Benefits of Antimicrobial Pesticides in Public-Health and Industrial Uses

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American Chemistry Council
Biocides Panel

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Why Do Antimicrobials Matter?

Many settings, processes and products offer ideal conditions for microbial growth that can lead to major health threats to people and animals. Unwanted microbial growth can also cause enormous economic losses or simply unpleasant and inhospitable surroundings. Antimicrobial pesticides are essential tools in controlling microorganisms in the inanimate environment and in processes, to the benefit of human and animal health, and to the benefit of economic welfare, resource conservation, and public safety. The advantages derived from their use are incalculable.

Antimicrobial pesticides used to mitigate the growth of human pathogenic microorganisms are regulated as public-health pesticides. Public-health antimicrobials are used in food processing plants, dairies, breweries, poultry houses and other animal feeding operations, hospitals and medical and dental clinics and offices, municipal drinking water and water treatment facilities, swimming pools and spas, schools, day-care centers, public access facilities, and homes.

Industrial antimicrobial pesticide uses are essential to the economic health of an industrialized society, including extending the in-use life of manufactured goods and other products, protecting equipment used in industrial processing and manufacturing systems, and preserving energy efficiency in numerous systems and operations.

Antimicrobials are also used to maintain quality of life by mitigating microorganism growth that causes odors, visual contamination resulting from mold and mildew growth, and other microbiologically induced contamination.

BENEFITS OF ANTIMICROBIAL PESTICIDES
IN
PUBLIC-HEALTH AND INDUSTRIAL USES

INTRODUCTION

Paper, leather, drinking water, latex paints, canvas, roofing shingles, plastics, food-processing plants, day-care centers, home bathrooms, marine piles, air-conditioning systems, fuels, households, kitchens, schools, oil and gas wells, naval vessels, industrial heat exchangers, dairies, poultry houses, breweries, hospitals, grout, cardboard, cooling towers, air craft, telephone poles, and swimming pools. All these products and sites present highly hospitable environments for the growth of harmful microorganisms. Anywhere there is moisture and a potential food source, which can be almost anything, there is the potential for microorganism growth. Many locations, processes and products offer ideal conditions for microbial growth that can lead to major health threats to people and animals, enormous economic losses, or simply unpleasant and inhospitable surroundings. Antimicrobial pesticides[1] are essential to controlling microorganism growth in or on numerous inanimate materials and in many processes.

This document will briefly describe myriad situations in which antimicrobial pesticide products are needed and used to control microbiological contamination. It will describe the impacts of uncontrolled contamination and the benefits derived from the use of antimicrobials, in economic terms, public-health needs, or other measures, as appropriate.

What is an antimicrobial pesticide?

An antimicrobial pesticide is defined as a substance intended to disinfect, sanitize or otherwise mitigate the growth of microorganisms, or to protect inanimate objects, industrial processes, surfaces, water or other chemical substances from contamination, fouling or deterioration caused by microorganisms.[2]

[1] Antimicrobials pesticides are sometimes called biocides. Use of the term biocide is often used to distinguish certain types of pesticide compounds. The scope of the term biocide differs among various regulatory authorities throughout the world. In the U.S., the terms “antimicrobial” and “biocide” refer to pesticide compounds that target various types of microorganisms, and include antifoulants and wood preservatives that target microorganisms. For the purposes of this document, the terms “antimicrobial” and “biocide” are used interchangeably.

[2] See Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) section 2(mm). Although the FIFRA definition excludes antimicrobials with food-contact uses from its definition, they are in fact antimicrobial pesticides and are regulated as such by U.S. EPA. The *Pesticide Registration Improvement Act* (PRIA), first enacted in 2003, instituted a fee program for most pesticide registration action, with the collected funds used to support the EPA’s registration, reregistration, registration review, and various worker safety and outreach programs. Prior to enactment of PRIA, FIFRA section 3(h) provided timeframes for review of most antimicrobial pesticides. At that time, statutory timeframes for registration actions were unique to antimicrobial pesticides. However, food-use antimicrobials were excluded by definition to exempt these actions from the 3(h) timeframes. The exemption was intended to reflect the longer timeframes required for EPA review of food-use actions than those included in FIFRA 3(h).

How antimicrobials are regulated as pesticides

Antimicrobials used to disinfect or sanitize inanimate surfaces that may contact food generally are regulated by the EPA as antimicrobial pesticides. Antimicrobials used to control microorganisms in or on living people or other animals are regulated by the FDA as drugs. However, if the antimicrobial is used to mitigate microorganism growth on inanimate surfaces in medical facilities (other than invasive medical instruments), it is regulated as an antimicrobial pesticide. Antimicrobials directly added to processed food are regulated by the FDA as direct food additives; they are not regulated as pesticides. Similarly, antimicrobials used in cosmetics and other personal care products, such as shampoos and hand sanitizers, are not considered to be antimicrobial pesticides and are regulated instead as cosmetics by the FDA. However, antimicrobials used to preserve cleaning products, laundry products, and other non-cosmetic consumer products are regulated as antimicrobial pesticides. In summary, an antimicrobial used to control microorganism growth in or on inanimate materials, other than processed food, invasive medical instruments, drugs or cosmetics, is an antimicrobial pesticide.

Public-health and industrial uses of antimicrobial pesticides

One of the primary approaches in the U.S. to categorizing antimicrobial pesticides for regulatory purposes is based on target organisms and their potential negative impacts. Antimicrobials used to mitigate the growth of human pathogenic microorganisms are regulated by the EPA as public-health pesticides. Public-health antimicrobial use-sites include food processing plants, dairies, breweries, poultry houses and other animal-feeding operations, hospitals, medical and dental clinics and offices, municipal drinking water and wastewater treatment facilities, schools, day-care centers, public access facilities and homes.

Industrial antimicrobial pesticide uses are essential to the economic health of an industrialized society. Their uses include extending the in-use life of manufactured goods and other products, protecting equipment used in industrial processing and manufacturing systems, and preserving energy efficiency in numerous systems and operations.

Antimicrobials are used to maintain quality of human life by mitigating microorganism growth that causes odors, visual contamination resulting from mold and mildew growth, and other microbiologically induced contamination.

The following discussion is separated into two sections: the first describes benefits derived from public-health uses of antimicrobials and the second deals with benefits of industrial applications.

BENEFITS OF USING ANTIMICROBIAL PESTICIDES TO PROTECT PUBLIC HEALTH

There are numerous human health, safety and economic benefits derived from public-health antimicrobial uses. Antimicrobial pesticides with claims for use against human pathogens, or to protect human health, are regulated by the EPA as public-health antimicrobial pesticides. Claims and use patterns trigger the requirement for submitting efficacy data to EPA reviewers for evaluation. Prior to registering products or adding a new human pathogen to a registered product, the EPA must find these data to be both scientifically acceptable and compliant with EPA performance standards.

Following are brief discussions of some of the most prominent antimicrobial public-health uses.

Municipal drinking water

The treatment of municipal drinking water supplies is widely acknowledged as one of the most important public-health accomplishments of modern societies. In the 19th century, major outbreaks of waterborne diseases were common in the United States, Canada, and other developed nations. Beginning in the early years of the 20th century, the provision of chlorinated drinking water virtually eliminated typhoid fever, cholera and other waterborne diseases, representing one of the great achievements of public-health safety.[3]

The use of antimicrobials in drinking water systems is not limited to preventing waterborne illnesses. It is also an essential part of system maintenance. The EPA has stated that an average American family of four consumes approximately 400 gallons of treated water per day.[4] There are approximately 1 million miles of pipes delivering drinking water in the U.S.[5] A Congressional study found that pipe corrosion costs U.S. municipal water and sewer systems $50.7 billion annually in 2008 dollars.[6] Pipe corrosion also increases water pumping energy requirements. The total annual direct impact of corrosion in all sectors of the U.S economy is estimated at 3.1 percent of Gross Domestic Product – the most severely affected sector being water and wastewater.[7]

Drinking water disinfection is also a critically important part of the response to emergency situations resulting from floods, earthquakes, and other natural and civil disasters.[8] While the EPA registers biocides as disinfectants for emergency use, they are also effective for use by campers, boaters and others who may need to disinfect water from untreated sources.

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[3] Wigle, Donald T., *Safe Drinking Water: A Public Health Challenge,* Chronic Diseases in Canada 19, no. 3 (2000), http://www.phac-aspc.gc.ca/publicat/cdic-mcc/19-3/c_e.html

[4] WaterSense, An EPA Partnership Program, "Indoor Water Use in the United States," http://www.epa.gov/WaterSense/pubs/indoor.html

[5] Corrosion Doctors, "Corrosion Cost to Society," http://www.corrosion-doctors.org/Principles/ Cost.htm

[6] U.S. Department of Transportation and the National Association of Corrosion Engineers: *Corrosion Costs and Preventive Strategies in the United States,* March 2002.

[7] *Id.*

[8] See the EPA's Web site for various actions recommended during emergencies to treat water for drinking, cooking and bathing. http://www.epa.gov/safewater/faq/emerg.html

Wastewater treatment

While wastewater treatment is not considered a public-health use by the EPA, it is the other half of the municipal water system, and completes the discussion of the benefits that accrue during municipal water treatment. Therefore, it has been included in the public-health section of this document. Drinking water delivery systems are completed by the sewer system and wastewater treatment operations that many municipalities maintain. It is estimated that 16,400 publicly-owned treatment works (POTWs) release 41 billion gallons of wastewater daily. These systems rely on biocide treatments as a component of routine maintenance to prevent biologically induced corrosion. The cost to municipalities to maintain these drinking water and wastewater treatment systems is estimated at $36 billion annually in the U.S. This figure includes replacement of aging infrastructure, water losses from leaks, chemicals and other equipment to prevent corrosion and fouling, and other system maintenance operations. These costs would be significantly greater without effective tools to control corrosion and levels of biological fouling and their negative impacts on equipment and system integrity.

Municipal wastewater disinfection is necessary for safe, potable-water supplies and for healthy rivers and streams. Microorganisms are present in large numbers in sewage treatment plant effluents, and waterborne disease outbreaks have been associated with sewage-contaminated water supplies and recreational waters.

Chlorination is by far the most common method of wastewater disinfection and is used worldwide to destroy pathogens before wastewater is discharged into receiving streams, rivers or oceans. Chlorine is known to be effective in destroying a variety of bacteria, viruses and protozoa in wastewater, including *Salmonella*, *Shigella* and *Vibrio cholera*.[9]

Food processors, dairies, breweries

The food and beverage industries generate 13 percent of all U.S. manufacturing shipments.[10] Water is integral to food and beverage production. It is an ingredient, especially in beverages, a mixing or seeping medium in food processing, and a medium for cleaning and sanitizing in all production facilities. Numerous process considerations rely on biocides to protect equipment, maintain performance, conserve energy, and maintain water quality, as discussed in more detail below. There are also special concerns to assure the safety of the foods and beverages produced.[11]

In September 1999, the Centers for Disease Control and Prevention (CDC) released an authoritative study on overall food-borne disease rates.[12] "Food-Related Illness and Death in the United States" appeared in the September-October 1999 edition of the CDC journal, *Emerging Infectious Diseases*. It estimated that food-borne pathogens cause 76 million illnesses, 325,000 hospitalizations and

[9]American Chemistry Council, "Wastewater Chlorination: An Enduring Public Health Practice," American Chemistry Council, http://www.americanchemistry.com/s_chlorine/sec_content.asp?CID=1198&DID=4550&CTYPEID=107 (accessed April 2, 2010).

[10] Sector Strategies, "2008 Sector Performance Report: Food and Beverage Manufacturing — At a Glance 1996-2005," Office of Cross-Media Programs, U.S. Environmental Protection Agency, http://www.epa.gov/ispd/pdf/2008/food_beverage_ manufacturing.pdf, 47 (accessed April 2, 2010).

[11] Sector Strategies, 50.

[12] Food Marketing Institute, "FMI Backgrounder: Food Safety and Foodborne Illness," Food Marketing Institute, www.fmi.org/media/bg/FoodSafety_Foodborne_Illness.pdf, 4 (accessed April 2, 2010).

5,000 deaths per year. The CDC relied on extrapolation to develop these statistics because so many cases go unreported or the causative pathogenic organism is not identified. Nonetheless, these estimates are considered more definitive than prior research findings. For example, of the 5,000 estimated deaths, only 1,800 reported deaths are associated with documented food-borne illnesses. The CDC believes that 3,200 additional deaths annually result from food-borne illness in which the causative pathogen is unidentified. Similar ratios are seen in the confirmed and estimated number of total illnesses and hospitalizations for which the disease-causing agent was not identified.[13]

In a report funded by the Produce Safety Project at Georgetown University, it has been estimated that food-borne illnesses cost the U.S. economy more than $152 billion per year.[14] There are enormous, but, as yet uncalculated, additional costs, because this number represents only illness caused by the major pathogens associated with food-borne illnesses, *E. coli O157:H7*, *Campylobacter, Listeria monocytogenes* and *Salmonella*. Included in these costs are medical expenses, productivity losses from missed work, and the estimated value of premature deaths. However, they do not include the costs to industry for product embargoes, product destruction and recalls, or the extensive measures undertaken daily to reduce the presence of food-borne pathogens in the food supply. Antimicrobials are an indispensable tool used to protect the nation's food supply from pathogenic microorganisms.

Hospitals, clinics, and medical offices

It has been well-understood for more than 150 years that microscopic organisms are responsible for many diseases and infections. This concept revolutionized the entire practice of medicine and has led to the growing body of knowledge surrounding the prevention of microbial contamination and the control of infectious disease. Antimicrobial pesticides are an essential component in the arsenal used to control microbiological contamination in hospitals and other medical facilities. However, the struggle against infectious disease remains one of the major challenges in medicine. Increasingly, modern medicine prolongs the lives of those who are immuno-compromised, burn victims, premature babies, and the elderly. However, these medical advances have had the unwelcome and previously unanticipated effect of giving rise to opportunistic or aggressive infectious diseases in hospitals and other health care settings. In the U.S., it is estimated that more than 2 million patients are afflicted with hospital-acquired infections annually, and that 90,000 people die annually from such infections.[15] It is estimated that hospital-acquired infections cost American society $4 - 5 billion annually. [16] Medical and infection control experts use antimicrobial registrants to help control the spread of these dangerous infections.

[13] Food Marketing Institute, 4.

[14] Robert L. Scharff, "Health-Related Costs From Foodborne Illness in the United States," Produce Safety Project, Georgetown University, http://www.producesafetyproject.org/admin/assets/files/Health-Related Foodborne-Illness-Costs-Report.pdf-1.pdf (March 3, 2010), 1 (accessed April 2, 2010).

[15] Campaign to Prevent Antimicrobial Resistance in Healthcare Settings, "Why a campaign?", U.S. Centers for Disease Control and Prevention, http://www.cdc.gov/drugresistance/healthcare/ problem.htm (accessed April 2, 2010).

[16] U.S. Centers for Disease Control and Prevention, "National Nosocomial Infections Surveillance (NNIS) system report, data summary from January 1992-June 2001," *Am J Infect Control*. 29 (2001):404-421.

Swimming pools and spas

Antimicrobials are essential to maintaining the safety and usefulness of swimming pools and spas. In the U.S., there are more than 4.5 million residential in-ground pools, another 3.5 million residential above-ground pools, 270,000 commercial spas, and 5 million residential hot tubs.[17] Pools offer opportunities for recreation, exercise and therapy. Spas also are both recreational and therapeutic. It would be impossible to maintain water quality by replacing it after each use. Biocides are essential to the prevention of diseases and also for aesthetics (e.g., algae prevention). The importance of biocide use is reflected in the fact that, in addition to pesticide regulations that establish safety and efficacy of treatment chemicals, public pools are subject to state, county and local health department regulations. In addition, the Association of Pool and Spa Professionals and CDC have published extensive standards and guidance for pool and spa operation and maintenance.[18]

Hospitality and transportation industries

Americans have a reasonable expectation that hotels, restaurants, and other public-access facilities will be clean and safe. This industry employs approximately eight percent of all U.S. workers, and its employment numbers are expected to grow at a faster rate than general employment during the next few years.[19] Sanitizers and disinfectants are essential tools in maintaining the cleanliness and safety of these premises.

Airplanes, trains, and buses also rely on sanitizers and disinfectants to maintain cleanliness and safety. The cruise industry provides transportation, lodging, food, and multifaceted entertainment. This industry continues to grow at a steady rate, with an estimated $38 billion contribution to the U.S. economy in 2007.[20] An industry trade association estimated that the cruise industry employed 350,000 in the U.S. in 2007.[21] In addition, 9.45 million U.S. residents were cruise passengers in 2007, accounting for 75 percent of all cruisers.[22] Clearly, it is essential for cruise ships to maintain sanitary surroundings. However, this presents a challenge when ill or infectious passengers go aboard ship, endangering an isolated, dense population of travelers. Following onboard outbreaks, it is essential to take ships out of use until they have been thoroughly cleaned and sanitized.[23] The

[17] Aquatic Resources Network, "MEDIA: Statistics — How Many Pools are there in the U.S.?" Aquatic Resources Network, http://www.aquaticnet.com/media-statistics3.htm (accessed April 2, 2010).

[18] U.S. Centers for Disease Control and Prevention, "Healthy Swimming," U.S. Centers for Disease Control and Prevention, http://www.cdc.gov/healthyswimming/ (accessed April 5, 2010); Association of Pool and Spa Professionals, "Technical and Standards Publications and Resources," Association of Pool and Spa Professionals, http://www.apsp.org/Public/Publications-Resources/Technical-Standards/index.cfm (accessed April 5, 2010).

[19] U.S. Employment and Training Administration, "High Growth Industry Profile: Hospitality," U.S. Department of Labor, http://www.doleta.gov/Brg/Indprof/Hospitality_profile.cfm (accessed April 5, 2010).

[20] Cruise Lines International Association, Inc., "Cruise Industry Creates More Than 350,000 Jobs, Generates Record $38 Billion to U.S. Economy in 2007," Cruise Lines International Association, Inc., http://www.cruising.org/node/231 (accessed April 5, 2010).

[21] *Ibid.*

[22] *Ibid.*

[23] National Center for Environmental Health, "Vessel Sanitation Program Operations Manual," U.S. Centers for Disease Control and Prevention, http://www.cdc.gov/nceh/vsp/operationsmanual/OPSManual2005.pdf (accessed April 5, 2010).

CDC's Vessel Sanitation Program has established standards and conducts routine inspections of water bunkering and distribution systems; swimming pool maintenance; communicable disease prevention, including hygienic practices; food handling, temperature control, and containers; food and non-food contact surfaces; washing facilities and equipment; and facility maintenance.[24] Antimicrobials are essential to enabling the cruise industry to meet CDC standards.

[24] Cramer, Elaine H., Blanton, Curtis J., and Otto, Charles, "Shipshape: Sanitation Inspections on Cruise ships, 1990–2005, Vessel Sanitation Program, Centers for Disease Control and Prevention," U.S. Centers for Disease Control and Prevention, www.cdc.gov/nceh/vsp/pub/biblio/cramer08.pdf (accessed April 5, 2010).

BENEFITS OF USING ANTIMICROBIAL PESTICIDES IN INDUSTRIAL PROCESSES AND PRODUCTS

Given the enormous challenges of identifying all industrial uses of antimicrobials and estimating the economic benefits derived from them, the following discussion highlights only some significant uses.

Material preservation

Antimicrobials are used as preservatives in a wide range of products to protect them from microbial contaminants that spoil, decrease in-use service life, and compromise product integrity. Material preservation results in decreased energy and natural resource consumption and waste generation, producing significant economic and societal benefits.

The need to protect against microorganisms in products has increased significantly because in many products, organic solvents, known as "volatile organic compounds" (VOCs), have been replaced by aqueous media. This substitution reduces air pollution, but increases the need to control microbial contaminants because aqueous media are far more conducive to microorganism growth than are most organic solvents.

It is useful to consider material preservatives as fulfilling the need for three different durations of effectiveness:

- Short-term preservation – Raw material inputs, primarily dispersions, emulsions and slurries, are treated for short-term preservation during storage and transport;
- In-can preservation – Finished manufactured goods with aqueous solvent content require in-can preservation for the time spent in commerce prior to use;
- Longer-term preservation – Some products require longer-term preservation so they are protected during their in-use lifetimes. Examples include dry-film preservatives (mold-resistant outdoor paints and adhesives), fabrics (awnings, sails, tents), and extruded plastics used to manufacture outdoor furniture.

Following is a discussion of a few of the product categories that rely on material preservatives.

Dispersions, emulsions, slurries, and other material inputs

Polymer or latex dispersions, emulsions, and slurries are used to manufacture many products, including adhesives, paints, coatings, non-woven fabrics, paper, printing inks, and construction materials. As noted, with the replacement of VOCs and also with decreasing residual monomer concentrations of polymers, these and other products have become more prone to microbial contamination from bacteria, yeasts and fungi. These inputs to manufacturing are typically stored in large tanks that are continually topped off and rarely allowed to empty. They are usually bottom-filled, and the top portions may become stagnant and contaminated. Materials are transferred to tanker trucks or railcars for shipment to a manufacturer, and may remain stored for several months. Slurries, which are mineral dispersions, are growing in popularity for coatings, paper and the building industry. They are easier to transport than dry pigments, and can be significantly more economical for manufacturers. Again, they offer significant growth media for microbial contaminants.

Slurries and polymer emulsions may constitute up to 40 percent of the final manufactured product. Maintaining their quality and preventing spoilage by adding antimicrobial products are essential to the integrity of the final products manufactured using these materials.

Adhesives

Adhesives are used in the construction and automotive industries, and in medical, dental, packaging, and consumer product applications. The major components include binders, pigments, solvents and additives, such as plasticizers. As noted in the preceding section, polymer or latex dispersions and emulsions used to manufacture adhesives require preservation. The final manufactured good also typically requires preservation while packaged to prevent loss of viscosity, or staining and gas generation. Depending on conditions of use (for example, in areas that are wet or humid), antimicrobials may be added to prevent premature deterioration of the adhesive, surface staining, and product failure during use.

Paints and coatings

North American paint and coatings are produced in the millions of gallons. Much of this production is treated with in-can preservatives, with a smaller amount treated with dry-film preservatives. The U.S. paint and coatings industry employs about 46,000 workers at nearly 1,500 establishments,[25] making it the fourth largest U.S. manufacturing sector. It is important to understand that the latex paint industry could not exist without the use of biocides as in-can preservatives. The latex emulsions and aqueous bases used to manufacture latex paints provide the perfect combination of food and water essential for microbial growth. Without biocides, latex paints would fail in storage, typically presenting a loss of viscosity, malodor and complete product breakdown. Indeed, untreated latex paint formulations can produce sufficient microorganism growth generating gases that can potentially cause explosive, catastrophic container failure. The ruptures occur as gas pressures generated from fungal or other growth increase beyond the ability of the container to contain the pressure. The importance of antimicrobial preservatives to these aqueous-based products cannot be overstated for product safety, utility and economic benefits.

Metalworking fluids

Metalworking fluids (MWFs) are used to reduce heat and friction, and to improve product quality in industrial machining and grinding operations. Water-based MWFs support microbial growth, with biological contaminants including bacteria, fungi and their related biological byproducts, such as endotoxins, exotoxins and mycotoxins.[26] Sources of contaminants include airborne materials, soils from parts, shoes, floor sweepings, and even workers (perspiration, skin cells, spittle, etc.). Re-inoculation is continuous, and water-

[25] Sector Strategies, "February 2009 Supplement; 2008 Sector Performance Report," Office of Cross-Media Programs, U.S. Environmental Protection Agency, http://www.epa.gov/sectors/pdf/2008/ 2008-sector-report-supplement.pdf (accessed April 5, 2010).

[26] The National Institute for Occupational Safety and Health (NIOSH), "NIOSH Safety and Health Topic: Metalworking Fluids," U.S. Centers for Disease Control and Prevention, www.cdc.gov/niosh/topics/ metalworking/ (accessed April 5, 2010).

based fluids must be protected from costly deterioration, equipment obstructions, and performance failures. The annual adverse economic impact of uncontrolled microbial growth is valued in the tens of millions of dollars.[27] Biocidal prevention of uncontrolled microbial growth helps to ensure continuous and smooth equipment operation, energy and input cost savings, and safe and healthy workplaces.

Fuel preservatives

Distillation of crude oil generates hydrocarbon fuels of varied carbon chain lengths for use in many different energy-generating applications. Fuel performance properties, such as efficiency and stability, can be negatively impacted by spoilage microorganisms, for example, in an airplane setting. Preventing expensive and potentially life-threatening engine failure and aircraft gauge malfunction is one of the most important reasons for biocide usage in the fuel industry. Biocides are valuable additions to storage tanks, aviation fluids, fuel tanks, diesel fuel, gasoline, kerosene, marine fuels, biodiesel fuels, and in mixtures with other fuel additives and enhancers. Biocide usage is critical in some fuels to maintain their integrity during storage, distribution, and use.

Leather and suede

The vast majority of hides and skins used to manufacture leather originate from the commercial meat market as waste. Transforming a putrescible waste product into durable, useful and valuable materials for manufacturing shoes, hand bags, furniture, clothes and other high-end goods is a true example of recycling a sustainable renewable resource. Leather manufacture is a complex process, which involves numerous steps to unhair, cure and tan hides. All of these steps require using biocides to prevent spoilage and contamination. A fungicide may also be required post-tanning to permit storage in humid or uncontrolled ambient surroundings. Biocides are also important in cleaning and sanitizing facilities in which hides are processed to assure worker safety. The value of the global leather industry is around $40 billion annually. Biocides used globally to support this industry are estimated at $70 million.[28] The U.S. is a major supplier of cattle hide and partially processed leather to the world market. This industry segment is entirely dependent on biocides, both in terms of product integrity and worker safety.

Construction materials

In 2006, the value of the construction industry was $1.1 trillion or 9 percent of total GNP.[29] More than 90 percent of the companies in the industry have fewer than 20 employees, making this industry a major representative of U.S. small business interests.[30] The continued replacement of VOCs in construction materials has elevated the importance of

[27] Metalworking Fluids, 2nd Edition, edited by Jerry P. Byers, 196. New York: Taylor & Francis.

[28] Personal Communication with Elton Hurlow, Marketing Manager, Leather Technologies, Buckman International; www.tannerscouncilict.org/perspective.htm; www.fao.org/es/esc/en/15/352/index.html; www.ushsla.org/ht/d/Home/pid/26133; www.fas.usda.gov/

[29] Sector Strategies, "2008 Sector Performance Report: Construction — At a Glance 1996-2005," Office of Cross-Media Programs, U.S. Environmental Protection Agency, www.epa.gov/ispd/pdf/2008/construction.pdf (accessed April 5, 2010).

[30] *Ibid.*

biocides to preserve most critical building materials. These include concrete, wood, drywall, and asphalt shingles. A significant part of this sector involves concrete additives or admixtures, used for enhancing or retarding the curing of concrete, or to provide other product attributes. For example, because lignosulfonate solutions are very susceptible to bacterial and yeast contamination, it is not uncommon for inadequately protected drums of this material to explode as a result of carbon dioxide build-up from yeast fermentation. Consequently, preservation with appropriate biocides inhibits this build-up, and contributes to product integrity and worker safety.

Preservation with biocides also prevents the early failure of many construction materials while in service. For example, in the southeastern U.S., high heat and humidity much of the year take their toll on many building materials, especially roofing shingles. However, incorporating biocides during manufacture produces shingles that maintain their appearance and integrity for significantly longer than those left untreated. Extending the useful life of these products not only helps conserve resources and energy, but also plays an important role in decreasing waste streams destined for landfills. Biocide use is essential in reducing unnecessary construction materials' deterioration and waste generation.

Numerous other aqueous-based compounds used for construction—such as sealants, moisture barriers, joint compounds, caulks, fillers, grouts, construction adhesives, surface preparations, water-proofing compounds, degreasers, cleaners, coatings and dyes—rely on biocides for in-can preservation. Typically, in-can preservatives represent between 0.1 and 0.3 percent of the finished formulation. Dry-film protectants are used at a slightly higher concentration, with levels up to 0.6 percent or more. While biocides constitute some of the smallest inputs to the manufacture of construction materials, their economic value to the industry is enormous.

Wood and wood products

The unique characteristics and abundance of wood make it a natural material for the construction of homes and other structures. Wood is flexible, durable, and easy to work, and it is a renewable resource. However, wood left exposed to the outdoor environment is subject to degradation by a variety of natural causes. While some wood is decay-resistant, the most commonly used wood species, which also tends to be the fastest growing, and, therefore, most sustainable, possess little decay resistance. Typically, treated wood products offer representative service lives of 20 years or more. A longer service life means a lower demand on forests and less frequent transport of materials.

Treated wood products are essential to telephone and electronic transmission, railroads, marine structures, and highway and other infrastructure functions. Moreover, treated wood continues to serve as the material of choice for utility poles, cross-ties and related structures. Treated wood poles form the backbone of the U.S. electrical distribution network. It is estimated that in 2002, there were approximately 140 million treated wood poles in service, with about 800,000 new ones placed in service annually. These industries do not see any viable alternatives to treated wood poles and railroad ties for the vast majority of their needs.[31]

[31] Utility Solid Waste Activities Group ("USWAG") Submissions to U.S. EPA: EPA Document No. EPA-HQ-OPP-2004-042-0087, "Comments on Pentachlorophenol Revised Risk Assessments; Notice of Availability

Pressure-treated, round timber piling is a dependable choice for foundation, land, fresh water, and marine piling. Foundation piles submerged in groundwater may last indefinitely, and fully embedded, treated, concrete-capped foundation piles that are placed partially above the groundwater may last 100 years or longer.[32] The importance of the longevity of treated piling is evident, considering that wood piling is a mainstay of foundation systems. For example, thousands of pressure-treated wood pilings form the foundation of the new construction projects for JFK Airport in New York and Dulles Airport in northern Virginia; and, the city of New Orleans is built on timber piles.[33]

Industrial processes

Industrial water treatments

It is impossible to overstate the importance of microbiological control in all water systems. The primary problems arising in water systems are fouling and biofouling. Fouling generally is the presence of unwanted surface-attached materials on submerged materials. Biofouling, in simplest terms, is the attachment of any organism to submerged surfaces.[34] Controlling fouling is essential to the integrity of water systems and the primary goal of water treatment.

Industrial uses of water include boiler-makeup, processing, product treatment and cleaning, cooling, and many others. The largest users per unit price of product manufactured are the steel, chemical, and pulp and paper industries. Industrial water consumption is a significant factor in production costs, and has become important as part of ongoing efforts to conserve limited water resources. For example, throughout the chemical industry, more than 80 percent of water used for cooling and steam generation is recycled.[35] Therefore, in-plant water recycling and wastewater treatment systems are significant parts of the industrial process for many facilities. There is always a need to control water quality to prevent corrosion, scale deposits and slime formation, which has become even more important with the growing use of recycled water or recovered wastewaters.

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and Solicitation of Risk Reduction Options – Docket No. EPA-HQ-OPP-2004-0402" (posted June 23, 2008); EPA Document No. EPA-HQ-OPP-2003-0248-0056, "Comments on Creosote Revised Risk Assessments and Qualitative Economic Analysis of the Alternatives; Notice of Availability and Solicitation of Risk Reduction Options – Docket No. EPA-HQ-OPP-2003-0248" (posted June 20, 2008); Association of American Railroads Submission to U.S. EPA, EPA Document No. EPA-HQ-OPP-2003-0248-0055, "Comments on Creosote Revised Risk Assessments and Qualitative Economic Analysis of the Alternatives; Notice of Availability and Solicitation of Risk Reduction Options – Docket No. EPA-HQ-OPP-2003-0248" (posted June 19, 2008).

[32] Timber Piling, "Pile Durability," Timber Piling Council, www.timberpilingcouncil.org/durability.html (accessed April 6, 2010).

[33] Timber Piling, "History of Piling," Timber Piling Council, www.timberpilingcouncil.org/history.html (accessed April 6, 2010).

[34] Stanczak, Marianne, "Biofouling: It's Not Just Barnacles Anymore," ProQuest, http://www.csa.com/discoveryguides/biofoul/overview.php (accessed April 5, 2010).

[35] Sector Strategies, "2008 Sector Performance Report: Chemical Manufacturing – At a Glance 1996-2005," Office of Cross-Media Programs, U.S. Environmental Protection Agency, http://www.epa.gov/ispd/pdf/2008/chemical_manufacturing.pdf (accessed April 5, 2010).

Preventing corrosion, scale and slime in water systems is essential to almost all industrial, commercial and institutional activities, because preventing water degradation allows the water to be recirculated. Applications as diverse as drinking-water treatment, oil and gas recovery, air-conditioning systems, and pulp and paper production are all dependent on water-treatment technologies. Antimicrobials are an integral part of these technologies. It is difficult, if not impossible, to separate out the costs of corrosion control due to microbial contamination from its other causes. Other elements involved in water quality problems include pH, temperature, and mineral and chemical content. Nonetheless, the various causes of water contamination and the resulting damage to systems are interrelated and must be dealt with in a comprehensive manner since the interaction among the factors is continuous and complex. Estimates of corrosion costs to water systems generally are available. In a study prepared for the Federal Highway Administration it was estimated that the cost of corrosion to the U.S. economy is $276 billion per year.[36] These costs represent the total investments needed annually to protect and prevent corrosion and to repair the inevitable damage to equipment. The costs of damage to systems in the event that water treatment is not maintained on a routine basis would be prohibitive. Biocides are an essential tool in the proper operation and maintenance of any water system, be it industrial, commercial, institutional or municipal.

Oil and gas recovery

The oil and gas industry engages in the extraction of oil and gas from deep underground and offshore, and its subsequent transportation to refineries and chemical plants for further processing. The U.S. is the third-largest producer of oil and the second-largest producer of natural gas in the world. This industry serves vital economic and national security interests. Biocides are added to drilling mud, workover, and completion fluids used in drilling production wells, water floods where water "pushes" oil to an extraction well, treatment of oil and gas field process waters, and oil and gas pipeline and tank maintenance. Petroleum recovered in this manner, as well as petroleum containing naturally occurring water, must be treated to separate the oil from water. Microorganism growth can cause severe problems at any point in the water-handling systems, including generation of hydrogen sulfide or oil-entrapping solids, and severe corrosion of equipment. Therefore, biocides are also added directly to the producing wells to minimize microbial growth, thereby protecting equipment and maintaining the integrity of oil-producing formations.

Conditions in oilfields are conducive to bacterial growth. Bacterial contamination can lead to increasingly frequent equipment failure from corrosion, increasing hydrogen sulfide concentrations, reservoir souring, declines in production and transmission, metal sulfide scales with subsequent failure of downhole equipment, filter plugging, loss of injectivity and inefficient heat exchange. Losses due to the proliferation of sulfate-reducing bacteria (SRBs) and subsequent corrosion in untreated systems can reach several billion dollars annually (based on experiences in Australia). In the U.S., it is estimated that the annual cost of corrosion is $1.6 billion to the oil and gas recovery industry, $3.7 billion to the refining industry, and $1.7 billion to the chemical, petrochemical, and pharmaceutical industries.[37]

[36] Corrosion Doctors.

[37] U.S. Federal Highway Administration, Gerhardus H. Koch, et al., "Corrosion Costs and Preventive Strategies in the United States," NACE International, Publication No. FHWA-RD-01-156, http://events.nace.org/publicaffairs/images_cocorr/ccsupp.pdf

These costs would grow exponentially if biocides were not routinely employed to prevent contamination.

Pulp and paper

The pulp and paper industry consists of hundreds of manufacturers, ranging from large global concerns to small, individually-owned, specialty paper producers. The goods produced include linerboard, corrugated boxboard, building products, paper bags, tissues and toweling, printing and writing paper, newsprint, bleached board, magazine stock, and literally hundreds of specialty papers. Some paper grades are even used in electronic circuit boards, furniture, absorbent materials, and automobile parts. The inputs for pulp and papermaking offer ideal growth media for microorganisms, and biocides are essential as both material preservatives and in treating the massive volumes of water involved in pulp production and papermaking.

Pulping is the process by which fibers from sawmill waste, pulp wood and/or wood chips are separated and treated. The process used depends on the paper grade to be manufactured. Pulp can be dried for shipment or can be sent to the paper mill via pipeline as slurry. The production of most paper and paperboard involves the same basic, continuous process. At the "wet end," the pulp is continuously blended and diluted to form a dilute stock mixture that is approximately 97 percent water. It is then drained on a moving belt, forming a wet sheet. The wet sheet is transferred to a press section where more water is removed, then to a dryer section where moisture is removed using steam-heated dryer "cans." The paper is rolled into a spool at the "dry end." The vast majority of water used in pulping and paper manufacture is recovered, treated, and reused.

The cellulosic material used in paper production is an ideal food source for microorganisms, and the high heats employed in the process offer ideal conditions for them to thrive. Bacterial slime growth is a significant problem in every mill, and must be controlled to protect the massive capital investments required to construct a mill, and to assure efficiency and product integrity. In 2000, the industry employed 182,000 people and produced $79 billion in shipments.[38] The production value is dependent on effective microbiological control to a significant degree. Depending on the size of the mill, the costs incurred when a machine is down for cleaning or repair can be tens of thousands of dollars per hour. Ineffective microbiological control results in numerous shutdowns, as many as one per day, to what should be a continuous process. Stopping the production process can be costly, totaling hundreds of thousands of dollars weekly.

Catastrophic events have occurred as a result of ineffective biological control. For example, in a Wisconsin paper mill in 2008, a storage tank exploded, killing three workers. The three workers were welding on a catwalk above a storage tank where flammable hydrogen gas, produced by high bacteria levels, was present.[39] While this is an extreme example of the

[38] Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, Office of Enforcement and Compliance Assurance, U.S. Environmental Protection Agency, www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/pulppasnp1.pdf

[39] U.S. Chemical Safety Board (CSB) Press Release, March 4, 2010, Following Deadly Explosion at PCA Corrugated

consequences of ineffective control, it is nonetheless a real-world consequence of ineffective control of microbial growth.

Cooling towers, evaporative condensers, and fluid coolers

Cooling towers, evaporative condensers, and fluid coolers may be considered a subset of industrial process systems. However, they raise some unique issues. And, although this subpart discusses the need to control human pathogenic bacteria, it is included in the industrial uses section of this document, consistent with the manner in which these uses are regulated by the EPA, since registrants make no claims against pathogenic organisms. Despite the absence of such claims on registered biocide product labels, according to the Occupational Safety and Health Administration, the ambient temperatures in these systems provide an ideal environment for the growth of microbes, including the Legionnaires' disease bacteria (LDB), making maintenance essential for both effective operation and to control LDB growth. Cooling towers, evaporative condensers, and fluid coolers all use fans to move air through recirculating water systems that produce water vapor and droplets that may be present in the environment. Design factors are employed to reduce or eliminate the potential for drift of water vapor and droplets. Nonetheless, biocide treatment of these recirculating water systems is essential for public-health protection, in addition to the significant benefits derived from protecting equipment, maintaining recycled water quality, conserving energy and resources, and overall efficiency.[40]

Preventing waterborne illnesses from exposure to sources other than drinking water is an important public-health issue. The CDC publishes annual reports on waterborne illnesses that result from drinking water, recreational waters (pools and spas), and other water sources. The reports are instructive about the continuing need for vigilance in controlling waterborne microbiological contaminants.[41]

Antifoulant coatings

Marine biofouling results from the build-up of organisms, primarily barnacles, macroalgae and microbial slimes, that accumulate on the surfaces of ships' hulls and submerged permanent structures, such as piers and drilling platforms. If left uncontrolled, these organisms cost society greatly in terms of lost productivity, decreased efficiency, increased energy use, time losses, and environmental damage.

Modern marine shipping plays an important role in the global economy. The fuel consumed by the marine shipping industry is reduced significantly through the use of coatings that not only protect

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Mill in Wisconsin, CSB Issues Safety Bulletin on Hazards of Welding and Other Hot Work: *Proper Combustible Gas Monitoring Among Seven Key Safety Lessons from a CSB Investigation of Multiple Hot Work Disasters,* www.csb.gov/newsroom/detail.aspx?nid=307

[40] U.S. Department of Labor, Occupational Safety and Health Administration, *Section II:A. Cooling Towers, Evaporative Condensers, and Fluid Coolers,* http://www.osha.gov/dts/osta/otm/legionnaires/cool_evap.html (accessed April 5, 2010).

[41] CDC, Surveillance for Waterborne Disease and Outbreaks Associated with Recreational Water Use and Other Aquatic Facility-Associated Health Events — United States, 2005–2006 and Surveillance for Waterborne Disease and Outbreaks Associated with Drinking Water and Water not Intended for Drinking — United States, 2005–2006. http://www.cdc.gov/legionella/patient_facts.htm

ships from corrosion, but also prevent organic material from growing on the outside of ships. In this context, antifouling coatings have a strong effect on minimizing drag, and, thus, optimizes fuel consumption.

It was estimated that the average fuel consumption of ships without antifouling coatings would be 29 percent higher. With a yearly fuel consumption of 220 Mt of fuel in the marine shipping industry, this translates into fuel savings of 63 Mt, which corresponds to gross savings of 200 MtCO2e per year. After taking into consideration the production footprint of the coatings and average coating lifetime of 12 years, the net abatement volume is ~190 MtCO2e.[42]

On ships' hulls, biofouling results in an increase in roughness, turbulence, and extra weight. Compare a more effective paint (which only allows a thin slime to form on the ships' hulls) with a less effective paint (which allows medium fouling of macroalgae and calcareous fouling), and the result is an additional shaft power of approximately 43 percent (Table 3.6.1). This, in turn, would increase fuel consumption by an additional 209 million tons in the year 2020, and result in an emission of 634 million tons of extra carbon dioxide into the atmosphere.

Table 3.6.1. Estimated effect of fouling control on annual shaft power, fuel consumption, CO_2 emissions and fuel costs. All figures are projected to 2020 and are compared to a fouling-free hull. (The increased shaft power as a function of the fouling degree is obtained from Schultz [2007] and is based on his calculations for an Oliver Hazard Perry class frigate sailing at 15 knots.)[43]

	Additional shaft power (%)	Additional fuel in 2020 (million tons)	CO_2 emissions (million tons)	Additional fuel cost ($ billions)
Freshly applied coating	0	0	0	0
Deteriorated coating or thin slime	9	44	134	22
Heavy slime	19	92	279	46
Small calcareous fouling or macroalgae	33	160	486	80
Medium calcareous fouling	52	253	768	127
Heavy calcareous fouling	84	408	1238	204

Other costs are also incurred when fouled hulls are cleaned and repainted, which includes complying with appropriate regulation to prevent environmental impacts from these activities. The U.S. Navy estimates that biofouling increases fuel consumption by as much as 20 percent or $200 million in additional energy expenditures annually. Underwater hull cleanings, scheduled docking to perform the cleaning, and hazardous waste removal are estimated to cost another $90 million

[42] Innovations for Greenhouse Gas Reductions: A life cycle quantification of carbon abatement solutions enabled by the chemical industry, July 2009. http://www.icca-chem.org/ICCADocs/ ICCA_A4_LR.pdf

[43] IPPIC (April 2009), "The environmental importance of using effective antifouling coatings in relation to GHG emissions." Produced in Cooperation with the IPPIC Antifouling Working Group.

annually.[44] The cost of fouling to shipping fleets and marine industries, naval vessels, seawater pipelines, and aquaculture are likewise significant. It is estimated that the cost of marine fouling to the U.S. economy in 1992 was over $14 billion.[45]

Other significant costs associated with marine fouling involve damages caused by non-native and nuisance species introduced into U.S. waters from fouled hulls. One estimate is $120 billion in annual losses in the U.S. However, according to a U.S. government report, most experts consider this estimated damages figure to be significantly less than actual costs.[46]

Non-native species that invade the United States cause major environmental damage. There are approximately 50,000 foreign species and the number is increasing. About 42 percent of native species on the threatened or endangered species lists are at risk primarily because of alien-invasive species.[47] Clearly, antifoulant coatings are an important tool in the struggle to protect our nation's environmental integrity.

Animal biosecurity

Contagious disease among livestock is a great concern, and control of infectious organisms has become a significant activity, especially in light of several trends in livestock husbandry in the modern era. First, livestock farms in the U.S. have grown into large operations with dense livestock populations. While this consolidation into larger and larger operations has significant economic advantages, it also increases the challenge to control disease threats. Second, there has been a marked decrease in the routine use of antibiotic drug additives in animal feeds. This has led directly to an increased need to disinfect equipment, buildings and other surroundings.

Foot and Mouth Disease (FMD) is considered the most economically devastating of contagious diseases among livestock because of the variety of species potentially involved, its rapid spread, and the difficulty in controlling outbreaks. There were nine outbreaks of FMD in the U.S. between 1905 and 1929, during which it was eliminated. Others nations have not been so fortunate. The 2001 FMD outbreak in Great Britain resulted in the slaughter of more than 6 million animals, which is the primary method used to prevent spread of an established infestation, and an estimated economic loss of $20 billion.[48]

[44] Carderock Division, Naval Surface Warfare Center, *Fouling Control Technology*, www.dt.navy.mil/sur-str-mat/fun-mat/pai-pro-bra/fou-con-tec/index.html (accessed April 5, 2010).
[45] Stanczak.
[46] U.S. Dept of Homeland Security, U.S. Coast Guard Research and Development Center, "Preliminary Investigations of Biofouling of Ships' Hulls: Non-Indigenous Species Investigations in the Columbia River." (2006). www.dtic.mil/srch/doc?collection=t3&id=ADA455206
[47] College of Agriculture and Life Sciences, Cornell University, "Update on the environmental and economic costs associated with alien-invasive species in the United States." David Pimentel (2004). Cornell University, Ithaca.
[48] Center for Food Security and Public Health, Iowa State University, "Foot and Mouth Disease *USDA. Animal and Plant Health Inspection Service;* Foot and Mouth Disease." (2007), Iowa State University.

It has been estimated that an FMD outbreak in the U.S. would result in a loss of farm income of $14 billion, or 9.5 percent of the total annual U.S. farm income. This loss of farm income would result from both lost export markets and decreased domestic consumption.[49] Antimicrobial disinfectants provide a crucial link in maintaining the safety, viability, and value of livestock production in the U.S.

[49] Paarlberg, PL, et al., "Potential revenue impact of an outbreak of foot-and-mouth disease in the United States," *J. Am. Vet. Med. Assoc.* 2002;220(7):988-992, doi:10.2460/javma.2002.220.988.

CONCLUSION

Bacteria and other microscopic plant and animal species are the most prolific life forms on our planet. They continue to astound scientists as knowledge grows about their ability to adapt and flourish in even the most extreme environments. They are omnipresent in, on, and around humans and their environment. Some of these organisms are beneficial and many are harmless. However, others are dangerous or destructive. Antimicrobial pesticide products are essential tools in controlling these organisms to the benefit of human and animal health, as well as to the benefit of economic welfare, resource conservation, and public safety. The benefits derived from their uses are incalculable.

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