products/blends is anionic in character?

   a. **TBTO** dispersion blend
   b. **Guanides**i (including Guanidine and Biguanides)
   c. **Carbamate** blend
   d. **MBT** blend.

10. Which one of the following products has only limited effectiveness against fungi?

   a. **Glutaraldehyde**
   b. **Guanides**
   c. Isothiazolines
   d. **Sulfone**