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EVALUATION OF BIOCIDES FOR POTENTIAL
TREATMENT OF BALLAST WATER

FINAL REPORT

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Robert C. Richards
Director of Technical Development
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6048

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The R&D Center's technical point of contact is Gail E. Roderick, 860-441-2658, e-mail: groderick@rdc.uscg.mil

16. Abstract (MAXIMUM 200 WORDS)

This report documents the investigation, characterization, and evaluation of biocides that demonstrate potential for ballast water treatment application. A literature search was conducted for information on various aspects of biocides, including their biological treatment efficacy, environmental acceptability, and shipboard safety and practicality, and regulations governing them. Vendors and manufacturers of biocides were also contacted, in order to obtain the most recent data regarding the candidate biocides. The information was organized into a searchable relational database designed to generate a fact sheet for each biocide, summarizing a series of evaluation criteria. Each biocide was evaluated to determine its applicability to ballast water. Chlorine dioxide, glutaraldehyde, SeaKleen®, and cationic surfactants were identified as potential ballast water treatment agents for marine and freshwater use. Copper, bromine, iodine, sodium chlorite, chloramines, ozone, formaldehyde, ethylene oxide, and Dowacil® 75 were determined to be poor biocidal options for ballast water treatment. Several other biocides demonstrated some efficacy but further research would be required before they could be characterized. The recommendations offered to support future decisions on biocide use include continuing research on environmentally-friendly chemicals for use as biocides, conducting experiments on the effects that marine conditions could have on the efficacy and fate of those biocides, and encouraging pilot-scale design studies of ballast water biocidal treatment processes.

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Executive Summary

The introductions of nonindigenous aquatic nuisance species (ANS) have had profound negative impacts on aquatic ecosystems worldwide. One of the major vectors for the introduction of ANS is the discharge of ships' ballast water. In normal shipping operations, ballast water is brought aboard or discharged to adjust the total ship weight, compensating for changes in cargo and fuel loads, which in turn adjusts and optimizes ship characteristics such as hull bending moment, draft, hull loading, and propulsive efficiency.

The U.S. Coast Guard (USCG) is in the process of developing a program for approving multiple environmentally sound methods of ballast water management that will prevent and control ANS introductions during ballast water discharge. Environmentally sound methods of ballast water management that are under investigation worldwide include filtration, hydrocyclonic separation, ultraviolet (UV) radiation, ultrasound, deoxygenation, biocides, and thermal treatment.

Treatment of ballast water with biocides is an attractive option due to their potential for eradicating a broad range of organisms and the potential ease of incorporating the technology into existing and future vessel designs. However, information on potential biocides has not been compared against a common set of criteria, even though biocides have been used extensively for drinking and wastewater disinfection and the body of literature supporting these applications is considerable. The use of biocides to the ballast tank environment is different from these applications and the ballast tank and water may not be compatible with certain biocides. Moreover, few studies have been conducted on the feasibility of using these biocides to treat the range of organism types found in estuarine and ocean water.

To address the effectiveness and practicality of biocides to treat ballast water for the organisms in marine waters, USCG requested an evaluation of biocides with the potential to eliminate viable organisms in ballast water that could pose an ecological or economic threat to coastal waters. Currently, there are no state or federal permitting requirements for ballast water discharges. In fact, point-source discharge regulations provide exemptions for ballast water discharges. However, discharges of ballast water treated with any biocide would need to be of such quality so as to protect the designated uses of receiving waters. Before approving any biocides for ballast water treatment, USCG needs to understand what biocides and byproducts are regulated at the state, federal, and/or international levels, how they are being regulated (e.g., maximum discharge limits), and by whom. Therefore, USCG requested information regarding international conventions and United States laws and regulations for the use of biocides. This report documents the characteristics of biocides that have potential application for ballast water treatment, as well as the regulations governing them.

A literature search was conducted to obtain information on various aspects of biocides, including their biological treatment efficacy, environmental acceptability, shipboard practicality and safety, cost of raw materials, and regulations. The literature search was not restricted to seawater and included the use of biocides in freshwater, wastewater, and industrial water systems. The search also included biocides commonly used in marine antifouling paints.

A total of 32 chemicals that are used as biocides in various applications were identified for characterization. The information on these biocides was reviewed and organized into a searchable relational database based on a specific set of evaluation criteria. These criteria were developed to provide a consistent means of comparison and to help guide the assessment of each identified biocide in its potential application for ballast water treatment. The criteria included:

- Dosage/toxicity information
- Inhibitors/interferences to/with biocide reactivity
- Efficacy on classes of organisms
- Stability of the biocide
- Biocide degradation/byproducts (rates and causes) and environmental acceptability
- Crew safety
- Availability of the biocide (includes whether the biocide is a common commercial product, a specialty product, etc.)
- Shipboard application considerations (e.g., on board storage, on board generation, biocide unit costs [i.e., $/unit volume or mass])
- Conventions, laws, and regulations governing the use of biocides

The database was designed to generate a fact sheet for each biocide. Information for each biocide was then evaluated using a set of qualitative rankings to assess how the various characteristics of a given biocide might be advantageous or disadvantageous for ballast water treatment.

This study identified a number of questions regarding biocide use in ballast water that must be addressed before widespread use can be sanctioned. For example, factors such as the degradation rate of a particular biocide and the potential release of undesirable byproducts into the receiving waters are not well documented for marine waters. Also, many of the physical and chemical properties of seawater raised questions about whether some biocides can be applied effectively to marine waters. Moreover, the safe use of biocides on board ships, their compatibility with ballast tank structural materials are not well understood. Due to the limited available information on biocide use in the marine environment, the effectiveness of biocides in treating ballast water is uncertain. In spite of these data shortcomings, several biocides did show potential for use in treating ballast water. Several biocides were also identified as having poor potential for ballast water applications. Other biocides were identified as chemicals requiring additional information before their potential for ballast water treatment could be evaluated.

The results of the qualitative evaluation for individual biocides are as follows:

- Chlorine dioxide, glutaraldehyde, SeaKleen®, and cationic surfactants, such as C_{16}-alkyltrimethylammonium chloride, were identified as potential agents for ballast water treatment in both marine and freshwater environments;
- Copper, bromine, iodine, sodium chlorite, chloramines, ozone, formaldehyde, ethylene oxide, and Dowicil® 75 were determined to be poor potential biocides for ballast water;
- Mexel® 432, Dibromonitrilopropionamide (DBNPA), Polyhexamethylene biguanide (PHMB), 2-thiocyanomethylthio benzothiazole (TCMTB), benzalkonium chloride, chlorine, chlorothalonil, dichlofluanid, Grotan®, hydrogen peroxide, potassium

permanganate, silver, Peraclean®, zinc pyrithione, Irgarol® 1051, phenol, triclosan, and zineb were identified as biocides with demonstrated efficacy against some of the target organisms, but recommending these biocides for ballast water treatment requires information regarding other evaluation criteria;

- Sea-Nine® (also known as Kathon®) was identified as an antifouling agent with potential efficacy against target organisms, but information regarding its efficacy in water was not available in the literature reviewed;
- Intersmooth® was identified as an antifouling agent with potential efficacy against target organisms, but because this compound is an organotin, its use for treating ballast water is limited by certain federal and national laws. Therefore, this biocide was not evaluated in this report.

Because much of the information obtained from the literature search was not specifically the result of scientific research targeted for ballast water treatment, the use of this information to determine ballast water applicability should be used cautiously. The following recommendations are made to support future decisions on the applicability of biocide use in ballast water:

- Continue research using environmentally friendly chemicals as biocides in the marine environment.
- Conduct laboratory bench-scale studies aimed at the effects of marine environmental conditions, efficacy, and fate of potential biocides.
- Encourage pilot-scale design studies of ballast water biocidal treatment processes.

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List of Acronyms and Abbreviations

AISE	Association Internationale de la Savonnerie
ANS	aquatic nuisance species
AWWA	American Water Works Association
BWM	ballast water management
°C	degrees Celsius
CFR	Code of Federal Regulations
CPO	chlorine-produced oxidants
CTI	Cooling Technology Institute
DBNPA	dibromonitrilopropionamide
DOT	United States Department of Transportation
EC	European Community
EC_{50}	effective concentration at which 50% of test organisms are affected
EEZ	exclusive economic zone
ENEV	estimated no-effects value
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
h	hours
IMO	International Maritime Organization
LD_{50}	lethal dose that kills 50% of the organisms tested
m^3	cubic meter
MBARI	Monterey Bay Aquarium Research Institute
mg/L	milligrams per liter
mg-min/L	milligrams per minute per liter

List of Acronyms and Abbreviations continued

MPRSA	Marine Protection, Research, and Sanctuaries Act
MSDS	Material Data Safety Sheet
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Act
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo-Paris Commissions)
PHMB	polyhexamethylene biguanide
ppm-Cl	parts per million of chlorine
TBT	tri(butyl) tin
TCMTB	2-thiocyanomethylthiobenzothiazole
TDS	total dissolved solids
THM	trihalomethane
µg/L	micrograms per liter
USCG	United States Coast Guard
U.S. EPA	United States Environmental Protection Agency
UV	ultraviolet

1.0 Introduction

Introductions of non-indigenous aquatic nuisance species (ANS) have had profound negative impacts on aquatic ecosystems worldwide. This impact is particularly evident in the coastal regions of the United States (including the Great Lakes) where introductions of ANS have altered important ecological processes and caused serious economic damage. Nonindigenous species (also known as introduced, invasive, exotic, alien or aquatic nuisance species) are defined as "any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organisms transferred from one country into another" (National Resource Council (NRC), 1996). These species affect their new environment and native species through competition for food or habitat, predation of organisms, overgrazing, alteration of nutrient cycles or soil fertility, increased erosion, pathogen introduction, or hybridization with native species. Not all species that are introduced to an ecosystem are injurious or harmful to the resident biota, but it is difficult to predict which ones will have adverse effects, or to what degree the species might infiltrate. Therefore, precautions must be taken to prevent any nonindigenous species from being introduced into a new environment.

Ballast is any solid or liquid that is brought on board a vessel to stabilize it, alter its weight, and adjust its center of gravity. Ships typically use ballast water to provide stability and maneuverability during a voyage. Water is taken up at one port when cargo is unloaded and usually discharged at another port when the ship receives cargo. As organisms ranging in size from viruses to fish are taken on board with ballast water at one port, there is potential that these organisms will be released at the next port when cargo is loaded on the vessel. As ships travel faster and world trade grows, species are better able to survive the journey, and the threat of ANS increases. The United States alone receives at least 21 billion gallons of ballast water each year from around the world, leading to ecosystem-level impacts like the displacement of native freshwater mussels and alteration of the food web by *Dreissenia polymorpha* (Eurasian zebra mussel) in the Great Lakes, and the Mississippi and Hudson Rivers. *Mnemiopsis leidyi* (American comb jelly), probably transported from New England by vessel to the Black and Azov Seas in Europe, has caused drastic declines in zooplankton abundances, increased the hypoxia level, and virtually destroyed the fishing industries in its adopted environment. The recent discovery of several new ANS (Grigorovich and MacIsaac, 1999) demonstrates the urgent need for ballast water management (BWM) to reduce the risk of future introductions.

The economic, environmental, and health problems caused by nonindigenous aquatic nuisance species persuaded the United States Congress to pass legislation in 1990 and 1996 to address the issue. Under the legislation (Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) and National Invasive Species Act of 1996 (NISA)), the United States Coast Guard (USCG) was ordered to establish regulations that would prevent further ANS introductions through ballast water into U.S. waters. The USCG has focused efforts on reducing ANS introductions via ballast water and has developed a voluntary Ballast Water Management Program. Because the voluntary nature of this program was found not effective for managing the introduction of ANS via ballast water (USCG, 2001), the USCG proposed rules that would make ballast water management mandatory, particularly for vessels that operate outside the exclusive economic zone (EEZ) before entering U.S. waters (USCG, 2003). These rules, which were finalized in August 2004, revised subpart D of 33 CFR 151 to require mandatory ballast water management for all vessels equipped with ballast water tanks entering U.S. waters after

operating outside of the EEZ. Existing mandatory BWM requirements for vessels entering into the Great Lakes and Hudson River remain unchanged. This mandatory BWM program requires all vessels to conduct one of the following BWM practices:

1. *Exchange ballast water beyond the EEZ in an area more than 200 nautical miles from any shore.*
This refers to conducting mid-ocean ballast water exchange (exchanging ballast water obtained from ports or coastal waters outside of the EEZ with mid-ocean waters) prior to ballast water discharge in U.S. waters.

   A. *Empty and refill exchange*. Ballast water taken on in ports or coastal waters outside of the EEZ is discharged until the ballast tank is empty (as close to 100 percent empty as vessel navigation and safety considerations will allow). The tank is then refilled with mid-ocean water.

   B. *Flow-through exchange*. Ballast water taken on in ports or coastal waters outside the EEZ is flushed out of the ballast water tanks by pumping in mid-ocean water at the bottom of the tank and continuously overflowing the tank at the top. This flushing continues until three full ballast water tank volumes have been pumped.

2. *Retain ballast on board the vessel.* A vessel that does not choose to conduct mid-ocean exchange may elect to retain its ballast water on board while in U.S. waters.

3. *Use an "environmentally sound" USCG-approved alternative ballast water management method before the vessel enters the U.S. EEZ.* An alternative environmentally sound method of BWM is a method, effort, action, or program that will prevent and control non-indigenous species (NIS) introductions during ballast water discharge. The USCG is in the process of developing a program for approving this type of ballast water management.

4. *Discharge ballast water to an approved reception facility.* An approved reception facility is a land-based ballast water holdingor treatment facility that is specifically used to accommodate ballast water discharge from vessels.

Environmentally sound methods of BWM that are presently under investigation by government, industry, academic, and non-governmental interests include filtration, hydrocyclonic separation, ultraviolet (UV) radiation, ultrasound, deoxygenation, biocides, and thermal treatment. However, the capabilities and limitations of these treatment technologies relative to conditions likely to be met during ballasting operations are poorly understood. This report is limited to the use of biocides as an environmentally sound ballast water treatment method.

Biocides may be added to both ballasted and non-ballasted vessels to eliminate viable organisms. Treatment with biocides is potentially attractive because the technology may be readily incorporated into both existing and future vessel designs and may be effective against a broad range of organisms. There are, however, a number of questions regarding the use of biocides to treat ballast water that must be addressed before widespread use can be sanctioned.
Factors such as the degradation rate of a particular biocide and the potential release of undesirable byproducts into the receiving waters must be known. In fact, many physical and

chemical properties of seawater raise questions on whether biocides can be applied safely to the marine environment and on board vessels. Moreover, although biocides have been used extensively in certain industries for disinfection, application in a ballast tank environment is different and may not be compatible with certain biocides. For example, some biocides may react with organic material or may be corrosive at higher concentrations. Even though the body of research regarding the successful use of biocides for control of organisms in drinking and wastewater is considerable, few studies have been conducted on the feasibility of using these biocides to treat a range of organisms in estuarine and ocean water. Thus, the effectiveness of biocides to treat marine or estuarine water for potentially invasive species is uncertain. The safe use of biocides on board ships, their compatibility with ballast tank structural materials, their potential interaction with particles, salt, or dissolved organic matter in water, and the impacts of the release of the biocide or its byproducts into the receiving waters are also not well understood. Information is lacking on environmental safety and biocide effectiveness across the range of organisms that ballast water treatment is intended to manage.

To address these and other questions concerning the ability of biocides to treat marine waters, an evaluation was conducted of biocides that might be applied to ballast water to eliminate viable organisms that could pose an ecological or economic threat to coastal waters. This report documents the investigation, characterization, and evaluation of biocides for ballast water treatment.

For clarity of presentation and understanding, it is important to define the term "biocide." Block (1991) defined biocide as "…a substance that kills all living organisms, pathogenic and nonpathogenic." He also commented that "…because a biocide kills spores as well as vegetative cells, it is presumably a sterilizing agent. The definition includes all species of living organisms, micro and macro, but the term is commonly used with reference to microorganisms." The Organization for Economic Co-operation and Development (OECD), which includes 30 member countries from Europe, North America, Australia, and Asia, considers the working definition of biocides to be "…products that have an effect on an unwanted organism but are not controlled as agricultural pesticides, veterinary medicines, medicine or in any other relevant legislation." More specifically, the European Community (EC), Biocidal Products Directive, (BPD) (98/08/EC) defines biocides as chemical preparations containing one or more active substances that are intended to control harmful organisms by either chemical or biological means (European Parliament Council, 1998). The EC definition is not firmly agreed upon as there are a number of scope issues, such as the range of compound complexity, lack of risk assessment tools, and efficacy data that have yet to be resolved. In the United States, the majority of the "EC biocidal product types" are known as "anti-microbials" (e.g., disinfectants, sanitizers, and pesticides). For this study, "biocide" is defined as those chemicals available off-the-shelf or generated aboard a vessel by a physical process, such as electro-ionization, or by mixing of two or more chemicals that are used to control or inactivate unwanted organisms.

The recently passed International Convention for the Control and Management of Ship's Ballast Water and Sediments (International Maritime Organization (IMO) February 13, 2004) includes requirements for the use of active substances, meaning chemical or biological biocides (IMO, 2004). A number of such biocides are presently under investigation for use in ballast water treatment. Examples of biocides include chlorine-based treatments (e.g., chlorine gas, chlorine dioxide, chloramines), glutaraldehyde, peroxide, ozone, copper, SeaKleen® (vitamin K), and

Peraclean® (peracetic acid). Although these biocides are included in this study, the investigation was not restricted to these.

1.1 Organization of the Report

The report is organized into seven sections. Section 1 includes this introduction and additional background information. Section 2 describes the literature search and the database development conducted for the investigation phase of the evaluation. Section 3 identifies and characterizes the biocides identified through the literature search. Section 4 presents the evaluation of the biocides using a set of specific criteria that were developed to characterize and rank the various biocides. Section 5 describes the application of biocides to ballast water treatment. Section 6 summarizes the findings and recommendations and Section 7 lists the references cited in this report. Appendix A provides a discussion of the interactive database developed to house information gathered for the investigation. Appendix B provides fact sheets with detailed information on each biocide investigated.

2.0 Literature Search

The investigation began by conducting a literature search to identify potential biocides and to obtain available information on various aspects of biocides, including their biological treatment efficacy (i.e., the ability to kill or otherwise inactivate organisms), environmental acceptability, shipboard practicality, and cost of raw materials. The literature search also included antifouling agents to provide a comprehensive list of chemicals with potential biocidal applications. Antifouling agents are biocides that are typically added to the paint used to coat the outside of a vessel's hull to prevent organisms from growing or attaching themselves to the hull. In addition, information regarding international conventions and United States laws and regulations for the use of biocides was obtained.

The literature search began by conducting preliminary searches based on key words and phrases associated with biocides and biocide characteristics. The literature search employed general Internet searches, as well as searches of dedicated literature tools, such as Scifinder® (Chemical Abstract Services) and Sciencedirect® (Elsevier). The Internet search included major search engines, as well as specific web sites, including those for the United States Environmental Protection Agency (U.S. EPA), American Water Works Association, the environmental protection agencies of Canada, New Zealand, and Australia, West Coast Ballast Outreach Project, U.S. Federal Register, and various technical websites containing relevant information such as the Global Ballast Water Management Program and the North American Pesticide Action Network (PAN) Pesticides Database. Table 2-1 illustrates some of the web sites visited during the Internet searches. Many of the web sites encountered provided links to other relevant sites that included literature, proceedings from workshops/symposiums, vendor information, and other information on biocides.

Table 2-1. Summary of Web Sites Containing Key Information.

Web Sites	Information Obtained
http://www.anstaskforce.gov/toc.htm	ANS Task Force
http://www.aquahabistat.com	Aquihabistat
http://www.pml.ac.uk/ace/default.htm	Assessment of Antifouling Agents in Coastal Environments (ACE)
http://www.affa.gov.au	Australian Government Department of Agriculture, Fisheries, and Forestry
http://www.awwarf.com	American Water Works Association (AWWA) Research Foundation
http://massbay.mit.edu/exoticspecies/ballast/ref.html	Ballast Water References
http://www.nemw.org/Ballast%20Water%20Vendors.pdf	Ballast Water Technology Treatment Vendors from the Northeast-Midwest Institute website
http://www.biochem.techdevices.co.uk	Biochem Products Ltd
http://www.chemflow.com/web/cfhome2.nsf/publicgeneralinfo/10	Biocide information center at Chem Flow
http://www.greenmarineinc.com/epbromination.html	Bromination Vendor
http://c3.org/chlorine_issues/disinfection/disinfection_index.html	Chlorine issues
http://www.coatingsworld.com	Coatings World
http://www.cqdjournal.com	CQD Journal for the Maritime Environment Industry (E.M. Miller Associates, Inc.)
http://www.cti.org/	Cooling Technology Institute bibliography of technical papers
http://www.electrichlor.com	Electrichlor
http://www.clo2.com	ERCO™ Worldwide chlorine dioxide water treatment resource center
http://globallast.imo.org/Abstracts	Global Ballast Water Management Programme 1st International Ballast Water Treatment R&D Symposium
http://globallast.imo.org	Global Ballast Water Management Programme Search Projects
http://www.haloztechnologies.com	Halox Technologies, Inc.
http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB	Hazardous Substances Databank
http://www.hydemarine.com/ballast/seakleen.htm	Hyde OptiMarin for SeaKleen®
http://www.inchem.org/	International Programme on Chemical Safety

Table 2-1. Summary of Web Sites Containing Key Information (cont'd).

Web Sites	Information Obtained
http://www.imarest.org	The Institute of Marine Engineering, Science and Technology (IMarEST) 2nd International Ballast Water Treatment R&D Symposium
http://www.mepi.net	Marine Environmental Partners, Inc.
http://www.michigan.gov/mesb/	Michigan Environmental Science Board Department of Environmental Quality
http://www.mbari.org	Monterey Bay Aquarium Research Institute (MBARI) News
http://www.glerl.noaa.gov	National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory
http://www.ballastwater.com/BWPapers.htm	OptiMarin A/S Optimar Ballast Systems
http://www.clr.pdx.edu/projects/ballast_water/ballast_intro.html	Oregon Ballast Water program
http://www.pesticideinfo.org	PAN Pesticides Database
http://www.performance-chemicals.net	Performance Chemicals Ltd.
http://www.pml.ac.uk/	Plymouth Marine Laboratory
http://www.rohmhaas.com/seanine	Sea-Nine® product
http://www.slc.ca.gov/	State of California
http://www.tramfloc.com	TRAMFLOC™, INC. (chlorine product vendor)
http://www.epa.gov/OGWDW/index.html	U.S. EPA Drinking water program
http://www.epa.gov/ecotox/	U.S. EPA ecotoxicity information
http://www.epa.gov/pesticides/factsheets	U.S. EPA pesticides program
http://www.h2o2.com	USPeroxide
http://www.hopkins-heic.org/infectious_diseases/water_table.htm	Water disinfection
http://www.accepta.com	Water treatment at Accepta
http://www.myregs.com/dotrspa/	U.S. Department of Transportation Regulations

The literature search was not restricted to seawater but included drinking water, wastewater, and industrial water to derive a list of biocides potentially applicable to ballast water treatment. In the course of the study, several peer-reviewed articles were also identified and examined.

To obtain additional information on biocides, various treatment technology vendors were contacted and asked the following questions:

- What is the specific biocide(s) used in the vendor's technology?
- What are the target species?
- What is the required dosage?

- What are the concentrations and the contact time?
- What percentage reduction is achieved with vendor's biocide?
- Do pH levels affect the biocide?
- Is the biocide affected by temperature?
- Is the biocide affected by salinity?
- Is the biocide affected by total dissolved solids (TDS)?
- Is the biocide affected by organic matter?
- Is the biocide affected by turbidity?
- What are the residual concentrations of the biocide in treated water?
- What is the method of organism inactivation?
- Is the biocide recalcitrant? If so, what is the nature of this recalcitrance?
- Are byproducts generated?
- Are there compatibility issues with vessel structure?
- Can this technology be used in freshwater as well as saltwater?
- What is the skill level or training requirements needed?
- What sort of maintenance is required?

Table 2-2 provides a summary of all the vendors contacted. The responses provided by each vendor are included in the fact sheets (Appendix B).

Table 2-2. Summary of Vendors Contacted.

Vendor	Phone	Website
Accepta	+44 (0) 1625 267 581	www.accepta.com
Electrichlor	(574) 773-8921	http://www.electrichlor.com
GDT Corporation	(623) 587-8858	www.gdt-h2o.com
Marine Environmental Partners	(561) 842-9900	www.mepi.net
Maritime Solutions, Inc	(212) 747-9044	http://www.maritimesolutionsinc.com
Miox Corporation	(505) 343-0090	www.miox.com
Optimarin A/S	(203) 973-0678	www.optimarin.com
Pentair Water Treatment/ Plymouth Products	(800) 222-7558	www.plymouthwater.com; www.pentairwater.com
Severn-Trent	+44 (0) 121 722 4000	www.severn-trent.com
Tandem Technologies	(301) 805-6823	http://www.tandemtechnologies.com

2.1 Database Development

The information gathered from the literature search was reviewed and organized into a searchable relational database (Microsoft Access®) based on a specific set of evaluation criteria. The criteria were developed to provide a consistent means of comparison and to help guide the assessment of each identified biocide in its potential application for ballast water treatment.

These criteria include:

- Dosage/toxicity information
- Inhibitors/interferences to/with biocide reactivity
- Efficacy on the major classes of organisms present in fresh and marine water ecosystems (viruses, bacteria, protozoa, fungi, zooplankton, algae, seaweeds, invertebrates, and fish)
- Stability of the biocide
- Degradation/byproducts of the biocide (rates and causes) and environmental acceptability
- Personnel Safety
- Availability of the biocide (includes whether the biocide is a common commercial product, specialty product, etc.).
- Shipboard application considerations (e.g, on board storage, on board generation, biocide unit costs [i.e., $/unit volume or mass]).
- Conventions, laws, and regulations governing the use of the biocide.

Vendor contact information and citations are also included in the database. For each biocide, the database allows the user to generate one fact sheet that summarizes the available evaluation criteria. The physical and chemical properties of the biocides, as well as the feasibility for shipboard use of each biocide, are included in the fact sheets. Appendix A provides a descriptive summary of this database as well as instructions for accessing and editing it. Fact sheets for each investigated biocide, as generated by the database, are included in Appendix B. Due to the limited availability of data, information on some of the evaluation criteria could not be presented in every fact sheet. Information considered useful for characterizing those biocides was lacking and requires further research and investigation.

3.0 Characterization and Identification of Biocides

The characterization and identification of biocides were based on the availability of information on various factors potentially affecting the suitability of the biocide for ballast water treatment. Factors influencing this suitability included chemical, physical, and toxicological properties of the biocide, as well as shipboard design characteristics, including personnel safety and application considerations.

3.1 Identification of Biocides

Thirty-two biocides were identified during the literature search (Table 3-1). The identified biocides included oxidizing (halogenated, non-halogenated) as well as non-oxidizing (acids, aldehydes, amines, ketones, metals) substances. Many of these biocides are currently used for treatment of drinking water, wastewater, and industrial water (e.g., cooling water, metal finishing, and others). Only a few of these biocides have been specifically evaluated for application in controlling ANS in ballast water. Active research, such as on the use of chlorine, glutaraldehyde, hydrogen peroxide, ozone, bromine, and SeaKleen® (active ingredient is vitamin K) as biocidal treatments in ballast water are currently being conducted (U.S. EPA, 2001; Glosten-Herbert-Hyde Marine, 2002; Cooper *et al*., 2002). In September 2000, for example, a prototype ozonation system was installed on the 11 million gallon-capacity oil tanker *S/T Tonsina* in an effort to analyze ozone's ability to remove ANS from marine ballast water (Cooper *et al*., 2002). The National Research Council (1996) also identified a list of chemicals

that could be added to shipboard applications to eliminate viable organisms, although data on efficacy and environmental fate are limited for these biocides. They were retained in the list of biocides to ensure completeness.

The list also includes biocides that are commonly used in marine antifoulants. Although antifoulants containing organotins were identified as biocides, because of the strict national and international regulations banning their use they were not included in the list nor in the report.

Table 3-1. Summary of Biocides Identified.

Biocide	**Common Application**
Metal	
Copper (ionic or salts)	Disinfection of industrial water systems
Silver (ionic or salts)	Disinfection of industrial water systems
Oxidizing	
Halogen containing compounds	
Bromine	Disinfection of drinking water, cooling systems, and surfaces
Chloramines	Disinfection of drinking water, cooling systems, and surfaces
Chlorine	Disinfection of drinking water, cooling systems, and surfaces
Chlorine Dioxide	Disinfection of drinking water, cooling systems, and surfaces
Iodine	Disinfection of drinking water, cooling systems, and surfaces
Sodium chlorite	Disinfection of drinking water, cooling systems, and surfaces
Non-halogen containing compounds	
Hydrogen peroxide	Disinfection of drinking water, cooling systems, and surfaces
Ozone	Disinfection of drinking water, cooling systems, and surfaces
Potassium Permanganate	Disinfection of drinking water, cooling systems, and surfaces
Non-oxidizing	
Acids	
Peraclean® (peracetic acid)	Wastewater treatment; fungicide
Aldehydes	
Formaldehyde	Disinfectant in hospitals, laboratories, and biological fixatives
Glutaraldehyde	Disinfectant in hospitals, laboratories, and biological fixatives

Table 3-1. Summary of Biocides Identified (cont'd).

Biocide	Common Application
Amines and halogenated amides	
Dibromonitrilopropionamide (DBNPA)	Pulp and paper water treatment systems; disinfection of industrial water systems
Mexel® 432 (fatty amines)	Corrosion inhibitor; scale dispersant; molluscide
Heterocyclic ketones	
Polyhexamethylene biguanide (PHMB)	Disinfection of industrial water systems
Sea-Nine® (isothiazolone)	Antifouling agent
Others	
2-thiocyanomethylthio benzothiazole (TCMTB)	Disinfection of industrial water systems; antifouling agent
Benzalkonium chloride	Disinfection of industrial water systems
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	Disinfection of industrial water or wastewater treatment
Chlorothalonil	Antifouling agent; fungicide
Dichlofluanid	Antifouling agent; fungicide
Dowicil® 75 (N-(3-chloroallyl)hexaminium chloride)	Metalworking fluids, preservative for paints
Ethylene oxide	Sterilant/fumigant
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)	Metalworking fluids; bactericide and fungicide
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	Antifouling agent
Phenol	Disinfectant and slimicide
SeaKleen® (Vitamin K)	Ballast water treatment
Triclosan	Wastewater treatment
Zinc pyrithione	Antifouling agent
Zineb (thiocarbamate)	Disinfection of industrial water systems; antifouling agent

As mentioned, antifoulants are coatings containing toxic compounds that can be applied to the hull of a vessel to prevent the growth of organisms on the submerged sections of a vessel. The movement of water against the hull often activates the biocide in the coating. Laughton *et al.* (1992) suggested that increasing the amount and toxicity of antifoulant coatings and applying them to the inside of the ballast tank could kill organisms in ballast water. However, the use of poisonous wall coatings has been found by some researchers to be inappropriate for the inside of ballast tanks (Carlton *et al*., 1995). The New York State Division of Fish and Wildlife's Bureau of Habitat completed an assessment of two antifouling paints, ZO® and EP 2000®, both of which contain the active ingredient zinc pyrithione/zinc omadine. This assessment associated these paints with acute risks to freshwater vertebrates and freshwater and estuarine/marine invertebrates, as well as chronic risks to freshwater and estuarine/marine fish and invertebrates (NYS DEC Letter, September 15, 2003). Arends *et al.* (2001) found that the application of antifouling agents (e.g., organotins) to the inside of a ballast tank may not be effective due to a

reduced leaching rate (the water motion against the sides of the tank would be insufficient to activate the biocide) and a limited effectiveness on benthic organisms, which adhere to surfaces. Additionally, some chemicals, like tri(butyl) tin (TBT) and their residues, would be discharged with the ballast water and are not considered environmentally acceptable. Thus, the application of antifouling coatings to the inside of ballast tanks is not considered a proven method of ballast water treatment.

A number of other biocides that are described in the literature have not found wide application for controlling the growth of organisms. For example, a combination of copper and chloramines have been used to inactivate *Escherichia coli* and MS-2 coliphage (Straub *et al.*, 1995). Ferrate has been used to inactivate the f2 virus and coliforms in sewage effluent (Haas and Gould, 1980). Sodium azide is ineffective at removing dinoflagellate cysts at doses up to 500 milligrams per liter (mg/L) (Montani *et al.*, 1995). However, with respect to other organisms and species, very limited research data are available for these chemicals.

As previously indicated, only a few (chlorine, chlorine dioxide, glutaraldehyde, hydrogen peroxide, ozone, bromine, SeaKleen®) of the 32 biocides or biocide groups identified have been investigated for ballast water treatment to date[1]. The majority of biocides identified have been primarily used for industrial and drinking water treatment. Therefore, information on each specific evaluation criterion of this study is not readily available for these biocides/biocide groups. For example, while information regarding efficacy on target organisms was often available, information regarding its stability in the marine environment was lacking. On-going and future research in this area is expected to provide more information.

3.2 Biocide Modes of Action and Efficacy

Biocides may act through any of several modes of organism inactivation (Chattopadhyay *et al.*, 2002). These include (i) disruption of membrane, envelope, or capsid lipid or protein constituents; (ii) blockage of receptor-ligand interactions essential for infectivity; (iii) inhibition of replication of pathogens; (iv) alteration of the environment and reduction of susceptibility of infection; and, (v) enhancement of the local immune responses. In addition to the mode of action, there are many other factors that influence the efficacy of biocides on microorganisms and other aquatic species. These factors include the biocide's chemical properties, treatment process, the size and characteristics of the organism, biocide concentration, dosage and contact time, and water quality (e.g., salinity, pH, temperature, oxygen content). A comparison of the efficacy of selected biocides on selected microorganisms (bacteria, viruses, and bacterial spores) is shown in Table 3-2. The modes of action for all of the biocides evaluated were not identified, thus Table 3-2 provides a representative set. The shape of the symbol represents the type of microorganism, while the degree of shading provides a measure of the susceptibility of the microorganism class to the biocide.

[1] Additional potential biocides (e.g., hydroxyl radicals generated through electrochemical processes, oxygen stripping with pH changes, ferrate ions, and menadione nicotinamide bisulfate (MNB)) described during the 2nd International Conference and Exhibition on Ballast Water Management, 19-21 May 2004, Singapore are not evaluated in this report due to delivery schedule

Table 3-2. Effects and Mode of Action of Selected Biocides on Microorganisms.

Biocide	Type of Microorganism						Mode of Action
	Vegetative bacteria (gram positive)	Vegetative bacteria (gram negative)	Mycobacteria (gram positive)	Fungi	Viruses	Bacterial Spores	
Oxidizing							
Halogen containing compounds							
Chloramines							Oxidizer of biological molecules (e.g., proteins, nucleic acids).
Iodine Compounds							Attacks N-H and S-S/S-H protein bonds.
Sodium hypochlorite							Similar to chloramines but more active.
Non-halogen containing compounds							
Hydrogen peroxide							Generates hydroxyl free radicals, which attack biological molecules.
Non-oxidizing							
Cationic surfactants							Affects proteins metabolic reactions, cell permeability, etc.
Formalin (37% formaldehyde)							Affects the cell wall and denatures amino proteins.
Glutaraldehyde							Affects proteins (e.g., enzymes, transport of nutrients, cell wall, etc.)
Peraclean® (peracetic acid)							Potent oxidizer
Phenol							Combines with and denatures proteins.

= Resistant; = Somewhat susceptible; = Susceptible at high concentrations; = Susceptible

Biocides exert inactivation or inhibitory effects by interacting with one or more targets in the microbial cells (Figure 3-1). Though the effect of biocides has not been established for many invertebrates, it is well known for fish. For example, chloramine passes through the gills of fish and enters the blood stream, where it reacts with hemoglobin (responsible for carrying oxygen in the blood) to form methemoglobin. Fathead minnows (*Pimephales primelas*) that are exposed to one part per million (ppm) monochloramine as chlorine have about thirty percent of their hemoglobin converted into methemoglobin (Grothe and Eaton, 1975). The fish then suffer from anoxia (low oxygen in their tissues) due to the loss of hemoglobin.

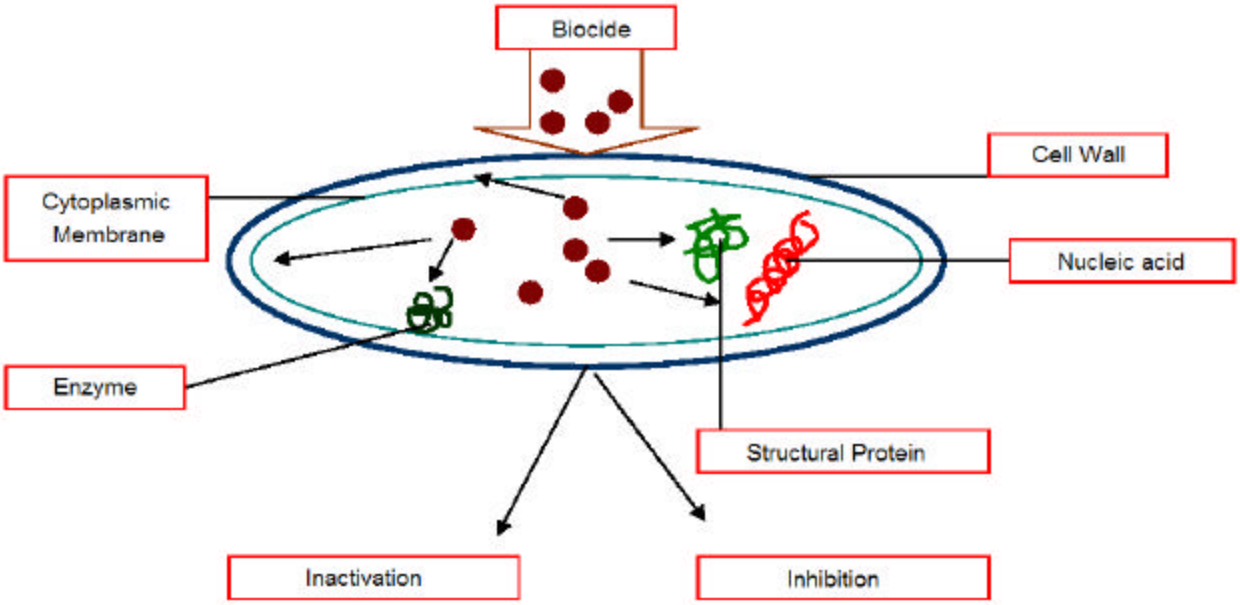

Figure 3-1. Target Sites of Biocides in Microbial Cells.
(modified after Bitton, 1999)

Biocides may be used to eliminate aquatic organisms in either a primary (without pretreatment) or a secondary treatment approach. The secondary treatment approach requires initial removal of interfering compounds and materials prior to the biocide being applied. Many believe that chemical treatment of ballast water cannot be a stand-alone treatment because of the high dosages required to kill larger organisms (Glosten-Herbert-Hyde Marine, 2002). However, a higher kill or removal rate may be accomplished when the biocide is applied as a secondary or tertiary treatment technique, such as application after filtration.

4.0 Comparison of Biocides to Evaluation Criteria

Nine criteria were developed to characterize the biocides (Section 2.1). Two of these, the physical characteristics and mode of action, were considered in Sections 3.1 and 3.2, respectively. An assessment of the biocides against the remaining characterization criteria is provided in this section. This assessment serves to: 1) compare the biocides; 2) qualitatively rate the biocides according to their potential usefulness as a ballast water treatment; and 3) illustrate those areas requiring further investigation. No attempt has been made to weigh the relative importance of the criteria, so arithmetic manipulation of the ratings should not be done. General information on biocide characteristics is presented in Table 3-3. Detailed information on the characteristics of each of the biocides can be found in the fact sheets in Appendix B.

Table 3-3. General Characteristics of Biocides.

Biocide	General Characteristics
Metal	
Copper (ionic or salts) Silver (ionic or salts)	• Limited applications of metal ions or salts (e.g., copper sulfate for the control of algal blooms in lakes and reservoirs). • Not generally used due to human toxicity risk.
Oxidizing	
Halogen containing compounds	
Bromine Chloramines Chlorine Chlorine Dioxide Iodine Sodium chlorite	• Provide wide germicidal activity but are corrosive. • Not effective as sporocidal agents. • Limited activity in the presence of organic matter. • Residuals remain in water after treatment, low toxicity. • Low cost but require frequent applications.
Non-halogen containing compounds	
Hydrogen peroxide Ozone Potassium Permanganate	• Moderate to wide germicidal activity, not sporocidal. • Rendered ineffective in the presence of organic matter. • Ozone requires very little contact time. • Moderately corrosive, limited toxicity. • Some residuals remain in water after treatment.
Non-oxidizing	
Acids	
Peraclean® (peracetic acid)	• Effective disinfectant with no known toxic residual. • More potent than hydrogen peroxide. • Rapidly active at low concentrations against a wide range of microorganisms. • High bactericidal and virucidal effects. • Corrosive and toxic at high concentrations. • Highly efficient in presence of organic matter. • Moderately expensive.
Aldehydes	
Formaldehyde Glutaraldehyde	• Wide germicidal, sporocidal and fungicidal activity. • Slight to moderate efficiency in presence of organic matter. • Some residuals remain in water after treatment. • Moderately toxic. • Moderately expensive.

Table 3-3. General Characteristics of Biocides (cont'd).

Biocide	General Characteristics
Amines and halogenated amides	
Dibromonitrilopropionamide (DBNPA)	• Microbiocide • White or pale yellow crystalline powder
Mexel® 432 (fatty amines)	• Toxic to fish and mollusks, low mammalian toxicity. • Rapid degradation in the environment.
Heterocyclic ketones	
Polyhexamethylene biguanide (PHMB)	• Effective against bacteria and fungi, particularly pseudomonads.
Sea-Nine® (isothiazolone)	• Proposed as alternative to organotin compounds. • Toxic to bacteria, diatoms, algae and barnacles.
Others	
2-thiocyanomethylthiobenzothiazole (TCMTB)	• Proposed as alternative to organotin compounds.
Benzalkonium chloride	• Corrosive, toxic; can cause burns. • May act as a mutagen. • Incompatible with strong oxidizers and moisture.
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	• Bactericide, virucide, and fungicide. • Not sporocidal, limited germicidal capacity. • Organic matter and salts cause reduced efficacy. • Non-irritating, non-corrosive and low toxicity. • Residual surfactant concentration dictates extent of recontamination. • Low cost.
Chlorothalonil	• Proposed as alternative to organotin compounds.
Dichlofluanid	• Proposed as alternative to organotin compounds.
Dowicil® 75 N-(3-chloroallyl)hexaminium chloride)	• Slightly toxic to fish and aquatic invertebrates. • Not persistent and degrades rapidly under acidic conditions.
Ethylene oxide	• Low to moderate aquatic toxicity. • Non-persistent in the environment. • Does not adsorb to sediments.
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)	• Broad spectrum bactericide, effective fungicide • Protects from corrosion.
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	• Proposed as alternative to organotin compounds.
Phenol	• Wide germicidal range, not sporocidal. • Low toxicity and low corrosivity. • Little or no residuals remain in water after treatment. • Low to moderate cost.

Table 3-3. General Characteristics of Biocides (cont'd).

Biocide	General Characteristics
Others	
SeaKleen® (Vitamin K)	• Toxic to a broad spectrum of marine and freshwater organisms (fish larvae and eggs, planktonic crustaceans, bivalve larvae, *Vibrio* bacteria, and dinoflagellates).
Triclosan	• White crystalline powder • Broad spectrum bactericide. • Stable and incompatible with strong oxidizing agents.
Zinc pyrithione	• Proposed as alternative to organotin compounds.
Zineb (thiocarbamates)	• Insecticide, herbicide, and fungicide.

A similar type of qualitative assessment was conducted by Greenman *et al.* (1997) (Table 4-1). These authors compared how a variety of biocides (chlorine, hydrogen peroxide, ozone, organic biocides, and coagulants) performed in the removal or inactivation of selected organisms. In addition, the modification of environmental conditions (pH adjustment, deoxygenation, and salinity adjustment) were ranked for biocidal capability. The first eight columns in Table 4-1 compare the removal/inactivation performance of the biocide on several species groups, as described by Greenwood *et al*. (1997). The ratings used in these eight columns (i.e., "***" = good; "**" = fair; "*" = poor) correspond to the efficacy of the biocide in removing or inactivating the organism in question. The next seven columns rate the biocides or treatment processes with respect to stage of development, reliability of operation, suitability for installation on new ships, suitability for land-based installation, occupational health and safety, and environmental acceptability. These factors were qualitatively rated as good, fair, and poor, as described above. An additional five performance characteristics (space requirements, energy consumption, monitoring requirements, capital cost, and operating cost) were evaluated with "high," "medium," and "low" ratings. Due to limited information on some biocides and their evaluation criteria, the authors also indicated uncertainty due to literature data gaps.

A similar comparison was performed on the 32 biocides identified under this study. The comparisons are provided against each evaluation criterion identified in Section 2.1.

4.1 Efficacy on Target Organisms

The efficacy of the biocides against nine major classes of organisms (viruses, bacteria, protozoa, fungi, zooplankton, algae, seaweeds, invertebrates, and fish) (National Water Quality Management Strategy, 2000) was evaluated. These nine organism classes characterize the expected taxa that would be encountered in marine or freshwater environments. According to the U.S. EPA's ECOTOX Database, a biocide can have numerous types of effects on aquatic organisms. These effects include direct mortality (which corresponds to the acute toxicity rating), bioaccumulation of the biocide in tissues, developmental disruptions, alteration of enzymatic activity, changes in feeding behavior and mobility, and reproductive system damage. A relative rating of the biocide's efficacy on the target organism was developed to provide a qualitative effectiveness assessment across biocides.

Table 4-1. Comparison of Biocide Treatments and Their Performances.

(after Greenman *et al.*, 1997)

Biocides/ Treatment	Criteria for Comparison																			
	Performance (Removal/Inactivation)																			
	Viruses	Bacteria	Protozoa[a]	Fungi[a]	Algae[a]	Seaweeds[a]	Invertebrates	Fish (Juvenile Larvae)	Stage of Development	Reliability of Operation	Suitability for Installation on New Ship	Suitability for Land-Based Installation	Suitability for Port-Based Installation	Occupational Health and Safety	Environmental Acceptability	Space Requirements	Energy Consumption	Monitoring Requirements	Capital Cost	Operating Cost
Chlorine	**	***	*	**	*	*	*	***	***	***	**	***	**	*	*	ooo	ooo	oo	ooo	o(o)
Hydrogen peroxide	**	***	-	-	*	-	-	***	***	***	**	***	**	*	**	ooo	ooo	oo	ooo	o
Ozone	***	***	**	-	-	-	-	***	***	***	*	***	**	**	**	oo	oo	oo	o	oo
Organic biocides	**	***	-	-	*	-	*	**	**	**	**	***	**	*	*	ooo	ooo	oo	ooo	o
Coagulants	*	*	-	-	-	-	-	-	***	***	**	***	***	**	***	ooo	ooo	oo	ooo	oo
pH adjustment	**	**	-	-	*	-	-	**	***	***	*	***	**	**	**	ooo	ooo	oo	ooo	oo
Deoxygenation	*	**	*	*	*	*	-	-	***	***	**	***	**	**	**	ooo	ooo	oo	ooo	oo
Salinity adjustment	*	-	-	-	*	-	-	**	**	**	*	**	*	***	**	ooo	oo	oo	ooo	o

*** Good
** Fair
* Poor
o High
oo Medium
ooo Low
- Uncertain
[a] Performance rating based on cyst or spore usage

For this qualitative assessment, biocide effectiveness does not consider the conditions under which the biocide was tested; rather, the evaluation only considers whether the outcome of the study resulted in the desired effect. The qualitative ranking system is described below:

- A biocide was considered good and designated with a "1" if the LC_{50} (i.e., the biocide concentration that is lethal to 50 percent of the tested organisms) was determined to be 1,000 micrograms per liter (µg/L) or less, if the EC_{50} (i.e., the effective biocide concentration at which 50 percent of the tested organisms are impacted) included mortality of the organism as an impact, or if the reviewed literature designated the biocide as "effective."
- A biocide was considered fair and designated with a "2" if the LC_{50} was between 1,000 and 100,000 µg/L or the EC_{50} reported endpoints other than mortality, such as inhibition of growth or biochemistry, intoxication, etc.
- A biocide was considered poor and designated with a "3" if the LC_{50} was reported as greater than 100,000 µg/L or if the literature reported no effects observed or stated that the biocide was ineffective against that particular organism.

Table 4-2 shows which biocides were effective on the various target organism classes and also indicates the degree of effectiveness these biocides had on each organism class.

Table 4-2. Efficacy of Biocides on Target Organisms.

Biocide	**Efficacy on Target Organisms**								
	Viruses	**Bacteria**	**Protozoa**	**Fungi**	**Zoo-plankton**	**Algae**	**Seaweeds**	**Inverte-brates**	**Fish**
Metal									
Copper (ionic or salts)	-	-	-	2	1	1-2	2	1-2	2
Silver (ionic or salts)	-	-	-	2	1-2	1-2	1-2	1-2	1-2
Oxidizing									
Halogen containing compounds									
Bromine	-	1	-	-	2	-	-	1-2	1
Chloramines	3	2	3	3	-	-	-	2	-
Chlorine	2	1	1	2	1	1-2	2	1-2	1
Chlorine Dioxide	2	1	-	2	2	2	-	1-3	1-3
Iodine	1	1	-	1	1	-	-	-	1-2
Sodium chlorite	-	-	-	2	1	2	-	1-2	3
Non-halogen containing compounds									
Hydrogen peroxide	2	1	-	1	1-2	1-2	-	1-2	2-3
Ozone	2	1	2	-	-	-	-	1-2	1-2
Potassium Permanganate	3	3	3	2	1	1-2	-	1-2	1-2
Non-oxidizing									
Acids									
Peraclean® (peracetic acid)	2	3	1	2	2	-	-	-	1-2

1 = good
2 = fair
3 = poor
- = information not available in the reviewed literature

Table 4-2. Efficacy of Biocides on Target Organisms (cont'd).

Biocide	Efficacy on Target Organisms								
	Viruses	Bacteria	Protozoa	Fungi	Zoo-plankton	Algae	Seaweeds	Inverte-brates	Fish
Aldehydes									
Formaldehyde	-	-	-	1-2	1-3	1-2	-	1-3	1-3
Glutaraldehyde	1	1	-	2	2	1	-	1-2	2
Amines and halogenated amides									
Dibromonitrilopropionamide (DBNPA)	-	-	-	-	1	1	-	2	2
Mexel® 432 (fatty amines)	-	2	-	-	-	2	-	1	2
Heterocyclic ketones									
Polyhexamethylene biguanide (PHMB)	-	1	-	1	2	-	-	1-2	2
Sea-Nine® (isothiazolone)	3	3	-	3	-	1-2	1-2	1-2	-
Others									
2-thiocyanomethylthio benzothiazole (TCMTB)	-	-	-	-	1-2	-	-	1-2	1
Benzalkonium chloride	-	-	-	-	1	2	-	1-2	1-2
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	2	2-3	-	1	2	2	-	2	2
Chlorothalonil	-	-	-	1	1-2	2	-	1-2	1
Dichlofluanid	-	-	-	1	-	-	-	1-2	1
Dowicil® 75 (N-(3-chloroallyl)hexaminium chloride)	-	-	-	-	1-2	-	-	2-3	2
Ethylene oxide	-	-	-	-	-	-	-	3	3
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)	-	1	-	1	-	-	-	-	-
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	-	-	-	-	2	2	2	2	1-2
Phenol	2	2-3	-	2	2	2	2-3	1-2	1-2
SeaKleen® (Vitamin K)	1	1	1	-	1	1	-	1	1
Triclosan	-	1	-	-	2	-	-	-	1
Zinc pyrithione	-	1	-	1	-	-	-	2	2
Zineb (thiocarbamate)	-	-	-	1	2	2	-	2-3	1-2

1 = good
2 = fair
3 = poor
- = information not available in the reviewed literature

Of the 32 biocides evaluated, eight of them demonstrated "fair" to "good" biocidal activity against a broad spectrum of organisms (chlorine, chlorine dioxide, hydrogen peroxide, glutaraldehyde, Peraclean®, SeaKleen®, phenol, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride)) (Table 4-2). However, chlorine and hydrogen peroxide did not demonstrate significant efficacy against algae. Twenty-two biocides demonstrated "fair" to "good" biocidal activity against a smaller spectrum of target organisms, although information in the literature regarding effectiveness against each type of organisms was lacking. Of these 22 biocides, copper, iodine, sodium chlorite, formaldehyde, DBNPA, TCMTB, benzalkonium chloride, Irgarol®, and Dowicil 75® demonstrated good biocidal activity against zooplankton or phytoplankton (i.e., algae) or both.

Two biocides received "fair" to "poor" ratings: Sea-Nine® and potassium permanganate (Table 4-2). Sea-Nine® demonstrated "fair" to "good" biocidal activity against algae, seaweeds, and invertebrates, but was not effective against fungi, bacteria, and viruses. Similarly, potassium permanganate is effective for all organisms studied except viruses, bacteria, and protozoa.

The literature suggests that combining two or more biocides may allow for higher efficacy than using one biocide alone. In theory, biocides used in combination may address an organism's resistance to a particular substance or the weak or sub-lethal impacts of a single biocide. Biocidal combinations may be applied simultaneously or sequentially. The order of application can be manipulated to determine whether the impacts on the target organism(s) are greater when the single biocide is used, when the biocides are combined, or in a different permutation. For example, simultaneous application of ozone and chlorine dioxide to inactivate poliovirus type 1 was found more effective than the application of individual biocides sequentially (Wickramanayake, 1990). The order in which biocides used in combination are applied can be significant. For example, adding chlorine oxide after ozonation has been found to be more effective against poliovirus type 1 than when the treatments are applied in reverse order. Significant changes in virus inactivation results were also observed when the order of application of cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride) and metals (minerals) was reversed (Chattopadhyay *et al*., 2002). This report does not evaluate combinations of biocides since the literature is limited.

4.2 Dosage Information

The effectiveness of a biocide depends on several factors including the concentration, duration of contact, and water quality variables (e.g., temperature, pH, turbidity, organic matter, dissolved solids). The type and dosage of a biocide need to be selected carefully because background conditions can vary substantially. This section provides information on percent organism inactivation or reduction after contact periods at defined biocide concentrations, pHs, and temperatures. Information was sought for each biocide across a broad spectrum of environmental variables for viruses, bacteria, fungi, and sub-cellular components. Different microorganisms and different strains of the same microorganism can exhibit variations in their inactivation percentages across a range of water conditions and application methods. The higher the chemical reactivity of a biocide, the greater its sensitivity to changes in temperature.

The Association Internatinale de la Savonnerie (AISE, 1997) has researched biocide dosage effectiveness on certain organism classes. The percentage of bacteria, fungi, viruses, and spores that remained active (i.e., log 5 kill) after application of the minimum amount of biocide are reported in Table 4-3. The results reported in this table indicate that sodium hypochlorite is relatively effective on the four studied organism classes. The other biocides have limited organism-specific effectiveness. The relative performance of six oxidizing biocides on bacteria (*Escherichia coli*) and poliovirus type 1 is presented in Figure 4-1. This figure is based on the information summarized by Wickramanayake (1990). Chlorine, chlorine dioxide, and ozone appear to be more effective than the other three oxidizing biocides. However, the study conditions, such as biocide dose (0.05 – 2700 mg-min/L), pH (5.9 – 7.2), and temperature (0 ºC – 25 ºC), varied significantly during treatment processes, making direct comparison problematic.

Table 4-3. Activity of Microorganisms after Application of Biocide.

(AISE, 1997)

Biocide	**% Remaining Active**			
	Bacteria	**Fungi**	**Viruses**	**Spores**
Formaldehyde	1	1	2	8
Glutaraldehyde	2	0.5	2	2
Phenol	1.5	5	5	Not effective
Surfactants (quaternary ammonium compounds)	0.0033	Not effective	>10	Not effective
Hydrogen peroxide	5	10	NA	10
Chlorine (sodium hypochlorite)	0.0005	0.01	0.001	0.005

NA = not available

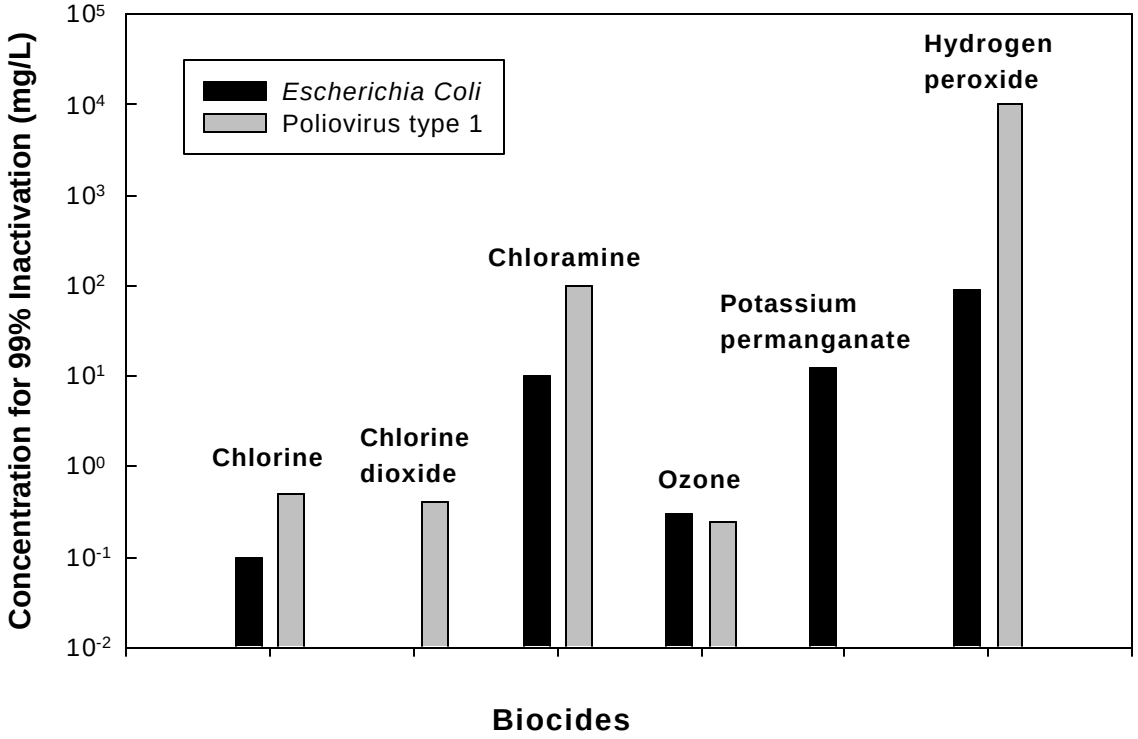

Figure 4-1. Inactivation of *Escherichia coli* and Poliovirus type I by Selected Biocides.

(based on the data summarized by Wickramanayake, 1990).

A complication of marine systems is that some biocides, like chloramine and chlorine, react with substances in seawater, forming other toxic chemical species. In the case of chlorine, these toxic species are often referred to as chlorine-produced oxidants (CPOs). For example, monochloramine is known to react with bromide in seawater over a period of hours to form bromochloramine (Br-NH-Cl) (Trofe *et al.,* 1980). If toxic species are detected, identifying the exact chemical substance causing toxicity is often difficult. Table 4-4 shows examples of the concentration of chlorine delivered by the chloramine or CPO that will kill half of the exposed individual organisms in 48 to 96 hours. This concentration is called the LD_{50}. In its ecological risk assessment of chloramine toxicity to marine invertebrates, Environment Canada determined the Estimated No-Effects Value (ENEV) to be 0.002 ppm-Cl for marine and estuarine environments (Wan *et al*., 2000). There is, however, substantial uncertainty in determining exactly which levels are acceptable and which are not, since there are so little data available.

Table 4-4. Toxicity of Chloramine and CPOs to Marine Species.

Species	Concentration to kill half of the individuals in 48-96 h (LD_{50}) (ppm-Cl)	References
Amphiporeia virginiana (amphipod)	0.57	Wan *et al.*, 2000
Eohaustorius washingtonianus (amphipod)	0.63	Wan *et al.*, 2000
Syngnathus fuscus (pipe fish)	0.27	Bender *et al.*, 1977
Crassostrea virginica larvae (oyster)	<0.005	Bender *et al.*, 1977
Mercenaria mercenaria larvae(clam)	<0.005	Bender *et al.*, 1977
Acartia tonsa (copepod)	<0.005	Bender *et al.*, 1977
Natural mixed phytoplankton	0.1	Bender *et al.*, 1977
Homarus americanus larvae (lobster)	0.3	Capuzzo *et al.*, 1977
Homarus americanus larvae (lobster)	0.6	Capuzzo *et al.*, 1976
Homarus americanus larvae (lobster)	0.05 ppm-Cl caused respiratory distress	Capuzzo *et al.*, 1976
Juvenile killifish	>0.8	Capuzzo *et al.*, 1977

The required dosage levels for 12 of the biocides evaluated in this report (Kim *et al*., 2002) to inactivate *Legionella* bacteria, the contact time, and the relevant water applications are shown in Table 4-5. Oxidizing biocides were found to be more effective in killing *Legionella* than non-oxidizing biocides. Among the non-oxidizing biocides tested, halogenated amides appear to be most effective followed by glutaraldehyde, polyhexamethylene biguanide (PHMB), and halogenated glycols.

The available information points to severe data gaps for biocide effectiveness across organism classes. Lacking standardized dosages, water quality conditions, and systematic inactivational kill data, it is difficult to provide robust comparison of the biocides. Regardless, the evidence at hand demonstrates that the type and dosage of a biocide must be selected carefully because background conditions can vary (e.g., pH, temperature, levels of organic and inorganic constituents, etc.).

Table 4-5. Ranges of Reported Dosages of Biocides Against *Legionella* Bacteria.
(modified after Kim *et al.*, 2002)

Biocides	Typical dosage (mg/L)	Contact time	Application Target
Metals			
Copper (Cu^{2+})	0.1 – 1	Hours to days	Drinking water
Silver (Ag^{+})	0.1 – 1	Hours to days	Drinking water
Oxidizing biocides			
Halogen containing compounds			
Chlorine	0.1 – 10	Minutes to hours	Drinking water, Cooling water
Bromine	0.1 – 10	Minutes to hours	Cooling water
Chlorine dioxide	1 – 10	Minutes to hours	Drinking water

Table 4-5. Ranges of Reported Dosages of Biocides Against *Legionella* Bacteria. (cont'd.)

Biocides	Typical dosage (mg/L)	Contact time	Application Target
Monochloramine (chloramines)	1 – 10	Hours to days	Drinking water
Non-halogen containing compounds			
Ozone	0.1 – 1	Minutes to hours	Drinking water, Cooling water
Potassium permanganate		Ineffective	
Non-oxidizing biocides			
Heterocyclic ketones (isothiazolones)			
Kathon (Sea-Nine®)	1 –100	Hours to days	Cooling water Metal-working fluids
Polyhexamethylene biguanide (PHMB)	1 – 100	Hours to days	Cooling water Metal-working fluids
Dibromonitrilopropionamide (DBNPA)	1-100	Hours to days	Cooling water Metal-working fluids
Aldehydes (Glutaraldehyde)	10-500	Hours to days	Cooling water

4.3 Inhibitors/Interferences to/with Biocide Reactivity

The efficacy of the biocides may vary depending on certain environmental conditions such as pH, alkalinity, total dissolved solids, and the amount of organic matter (including sediments and suspended particulate matter) present in the water to be treated. Dissolved solids refer to any minerals, salts, metals, cations, or anions dissolved in water. Total dissolved solids (TDS) are comprised of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Ballast water can have a wide range of pH and total dissolved solids values due to geographic, climatic, and water quality variations. A biocide's ability to treat organisms over a wide range of water quality conditions, for example, is important.

The pH of the water to be treated can impact the efficacy of the biocide in several ways. For example, hypochlorus acid (the biocidal oxidizing agent created when chlorine comes into contact with water) will ionize into the inactive hypochlorite ion as the water pH value increases, thereby rendering the biocide ineffective. A similar reaction occurs with bromine. The hypobromite ion (an ineffective biocide) will replace hypobromous acid (an effective biocide) as water pH levels rise. Dissolved solids in the water also affect biocidal properties of some materials. For example, in the presence of organics or inorganics in the water, potassium permanganate will be partially consumed in the oxidation of these dissolved substances. Adsorption to particles in the water can also have a negative effect on the efficacy of some biocides. Copper, for example, is a particle reactive chemical that tends to adsorb to sediments in the water column or on the bottom, making any biocidal reactions difficult.

A relative rating of the biocides with regard to biocide efficacy and pH, dissolved solids, and organic matter is provided in Table 4-6. A rating of "1" indicates that the biocide efficiency is not affected by that particular parameter, a "2" indicates that the biocide is somewhat affected, and a "3" indicates that the biocide is significantly affected by that parameter. Dashes indicate that the available information is insufficient to characterize the biocide. For instance, chlorine

dioxide has been assigned a "1" for all three environmental parameters, indicating that this biocide is effective over a wide range of pH values, does not react with dissolved solids, and does not adsorb to organic particulates. Conversely, the scoring for chlorine ("3"s for each parameter) reveals that this biocide is significantly affected by all three parameters such that it is only effective at small pH ranges, reacts with dissolved solids, and will adsorb to organic particulates.

Table 4-6. Level of Inhibition/Interference with Biocide Effectiveness by pH, Total Dissolved Solids, and Organic Matter.

Biocides	Inhibitors/Interferences		
	pH Inhibition	**Reactivity with Total Dissolved Solids**	**Adsorption to Particles or Organic Matter**
Metal			
Copper (ionic or salts)	2	3	3
Silver (ionic or salts)	-	3	2
Oxidizing			
Halogen containing compounds			
Bromine	3	-	3
Chloramines	1	-	2
Chlorine	3	3	3
Chlorine Dioxide	1	1	1
Iodine	-	-	-
Sodium chlorite	-	-	-
Non-halogen containing compounds			
Hydrogen peroxide	3	-	-
Ozone	2	-	3
Potassium Permanganate	2	2	2
Non-oxidizing			
Acids			
Peraclean® (peracetic acid)	-	-	3
Aldehydes			
Formaldehyde	2	-	-
Glutaraldehyde	3	1	1
Amines and halogenated amides			
Dibromonitrilopropionamide (DBNPA)	-	-	2
Mexel 432 (fatty amines)	-	-	-

1 = not affected (if the table goes two pages, the legend should appear on both pages)
2 = somewhat affected
3 = significantly affected
- = information not available in the reviewed literature

Table 4-6. Level of Inhibition/Interference with Biocide Effectiveness by pH, Total Dissolved Solids, and Organic Matter (cont'd).

Biocides	Inhibitors/Interferences		
	pH Inhibition	Reactivity with Total Dissolved Solids	Adsorption to Particles or Organic Matter
Heterocyclic ketones			
Polyhexamethylene biguanide (PHMB)	1	-	-
Sea-Nine® (isothiazolone)	-	-	-
Others			
2-thiocyanomethylthiobenzothiazole (TCMTB)	-	-	-
Benzalkonium chloride	-	-	-
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	-	-	1
Chlorothalonil	-	-	-
Dichlofluanid	-	-	2
Dowicil® 75 (N-(3-chloroallyl)hexaminium chloride)	1	-	3
Ethylene oxide	3	-	1
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)	-	-	-
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	-	-	1
Phenol	-	-	3
SeaKleen® (Vitamin K)	-	-	1
Triclosan	-	-	-
Zinc pyrithione	-	-	-
Zineb (thiocarbamate)	-	-	-

1 = not affected (if the table goes two pages, the legend should appear on both pages)
2 = somewhat affected
3 = significantly affected
= information not available in the reviewed literature

Some chemicals are affected by the dissociation of acids at high pH. For example, Oemcke (1999) reports that bromine becomes about 20 percent less effective at a typical seawater pH of 8.2 because the hypobromite ion, which is a less effective disinfectant, forms as pH increases. Oemcke also indicates that ozone, chlorine dioxide, and chloramines are not affected by pH. Simpson *et al.* (1993) found that chlorine dioxide retains its biocidal effectiveness over a wide pH range. The alkalinity of the water can also affect the biocidal activity. According to Lubomudrov (1997), the biocidal activity of glutaraldehyde decreases with increasing alkalinity, as does chlorine (U.S. EPA, 1999). Biocides that are strongly influenced by pH include chlorine, hydrogen peroxide, potassium permanganate, glutaraldehyde, bromine, and ethylene oxide (Table 4-6). Those less affected or not affected by pH are chlorine dioxide, chloramines, copper,

ozone, Dowicil® 75, and polyhexamethylene biguanide (PHMB). Information on the impacts of pH values on the other biocides was not available in the reviewed literature.

The presence of dissolved solids in the water can impact the efficacy of a particular biocide through various reactions and changes in the speciation of the chemical (Table 4-6). The biocides that tend to react with dissolved solids include copper, silver, and chlorine. Those less affected or not affected at all by the presence of dissolved solids are chlorine dioxide, potassium permanganate, ozone, and glutaraldehyde. Information regarding reactivity with dissolved solids for the other 25 biocides was not available in the reviewed literature.

Biocides expected to adsorb to particles or react with organic matter in the water are also indicated in Table 4-6. Biocides having a strong affinity to adsorb are noted with a "3". These biocides include copper, chlorine, bromine, ozone, Peraclean®, Dowicil® 75, and phenol. Biocides with a moderate to weak affinity to adsorb include potassium permanganate, chloramines, dichlofluanid, and DBNPA. Biocides that would not adsorb or react with organic matter include chlorine dioxide, glutaraldehyde, SeaKleen®, cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride), ethylene oxide, and Irgarol® 1051.

4.4 Degradation and Byproducts of the Biocide

The stability of a biocide in water depends on the properties of the biocide and the environmental conditions of the water (e.g., pH and temperature). The stability of a biocide can be defined in terms of degradation rates (i.e., half-life), or its recalcitrance (resistance to biodegradation) in the environment. In addition, stability can be defined by the biocide's propensity to react with other compounds to form byproducts and to experience hydrolysis (i.e., reaction with water). The generation of reaction byproducts is a concern as these byproducts should not produce more harm than the biocide itself, particularly if these byproducts would be released into harbor waters during deballasting operations. The rate of degradation of biocidal agents generally depends on the concentration applied and the concentration of suspended particles in the ballast tanks. The byproducts produced by a biocide and the associated degradation rates are two characteristics that may be regulated by state, federal, or international statute or convention.

Table 4-7 presents the relative rankings of toxic byproduct formation, recalcitrance, and regulatory concerns for each biocide. Ratings of "1", "2", or "3" were assigned to each of the biocides for each category. For the toxic byproduct formation rating, a score of "1" indicates that the biocide does not form toxic byproducts; a "2" indicates that the biocide may produce byproducts of low toxicity; and a "3" indicates that the byproducts produced are more toxic than the biocide itself. For the recalcitrance rating, a rank of "1" signifies that the biocide degrades quickly, usually within a one to two-day period; a "2" denotes that the biocide requires more than two days but less than one week to degrade; and, a "3" indicates that the biocide requires more than one week to degrade. For the regulatory concerns rating, a "1" indicates that there are no known regulations associated with the biocide or its degradative compound either in the aquatic environment or for storage or transportation; a "2" denotes that there are no environmental regulations associated with the biocide or its degradative compounds in the aquatic environment, but regulatory requirements (i.e., registration) are necessary for the use, transport, or storage; and a "3" signifies that the biocide or its degradation byproducts are strictly governed by regulations with regard to its presence in water and regulatory requirements (i.e.,

registration) are necessary for use, transport, or storage. Dashes indicate that the available information is insufficient to characterize the biocide. The regulatory concerns for the biocides are further discussed in Section 4.8.

Table 4-7. Environmental Concerns on Biocide Use.

Biocides	Environmental Concerns		
	Toxic Byproduct Formation	**Recalcitrant**	**Regulatory Concerns**
Metals			
Copper (ionic or salts)	1	2	3
Silver (ionic or salts)	1	2	3
Oxidizing			
Compounds containing halogen			
Chlorine	3	2	3
Bromine	3	-	1
Iodine	3	-	1
Chlorine Dioxide	2	2	2
Sodium chlorite	3	2	3
Chloramines	3	2	-
Compounds not containing halogen			
Hydrogen peroxide	2	1	2
Ozone	2	1	3
Potassium Permanganate	1	2	2
Non-Oxidizing			
Acids			
Peraclean® (peracetic acid)	-	-	2
Aldehydes			
Formaldehyde	1	1	3
Glutaraldehyde	1	1	1
Amines and halogenated amides			
Dibromonitrilopropionamide (DBNPA)	-	1	1
Mexel® 432 (fatty amines)	1	1	1
Heterocyclic ketones			
Polyhexamethylene biguanide (PHMB)	-	-	2
Sea-Nine® (isothiazolone)	1-2	1	-
Others			
2-thiocyanomethylthio benzothiazole (TCMTB)	-	-	1-2
Benzalkonium chloride	-	-	1
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	-	2	2
Chlorothalonil	-	1	2

- = information not available in the reviewed literature

Table 4-7. Environmental Concerns on Biocide Use (cont'd).

Biocides	Environmental Concerns		
	Toxic Byproduct Formation	Recalcitrant	Regulatory Concerns
Dichlofluanid	-	1	1
Dowicil® 75 (N-(3-chloroallyl)hexaminium chloride)	3	1	2
Ethylene oxide	2	1	3
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)	-	-	2
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	-	3	1
Phenol	1	1	3
SeaKleen® (Vitamin K)	1	1	1
Triclosan	1	1	1-2
Zinc pyrithione	-	1	-
Zineb (thiocarbamate)	-	-	1

- = information not available in the reviewed literature

The formation of toxic byproducts depends on the environmental conditions of the water. For example, naturally occurring constituents such as bromide in sea water may readily react with chlorine to change the disinfection effect relative to those in freshwater (Oemcke, 1999). In addition, chlorine and bromine react with naturally occurring organic matter in the water to produce trihalomethanes (THM) such as chloroform. THMs are regulated under the United States' Clean Water Act; thus, consideration of environmental acceptability is required before these particular biocides could be approved for ballast water treatment. Ozone is known to react with the bromide ion present in sea water to form the byproducts bromoform and the bromate ion (Simpson *et. Al.*, 1993; Oemcke, 1999; Cooper *et. Al.*, 2002). Bhaskar and Pederson (2003) found that reactions between some biocides and seawater could produce harmful byproducts that have not been extensively studied.

Toxic byproducts are formed from the application of chlorine, bromine, sodium chlorite, chloramines, and Dowicil® 75. Depending on existing environmental conditions, toxic byproducts may be associated with chlorine dioxide, ethylene oxide, ozone, hydrogen peroxide, and Sea-Nine®. Toxic byproducts are not associated with copper, silver, potassium permanganate, formaldehyde, glutaraldehyde, Mexel® 432, phenol, SeaKleen®, and triclosan. Information for the other 13 biocides was not available in the reviewed literature.

As presented in Table 4-7, compounds that are not recalcitrant and are described in the literature as disappearing quickly or have half-lives less than two days include hydrogen peroxide, ozone, formaldehyde, glutaraldehyde, Mexel® 432, DBNPA, Sea-Nine®, chlorothalonil, dichlofluanid, Dowicil® 75, ethylene oxide, phenol, zinc pyrithione, SeaKleen®, and triclosan. Cooper *et. Al.*, (2002) found that ozone catalytically decomposes in sea water with a half-life of five seconds and reverts to oxygen (O_2). Compounds that are somewhat recalcitrant (taking more than two days but less than one week to degrade) include copper, silver, chlorine, chlorine dioxide,

sodium chlorite, chloramines, potassium permanganate, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride). Only Irgarol® 1051 was identified as highly recalcitrant, taking over one week to fully degrade. Information for the other eight compounds was not obtained from the reviewed literature.

Regulatory concerns (Table 4-7) are a major issue for copper, silver, chlorine, sodium chlorite, ozone, formaldehyde, ethylene oxide, and phenol. Some regulatory consideration must be given to the following biocides: chlorine dioxide, hydrogen peroxide, potassium permanganate, Peraclean®, PHMB, TCMTB, chlorothalonil, Dowicil® 75, zinc pyrithione, cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride), and triclosan. Regulatory restrictions are not a concern for bromine, iodine, glutaraldehyde, Mexel® 432, DBNPA, benzalkonium chloride, dichlofluanid, Irgarol® 1051, SeaKleen®, and zineb.

4.5 Availability of the Biocide

To gather information on commercially available forms of biocides, vendors and manufacturers were contacted and marketing literature was reviewed. Biocide vendors were found to offer several forms of product material depending on the types of biocide sold. The information obtained indicated that some biocides could be shipped with few restrictions while others were more extensively regulated. Still others are too unstable to be shipped and would require on-site generation (i.e., on the vessel during transit). Ozone, monochloramine, and chlorine dioxide are examples of biocides that must be generated on-site. Table 4-8 summarizes commercially-available biocides and the forms in which they are available. This table also indicates whether a biocide is capable of being generated on-site.

Several forms of free chlorine including molecular chlorine (chlorine gas), liquid sodium hypochlorite, and granulated calcium hypochlorite are available. Biocides generally may be purchased in full strength or mixed solutions, solid, powdered, or crystalline form.

Table 4-8. Forms of Commercially Available Biocides.

Biocides	Commercially-Available Forms			
	Solid	**Liquid**	**Gas**	**On-Site Generation**
Metals				
Copper ions	X			X
Copper sulfate	X	X		
Silver ions		X		X
Oxidizing				
Halogen-containing compounds				
Chlorine			X	
Bromine		X	X	
Iodine	X	X		

X = the biocide is commercially available in that form or the biocide requires on-site generation
[1] dry media capable of releasing ClO_2 when activated with moisture or humidity.
[2] stabilized chlorine dioxide solutions or buffered sodium chlorite that must be reacted with an acid.
[3] unable to transport in this form due to instability.

Table 4-8. Forms of Commercially Available Biocides (cont'd).

Biocides	Commercially-Available Forms			
	Solid	**Liquid**	**Gas**	**On-Site Generation**
Chlorine Dioxide	X[1]	X[2]	X[3]	X
Sodium chlorite	X	X		
Chloramines	X			X
Non-halogen containing compounds				
Hydrogen peroxide	X	X		
Ozone	X	X	X[3]	X
Potassium Permanganate	X	X		
Non-Oxidizing				
Acids				
Peraclean® (peracetic acid)		X		
Aldehydes				
Formaldehyde		X	X	
Glutaraldehyde		X		
Amines and halogenated amides				
Mexel® 432 (fatty amines)		X		
Dibromonitrilopropionamide (DBNPA)	X	X		
Heterocyclic ketones				
Polyhexamethylene biguanide (PHMB)	X	X		
Sea-Nine® (isothiazolone)		X		
Others				
2-thiocyanomethylthio benzothiazole (TCMTB)		X		
Benzalkonium chloride	X	X		
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	X	X		
Chlorothalonil	X			
Dichlofluanid		X		
Dowicil® 75 (N-(3-chloroallyl)hexaminium chloride)		X		
Others				
Ethylene oxide			X	
Grotan® (Hexahydro-1,3,5-tris(hydroxyethyl)-s-triazine)		X		

X = the biocide is commercially available in that form or the biocide requires on-site generation

[1] dry media capable of releasing ClO_2 when activated with moisture or humidity.

[2] stabilized chlorine dioxide solutions or buffered sodium chlorite that must be reacted with an acid.

[3] unable to transport in this form due to instability.

Table 4-8. Forms of Commercially Available Biocides (cont'd).

Biocides	Commercially-Available Forms			
	Solid	Liquid	Gas	On-Site Generation
Irgarol® 1051 (2-methylthio-4-tert-butylamino-6-cyclo-propylamino-s-triazine)	X			
Phenol	X	X		
SeaKleen® (Vitamin K)	X			
Triclosan	X	X		
Zinc pyrithione	X			
Zineb (thiocarbamate)	X			

X = the biocide is commercially available in that form or the biocide requires on-site generation
[1] dry media capable of releasing ClO_2 when activated with moisture or humidity.
[2] stabilized chlorine dioxide solutions or buffered sodium chlorite that must be reacted with an acid.
3 unable to transport in this form due to instability.

4.6 Shipboard Considerations

The application of a biocide on board a ship may be constrained by several factors, including the size of the treatment system in relation to the size of the ship, the biocide's concentration, storage requirements, how the biocide is generated (if shipboard), biocide compatibility with the structural material of the ship, and the unit cost of application. A variety of approaches may be used to introduce biocides to ballast water depending on the physical and chemical properties of the biocide. For example, a liquid or aqueous biocidal solution could be administered by metered injection into ballast fill lines to ensure adequate mixing and proper application rate. Alternatively, solids (sparingly soluble or slow dissolution rate) or liquid chemical dosing packets can be added directly into the tanks. The chemical injection equipment is relatively inexpensive and requires few ship resources in terms of space and power. Further consideration for shipboard application can be found in Section 4.7. Table 4-9 provides an analysis of the biocides in terms of shipboard storage, compatibility, and generation.

The safe storage of sufficient quantities of a biocide is one of the major considerations in considering a shipboard treatment. For example, bromine has several safety-related concerns, including a requirement to keep it as cool as possible. In addition, the corrosive and poisonous nature of bromine demands that it be stowed clear of living quarters and separated from flammable solids, oxidizers, and radioactive materials. Hydrogen peroxide is another biocide with storage concerns, including its sensitivity to heat and light, both of which can lead to a reduced lifetime in the storage tanks. In the United States, the Department of Transportation regulates the storage and transportation of hazardous materials aboard vessels. The table of hazardous materials in 49 CFR 172.101 was used in rating shipboard storage requirements (DOT, 2002). The biocides rated "3" in Table 4-9 require storage away from living quarters, are extremely reactive with other materials, and can be highly flammable or poisonous to humans. A "2" was given to biocides that require certain conditions to maintain their shelf life but generally have moderate storage requirements. A "1" was assigned to biocides that had minimal or no storage concerns related to safety.

A biocide management system will generally be easier to install in new ships than retrofitting already existing vessels. Table 4-9 also presents rankings for the difficulty of installing a biocide management system on a vessel. This rating was based primarily on storage requirements, compatibility with the vessel's structural material, and safety considerations. A ranking of "1" in Table 4-9 indicates that the biocide management system is easily installed; a "2" signifies that shipboard installation may require additional storage and conveyance requirements; and, a "3" indicates that shipboard installation may entail considerable extra power requirements, size constraints, and safety considerations, and, therefore, would be relatively difficult to install.

The compatibility of the biocide with the ship's structural material proves important during storage and dosing but also while the biocide degrades within the ship's tanks. Corrosivity and reactivity were considered when rating a biocide's vessel compatibility in Table 4-9. Extremely corrosive materials were rated with a "3"; a "2" indicates a slightly acidic or alkaline material or a low-medium range oxidizer that requires care when storing/handling and may be slightly corrosive; and, a "1" indicates a biocide that would have no known adverse effects on the structural integrity of a vessel. Over long periods of time, biocides rated with a "2" or "3" may adversely impact the vessel's integrity.

Some biocides like ozone and chlorine dioxide must be generated on board the vessel because they cannot be safely stored. A dry form precursor of chlorine dioxide has been developed and, when activated with water or moisture, chlorine dioxide is released (Raytec Corp, 2004). When biocides are generated on board a vessel, additional maintenance checks of the generation equipment will be required. These maintenance requirements will need to be conducted in accordance with vendors' recommendations. In Table 4-9, a "1" was assigned if the requirements surrounding on board generation are minimal. When the potential exists for noxious fumes to form or off-gassing to occur during biocide generation, a "2" was assigned to the shipboard generation category. A "3" indicates intensive maintenance requirements for the generation equipment and the creation of hazardous conditions when pre-cursors are mixed to form a biocide.

The costs related to using biocide treatment vary and depend on several factors. Some of these factors include: ballast water characteristics, biocide market demand, ballast capacity, trip length, and size of ballast tanks and pumps (Oemcke, 1999). Other cost factors are related to the biocide and include what form it is in (solid, liquid, or gas), concentration, decay rate, and availability. Additional costs can be incurred from operating the treatment system including fuel consumption and maintenance (Rigby and Taylor, 2001). In an Australian study, cost estimates to treat ballast water with biocides ranged from \$0.24 - \$40.00/m^3 (Rigby, 2001). The costs of a biocide can vary according to supplier, biocide form, and dosage. The biocide form and dosage can, in turn, vary with safety and storage requirements. In Table 4-9, a ranking of "1" indicates that the biocide is relatively inexpensive to use; a "2" indicates that the biocide and any technology associated with it can have a moderate maintenance and unit cost; and a "3" signifies that the biocide and technology can have a high maintenance and unit cost. Dashes indicate that the available information is insufficient to characterize the biocide.

Table 4-9. Biocide Use with Regard to Shipboard Application.

Biocide	Application				
	Storage	Ship Installation Difficulty	Vessel Compatibility	Shipboard Generation	Costs
Metals					
Copper (ionic or salts)	2	2	-	2	1
Silver (ionic or salts)	2	2	-	2	1
Oxidizing					
Halogen containing compounds					
Bromine	3	2-3	3	-	1
Chloramines	-	2	3	2	1
Chlorine	3	3	3	-	2
Chlorine Dioxide	2-3	2	3	3	2-3
Iodine	2	2	2	-	2
Sodium Chlorite	2	2	2	-	1
Non-halogen containing compounds					
Hydrogen Peroxide	2	2	3	-	2
Ozone	-	3	3	3	3
Potassium Permanganate	2	2	2	-	-
Non-oxidizing					
Acids					
Peraclean® (peracetic acid)	1	1	2	-	1
Aldehydes					
Formaldehyde	2	2	2	-	2
Glutaraldehyde	2	1	1	-	2
Amines and halogenated amides					
Dibromonitrilopropionamide (DBNPA)	-	-	-	-	-
Mexel® 432 (fatty amines)	1	1	1	-	-
Heterocyclic ketones					
Polyhexamethylene Biguanide (PHMB)	-	-	-	-	-
Sea-Nine® (isothiazolone)	2	2	-	-	-

Storage: 1 = minimal concerns in storing product; 2 = requirements for cool, dry, or ventilated area; 3 = "on deck only" requirements to keep clear of living quarters, poisonous, extremely reactive or flammable

Suitability for Installation: 1 = easily installed; 2 = additional biocide storage and conveyance requirements; 3 = power requirements, size constraints, and safety considerations may make installation difficult

Vessel Compatibility: 1 = no corrosive effects; 2 = low-medium level oxidizer or slightly corrosive; 3 = extremely corrosive

Generation: 1 = minimal requirements for generation; 2 = additional maintenance checks on equipment, potential for fumes or off-gassing; 3 = maintenance intensive, hazardous conditions while mixing

Cost Effectiveness: 1 = inexpensive; 2 = capital investment with moderate maintenance and biocide unit cost; 3 = high capital investment, high maintenance and biocide unit cost

Table 4-9. Biocide Use with Regard to Shipboard Application (cont'd).

Biocide	Application				
	Storage	Ship Installation Difficulty	Vessel Compatibility	Shipboard Generation	Costs
Others					
2-thiocyanomethylthio benzothiazole (TCMTB)	-	-	-	-	-
Benzalkonium Chloride	-	-	-	-	-
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)	-	-	-	-	2
Chlorothalonil	2	-	-	-	-
Dichlofluanid	1	-	-	-	-
Dowicil® 75	1	-	-	-	-
Ethylene Oxide	2	2-3	-	-	-
Grotan	2	2	-	-	-
Irgarol 1051	-	-	-	-	-
Phenol	2	2	-	-	2
SeaKleen® (Vitamin K)	1	1	1	-	1
Triclosan	-	-	-	-	-
Zinc pyrithione	-	-	-	-	-
Zineb (thiocarbamate)	-	-	-	-	-

Storage: 1 = minimal concerns in storing product; 2 = requirements for cool, dry, or ventilated area; 3 = "on deck only" requirements to keep clear of living quarters, poisonous, extremely reactive or flammable
Suitability for Installation: 1 = easily installed; 2 = additional biocide storage and conveyance requirements; 3 = power requirements, size constraints, and safety considerations may make installation difficult
Vessel Compatibility: 1 = no corrosive effects; 2 = low-medium level oxidizer or slightly corrosive; 3 = extremely corrosive
Generation: 1 = minimal requirements for generation; 2 = additional maintenance checks on equipment, potential for fumes or off-gassing; 3 = maintenance intensive, hazardous conditions while mixing
Cost Effectiveness: 1 = inexpensive; 2 = capital investment with moderate maintenance and biocide unit cost; 3 = high capital investment, high maintenance and biocide unit cost

4.7 Personnel Safety

Safety is a critical aspect of all vessel operations, particularly in terms of biocide usage. A ship must be recognized as an unstable platform subject to a variety of weather conditions and other operational problems. The safe storage and handling of chemicals under these conditions can be quite different from land-based operations (Rigby and Taylor, 2001). In addition to safety concerns, consideration must also be given to the level of training required to use the biocide. Table 4-10 presents the various safety concerns, according to Material Safety Data Sheets (MSDSs), of the investigated biocides. "X" indicates there is an associated safety concern for the category.

In determining a biocide's ease of use, any special training requirements must be considered as well as the level of difficulty expected in obtaining or generating the biocide. Generally, biocide

usage is not complex. Training for personnel would be required for compounds that require on board generation (e.g., chlorine dioxide). Based on the literature and information reviewed, no special training is required for the use of the following biocides: potassium permanganate, glutaraldehyde, Mexel® 432, and SeaKleen®. For compounds such as chlorine, bromine, chlorine dioxide, and ozone, some training is required. Training and usage information was not available in the reviewed literature for the other biocides.

Generally, personnel safety precautions are required when handling and storing any biocide, although no particular personnel safety concerns were described in the literature for silver ions, Irgarol® 1051, SeaKleen®, or zineb. The biocides with moderate safety concerns (i.e., inhalation or contact risks, but not both) in the literature include copper ions, chlorine dioxide, ozone, Peraclean®, DBPNA, Mexel® 432, PHMB, Grotan®, benzalkonium chloride, potassium permanganate, glutaraldehyde, Dowicil® 75, zinc pyrithione, cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride), and TCMTB. Those biocides with significant personnel safety concerns (i.e., any combination of two or more of the following dangers: flammability, inhalation, and contact) include bromine, chlorine, iodine, chloramines, hydrogen peroxide, sodium chlorite, formaldehyde, Sea-Nine®, dichlofluanid, chlorothalonil, ethylene oxide, and phenol.

Table 4-10. Safety Concerns of Biocides.

Biocide	Flammability	Inhalation	Contact	Other
Metal				
Copper Ions		X		Poison
Silver Ions				None Known
Oxidizing				
Halogen containing compounds				
Bromine		X	X	Poison
Chloramines		X	X	
Chlorine		X	X	Poison
Chlorine Dioxide		X		
Iodine		X	X	Strong Oxidizer
Sodium Chlorite		X	X	Strong Oxidizer
Non-halogen containing compounds				
Hydrogen Peroxide		X	X	Strong Oxidizer
Ozone		X		Strong Oxidizer
Potassium Permanganate		X		Strong Oxidizer
Non-oxidizing				

Table 4-10. Safety Concerns of Biocides (cont'd).

Biocide	Flammability	Inhalation	Contact	Other
Acids				
Peraclean® (peracetic acid)		X		
Aldehydes				
Formaldehyde	X	X	X	
Glutaraldehyde		X		
Amines and halogenated amides				
DBNPA			X	Strong Oxidizer
Mexel 432		X		
Heterocyclic ketones				
Polyhexamethylene Biguanide (PHMB)			X	
Sea-Nine® (Kathon® 5287)		X	X	
Others				
Benzalkonium Chloride		X		
Cationic surfactants (example: C_{16}-alkyltrimethylammonium chloride)			X	
Chlorothalonil		X	X	
Dichlofluanid		X	X	
Dowicil® 75			X	
Ethylene Oxide	X	X	X	
Grotan®			X	
Irgarol® 1051				None Known
Phenol	X	X	X	Poison
SeaKleen® (Vitamin K)				None Known
TCMTB			X	
Zinc pyrithione		X		
Zineb (thiocarbamate)				None Known

4.8 Laws and Regulations Governing the Use of Biocides

Biocides that are intended for use inside the ballast tank or on the outside of a vessel's hull (i.e., anti-fouling agents) are nationally and internationally regulated by a number of statutes, conventions, and treaties (Table 4-11). These laws and regulations apply to both the transport and handling of the material as well as their use and discharge into receiving waters. In the United States, pertinent regulations aim to protect the health and safety of handlers as well as the integrity of the receiving ecosystem. Many of the laws reviewed are likely relevant to the use of biocides to treat ballast water because the biocide-treated ballast water will be discharged at the vessel's destination and the biocide or its byproducts (although used to protect the receiving waters) may be considered a pollutant under the these regulations. For example, the United States' Clean Water Act of 1972 makes it unlawful for a pollutant to be discharged from a point

source into navigable waters, unless a valid permit is obtained. Although ballast water (and the organisms contained therein) is not considered a pollutant by the EPA[2], the Clean Water Act may still apply to any biocidal chemical or other substance added to the ballast tank prior to discharge.

A second United States law that may apply to biocides used to treat ballast water is the Marine Protection, Research, and Sanctuaries Act [MPRSA]) of 1972. This act prohibits any person, without a permit, from transporting from inside or outside the U.S. any material for the purpose of dumping (e.g., disposal versus discharge) it into ocean waters. While discharge of ballast water is not generally considered disposal (dumping), the applicability of this statute to biocides and byproducts used in the treatment of ballast water should be clarified.

A third United States law that may apply to the discharge of biocide-treated water is the Endangered Species Act (ESA) of 1973, which prohibits any action that can adversely affect an endangered or threatened species or its habitat. In compliance with the ESA, the U.S. Environmental Protection Agency (EPA) must ensure that use of the pesticides it registers will not harm endangered or threatened species. It is not clear how biocides not defined as pesticides would be regulated under this statute.

U.S. statutes that apply to the handling and use of the biocide itself include the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947. This act governs the sale, distribution, and use of pesticides through a licensing system. Under FIFRA, all pesticides used in the United States must have an EPA registration, which ensures that pesticides will be properly labeled and will not cause unreasonable harm to the environment. In addition, all users must complete an exam certifying them as applicators of pesticides. It is not clear to what extent biocides are termed or equated to pesticides, thus any biocide that is defined as pesticide probably would be regulated under FIFRA. Application of FIFRA to those biocides that are not defined as pesticides must be evaluated. A U.S. Army Corps of Engineers technical paper (1994) reported that "aquatic biocide use inconsistent with label instructions may result in enforcement action by EPA under FIFRA or by states having pesticide use enforcement primacy under FIFRA." This conclusion is based on the fact that the existing toxicity data for many biocides indicate that use at recommended concentrations will not comply with State water quality standards.

[2] In September 2003, the EPA denied a petition filed by the Pacific Environmental Advocacy Center, a coalition of environmental groups and fishermen, that sought to have the EPA revoke a section of the Clean Water Act. The section in question specifically exempts the following discharges from needing a National Pollutant Discharge Elimination System (NPDES) permit: "any discharge of sewage from vessels, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes, or *any other discharge incidental to the normal operation of a vessel*." The EPA denied the petition, deciding that ballast water will not be considered a pollutant under the Clean Water Act.

Table 4-11. National and International Regulations, Statutes, Conventions, and Treaties.

Regulation/Statute/Convention (Year Enacted)	Country(ies)/ Region(s)	Brief Description
Clean Water Act (1972)	United States of America	Makes it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit is obtained under CWA provisions
Ocean Dumping Act (MPRSA) (1972)	United States of America	Prohibits, without a permit, transporting from the U.S. or from a location outside the U.S. any material for the purpose of dumping it into ocean waters
Occupational Safety and Health Act (1970)	United States of America	Requires employers to provide their workers with a place of employment free from recognized hazards to safety and health.
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (1947)	United States of America	Governs the sale, distribution, and use of pesticides generally through a licensing system.
Endangered Species Act (ESA) (1973)	United States of America	Prohibits any action that can adversely affect an endangered or threatened species or its habitat. In compliance with ESA, EPA must ensure that use of the pesticides it registers will not harm these species.
Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) (1976)	Mediterranean Sea	To prevent, abate, and combat pollution of the Mediterranean Sea area caused by discharges from ships and to ensure the implementation in that area of the rules relating to this type of pollution.
Protocol Concerning Mediterranean Specially Protected Areas (1982)	Mediterranean Sea	To take the measures required against the dumping or discharge of wastes and other substances that are likely, directly or indirectly, to impair the integrity of the specially protected area.
Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea (1975)	Mediterranean Sea	To take all appropriate measures to prevent and abate pollution of the Mediterranean Sea area caused by dumping from ships and aircraft.
Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) (1974)	Baltic area	To abate pollution of the Baltic Sea area caused by discharges through rivers, estuaries, outfalls and pipelines, dumping and normal operations of vessels, as well as through airborne pollutants.
Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention) (1997)	Northeast Atlantic nations	To prevent and eliminate pollution and protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve maritime ecosystems.
Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (1981)	West coastal African nations	To prevent, reduce, combat and control pollution in the Convention area caused by normal or accidental discharges from ships, and to ensure the effective application in the Convention area of the internationally recognized rules and standards relating to the control of this type of pollution.
East Asian Seas Action Plan (1981)	East Asian nations	To provide for the protection and sustainable development of the marine environment and the coastal areas for the promotion of the health and well-being of present and future generations.
Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1981)	Caribbean nations	To prevent, reduce, and control the following types of pollution: pollution from ships, pollution caused by dumping, pollution from sea-bed activities, airborne pollution, and pollution from land-based sources and activities.

Table 4-11. National and International Regulations, Statutes, Conventions, and Treaties (cont'd).

Regulation/Statute/Convention (Year Enacted)	Country(ies)/ Region(s)	Brief Description
Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region (1985)	East coastal African nations	To prevent, reduce and combat pollution of the Convention area caused by discharges from ships and to ensure the effective implementation of the applicable international rules and standards established by, or within the framework of, the competent international organization.
Northwest Pacific Action Plan (1994)	Northwestern Pacific nations	To ensure the wise use, development, and management of the coastal and marine environment so as to obtain long-term benefits for humans, while protecting human health, ecological integrity, and the region's sustainability.
Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (1981)	Nations of the western coasts of Central and South America	To prevent and control pollution of the marine environment including, (a) Release of toxic, harmful or noxious substances, especially those which are persistent: (i) From land-based sources; (ii) From or through the atmosphere; and (iii) By dumping; and (b) Pollution from vessels, in particular, measures for preventing intentional discharges
Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (1982)	Nations bordering the Red Sea or the Gulf of Aden	To prevent, abate and combat pollution in the area caused by intentional or accidental discharges from ships and to ensure effective compliance in the area with generally recognized international rules relating to the control of this type of pollution.
Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region (1982)	Nations of the South Pacific	To prevent, reduce, and control pollution from any source and to ensure sound environmental management, using the best practicable means and in accordance with capabilities. All appropriate measures shall be taken to prevent, reduce, and control pollution in the Convention Area by dumping.
South Asian Seas Action Plan (1995)	South Asian nations	To provide for the protection and sustainable development of the marine environment and the coastal areas for the promotion of the health and well-being of present and future generations.
Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (1976)	Nations surrounding Persian Gulf	To prevent, abate and combat pollution of the marine environment
Northeast Pacific Action Plan (2001)	Northeastern Pacific nations	To control, halt, and prevent any further degradation and deterioration of the coastal and marine environment and its resources and to ensure long-term sustainability.
Biocidal Products Directive 98/8/EC (Anti-fouling) (1993)	European Union	To harmonize the European market for biocidal products and their active substances and to provide a high level of protection for humans, animals, and the environment. The removal of barriers to trade will not be at the expense of lowering health and environmental protection.
IMO Anti-Fouling Systems Convention (2001)	IMO	Prohibits the use of harmful organotins in anti-fouling paints used on ships and will establish a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems
Anti-Fouling Legislation	Canada	All anti-foulings applied in Canada require registration with the government. Application of TBT anti-foulings is completely banned from 10/31/02 forward. All registered anti-foulings containing copper must have a release rate of less than 40 µg copper/cm^2/day.
Anti-Fouling Legislation (Organotin Antifouling Paint Control [33 U.S.C. 2401]) (1988)	United States of America	All anti-foulings applied in the U.S. require registration both federally (EPA) and with each state's Environmental Agency. TBT anti-foulings must not be applied to vessels under 25m in length (aluminum hulls exempted) and must have a TBT release rate of less than 4 ug TBT/cm^2 paint/day.
Anti-Fouling Legislation	Malta	All anti-foulings applied in Malta require registration. Application of TBT anti-foulings is banned on vessels under 25 meters in length.

Table 4-11. National and International Regulations, Statutes, Conventions, and Treaties (cont'd).

Regulation/Statute/Convention (Year Enacted)	Country(ies)/ Region(s)	Brief Description
Anti-Fouling Legislation	Sweden	Registrations for TBT anti-foulings have been canceled. Anti-fouling products containing copper banned for use on pleasure craft in the Baltic Sea. Products used on pleasure craft on the West Coast of Sweden is subject to copper leaching rate restrictions. Must show leaching rate < 200 ug copper/cm^2 in first 14 days and < 350 ug copper/cm^2 in first 30 days after immersion.
Anti-Fouling Legislation	United Kingdom	Registrations for TBT anti-foulings have been canceled. Registrations for use of organic biocides Irgarol 1051 and diuron in anti-fouling of pleasure craft have been canceled.
Anti-Fouling Legislation	Netherlands	Use of products containing copper are banned for pleasure craft operating in fresh water areas.
Anti-Fouling Legislation	Japan	Anti-fouling paints containing biocides applied in Japan do not require registration but must contain biocides approved by Government/Industry committees, e.g., JSA/MITI. Application of TBT anti-foulings in Japan has been totally forbidden since 1992.
Anti-Fouling Legislation	Hong Kong	All anti-fouling paints applied in Hong Kong require registration. All TBT products must have a biocide release rate of less than 4ug TBT/cm^2/day.
Anti-Fouling Legislation	Korea	Use of TBT on small ships is forbidden. Korean government is considering the introduction of a registration scheme for anti-foulings.
Anti-Fouling Legislation	Australia	All anti-foulings applied in Australia require registration with NRA (National Registration Authority) under pesticide laws. Registration of TBT anti-foulings forbidden from June 2003 forward.
Anti-Fouling Legislation	New Zealand	All anti-foulings applied must be registered. Application of TBT anti-foulings is forbidden.
Marketing and Use Directive 76/769/EEC (1976)	European Union	To protect the general public and the environment from certain dangerous substances and preparations and to ensure the proper functioning of the common market by approximating the laws of the Member States relating to the marketing and use of these substances.
Council Directive 1967/548/EEC (1967)	European Union	To approximate the national measures on the classification, packaging and labeling of dangerous substances in order to protect public health and the environment and ensure the free movement of such products.
Dangerous Preparation Directive 88/379/EEC (1967)	European Union	The DPD's prime aim is to identify and control dangerous finished product formulations.
New Substances Directive 92/32/EEC (1981)	European Union	A new substance is one which was first marketed after September 18, 1981. Manufacturers are required to (1) provide information on themselves as manufacturers, and on the identity of the substance they are producing; (2) carry out tests to identify the properties of the substance, as well as gather data on toxicology and ecotoxicology; (3) provide information on the processes used in the production of the new substance, as well as the proposed use(s); (4) propose guidelines for classification and labeling, as well as safety precautions; and (5) draft a risk assessment.
Existing Substances Regulation 793/93/EEC (1981)	European Union	An existing substance is defined as one listed in the European Inventory of Existing Commercial Chemical Substances before September 18, 1981. Regulation 793/93/EEC set up a program designed to identify and control the risks posed by EINECS substances of high production volumes.
Canada Shipping Act – Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	Canada	Provides for the Governor in Council to make regulations with respect to prohibiting the discharge from ships of pollutants and prescribing substances and classes of substances that are pollutants. Under subsection 656(2) a pollutant can only be discharged from a ship in accordance with a permit.

Table 4-11. National and International Regulations, Statutes, Conventions, and Treaties (cont'd).

Regulation/Statute/Convention (Year Enacted)	Country(ies)/ Region(s)	Brief Description
Canada Pest Control Products Act	Canada	Regulates products used for the control of pests and the organic functions of plants and animals. Export of pesticide products from Canada and movement of products between provinces is prohibited unless the manufacturing establishment is licensed and complies with prescribed conditions. There is also a general prohibition against manufacture, storage, display, distribution or use of pest control products under unsafe conditions.
The Merchant Shipping Regulations (Control of Pollution by Noxious Liquid Substances in Bulk), Schedule I (1987)	Great Britain	Glutaraldehyde is a Class D substance. Discharge into the sea is prohibited and discharge of residual mixtures is subject to restrictions.

The Occupational Safety and Health Act (OSHA) of 1970, which aims to protect workers from harm when handling potentially dangerous substances, has relevance to the use of biocides for ballast water treatment. According to a list provided with the law's text, the following biocides identified for this investigation are regulated under OSHA: ozone, chlorine dioxide, chlorine, glutaraldehyde, ethylene oxide, formaldehyde, hydrogen peroxide, and phenol.

The international community has adopted a suite of protective treaties designed to prevent marine pollution. Virtually every nation with marine coastline has signed one of fourteen conventions that have been designed to protect coastal and ocean waters in the past few decades. All of these conventions cover very similar issues that would be of concern to a country economically and culturally dependent on its coastal waters. For example, the Nairobi Convention of 1985 (of which the signatories include Somalia, Kenya, Tanzania, Mozambique, South Africa, Comoros, Seychelles, Madagascar, La Réunion, and Mauritius) requires, among other things, that "the Contracting Parties take all appropriate measures to prevent, reduce, and combat pollution of the Convention area caused by discharges from ships and… to ensure the effective implementation of the applicable international rules and standards established by…the competent international organization." Another regional convention is the Paris Convention of 1992, which includes as contracting parties the nations bordering the Northeast Atlantic Ocean. The Paris Convention (OSPAR) aims to "to take all possible steps to prevent and eliminate pollution and the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve maritime ecosystems…". The remaining twelve conventions cover the Mediterranean Sea, the Baltic Sea, West and Central Africa, East Asian seas, the Caribbean nations, the Northwest Pacific, the Northeast Pacific, the Southeast Pacific, the Red Sea and the Gulf of Aden, the South Pacific, South Asian seas, and the Persian Gulf region. All of these conventions have the same goal: to protect the coastal and marine environments from pollution in general and, often, specifically from vessel discharge.

In response to international concern about aquatic nuisance species, the International Maritime Organization (IMO) Assembly adopted the International Convention for the Control and Management of Ships Ballast Water & Sediments in February 2004. The Convention will enter into force one year after it is ratified by 30 states, which represent 35 percent of world merchant shipping tonnage. The parties to the convention will agree to "prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments." (GloBallast, 2004). In addition, parties will agree to provide reception facilities at those ports where the cleaning or repair of ballast tanks will occur, promote further research on ballast water management, and ensure that vessels in their port are properly certified and inspected. The convention also includes specific ballast water exchange standards (which mandate that a vessel must exchange at least 95 percent of its ballast tank volume) and performance standards (which instruct the amount of organisms that may be discharged per unit of tank volume).

Many nations have adopted separate legislation designed to cover biocides that are applied to the outside of a vessel's hull. These biocides, often called antifouling agents, help prevent barnacles, algae, and other organisms from growing on the submerged surfaces of a vessel. These regulations recognize that potentially dangerous non-indigenous species can be introduced in

ways other than through the discharge of ballast water. The nations that have enacted laws prohibiting or severely restricting the use of anti-fouling agents include, among others, the United States, Canada, Sweden, the United Kingdom, the Netherlands, Japan, Korea, Australia, and New Zealand. Most of the anti-fouling legislation from these countries specifically target tributyltins (also known as TBTs), slow-degrading, highly toxic compounds that have proven negative impacts on native species and human health. TBTs are often added to hull paint so that vessel owners can acquire some measure of structural protection when repainting their vessel. Most of the aforementioned nations have completely banned any further application of TBTs (any vessel with TBT already applied must be registered) while just a few require that the vessel owner demonstrate a slow leaching rate. Passing these antifouling laws show the true concern most nations have for their marine ecosystems and the health of their human citizens.

5.0 Application of Biocides to Ballast Water Treatment

Most of the biocides identified and reviewed in this investigation were developed for drinking water or sewage applications, and not for saltwater applications (see Sections 2 and 4). There are two major questions regarding their efficacy for treating ballast water. The first relates to the effectiveness against the range of organism types found in ballast water. The second is the ability to treat water with high salt or particulate and organic matter content.

Only a few of the biocides identified demonstrated fair to good biocidal activity against a broad spectrum of organisms (Table 4-2). These include chlorine, chlorine dioxide, hydrogen peroxide, glutaraldehyde, Peraclean®, SeaKleen®, phenol, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride). Therefore, for the purposes of this discussion, all these biocides are designated as Group A biocides and are further evaluated below (Section 5.1).

Several other biocides demonstrated fair to good biocidal activity, but only against a subset of the range of target organisms typical of ballast water. The lack of experimental or other evidence to support the ability of these biocides to kill or inactivate all types of organisms makes it difficult to judge their ability to effectively treat ballast water. It is recommended that additional information be obtained and reviewed before their potential application to ballast water is determined. These biocides include copper, bromine, iodine, sodium chlorite, chloramines, ozone, formaldehyde, Mexel® 432, DBNPA, PHMB, TCMTB, benzalkonium chloride, chlorothalonil, dichlofluanid, Dowicil® 75, ethylene oxide, Grotan®, Irgarol® 1051, zinc pyrithione, triclosan, and zineb. These biocides were retained for further evaluation for potential use in ballast water and are designated as Group B biocides (Section 5.2).

The information reviewed indicated that silver, Sea-Nine®, and potassium permanganate were not effective against viruses and bacteria. Because of these and other limitations, these biocides were not further evaluated in this report. It is recommended that additional information be obtained and reviewed before their potential application to ballast water is determined.

5.1 Group A Biocides—Biocides with Fair to Good Efficacy against a Broad Spectrum of Organisms

A closer examination of the Group A biocides with respect to certain evaluation criteria is provided in Table 5-1. All eight biocides in Group A are commercially available and, despite price variability according to supplier and biocide concentration and form, most of these biocides are not considered cost prohibitive.

All but two of these biocides, SeaKleen® and phenol, are used to disinfect water systems so their effectiveness on large volumes of water has been researched. Phenol is an antifouling agent used in paints applied to ship hulls and does not have the research supporting its application to treat large volumes of water, as the other biocides do. However, SeaKleen® and phenol still possess some of the qualities necessary for potential use in ballast water, such as having no toxic byproducts, no recalcitrance in the environment, and being relatively cost effective. As indicated in Table 5-1, none of the biocides in Group A are recalcitrant and, therefore, have relatively short degradation times. Toxic byproducts are not a major concern for glutaraldehyde, SeaKleen®, phenol, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride).

Under some environmental conditions, chlorine dioxide and hydrogen peroxide can form toxic byproducts. Chlorine can produce trihalomethanes and haloacetic acid as byproducts, both of which are toxic. The efficacy of chlorine dioxide does not vary with pH. However, glutaraldehyde, chlorine, and hydrogen peroxide can all be impacted by pH values. For example, glutaraldehyde becomes more effective as pH values increase. Adsorption to suspended solids and sediments is not a concern for chlorine dioxide, glutaraldehyde, SeaKleen®, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride). Neither regulatory nor significant safety concerns were identified for glutaraldehyde or SeaKleen®. Based on the literature and vendor information, shipboard application is not considered difficult for glutaraldehyde, Peraclean®, or SeaKleen®. Finally, the costs of maintenance, installation, and operation of the respective technologies are considered relatively low for Peraclean® or SeaKleen®. The other biocides in Table 5-1 have relatively moderate costs (i.e., not prohibitive) associated with them, except for chlorine dioxide. Based on this evaluation, chlorine dioxide, glutaraldehyde, SeaKleen®, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride) are identified as the leading potential agents for ballast water treatment in both marine and freshwater environments.

5.2 Group B Biocides—Biocides with Fair to Good Efficacy against a Narrow Spectrum of Organisms

Group B biocides show potential for treating ballast water, however, additional information is required to fully determine their applicability. These biocides include copper, bromine, iodine, sodium chlorite, chloramines, ozone, formaldehyde, ethylene oxide, and Dowacil® 75. It is recommended (see Section 6) that additional information be reviewed for these biocides to determine their potential for ballast water treatment.

Table 5-1. Evaluation of Group A and Group B Biocides.

Biocide	Effective against Broad Range of Organisms?*	pH Inhibition	Adsorp -tion	Toxic byproducts	Recalci-trance	Shipboard Application Difficult	Cost Prohibitive	Safety Concerns	Regulatory Concerns
Group A Biocides									
Chlorine	Yes	Yes	Yes	Yes	Some	Yes	Somewhat	Yes	Yes
Chlorine dioxide	Yes	No	No	Yes†	Some	Somewhat	Yes	Yes	Some
Hydrogen peroxide	Yes	Yes	Un-known	Yes†	No	Somewhat	Somewhat	Yes	Some
Glutaraldehyde	Yes	Yes	No	No	No	No	Somewhat	No	No
Peraclean®	Yes	Unknown	Yes	Unknown	Unknown	No	No	Yes	Some
Cationic surfactants	Yes	Unknown	No	Unknown	Some	Unknown	Somewhat	Yes	Some
SeaKleen®	Yes	Unknown	No	No	No	No	No	No	No
Phenol	Yes	Unknown	Yes	No	No	Somewhat	Somewhat	Yes	Yes
Group B Biocides									
Copper	Yes	Some	Yes	No	Some	Somewhat	No	Yes	Yes
Bromine	No	Yes	Yes	Yes	Unknown	Yes	No	Yes	No
Iodine	No	Unknown	Un-known	Yes	Unknown	Somewhat	Somewhat	Yes	No
Sodium chlorite	No	Unknown	Un-known	Yes	Some	Somewhat	No	Yes	Yes
Chloramines	No	No	Some	Yes	Some	Somewhat	No	Yes	Unknown
Ozone	No	No	Yes	Yes†	No	Yes	Yes	Yes	Yes
Formaldehyde	No	Some	Un-known	No	No	Somewhat	Somewhat	Yes	Yes
Ethylene oxide	No	No	No	Yes†	No	Yes	Unknown	Yes	Yes
Dowicil® 75	No	No	Yes	Yes	No	Unknown	Unknown	Yes	Some

* If the biocide was found to be effective against six or more of the nine target organisms, a "yes" was entered. If it was effective against fewer than six, a "no" was entered.

† Toxic byproducts may form depending on existing environmental conditions

A comparison of the nine biocides in Group B with respect to the evaluation criteria is provided in Table 5-1. Based on the data obtained and evaluated for these nine biocides, recalcitrance is an issue for copper, sodium chlorite, and chloramines. Formation of toxic byproducts can be an issue for bromine, iodine, sodium chlorite, chloramines, and Dowicil® 75. Adsorption to suspended solids or sediment is expected to occur for copper, bromine, chloramines, ozone, and Dowicil® 75. Some level of safety is expected to be a concern for all Group B biocides, while regulatory concerns exist for copper, sodium chlorite, ozone, formaldehyde, ethylene oxide, and Dowicil® 75. For example, the maintenance and power requirements of ozone generation equipment along with the corrosive character of ozone make shipboard application more difficult and questions arise on the suitability of ozone as a stand-alone biocide. Based on the information reviewed, the biocides in Group B do not appear to be strong candidates for the treatment of ballast water at this time.

6.0 Summary and Recommendations

The literature search conducted to obtain available information on various aspects of biocides with the potential for treating ballast water, including their biological treatment efficacy, environmental acceptability, shipboard practicality, and associated costs, identified 32 candidate biocides. The list included biocides that are commonly used in marine antifouling paints or are being evaluated for use as alternative antifouling agents. The information gathered from the literature search was reviewed and organized into a searchable relational database with the ability to generate one fact sheet for each biocide, summarizing the information gathered on the evaluation criteria. Information regarding international conventions and United States laws and regulations for the use of biocides indicate that registration requirements of biocides are uncertain and need clarification.

An assessment of the biocides against a set of evaluation criteria allowed a qualitative comparison of the identified biocides according to their potential usefulness for ballast water treatment. Based on the results of the comparison, biocides were either identified as potential candidates for application in ballast water and evaluated more closely, identified as chemicals requiring additional information for further evaluation, or identified as unlikely candidates for ballast water treatment.

The qualitative evaluation and comparison found the following biocides have potential for use in ballast water treatment in both marine and freshwater environments: chlorine dioxide, glutaraldehyde, SeaKleen®, and cationic surfactants (such as C_{16}-alkyltrimethylammonium chloride).

The qualitative evaluation and comparison also concluded the following:

- Copper, bromine, iodine, sodium chlorite, chloramines, ozone, formaldehyde, ethylene oxide, and Dowicil® 75 were determined to be poor potential biocides for ballast water;
- Mexel® 432, Dibromonitrilopropionamide (DBNPA), Polyhexamethylene biguanide (PHMB), 2-thiocyanomethylthio benzothiazole (TCMTB), benzalkonium chloride, chlorine, chlorothalonil, dichlofluanid, Grotan®, hydrogen peroxide, Peraclean®, zinc pyrithione, Irgarol® 1051, phenol, triclosan, and zineb were identified as biocides with demonstrated efficacy against some of the target organisms, but recommending these

biocides for ballast water treatment requires information regarding other evaluation criteria.

Although treatment of ballast water with biocides is an attractive option primarily because of the potential to eradicate a range of organisms and the potential ease of incorporation into both existing and future vessel designs, a number of questions regarding their use in ballast water remain unanswered. For example, factors such as the degradation rate of a particular biocide and the potential release of undesirable byproducts into the receiving waters must be known. In addition, many properties of seawater raise questions on whether biocides can be applied safely to the marine environment. Although biocides have been used extensively in certain industries for disinfection, the ballast tank and shipboard environments are different and distinct from these applications and may not be compatible with certain biocides. Thus, the overall effectiveness of many of the 32 identified biocides in treating ballast water is uncertain.

While the evaluation of biocides shows several that have potential application for ballast water treatment, much of the information obtained from the literature search was not specifically the result of scientific research targeted for ballast water treatment. Thus, the use of such information to determine ballast water applicability must be used cautiously. To address these information shortcomings, the following recommendations are made to support future decisions on the applicability of biocide use in ballast water:

- Continue research using environmentally friendly chemicals as biocides in the marine environment (similar to glutaraldehyde study by Lubomudrov *et al.,* 1997).
- Conduct laboratory bench-scale study aimed at the effects of marine environmental conditions, efficacy, and fate of potential biocides.
- Encourage pilot-scale design studies of ballast water biocidal treatment processes.

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Appendix A
Biocide Relational Database

A Microsoft® Access relational database was developed to capture biocide data from multiple literature and biocide vendor interview sources. All of the biocides that were evaluated for this report are included in this database, along with a few others that were not evaluated by the study due to regulatory constraints for application in marine waters. Tables were created to hold information related to the biocides' physiochemical properties, treatment efficacy against target organisms, environmental acceptability, shipboard use, and other vendor information. Laws and regulations that influence the biocides' use and the sources of information are also captured in tables. The entity relationship diagram (ERD) for the biocide database is shown in Figure A-1. It depicts the database tables, columns in each of the tables, primary keys, and the table relationships.

The database also contains forms, queries, and reports that allow for loading, editing, reviewing, and generating standard reports. Upon opening the biocide database, a form opens that requests the selection of a biocide from a pull-down menu to create that biocide's fact sheet. The selected biocide links related data from various tables, generates, and compiles the results of different sub reports into a single biocide fact sheet report. CAS numbers and chemical structure are presented for those biocides for which this information was available. The biocide fact sheets included in Appendix B were created by selecting the respective biocide name to generate the report. Each fact sheet was created as an Adobe Acrobat file for inclusion in this report.

Table A-1. Key Biocide Database Objects.

Object Type	Object Name	Object Description
Tables	Biocide	Biocide naming convention and description
	Biocide_Reg	Biocides impacted by various regulations specific to area
	Chosen_Biocide	Selection table to create fact sheet
	Citations	Data collected during literature search and vendor contact related to a biocide
	Manufacturers	Original tracking of vendor contact information; translated into citations table
	Regulations	Description of regulations
	Toxicity	Target organism and treatment data related to a citation
	Vendor Contacts	Contact information
Forms	Biocide	Allows editing and data loading of general biocide data
	Biocide_Reg	Allows entry of additional biocides affected by legislation
	Citations	Main form to enter citation and biocide information from that source
	Regulations	Entry of regulations and areas impacted
	Select Biocide to Create Fact Sheet	Look up available biocides from pull-down menu to select which fact sheet to generate
	Toxicity	Subform embedded in Citations Form; allows multiple target organisms and treatment doses for a single citation
	Vendor Contacts	Allows entry and editing of vendor contacts
Reports	Biocide Fact Sheet	Generates the formatted fact sheet for the selected biocide
	Biocides ERD	Entity Relationship Diagram for the database
	various subreports	Portions of the fact sheet

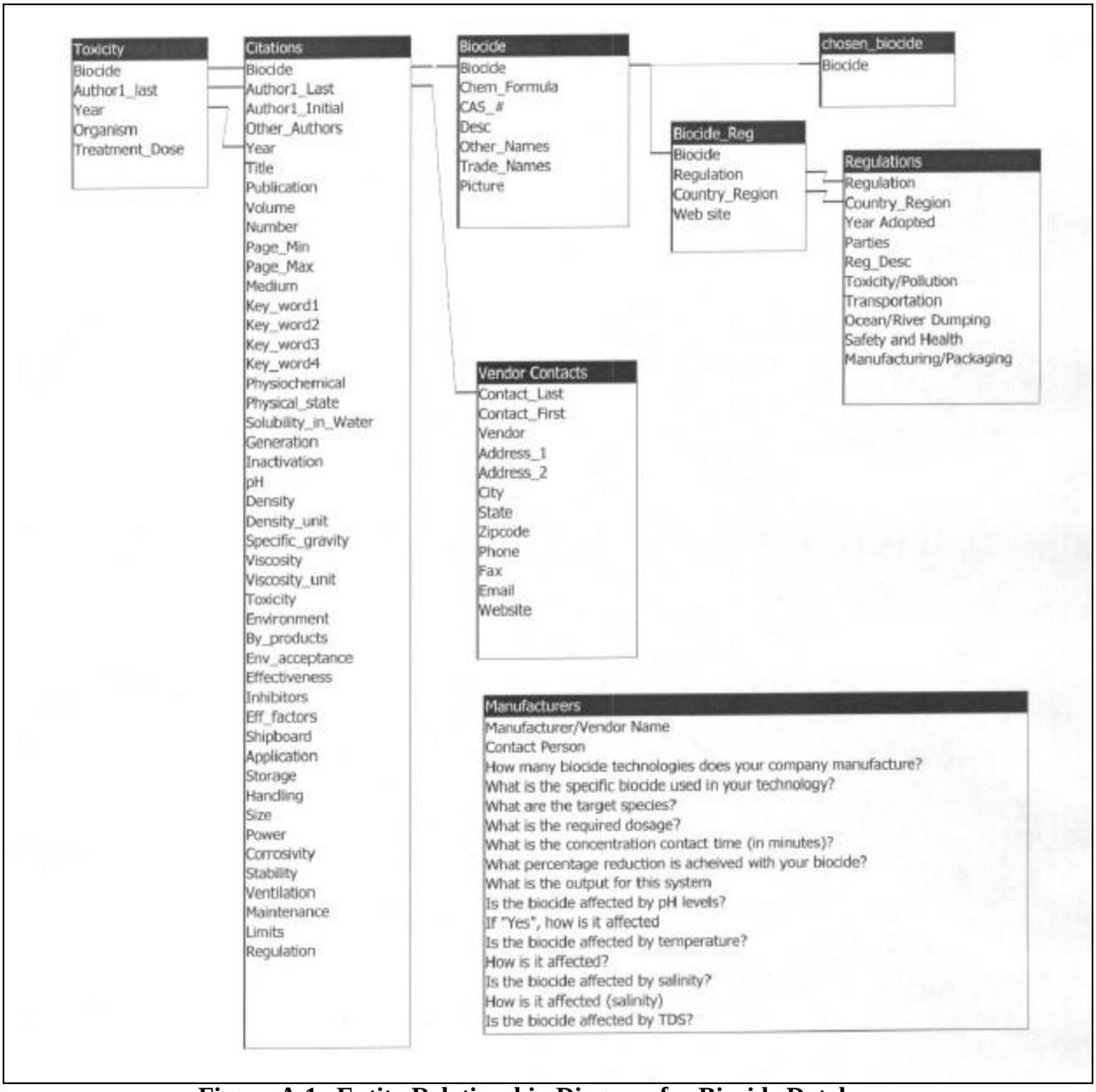
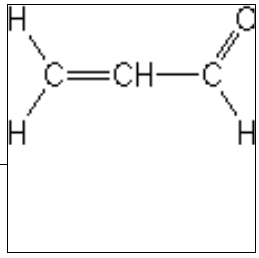


Figure A-1. Entity Relationship Diagram for Biocide Database.

Acrolein

C_3H_4O **CAS_#** 107-02-8



Clear or yellow liquid.

Other Names 2-Propen-1-one; 2-propenal; acquinite; Acraldehyde; Acrolein; Acrolein ; acrylaldehyde; Acrylic aldehyde; Allyl aldehyde; aqualine; biocide; crolean; ethylene aldehyde; magnacide; magnacide h; Magnacide H and B; prop-2-en-1-al; prop-2-enal; propenal; Propenaldehyde; propylene aldehyde; slimicide; trans-acrolein;

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Solubility in water	In water, 208 g/kg @ 20 deg C and In water, 2.12X10+5 mg/l @ 25 deg C	Hazardous Substances Data Bank 2004
Stability	very dependent on pH	Hazardous Substances Data Bank 2004
Inactivation	cytotoxic agent	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
amphibians	LC50: very highly toxic	PAN 2004
aquatic plants	EC50 : injury, mortality, population	PAN 2004
bacteria, algae, crustacea, and fish	Acute EC50 and LC50 values between 0.02 and 2.5 mg/liter, bacteria being the most sensitive species; Inhibition of cell multiplication starts at 0.44 mg/l in protozoa (Uronema parduczi Chatton-Lwoff); At 0.21 mg/l in bacteria (Pseudomonas putida); And at 0.04 mg/l in algae (Microcystis aeruginosa). The lowest observed avoidance concn in insects was above 0.1 mg/l for mayfly nymphs (Ephemerella walkeri); 0.1 mg/l for rainbow trout (Salmo gairdneri). The incipient Median Threshold Limit (TLm) for fathead minnow was 84 ug/l in a flow through bioassay; Inhibition of cell multiplication starts at ... 0.04 mg/l in algae (Microcystis aeruginosa).	Hazardous Substances Data Bank 2004
crustaceans	LC50: moderately toxic	PAN 2004
Daphnia magna	LC50 0.23 mg/l/24 hr; 0.083 mg/l/48 hr; No discernible effect conc= 0.034 mg/l. /Conditions of bioassay not specified	Hazardous Substances Data Bank 2004
fish	LC50: highly toxic	PAN 2004
fish	LD50 Carassius auratus (goldfish) <0.08 mg/l/24 hr; LC50 Lepomis macrochirus (bluegill sunfish) 79 ug/l/24 hr /Conditions of bioassay not specified;	Hazardous Substances Data Bank 2004
molluscs	LC50: highly toxic	PAN 2004
phytoplankton	EC50: injury, physiology, population	PAN 2004
Pimephales promelas (fathead minnow)	LC50 14.0 ug/1/96 hr (confidence limit not reliable), flow-through bioassay with measured concentrations, 17.4 deg C, dissolved oxygen 9.3 mg/l, hardness 45.2 mg/l calcium carbonate, alkalinity 42.9 mg/l calcium carbonate, and pH 7.4	Hazardous Substances Data Bank 2004
zooplankton	LC50: highly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	n natural unsterilized water was 29 hours compared with 43 hours in sterilized (thymol-treated) water. Half-life in water at pH 5, 150 hr; at pH 7, 120-180 hr; at pH 9, 5 to 40 hr.: not expected to adsorb to suspended solids and sediment based upon the estimated Koc of 3	Hazardous Substances Data Bank 2004
By Products	Hydrolysis is not expected to occur due to the lack of hydrolyzable functional groups; however primary loss process appears to be an initial hydration (and possibly some biotransformation) to beta-hydroxypropionaldehyde, which is then further biotransformed	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Material must be stowed "on deck only" on a cargo vessel and on a passenger vesel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overal vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded. The material must also be stored away from living quarters.	DOT 2002
Storage	Separate from oxidizing materials, peroxides, acids, and alkalies. Store in a cool, dry, well-ventilated location, protected from sunlight. Outside or detached storage is preferred. Inside storage should be in a standard flammable liquids storage warehouse, room, or cabinet. Do not store uninhibited acrolein	Hazardous Substances Data Bank 2004
Handling	Packing Group I: great degree of danger presented	DOT 2002
Handling	Toxic; may be fatal if inhaled, ingested or absorbed through skin. Inhalation or contact with some of these materials will irritate or burn skin and eyes	Hazardous Substances Data Bank 2004

Ventilation	Poison and flammable liquid: "on deck only" storage.	DOT 2002

Laws and Regulations

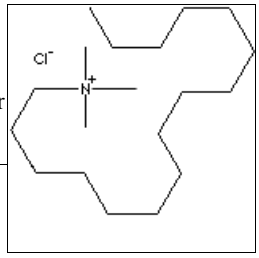
Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Hazardous Substances Data Bank, , . 2004.	Acrolein	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Alkyltrimethylammonium Chloride (ATMAC)

$CH_3(CH_2)_{15}N(Cl)(CH_3)_3$ **CAS_#** 112-02-7



C16 Alkyltrimethylammonium Chloride; cationic surfactant; quaternary ammonium compound; crystalline white powder or clear liquid used as microbiocide and frequently in hair conditioners and fabric softeners

Other Names 1-Hexadecanaminium; Cetyltrimethylammonium chloride; Cetyltrimethylammonium Chloride; 1-Hexadecanaminium, N,N,N-trimethyl-, chloride; Hexadecanaminium, N,N,N-trimethyl-, chloride; Cetyl Trimethyl Ammonium Chloride; Cetrimonium Chloride; Palmityltrimethylammonium chloride; Trimethylhexadecylammonium chloride

Trade_Names Adogen 444; Aliquat 6; Arquad 16/28; Arquad 16-29; Arquad 16-50; Barquat CT 29; Cation PB 40; Dehyquart A; Dodigen 1383; Genamin CTAC; Hansaquat 116; HTAC; Intexan CTC 29; Intexsan CTC 29; Intexsan CTC 50; Morpan CHA; NISSAN Cation PB 40; Surfroyal CTAC; Swanol CA 2350; Variquat E 228

Physiochemical Properties	Value or Comment	Citation
Physical State	colorless crystal (alkyltrimethylammonium chloride)	Hazardous Substances Data Bank 2004
pH	6-9	Hansa Chemie AG 2002
Density	1.07 at 20 deg C (alkyltrimethylammonium chloride)	Hazardous Substances Data Bank 2004
Specific gravity	0.971	Hansa Chemie AG 2002
Viscosity	9 mPa*s	Hansa Chemie AG 2002
Solubility in water	very soluble in water; log Kow is -2.17 (alkyltrmethylammoniumm chloride)	Hazardous Substances Data Bank 2004
Stability	avoid excessive heat	Hansa Chemie AG 2002

Target Organism	Treatment Dosage	Citation
Chlorella pyrenidosa	96-hour EC50 = 0.22-0.26 mg/L -- 95% confidence	Environmental and Health Assessment 2001
Crustacean Gammarus sp.	48-hour EC50 = 0.08-0.14 mg/L -- 95% confidence	Environmental and Health Assessment 2001
Dunaliella sp.	24-hour EC50 = 0.33-0.45 mg/L -- 95% confidence	Environmental and Health Assessment 2001
Fish	96-hour LC50 = 1-10 mg/L	Hansa Chemie AG 2002
Flatworm Dugesia sp.	48-hour EC50 = 0.58-0.80 mg/L -- 95% confidence	Environmental and Health Assessment 2001
Oligochaete Dero sp.	48-hour EC50 = 0.13-0.36 mg/L -- 95% confidence	Environmental and Health Assessment 2001

Environmental Acceptability

Environmental Acceptibility	if released to water, trimethylbenzylammonium chloride is expected to adsorb to suspended solids and sediments in water	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	cool, dry and well ventilated area	Hansa Chemie AG 2002
Handling	liquid irritating to skin and eyes; goggles or faceshield and rubber gloves required	Hazardous Substances Data Bank 2004
Ventilation	vapor irritating to eyes, nose, and throat; harmful if inhaled; vapor may explode if ignited	Hazardous Substances Data Bank 2004

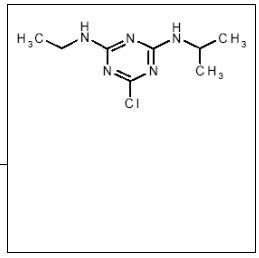
Laws and Regulations

Citations

Environmental and Health Assessment, , . 2001.	Environmental and Health Assessment of Substances in Household Detergents and Cosmetic Detergent Products	http://www.mst.dk/udgiv/publications/ : -
Hansa Chemie AG, , . 2002.	EC Safety Data Sheet	http://www.hansagroup.de/products/pdf/safetysheet/EN-2063.pdf : -
Hazardous Substances Data Bank, , . 2004.	TRIMETHYLHEXADECYLAMMONIUM CHLORIDE	National Library of Medicine Toxnet System : -

Atrazine

$C_8H_{14}ClN_5$ **CAS_#** 1912-24-9



Selective triazine herbicide. White crystalline solid.

Other Names 1,3,5-Triazine-2,4-diamine; 6-chloro-N-ethyl-N'-(1-methylethyl)-; 1-Chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine; 2-chloro-4-ethylamine-6-isopropylamino-S-triazine

Trade_Names Argezin, Atazinax, Atranex, Atrataf, Cyazine, Fenamin, Fenatrol, Candex, Weedex, Weedex A, Zeazine; Aatrex, Aktikon, Alazine, Atred, Atratol, Azinotox, Crisazina, Farmco Atrazine, G-30027, Gesaprim, Giffex 4L, Malermais, Primatol, Simazat, and Zeapos

Physiochemical Properties	Value or Comment	Citation
Solubility in water	33 mg/L in water at 22 deg C;	Hazardous Substances Data Bank 2004
Stability	rate of hydrolysis increases in either acidic or basic waters; resistant to hydrolysis at neutral pH.	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
amphibians	slightly toxic	PAN 2004
annelida	slightly toxic	PAN 2004
aquatic plants	highly toxic	PAN 2004
crustaceans	slightly toxic	PAN 2004
fish	slightly toxic	PAN 2004
molluscs	slightly toxic	PAN 2004
phytoplankton	highly toxic	PAN 2004
zooplankton	slightly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	halflife in anaerobic wetland was 224 days; at 25 deg C and pH of 4 half life was 244 days, but with 2% humic acid added the half life decreased to 1.73 days. In Great Lakes water, half lives ranged from 340 to 7,900 hours.; may adsorb to suspended solids and sediments; Koc ranges from 54 - 1164.	Hazardous Substances Data Bank 2004
By Products	hydroxyatrazine under anaerobic conditions with no carbon present	Hazardous Substances Data Bank 2004
Inhibitors	adsorption to suspended solids	Hazardous Substances Data Bank 2004
Effectiveness Factor	rate of hydrolysis increases with humic materials	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	shelf life of 3 years in unopened container. Slight sensitivity to light. Keep away from sources of heat, flame, spark.	Hazardous Substances Data Bank 2004
Handling	effects from exposure to substance may include skin irritation, shortness of breath. Rubber gloves and clothing made of cotton recommended. Highly flammable; easily ignited by flame, sparks, heat	Hazardous Substances Data Bank 2004

Laws and Regulations

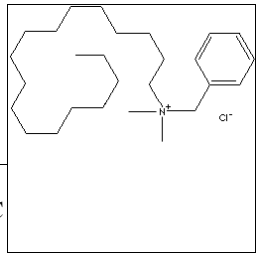
Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

Hazardous Substances Data Bank, , . 2004.	Atrazine	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -

Benzalkonium Chloride

$C_6H_5CH_2N(CH_3)_2RCl$ **CAS_#** 8001-54-5



white or light yellow/grey solid, or colorless aqueous solution used as a fungicide

Other Names alkyl benzyl dimethylammonium chloride; alkyl dimethyl benzylammonium chloride; alkyldimethyl(phenylmethyl) quaternary ammonium chlorides; quaternary ammonium compounds; BTC

Trade_Names Ammonyx; Arquad B 100; Barquat MB-50; Barquat MB-80; Bayclean; Benirol; Bionol; BTC 824; Bradophen; Catamin AB; Catamine AB; Cequartyl; Dimanin A; Disinall; Drapolene; Drapolex; Enuclene; Germicin; Germitol; Gesminol; Osvan; Paralkan; Parasterol; Reomergal CB; Rodalon; Zephiral; Zephiran; Zephiran Chloride

Physiochemical Properties	Value or Comment	Citation
pH	aqueous solution is slightly alkaline	Hazardous Substances Data Bank 2004
Specific gravity	0.988	Hazardous Substances Data Bank 2004
Solubility in water	very soluble	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
Carp	at oxygen saturation and 500 mg/L Damanin A, survival time was 15 minutes	Hazardous Substances Data Bank 2004
Guppy	at oxygen saturation and 500 mg/L Damanin A, survival time was 19 minutes	Hazardous Substances Data Bank 2004
Zebrafish	at oxygen saturation and 500 mg/L Damanin A, survival time was 14 minutes	Hazardous Substances Data Bank 2004

Environmental Acceptability

By Products	when heated to decomposition release very toxic fumes (hydrogen chloride and nitrogen oxides)	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	hygroscopic	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and	

	Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Beveridge, CM, Parr, A. C. S., Smith, M. J., Kerr, A., Cowling, M. J., and T. Hodgkiess. 1998.	The effect of benzalkonium chloride concentration on nine species of marine diatom	Environmental Pollution 103: 31-36
Hazardous Substances Data Bank, , . 2004.	Benzalkonium Chloride	National Library of Medicine Toxnet System : -

Bromine

Br_2 **CAS_#** 7726-95-6

Inorganic microbiocide. Available as a heavy, mobile, reddish-brown liquid.

Br — Br

Other Names Bromine; bromine gas

Trade_Names

Physiochemical Properties	Value or Comment	Citation
pH	6.5 -- 8.5	Lechter 2003
Inactivation	Bromine causes chemical action and cell/protein disruption	Lechter 2003
Inactivation	Production of halogens and injection of ionized air	Stewart 2003

Target Organism	Treatment Dosage	Citation
fish	EC50: behavior, mortality	PAN 2004
fish	LC50: highly toxic	PAN 2004
molluscs	EC50: mortality	PAN 2004
Waterborne microorganisms	Brominated resins: most waterborne microorganisms susceptible to doses up to 2 mg/L as Br2;	Lechter 2003
zooplankton	EC50: intoxication, mortality	PAN 2004
zooplankton	LC50: moderately toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Bromine at certain concentrations is toxic to certain fresh water and marine species. Acceptable levels for specific applications are not known.	Lechter 2003
Byproducts	Bromine: depending on the type of TTHM formation potential and pH, some brominated organics may form; reduced form of free bromine--bromide ion, Br-	Lechter 2003
Byproducts	Low levels of bromoform, but still below drinking water standards	Stewart 2003

Shipboard Use

Storage	Keep as cool as reasonably possible; stow clear of living quarters, separated from flammable solids, oxidizers, and radioactive materials.	DOT 2002
Handling	Packing Group I: great degree of danger presented	DOT 2002
Corrosivity	Corrosive Hazard Class of material	DOT 2002
Corrosivity	Bromine is naturally very corrosive but when it is diluted with this system (between 0.2 and 2 ppm), there is no risk of corrosivity.	Lechter 2003
Corrosivity	None	Stewart 2003
Power Requirements	Needs research	Lechter 2003
Power Requirements	< 1,500 KW	Stewart 2003
Ventilation	Corrosive and poison.	DOT 2002
Maintenance	Bromine cartridges need to be periodically changed.	Lechter 2003
Maintenance	Regular visual inspections and reading the maintenance log. Annual change out of Ionz cells and chlorine generators.	Stewart 2003

Laws and Regulations

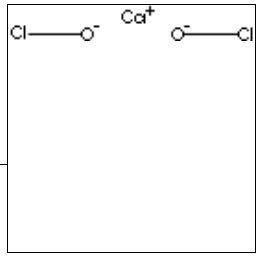
Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html

Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Lechter, J, . 2003.	Telephone conversation with Jerry Letcher, Sales Manager	Pentair Water Treatment/Plymouth Products : -
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Stewart, J, . 2003.	Telephone conversation with Jon Stewart, Vice President of Sales	Marine Environmental Partners : -

Calcium Hypochlorite



$CaCl_2O_2$ **CAS_#** 7778-54-3

White or yellowish powder with a strong chlorine odor; hygroscopic and corrosive; used for disinfection, color removal, iron and manganese removal, and taste and odor control.

Other Names B-Kpowder; bleaching powder; calcium hypochlorite; calcium oxychloride; hypochlorous acid; calcium salt; losatin; calcium hypochloride; chloride of lime; HTH

Trade_Names Hyporit; Induclor; Lo-bax; Mildew remover X-14; Perchloron; Pittchlor; Perchloron; Pittabs; Pittclor; Prestochlor; Pulsar; Repak; Stellos; Swim clear

Target Organism	Treatment Dosage	Citation
crustaceans	LC50: highly toxic	PAN 2004
fish	LC50: highly toxic	PAN 2004
molluscs	LC50: highly toxic	PAN 2004
phytoplankton	EC50: growth, mortality, population, physiology	PAN 2004
zooplankton	LC50: moderately toxic	PAN 2004

Environmental Acceptability

Shipboard Use

Storage	Material must be stowed "on deck only" on a cargo vessel and on a passenger vesel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overal vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded. Stow the material separated from liquid organic materials, powdered metals and their compounds, ammonia compounds, cyanides, and hydrogen peroxide. Shade from radiant heat and stow away from sources of heat.	DOT 2002
Handling	Packing Group II: medium degree of danger presented; oxidizing substance.	DOT 2002

Laws and Regulations

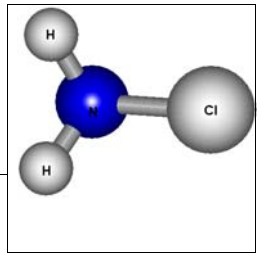
Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/http://www.myregs.com/dotrspa/

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Chloramine

ClH_2N **CAS_#** 10599-90-3



Chloramines are a mixture of monochloramine, dichloramine, or nitrogen trichloride. Monochloramine is a colorless and unstable liquid. It is the preferred chloramine species for disinfection because of taste and odor problems with the other species. The CAS number, formula, and molecule structure represent monochloramine.

Other Names Chloramide; chloramine/chlorine; chloroamide; chloroammonia; monochloramide; monochloroamine; monochloramine; monochloroammonia

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	Liquid	Health Canada 1996
Physical State	liquid	U.S. EPA 1994
pH	Optimum: 7.5-9.0 for monochloramine formation	Health Canada 1996
pH	At pH 8.5 the rate of its formation reaction reaches maximum. Monochloramine is the only chloramine formed when the pH of ammonia containing water is >8 and the molar ratio of hypochlorite to ammonia is <1.	U.S. EPA 1994
Solubility in water	Soluble	Health Canada 1996
Solubility in water	soluble	U.S. EPA 1994
Stability	Stable in freshwater: halflife of up to 10 days. Less stable in seawater: halflife between 2.5 hours to 2.5 days because of reaction with bromide	Oemcke 1999
Stability	Unstable but more stable than chlorine	U.S. EPA 1999
Inactivation	Bacteria attached to surfaces are difficult to inactivate.	Le Chavalier 1984
Inactivation	Inhibition of proteins and/or protein-mediated processes (i.e., respiration).	U.S. EPA 1999

Target Organism	Treatment Dosage	Citation
Asiatic clam	for the juvenile: 1.2 to 4.7 mg/L	U.S. EPA 1999
Bacillus subtilis	Monochloramine was able to induce scissions (strand breaks) in both cell-associated-isolated DNA, with the number of breaks increasing with both disinfectant concentration and contact time.	Shih 1976
Burkholderia pseudomallei	Chlorination may be a satisfactory method for controlling colimforms and preventing growth of B. pseudomallei in potable water.	Howard 2003
Cryptosporidium parvum oocysts	Concentration contact time of 9600 min*mg/L removes 1.7 logs	Oemcke 1999
Cryptosporidium parvum oocysts	80 ppm monochloramine for 90 min achieves 90% inactivation	Korich 1990
E. coli	Given 100 mg/L, 12% reduction with degradation rate of 0.05 mg Cl2/L*hr, 7% reduction with degradation rate of 0.02 mg Cl2/L*hr, 47% reduction with degradation rate of 0.01mg Cl2/L*hr; inactivation rate = 1.0 endotoxin unit (EU)/mL*hr.	Anderson 2003
Enterobacter cloacae	At any given pH, increasing the chlorine-ammonia ratio will increase the inactivation rate. Asa the pH increased from 6 to 8, the rate decreased by a factor of 5-6.	Ward 1984
F. aquatile	Potential sterilization for these organisms using chlorine. Contact times ranging from 1 to 30 minutes with a corresponding concentration range of 12 to 0.5 mg/L led to complete inactivation.	Gilpin 1985
Giardia cysts	For Giardia cysts: 0.5-log, 1.0-log, 1.5-log-2.0-log, 2.5-log and 3.0-log.310 mg-min/L, 615 mg-min/L, 930 mg-min/L, 1230 mg-min/L, 1540 mg-min/L, and 1850 mg-min/L, respectively.	Cowley 1999
Giardia muris cysts	Concentration contact time of 500-3000 min*mg/L removes 2 logs (99%) when temperatures are 5-15 degrees C and pH is 7.5-9.	Oemcke 1999
Klebsiella pnuemoniae	At any given pH, increasing the chlorine-ammonia ratio will increase the inactivation rate. Asa the pH increased from 6 to 8, the rate decreased by a factor of 5-6.	Ward 1984
Legionella bozemanii	Potential sterilization for these organisms using chlorine. Contact times ranging from 1 to 30 minutes with a corresponding concentration range of 12 to 0.5 mg/L led to complete inactivation.	Gilpin 1985
Legionella pneumophilia	Potential sterilization for these organisms using chlorine. Contact times ranging from 1 to 30 minutes with a corresponding concentration range of 12 to 0.5 mg/L led to complete inactivation.	Gilpin 1985
Pseudomonas aeruginosa	Potential sterilization for these organisms using chlorine. Contact times ranging from 1 to 30 minutes with a corresponding concentration range of 12 to 0.5 mg/L led to complete inactivation.	Gilpin 1985
Pseudomonas aeruginosa	At any given pH, increasing the chlorine-ammonia ratio will increase the inactivation rate. Asa the pH increased from 6 to 8, the rate decreased by a factor of 5-6.	Ward 1984

Viruses	For viruses: 2-log, 3-log, and 4-log;643 mg-min/L, 1067 mg-min/L, and 1491 mg-min/L, respectively.	Cowley 1999

Environmental Acceptability

Environmental Acceptibility	Unacceptable: persistance (particularly in freshwater) and toxicity to fish at levels <10 ug/L	Oemcke 1999
Environmental Acceptibility	will not react with organic compounds.	U.S. EPA 1999
Byproducts	In seawater, monobrmamine forms from reaction of monochloramine with bromide	Oemcke 1999
Byproducts	Diachloroacetic acid and other hydrophilic and large molecular organic halides.	U.S. EPA 1999
Inhibitors	strong oxidizing agents such as bromine, chlroine dixoide, iodine, permanganate, hydrogen peroxide, and ozone (the reduced forms do not interfere)	U.S. EPA 1999

Shipboard Use

Generation	Can also be produced by adding ammonia to a solution containing free residual chlorine or adding premixed solutions of ammonia and chlorine to water.	Health Canada 1996
Generation	Chloramines are generated by sequential addition of chlorine (hypochlorous acid) and ammonia at a Cl2:NH3 ratio of 3:1 to 5:1. Chloramines must be made on-site.	U.S. EPA 1999
Generation	Chlorine gas + ammonia solid salts or solution at a 5:1 ratio to form monochloramine	Walker 2002
Application	Natural ammonia concentrations will influence dosing.	Health Canada 1996
Application	Normal dose = 1.0-4.0 mg/L; miniumum residual in distribution system = 0.5 mg/L; Prevention of nitrification in distribution system = 2.0 mg/L.	U.S. EPA 1999
Storage	Nitrification potential for storing ammonia solution; chlorine gas	Walker 2002
Handling	Acrid monochloramine and dichloramine fumes can cause burning in eyes and throat, cough, nausea, and vomiting. Personal protective equipment should include appropriate gloves, faceshield, and respirator.	Health Canada 1996
Size	Storage, mixing, and pumping requirements	Walker 2002
Ventilation	Fumes generated when producing monochloramine should be vented.	Health Canada 1996
Maintenance	Dosing equipment and pumps	Health Canada 1996

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	

South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Cowley, G, . 1999.	Disinfection with Chlorine Dioxide	Sterling Pulp Chemicals : 1-9
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Health Canada, , . 1996.	Chloramines Guideline	Guidelines for Canadian Drinking Water Quality : -
Howard, K, TJ Inglish. 2003.	The effect of free chlorine on Burkholderia pseudomallei in potable water	Water Research 37: 4425-4432
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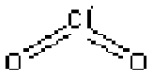
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
Shih, KL, J Lederberg. 1976.	Effects of chloramine on Bacillus subtilis deoxyribonucleic acid	Journal of Bacteriology 125: 934-
U.S. EPA, , . 1994.	Drinking Water Criteria Document for Chloramines	National Center for Environmental Assessment ECAO-CIN-D002 : -
U.S. EPA, , . 1999.	Alternative Disinfectants and Oxidants Guidance	EPA Report 815-R-99-014 : -
Walker, I, . 2002.	Chloramination -- Future Best Practice for the Water Industry?	www.wrcplc.co.uk/downloads : -
Ward, NR, RL Wolfe, BH Olsen. 1984.	Effects of pH, application, technique, and chlorine-to-nitrogen ratio on disinfectant activity of inorganic chloramines with pure culture bacteria	Applied and Environmental Microbiology 48: 508-

Chlorine Dioxide

ClO_2 **CAS_#** 10049-04-4

A gas used as a powerful biocide, disinfectant agent, and oxidizer. It is produced and used on location. The liquid and solid forms of chlorine dioxide are extremely unstable and explosive.



Other Names Chlorine oxide; chlorine peroxide; anthium dioxcide; chlorine (IV) oxide; chloroperoxyl; chloryl radical; alcide

Trade_Names doxcide 50

Physiochemical Properties	Value or Comment	Citation
Physical State	solid	Raytec Corp 2004
Physical State	gas	U.S. EPA 1999
pH	affects are noted for the generation of the disinfectant but does not influence biocidal properties	U.S. EPA 1999
Solubility in water	high, particularly in chilled water. Remains in solution as a dissolved gas.	U.S. EPA 1999
Stability	Unreactive in its dry form	Raytec Corp 2004
Stability	Decomposes in sunlight. Stable in dilute solution in a closed container in absence of light. Reacts violently with reducing agents and therefore cannot be transported.	U.S. EPA 1999
Inactivation	chlorine dioxide may react with amino acids to alter viral capsid proteins or RNA to impair RNA synthesis. Also can effect physiological functions such as increasing permeability of outer membrane.	U.S. EPA 1999

Target Organism	Treatment Dosage	Citation
crustaceans	not acutely toxic	PAN 2004
Cryptosporidium	For 1-log inactivation, CT values range 100-120 mg-min/L at temp between 5-15 deg C and pH between 6.5-8.5. Not effective at low temps.	Cowley 1999
Cryptosporidium parvum	Approximately 90% inactivation of oocysts after 1 hour of exposure to 1.3 mg/L (using infectivity method).	Korich 1990
Cryptosporidium parvum	30 minute contact time with 0.22 mg/L reduced oocyst infectivity; 3-log inactivation with 2.7 and 3.3 mg/L chlorine dioxide for contact times of 120 minutes at pH of 8 and temp of 22 deg C.	U.S. EPA 1999
Dreissena polymorpha	70% mortality with 5 mg/L in flow-through cooling water systems	Rigby 2001
E. coli and B. anthracis	dosages in the range of 1 - 5 mg/L	U.S. EPA 1999
fish	not acutely toxic	PAN 2004
Giardia cysts	0.5 log inactivation: 4 mg-min/L; 1.0 log inactivation: 7.7 mg-min/L; 1.5 log inactivation: 12 mg-min/L; 2.0 log inactivation: 15 mg-min/L; 2.5 log inactivation: 19 mg-min/L; and 3 log inactivation: 23 mg-min/L at 10 deg C and pH = 6-9.	Cowley 1999
Giardia cysts	60 minute contact time, doses from 1.5 to 2 mg/L provide a 3-log inactivation at 1 deg C and pHs of 6 and 9.	U.S. EPA 1999
molluscs	not acutely toxic	PAN 2004
total coliform and f2 coliphage virus in sewage	initial chlorine dioxide residuals between 0.85 and 0.95 mg/L resulted in 2.8-log inactivation of the total coliform and an average 4.4-log inactivatio of the f2 coliphage over a contact time of 240 minutes.	U.S. EPA 1999
Viruses	2-log inactivation: 4.2 mg-min/L; 3-log inactivation 12.8 mg-min/L; 4-log inactivation: 25.1 mg-min/L	Cowley 1999

Environmental Acceptability

Environmental Acceptibility	does not react with organic matter or bromides	Cowley 1999
Environmental Acceptibility	More effective than chlorine and chloramines for inactivation of viruses, cryptosporidium, and giardia. May enhance clarification process.	U.S. EPA 1999
Byproducts	No toxic products formed	Cowley 1999
Byproducts	Fewer by-products are generated using the electrochemical method of production.	Cowley 2000
Byproducts	Chlorine dioxide can produce two major by-products: chlorate and chlorite. Newer generators do not produce chlorate.	Oemcke 1999
Byproducts	Reaction of hypochlorous acid with sodium chlorite is sodium hydroxide. Chlorate also undesirable byproduct. Chlorine dioxide reacts with the soluble forms of iron and manganese to form precipitates.	U.S. EPA 1999
Inhibitors	pH and temperature	Cowley 1999

Inhibitors	high pH slows formation of chlroine dioxide and impels less efficient chlorate-forming reactions.	U.S. EPA 1999
Effectiveness Factor	Perstraction membrane isolates the reaction system and passes only ClO2 and other gasses which produces a high quality product (high conversion efficiency).	Cowley 2000
Effectiveness Factor	Humidity or moisture in the air can start the reaction between the chlorite salt and the proprietary activators impregnated on the solid substrate.	Raytec Corp 2004
Effectiveness Factor	Disinfection effeciency decreases as temp decreases. Suspended matter and pathogen aggregation affect the disinfection efficiency. More suspended matter means less efficiency.	U.S. EPA 1999

Shipboard Use

Generation	Produced onsite with an electrochemical cell and sodium chlorite; other methods include mixing chlorine gas and sodium chlorite or hydrochloric acid and sodium chlorite or hydrochloric acid, sodium hypochlorite, and sodium chlorite on site.	Cowley 1999
Generation	Electrolytic process that converts sodium chlorite solution to chlorine dioxide.	Halox Technologies 2003
Generation	When the dmClO2 comes in contact with water or is exposed to moisture a reaction occurs between the chlorite salts and the proprietary activators that are impregnated on the zeolitic substrate.	Raytec Corp 2004
Generation	Common precursor feedstock is sodium chlorite reacting with gaseous chlorine, hypochlorous acid, or hydrochloric acid. May also use sodium chlorate and hydrogen peroxide and concentrated sulfuric acid. Generally, few DBPs.	U.S. EPA 1999
Application	Dosed on site	Cowley 1999
Application	Requires softened, potable feedwater (~1900 gal/day at max generation).	Halox Technologies 2003
Application	If dosed during ballasting it can be expected to decline to low levels before release.	Oemcke 1999
Storage	Requirements for sodium chlorite solution (25% w/w), dosing tank, and electrochemical cassettes (6-month shelf-life).	Halox Technologies 2003
Storage	Loose powder or sachets must be kept dry to eliminate activation and production of ClO2.	Raytec Corp 2004
Storage	Cannot be compressed or stored as a gas.	U.S. EPA 1999
Handling	Can lead to production of noxious odors	U.S. EPA 1999
Size	2'x 4' for generating equip + dosing tank + storage.	Halox Technologies 2003
Corrosivity	Negligible	Raytec Corp 2004
Corrosivity	Corrosive effects on steel	Rigby 2001
Power Requirements	~ 4 kW operating at max capacity (5.2 lbs can be generated per day with Halox 2000 system with 4 cassettes).	Halox Technologies 2003
Ventilation	Hydrogen gas needs to be vented from cathode.	Cowley 2000
Maintenance	Every 2000 hours of operation.	Halox Technologies 2003
Limits	Forbidden from transporting as material; must be generated onsite.	DOT 2002
Limits	Catholyte product waste stream	Halox Technologies 2003

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html

Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Cowley, G, T Znajewski. 2000.	ECF™ Technology: The Chlorine Dioxide Generation System of the Future	Sterling Pulp Chemicals, http://clo2.com/reading/publications/pub.html : -
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
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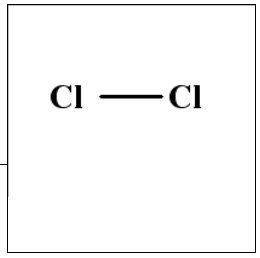
Halox Technologies, , . 2003.	Halox Technical Data Sheets	www.haloxtech.com : -
Korich, DG, JR Mead, MS Madore, NA Sinclair, CR Sterling. 1990.	Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on Cryptosporidium parvum Oocyst Viability	Applied and Environmental Microbiology 56: 1423-1428
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Raytec Corp, , . 2004.	dmClO2 Overview	Raytec Corporation,

		http://www.raytecnet.com/ : -
Rigby, G, AH Taylor. 2001.	Ballast Water Treatment to Minimise the Risks of Introducing Nonindigenous Marine Organisms into Australian Ports	Ballast Water Report Series : -
U.S. EPA, , . 1999.	Alternative Disinfectants and Oxidants Guidance Manual	: -

Chlorine

Cl_2 **CAS_#** 7782-50-5

A highly reactive gas used to remove color and disinfect water.



Other Names Bertholite, warfare gas, chloor (Dutch), chlore (French), chlor (German)

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	greenish-yellow, diatomic gas	Hazardous Substances Data Bank 2004
pH	persists as an element only at a very low pH (less than 2), and at the higher pH found in living tissue it is rapidly converted into hypochlorous acid.	Hazardous Substances Data Bank 2004
Specific gravity	1.564	Hazardous Substances Data Bank 2004
Solubility in water	Soluble in water at 25 deg C, more soluble in alkalies	Hazardous Substances Data Bank 2004
Inactivation	Bacteria and protozoa: breaches the cell wall and attacks nucleus; Viruses: attacks the DNA	Bolek 2003

Target Organism	Treatment Dosage	Citation
annelida	LC50: moderately toxic	PAN 2004
Baetis harrisoni	24 h LC50 - 11.2 and 10.1 ug/L; 48 h LC50 - 5.0 and 6.5 ug/L; 96 h LC50 - 4.1 and 4.8 ug/L.	Williams 2003
Centroptilium spp.	24 h LC 50 - 71 ug/l, 46 ug/l (8 h), and 502 ug/l (8 h); 48 h LC50 - 27 and 93 ug/L;	Williams 2003
Ceriodaphnia dubia	24 h LC50 - 5 ug/L (hypochlorus acid), 6 ug/L (hypochlorite ion), 16 ug/L (monochloramine), and 27 ug/L (dichloramine).	Williams 2003
crustaceans	LC50: highly toxic	PAN 2004
D. polymorpha (freshwater mussel)	continuous 1 mg/L mortality in 588 hours	Rajagopal 2003
Daphnia magna	24 h LC50 140 ug/L; 48 h LC50 - 116 ug/L	Williams 2003
Daphnia magna	48 h LC 50 - 45 ug/L and 17 ug/L	Williams 2003
fish	LC50: highly toxic	PAN 2004
Giardia cysts	17 mg-min/L, 35 mg-min/L, 52 mg-min/L, 69 mg-min/L, 87 mg-min/L, and 104 mg-min/L, respectively.	Cowley 1999
Hexagenia spp	48 h LC 50 - 357 ug/L	Williams 2003
M. Eduli (marine mussel)	continuous 1 mg/L mortality in = 966 hour	Rajagopal 2003
M. Leucophaeata (brakish water)	continuous 1 mg/L mortality within 1104 hours	Rajagopal 2003
Micororganisms, ghiardia, cryptosporidium	Depends on what is in the water. Ranges from 0.5 ppm to 50 ppm.	Bolek 2003
molluscs	LC50: highly toxic	PAN 2004
Pteronarcys spp	96 h LC50 400 ug/L	Williams 2003
Stenonema ithaca	96 h LC50 - 102 ug/L	Williams 2003
Viruses	For Giardia cysts: 0.5-log, 1.0-log, 1.5-log, 2.0-log, 2.5-log, and 3.0-log.for viruses: 2-log, 3-log, and 4-log;3 mg-min/L, 4 mg-min/L, and 6 mg-min/L, respectively.	Cowley 1999
zooplankton	LC50: highly toxic	PAN 2004

Environmental Acceptability

Byproducts	Chlorine will produce trihalomethanes, haloacetic acid	Bolek 2003
Effectiveness Factor	The time taken for 100% mortality of mussels decreased with increasing chlorine concentration. Chlorine serves as an excellent biocides for controlling biofouling in cooling water systems, its use is restricted due to environmental considerations, Efficacy of chlorine as an antifoulant depends on various parameters, most importantly resiudal levels of chlorine and contact time.	Rajagopal 2003

Shipboard Use

Storage	Material must be stowed "on deck only" on a cargo vessel and on a passenger vesel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overal vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded. This material must also be stowed clear of living quarters, and separated from acetylene, ammonia, diborane, hydrogen, and radioactive material.		DOT 2002
Corrosivity	Chlorine can be corrosive. System uses approximately 0.4-0.8% chlorine in the solution to prevent corrosion.		Bolek 2003
Power Requirements	Small system: 220V AC	Large system: 480V AC	Bolek 2003
Ventilation	Poisonous gas and must be stowed on deck.		DOT 2002
Maintenance	Periodic preventative maintenance, loading brine tank, keeping recording logs		Bolek 2003

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
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USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

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Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Bolek, K, . 2003.	Telephone conversation with Katie Bolek, Marketing Manager	Miox Corporation : -
Cowley, G, . 1999.	Disinfection with chlorine dioxide	Sterling Pulp Chemicals : 1-9
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
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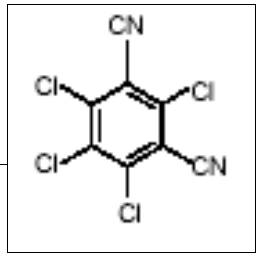
Korich, DG, JR Mead, MS Madore, NA Sinclair, CR Sterling. 1990.	Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on Cryptosporidium parvum Oocyst Viability	Applied and Environmental Microbiology 56: 1423-1428
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Rajagopal, S, GV Velde, M VDG Gaag. HA Jenner. 2003.	How Effective is intermittent chlorination to control adult mussel fouling in cooling water system	Water Research 37: 329-338
Rajagopal, S, Van der Velde, G., and H, A. Jenner. 2002.	Effects of low-level chlorination on zebra mussel, Dreissena polymorpha	Water Research 36: 3029-3034
Williams, ML, CG Palmer and AK Gordon. 2003.	Riverine macroinvertebrate responses to chlorine and chlorinated sewage effluents - Acute chlorine tolerances of Baetis harrisoni (Ephemeroptera) from	Water SA 29: 483-

Chlorothalonil

$C_8Cl_4N_2$ **CAS_#** 1897-45-6



White crystalline solid, used as a fungicide effective against a broad range of plant pathogens attacking many agronomic and vegetable crops. Also used as a preservative in paints and adhesives.

Other Names 1,3-Benzenedicarbonitrile, 2,4,5,6-tetrachloro-; 2,4,5,6-Tetrachloroisophthalonitrile;

Trade_Names Daconil 2787; Bravo; Sweep; Vanox

Physiochemical Properties	Value or Comment	Citation
Solubility in water	IN WATER @ ROOM TEMP 0.6 PPM; Solubility (25 deg C): 0.6 mg/kg water	Hazardous Substances Data Bank 2004
Stability	will readily biodegrade under aerobic and anaerobic conditions in aquatic ecosystems; DOES NOT HYDROLYZE IN MODERATE ALKALINE OR ACIDIC MEDIA	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
amphibians	LC50: highly toxic	PAN 2004
clams	LC50 Mya arenaria clams 35.0 5.9 mg/l/96 hr /Bravo 500; conditions of bioassay not specified; LC50 Mytilus edulis (blue mussels) 5.9 mg/l/96 hr; conditions of bioassay not specified; LC50 Rainbow trout 76 ug/l/96 hr /Technical chlorothalonil; conditions of bioassay not specified	Hazardous Substances Data Bank 2004
crustaceans	LC50: very highly toxic	PAN 2004
Fish	LC50: very highly toxic	PAN 2004
fish, aquatic invertebrates	47-84 ppb is highly toxic to fish; may affect fish populations at low levels (3 - 6.5 ppb). aquatic invertebrates and may affect their reproduction at low conc (> 79 ppb)	Hazardous Substances Data Bank 2004
molluscs	LC50: slightly toxic	PAN 2004
phytoplankton	EC50: accumulation, population	PAN 2004
zooplankton	LC50: moderately toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Half-life of 38.1 days in aqueous media at pH 9; Koc value of 1,800(6) indicates adsorption from the water column to sediment and suspended material may occur	Hazardous Substances Data Bank 2004
Environmental Acceptibility	anaerobic half life <0.5 days	Thomas 2003
Byproducts	At pH 9, chlorothalonil in water may hydrolyze to 4-hydroxy-2,5,6-trichloro-isophthalonitrile and 3-cyano-2,4,5,6-tetrachlorobenzamide;	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Keep in cool, dry, ventilated place	Hazardous Substances Data Bank 2004
Handling	Use gloves, apron, rubber or plastic boots; use mask for powders	Hazardous Substances Data Bank 2004
Corrosivity	Non-corrosive	Hazardous Substances Data Bank 2004
Ventilation	required	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html

Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Albanis, TA, DA Lambropoulou, VA Sakkas, IK Konstantinou. 2002.	Antifouling Paint Booster Biocide Contamination in Greek Marine Sediments	Chemosphere 48: 475-485
Hazardous Substances Data Bank, , . 2004.	Chlorothalonil	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Thomas, KV, M McHugh, M Hilton, M Waldock.. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution 123: 153-161

Copper Ions

Cu^{2+} **CAS_#** 15721-63-8

Algicide, toxic to heterotrophic bacteria in aquatic environments and has been used to control poliovirus; electrolytically generated

Cu^{2+}

Other Names

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	aqueous solution	Hazardous Substances Data Bank 2004
Inactivation	The presence of the high CU2+ concentration in the culture medium induced the morphological changes of the organism.	Gardea-Torresdey 1997
Inactivation	decrease in photosynthesis activity	Gustavson 1995
Inactivation	Neither bacterial nor phytoplankton viability appeared to be affected. Some influence on viability of zooplankton and dinoflagellate cysts. Effects may have resulted from inordinately high copper concentrations.	Rigby 2001

Target Organism	Treatment Dosage	Citation
	Freshwater: 33% effective at 167 ppb. Seawater (simulated): 70% effective at 68 ppb.	Gracki 2002
amphibians	LC50: very highly toxic	PAN 2004
crustaceans	LC50: highly toxic	PAN 2004
echnoderms	LC50: very highly toxic	PAN 2004
fish	LC50: moderately toxic	PAN 2004
Freshwater crayfish	LC50: 0.83 mg/L for 96 hours; 4.07 mg/L for 24 hours (intermoult adult male)	Oemcke 1999
Gymnodinium catenatum cysts	200 mg/L was ineffective for inactivation	Oemcke 1999
marine benthic community	LC50: highly toxic	PAN 2004
Microalgal communities	Concentration in the enclosure area: the copper concentration varied from 0.013 to 0.007 uM (low Cu), 0.087 to 0.032 (medium Cu), 0.205 to 0.157 (high Cu). A decrease in photosynthesis activity was observed when exposed to low and medium Cu, a drop of about 50%. For high Cu, a drop of less than 10%. The photosynthesis activity is not affected by the highest Cu anymore.	Gustavson 1995
molluscs	LC50: moderately toxic	PAN 2004
Mucor rouxii		Gardea-Torresdey 1997
nematodes and flatworms	LC50: moderately toxic	PAN 2004
Oocytis nephrocytiodes	A 5uM copper treatment increased the population from less than 1% in the control to 56%.	Soldo 2000
phytoplankton	LC50: very highly toxic	PAN 2004
zooplankton	LC50: very highly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Unsuitable: toxicity to fish if discharged at doses needed for effective inactivation.	Gracki 2002
Environmental Acceptibility	Communities that were exposed to copper also showed an increased co-tolerance to zinc, nickel, and silver.	Soldo 2000
Byproducts	Reacts with phosphates to form insoluble precipitate. It also forms complexes and chelates with ammonia, humic acid, and other organics reducing its bioavailability.	Oemcke 1999
Inhibitors	Presence of sediments (settled or suspended) reduces efficacy of copper as a biocide.	Gracki 2002
Effectiveness Factor	Copper reacts with dissolved organic matter; simulated seawater did not have proper amounts of solutes.	Gracki 2002
Effectiveness Factor	> 2 days: Low concentration of Cu--No effect on biomass, photosynthesis activity, or short-term tolerance. Small change in species composition. High concentration of Cu--There is a very strong reduction in biomass and photosynthesis activity. Increased short-term tolerance. Strong change in species composition. 2-14 days: Low concentration of Cu-- There is a decrease in photosynthesis activity. High concentration of Cu--Continuation of the effects seen during the first 2 days. 14-20 days: Low concentration of Cu--Increased tolerance for copper in the short-term test. Co-tolerance for zinc. High concentration of Cu--Increasing biomass and photosynthesis activity. High tolerance for	Gustavson 1995

	copper and co-tolerance for zinc.	
Effectiveness Factor	After 12 weeks of copper exposure to the freshwater periphyton communities, it was found that there was a change in the distribution of algal classes from a community dominated by Cyanophyceae to one dominated by Chlorophyta. Periphyton communities subjected to long-term exposure at different concentrations did not differ significantly in the photosynthesis rate.	Soldo 2000
Effectiveness Factor	Copper exhibits antifouling activity against organisms such as barnacles, tube worms, and the majority of algal fouling species. However, several algal species, such as Enteromorpha spp., Ectocarpus spp., Achnanthes spp., show physiological tolerance to copper.	Voulvoulis 2002

Shipboard Use

Generation	Electrically generated Cu ions	Rigby 2001
Storage	Solid form can be stowed "on deck" or "under deck", but clear of living quarters.	DOT 2002
Corrosivity	0.02-0.05 ppm can cause corrosion to aluminum.	Gracki 2002
Ventilation	Poison	DOT 2002

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
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Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html

West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Cabral, JP, . 2002.	Differential sensitivity of four lobaria lichens to copper in vitro	Environmental Toxicology and Chemistry 21: 2468-2476
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Gardea-Torresdey, JL, I Cano-Aguilera, R Webb, F. Gutierrez-Corona. 1997.	Enhanced copper adsorption and morphological alterations of cells of copper-stressed Mucor rouxii	Environmental Toxicology and Chemistry 16: 435-441
Gracki, JA, RA Everett, H Hack, PF Landrum, DT Long, BJ Premo, SC Raaymakers, GA Stapleton, KG Harrison. 2002.	Critical Review of a Ballast Water Biocides Treatment Demonstration Project Using Copper and Sodium Hypochlorite	Michigan Environmental Science Board, Lansing : -
Gustavson, K, SA Wangberg. 1995.	Tolerance induction and succession in microalgae communities exposed to copper and atrazine	Aquatic Toxicology 32: 283-302
Haslbeck, JS, . 2003.	Measurement of copper release rates from antifouling paint under laboratory and in-situ conditions: implications for loading estimation to marine wate	Marine Pollution Bulletin 46: 763-779
Hazardous Substances Data Bank, , . 2004.	Copper Compunds	National Library of Medicine Toxnet System : -
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Rigby, G, AH Taylor. 2001.	Ballast Water Treatment to Minimise the Risks of Introducing Nonindigenous Marine Organisms into Australian Ports	Ballast Water Report Series : -
Soldo, D, R Behra. 2000.	Long-term effects of copper on the structure of freshwater periphyton communities and their tolerance to copper, zinc, nickel, and silver	Aquatic Toxicology 47: 181-189
Voulvoulis, N, MD Scrimshaw, JN Lester. 2002.	Comparative environmental assessment of biocides used in anitfouling paints	Chemosphere 47: 789-795

Copper Sulfate

$CuSO_4 \bullet 5H_20$ **CAS_#** 7758-99-8

Available as a wettable powder or in liquid concentrate form.

Other Names Blue copper AS; Blue vitriol; Bluestone; copper sulfate (pentahydrate), copper sulphate pentahydrate; Copper(II)sulfate; Cupric Sulfate

Trade_Names Blue Vitriol

Physiochemical Properties	Value or Comment	Citation
Physical State	grayish white greenish white rhombic crystals	Hazardous Substances Data Bank 2004
Specific gravity	3.6	Hazardous Substances Data Bank 2004
Solubility in water	243 g/l at 0 deg C; 75.4 g/100 cc water at 100 deg C	Hazardous Substances Data Bank 2004
Stability	Aquatic fate highly dependent on pH, concentration of organic matter, iron and manganese oxide and hardness of water.	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
amphibians	highly toxic	PAN 2004
crustaceans	slightly toxic	PAN 2004
fish	moderately toxic	PAN 2004
molluscs	very highly toxic	PAN 2004
nematodes and flatworms	very highly toxic	PAN 2004
zooplankton	slightly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Soluble copper compounds sorb strongly to suspended particles.	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Keep tightly closed	Hazardous Substances Data Bank 2004
Handling	strong irritant; wear gloves, boots, and goggles.	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Hazardous Substances Data Bank, , . 2004.	Copper Sulfate	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Cupric Ascorbate

CAS_# 3333-33-3

Other Names

Trade_Names

Environmental Acceptability

Shipboard Use

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html

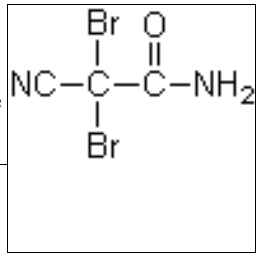
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551

Dibromonitrilopropionamide (DBNPA)

$C_3H_2Br_2N_2O$ **CAS_#** 10222-01-2



Algicide, bactericide, fungicide, and preservative used in paper industry and water treatment. Available as a slow-release solid or as a liquid solution.

Other Names 2,2-dibromo-3-nitrilopropionamide; 2,2-Dibromo -2-carbamoylacetonitrile; 2,2-dibromo-3-nitrilopropionamide, DBNPA; dibromocyanoacetamide

Trade_Names Acetamide; Slimicide 508; XD-1603, XD-7287L Antimicrobial

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid or solid	AMSA, Inc 2004
pH	6.61 in 0.01% aqueous solution at 25 deg C	Hazardous Substances Data Bank 2004
Solubility in water	15,000 mg/l.; log Kow= 0.80 @ pH 7; 0.795 @ pH 5; 0.82 @ pH 9.0	Hazardous Substances Data Bank 2004
Stability	quickly degrades to ammonia and bromide ion	AMSA, Inc 2004
Stability	Stable under normal conditions, decomposition accelerated by light & heat.	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
crustaceans	LC50: moderately toxic	PAN 2004
fish	LC50: moderately toxic	PAN 2004
molluscs	EC50: intoxication	PAN 2004
zooplankton	LC50: highly toxic	PAN 2004

Environmental Acceptability

Byproducts	ammonia and bromide ion	AMSA, Inc 2004
Byproducts	When heated to decomposition it emits very toxic fumes of bromine & nitrogen oxides.	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	non-explosive, non-combustible; incompatible with bases, reducing substances & nucleophiles	Hazardous Substances Data Bank 2004
Corrosivity	liquid is an oxidizer because of hypobromous acid in formulation	AMSA, Inc 2004
Corrosivity	Corrosive to mild steel, iron and aluminum	Hazardous Substances Data Bank 2004

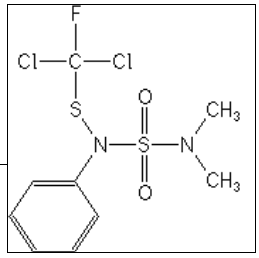
Laws and Regulations

Citations

AMSA, Inc, , . 2004.	DBNPA Overview	http://www.amsainc.com/prod-dbnpa-overview.asp : -
Hazardous Substances Data Bank, , . 2004.	DBNPA	National Library of Medicine Toxnet System : -
Klaine, SJ, Cobb, G.P., Dickerson, R.L., Dixon, K.R., Kendall, R.J., Smith, E.E., and K.R. Solomon. 1996.	An ecological risk assessment for the use of the biocide, dibromonitrilopropionamide (DBNPA), in industrial cooling systems	Environmental Toxicology and Chemistry 15: 21-30
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Dichlofluanid

$C_9H_{11}Cl_2FN_2O_2S_2$ **CAS_#** 1085-98-9



Fungicide. Available in liquid form.

Other Names 1,1-dichloro-N-[(dimethylamino)sulfonyl]-1-fluoro-N-phenylmethanesulfenamide; N-dichlorofluoromethylthio-N′,N′-dimethyl-N-phenylsulfamide; Aniline; dichlofluanide , N,N-Dimethyl-N'-phenyl-N'-((fluorodichloromethyl)thio)sulfamide; N-(Dichlorofluoromethylthio)-N',N'-dimethyl-N-phenylsulfamide; Sulfamide; N-((dichlorofluoromethyl)thio)-N',N'-dimethyl-N-phenyl-

Trade_Names Bay 47531; Bay KUE 13032C; Dichlofluanide (France) , Diclofluanida; Diklofluanid; Elvaron; Euparen; Euparene; KUE 13032C

Physiochemical Properties	Value or Comment	Citation
Solubility in water	1.3 mg/L in water	Hazardous Substances Data Bank 2004
Stability	degrades faster at higher pH (pH=9); in alkaline medium, DT50 at 22 deg C >15 days at pH =4; in alkaline medium, DT50 at 22 deg C >18 hours at pH =7 and <10 minutes at pH of 9	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
crustaceans	EC50: behavior, mortality	PAN 2004
fish	EC50: mortality	PAN 2004
fungi	not provided	Hazardous Substances Data Bank 2004
molluscs	EC50: growth, mortality	PAN 2004
molluscs	LC50: moderately toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	may adsorb to suspended solids and sediment in water, Koc of 1100	Hazardous Substances Data Bank 2004
Environmental Acceptibility	anaerobic half life <0.5 days. An increase half life of 1.4 days when is introduced as an antifouling paint.	Thomas 2003
Byproducts	in alkaline solution: N',N'-dimethyl-N-phenylsulphamide	Hazardous Substances Data Bank 2004
Byproducts	degrades will transform to N,N-dimethyl-N'-phenyl-Sulfamide (DMSA) with m-dichlorofluoromethylthion-aniline, aniline, and dichlorofluoromethane also being formed.	Thomas 2003
Inhibitors	adsorption to suspended solids and pH	Hazardous Substances Data Bank 2004
Effectiveness Factor	alkaline conditions	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	stable in storage for at least one year when worked up with small quantity of inert material; practically nonvolatile	Hazardous Substances Data Bank 2004
Handling	avoid contact with eyes and skin and inhalation.	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
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East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the	http://www.unepmap.gr/pdf/dumping

	Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
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Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
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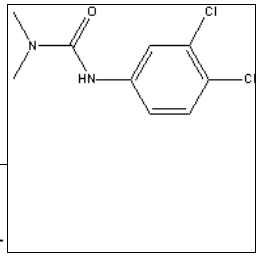
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Albanis, TA, DA Lambropoulou, VA Sakkas, IK Konstantinou. 2002.	Antifouling Paint Booster Biocide Contamination in Greek Marine Sediments	Chemosphere 48: 475-485
Hazardous Substances Data Bank, , . 2004.	Dichlofluanid	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Thomas, KV, M McHugh, M Hilton, M Waldock. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution 123: 153-161

Diuron

$C_6H_3Cl_2NHCON(CH_3)_2$ **CAS_#** 330-54-1



Herbicide. Available as a solid (white, odorless, crystalline) or a liquid solution.

Other Names 1,1-Dimethyl-3-(3,4-Dichlorophenyl)urea; 1-(3,4-Dichlorophenyl)-3,3-dimethylurea; 3-(3,4-Dichlorophenyl)-1,1-Dimethylurea; M Velpar; Aguron; Diater; Di-on; Diurex; Diuron; Diuron ; Diuron 4L; Diuron 80; Cekiuron; Crisuron; Dailon; DCMU; DMU; Drexel diuron 4L; N'-(3,4-Dichlorophenyl)-N,N-Dimethylurea;

Trade_Names Direx 4L; Direx 80W; Dynex; Karmex; Karmex 80W; Karmex DL; Unidron; Urox D; Vonduron; Xarmex, Krovar

Physiochemical Properties	Value or Comment	Citation
Solubility in water	n water, 36.4 mg/l @ 25 deg C	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
algae	reduced by 92% filamentous algae or common macrophytes (Potamogeton foliosus, Potamogeton pusillus, Najas flexilis, Najas gracillima, Ceratophyllum demorsum) during a study on twenty 3.048 m diameter pools. All the pools were stocked with fingerling bluegills (Lepomis macrochirus) and golden shiner (Notemigonus crysoleucas), which the diuron did not influence	Hazardous Substances Data Bank 2004
amphibians	LC50: slightly toxic	PAN 2004
ASELLUS	LC50 15.5 MG/L/96 HR (95% CONFIDENCE LIMIT 7.2-33.4 MG/L), @ 15 DEG C, MATURE /95% TECHNICAL GRADE/. STATIC BIOASSAY	Hazardous Substances Data Bank 2004
Bluegill	LC50 7.4 ppm/48 hr /Conditions of bioassay not specified	Hazardous Substances Data Bank 2004
carp	highly toxic	Hazardous Substances Data Bank 2004
crustaceans	LC50: slightly toxic	PAN 2004
Daphnia magna population	A concentration of 0.2 ppm diuron was lethal	Hazardous Substances Data Bank 2004
fish	LC50: slightly toxic	PAN 2004
molluscs	LC50: moderately toxic	PAN 2004
Oncorhynchus kisutch (fish)	LC50 16 mg/l/48 hr /Conditions of bioassay not specified	Hazardous Substances Data Bank 2004
phytoplankton	LC50: very highly toxic	PAN 2004
Rainbow trout	LC50 4.3 ppm/48 hr /Conditions of bioassay not specified	Hazardous Substances Data Bank 2004
zooplankton	LC50: slightly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	expected to adsorb to suspended solids and sediment based upon the range of Koc values 224-879; Diuron is 67-99% degraded in 10 weeks under aerobic conditions by mixed cultures isolated from pond water and sediment.	Hazardous Substances Data Bank 2004
Environmental Acceptibility	anaerobic half life of diuron: 14 days and CPD of 35 days	Thomas 2003
Byproducts	major product was 3,4-dichloroaniline(12). 3-(3,4-Dichlorophenyl)-1-methylurea and 3-(3,4-dichlorophenyl)urea (CPDU) were also identified	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Avoid freezing liquid suspension. Dry formulations are stable under normal storage	Hazardous Substances Data Bank 2004
Handling	Contact with diuron (particularly in concentrated form) may irritate the eyes, nose, throat, and skin. Exposure to diuron may even prove fatal if sufficient quantities are inhaled, swallowed, or absorbed through the skin	Hazardous Substances Data Bank 2004

Laws and Regulations

Citations

Hazardous Substances Data Bank, , . 2004.	Diuron	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -
Thomas, KV, M McHugh, M Hilton, M Waldock. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution 123: 153-161
Thomas, KV, TW Fileman, JW Readman, MJ Waldock. 2001.	Antifouling Paint Booster Biocides in the UK Coastal Environment and Potential Risks of Biological Effect	Marine Pollution Bulletin 42: 677-688

Dowicil 75

$C_9H_{16}ClN_4$•Cl **CAS_#** 4080-31-3

designed to provide reliable and effective antimicrobial protection in a wide range of water-based products and formulations

Other Names 1-(3-chloroallyl)-3,5,7-triaza-1-azonia; 3,5,7-triaza-1-azoniaadamantane, 1-(3-chloroallyl)-, chloride; 1 - (3 - Chloroallyl) - 3,5,7 - triaza - 1 - azoniaadamantane chlorid

Trade_Names Dowco 184, Dowicide Q, Dowicil 100, Dowicil 75; Quaternium 15

Physiochemical Properties	Value or Comment	Citation
Physical State	white to cream color powder	Hazardous Substances Data Bank 2004
pH	hydrolysis rate increases with increasing pH	Hazardous Substances Data Bank 2004
pH	acidic degrades rapidly; neutral to alkaline degrades slowly	U.S. EPA 1995
Density	0.4 g/cu cm	Hazardous Substances Data Bank 2004
Solubility in water	127.2 g/100 g water	Hazardous Substances Data Bank 2004
Stability	rapid degradation; half life is 1.5 days and 95-100% degradation after 7 days	Hazardous Substances Data Bank 2004
Stability	dissipates by abiotic hydrolysis; not persistant	U.S. EPA 1995

Target Organism	Treatment Dosage	Citation
crustaceans	LC50: not acutely toxic	PAN 2004
fish	LC50: slightly toxic	PAN 2004
fish and aquatic invertebrates	slightly toxic.	U.S. EPA 1995
molluscs	EC50: intoxication	PAN 2004
zooplankton	EC50: intoxication, mortality, reproduction	PAN 2004

Environmental Acceptability

Environmental Acceptibility	expected to adsorb to suspended solids and sediment based on Koc of 600. Log Kow of -0.10.	Hazardous Substances Data Bank 2004
Byproducts	decomposes to formaldehyde in aqueous solution	U.S. EPA 1995
Effectiveness Factor	degrades rapidly under acidic conditions. Under neutral to alkaline conditions, it degrades more slowly.	U.S. EPA 1995

Shipboard Use

Storage	stable under ambient conditions	Hazardous Substances Data Bank 2004
Handling	skin irritant use chemical resistant gloves at a minimum	Hazardous Substances Data Bank 2004
Handling	causes moderat acute dermal toxicity so workers should wear gloves.	U.S. EPA 1995

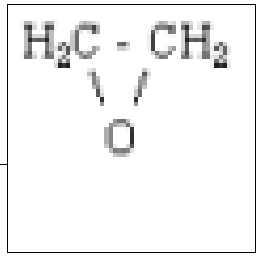
Laws and Regulations

Citations

Hazardous Substances Data Bank, , . 2004.	N-(3-CHLOROALLYL)HEXAMINIUM CHLORIDE	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -
U.S. EPA, , . 1995.	R.E. D FACTS Dowicil CTAC	EPA-738-F-95-016 : 1-5

Ethylene Oxide

C_2H_4O **CAS_#** 75-21-8



Available as colorless, liquified gas and used as a sterilant and fumigant.

Other Names Dihydrooxirene; dimthylene oxide; Epoxyethane; 1,2-Epoxyethane; Oxacyclopropane; Oxidoethane

Trade_Names Ethene oxide; ETO; Oxirene; T-Gas; Oxiran; Oxyfume; Oxirane

Physiochemical Properties	Value or Comment	Citation
Physical State	colorless gas or liquid	Dow Chemical Company 1999
Physical State	colorless gas	Hazardous Substances Data Bank 2004
pH	acidic conditions have positive effect on hydrolysis rate.	Dow Chemical Company 1999
Density	0.882 at 10 deg C	Hazardous Substances Data Bank 2004
Specific gravity	0.875	Dow Chemical Company 1999
Solubility in water	miscible	Dow Chemical Company 1999
Solubility in water	miscible in all proportions with water	Hazardous Substances Data Bank 2004
Stability	not persistent in the environment degrades by biochemical oxidation, reactivity, volatilization, and dilution. Does not readily adsorb onto sediments. Half life of 9 days in 3% salt water	Dow Chemical Company 1999
Stability	half-life if 1 hour to 3.8 days depending on water body. Degrade due to hydrolysis.	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
brine shrimp	24-h LC50 = 350, 570, >500 mg/L; 48-h LC50 = 490, >500, 1000 mg/L (static, salt water)	Dow Chemical Company 1999
Daphnia magna	24-h LC50 = 260, 270,>300 mg/L; 48-h LC50 = 137, 200, 300 mg/L (static, fresh water)	Dow Chemical Company 1999
fathead minnow	maximum safe concentration = 41 mg/L; 96-h LC 50 = 86, 90, 274 mg/L; 48-h LC50 = 89 mg/L; 96-h LC50 = 84 mg/L (static and fresh water)	Dow Chemical Company 1999
goldfish	24-h LC50 = 90 mg/L (static, freshwater)	Dow Chemical Company 1999

Environmental Acceptability

Environmental Acceptibility	Ethylene glycol degraded rapidly.	Dow Chemical Compan 1999
Environmental Acceptibility	primarily lost by volatilization, hydrolysis, and biodegradation. Not tend to adsorb to sediments - low Kow (log Kow of -0.3), Koc of 16	Hazardous Substances Data Bank 2004
Byproducts	ethylene glycol due to hydrolysis	Dow Chemical Compan 1999
Byproducts	ethylene glycol and ethylene chlorohydrin	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Depends on formulation.	DOT 2002
Storage	Store at ambient conditions. fire or explosion, may be ignited by heat, sparks, flame. Stable in water.	Hazardous Substances Data Bank 2004
Handling	irritating to eyes, respiratory tract, and skin. Wear chemical protective clothing, goggles, wear SCBA	Hazardous Substances Data Bank 2004

Laws and Regulations

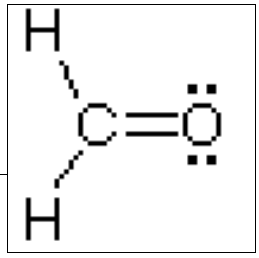
Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Dow Chemical Company, , Shell Chemical Co., Equistar Chemicals, Sunoco. 1999.	Ethylen Oxide Users Guide	Second Edition : -
Hazardous Substances Data Bank, , . 2004.	Ethylene Oxide	National Library of Medicine Toxnet System : -

Formaldehyde

CH_2O **CAS_#** 50-00-0



Formaldehyde is a colorless gas with a strong odor which is usually mixed in a water and Methanol solution. It is used as a bactericide, fungicide, an intermediate in chemical and resin manufacturing, in pressed-wood products, and in textile finishing. Also available as a colorless liquid.

Other Names Methanal; Methylene oxide; Formalin

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	colorless liquid	Hazardous Substances Data Bank 2004
pH	2.8 - 4.0	Hazardous Substances Data Bank 2004
pH	Ineffective throughout pH range on bacterial spores at 8% concentration	Sagripanti 1996
Density	1.067	Hazardous Substances Data Bank 2004
Specific gravity	0.816	Hazardous Substances Data Bank 2004
Solubility in water	400000 mg/L at 20 deg C	Hazardous Substances Data Bank 2004
Stability	degradation complete in 48 hours under anaerobic conditions	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
Bacillus subtillus spores	8% resulted in < 90% inactivation (ineffective)	Sagripanti 1996
Bacillus subtillus spores	8% for 30 min at 20 deg C is ineffective (< 90% inactivation)	Bacillus subtillus spores 1996

Environmental Acceptability

Environmental Acceptibility	Koc of 37, not expected to adsorb to suspended solids and sediments. Log Kow = 0.35	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Material may be stowed on deck or under deck on a cargo vessel and on a passenger vessel. If 25% or more formaldehyde in solution, material should be stowed clear of living quarters.	DOT 2002
Storage	Protect against physical damage. Separate from oxidizing and alkaline material. Flammable.	Hazardous Substances Data Bank 2004
Handling	contact with skin causes irritation, tanning effect, and allergic sensitization. Formaldehyde vapor is very irritating to mucous membranes and toxic to man.	Hazardous Substances Data Bank 2004
Corrosivity	Corrosive hazard class when solution is not less than 25% formaldehyde. All solutions should be labeled as corrosive and flammable.	DOT 2002
Corrosivity	aqueous formaldehyde is corrosive to carbon steel, but vapor phase is not.	Hazardous Substances Data Bank 2004
Ventilation	Corrosive and flammable.	DOT 2002

Laws and Regulations

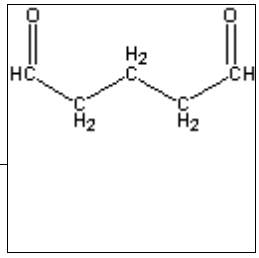
Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	

East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Hazardous Substances Data Bank, , . 2004.	Formaldehyde	National Library of Medicine Toxnet System : -
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551

Glutaraldehyde



$C_5H_8O_2$ **CAS_#** 111-30-8

A strong sporicide, generally unaffected by organic material, non-corrosive. Used in hospitals and laboratories as a disinfectant and in tanning as a biological fixative. Available as a colorless liquid.

Other Names 1,5-Pentanedial; Glutaral; Glutardialdehyde; Glutaric dialdehyde; Aqucar 545

Trade_Names Cidex; Cidex Long-life; Microcide; Nalco 7338; Neoquat LA; Safeguard; Sepacid GA 50; Sonacide; Ucarcide 125; Ucarcide 225; Ucarcide 250; Uconex 350

Physiochemical Properties	Value or Comment	Citation
pH	Rate of reaction is pH dependent, increasing over range of 4-9	Hopwood 1970
pH	Mildly acidic. Usually supplied in range of 3-6.	Lubomudrov 1997
pH	More effective at higher pH	Oemcke 1999
Density	1.13 (50%), 0.72 (100%)	Lubomudrov 1997
Specific gravity	1.129	Lubomudrov 1997
Solubility in water	100%	Lubomudrov 1997
Stability	Affected by pH	Lubomudrov 1997
Inactivation	Only aldehyde to exhibit excellent sporicidal activity.	Scott 1991
Inactivation	0.02% solution is rapidly effective against gram-positive and gram-negative species; 2 % solution is capable of killing vegetative species including S. aureus, P. vulgaris, E. coli, and P. aeruginosa within 2 minutes.	Stonehill 1963

Target Organism	Treatment Dosage	Citation
Algae	Dose depends on target organism and volume of ballast water.	Lubomudrov 1997
Bacillus anthracis	4-log inactivation in 15-30 minutes using ???? Concentration	Rubbo 1967
Bacillus spp	2% solution inactivated spores in 3 hours	Stonehill 1963
Bacillus subtillus spores	30 min*mg/L	Sagripanti 1996
Bacteria	Dose depends on target organism and volume of ballast water.	Lubomudrov 1997
Bacterial spores	20,000 mg/L	Oemcke 1999
Bacterial spores	20,000 mg/L	Oemcke 1999
Clostridium spp	2% solution inactivated spores in 3 hours	Stonehill 1963
Clostridium tetani	4-log inactivation in 15-30 minutes using ???? Concentration	Rubbo 1967
Daphnia magna	50% solution for 48 hours LC50 = 11.5 ppm, LC100 = 23 ppm.	Lubomudrov 1997
E. Coli	100 ug/mL alkaline glutaraldehyde completely inactivates 2x10^8 cells/mL in 10 minutes compared to 45% inactivation with solution	McGucken 1973
Feline Calicivirus (FCV)	Final concentration of 0-5 % Glutaraldehyde give a Log10 reduction of 5	Doultree 1999
fish	LC50: slightly toxic	PAN 2004
Fungi	Sonacide (an acid-based glutaraldehyde formulation) was effective against A. niger and A. fumigatus. Sporicidin (a glutaraldehyde-phenate mixture) was NOT effective even after 90 minutes. 0.5% alkaline glutaraldehyde inhibits mycelial growth and sporulation and spore swelling is entirely halted.	Scott 1991
fungi	EC50: population	PAN 2004
Grass shrimp	100% solution for 96 hours LC50 = 41 ppm, LC100 = 82 ppm.	Lubomudrov 1997
molluscs	EC50: intoxication	PAN 2004
Poliovirus	500 mg/L	Oemcke 1999
Rainbow trout	50% solution for 96 hours LC50= 23.7 ppm, LC100 = 47.4 ppm.	Lubomudrov 1997
Viruses	500 mg/L for poliovirus	Oemcke 1999
Viruses	Dose depends on target organism and volume of ballast water.	Lubomudrov 1997
zooplankton	LC50: slightly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	concentration released into environment depends on initial concentration. Levels <5ppm are considered to be nonbiocidal. Concentrations <1ppm are classified as "readily" biodegradable. Once released into the environment, it will remain in aqueous solution. Under aerobic conditions, glutaraldehyde decomposes to carbon dioxide. Under anaerobic conditions, glutaraldehyde decomposes to 5-hydroxypentanal which is further metabolized to 1,5-pentanediol.	Lubomudrov 1997
Byproducts	Reaction products with amino acids	Kirkeby 1987
Byproducts	Reacts with protein to form unsaturated polymer	Monsan 1975
Inhibitors	Generally unaffected by organic material. Low pH reduces effectiveness. Efficacy improves as temberpature increases.	Oemcke 1999
Effectiveness Factor	Mixing into ballast tank residuals likely to be difficult. 20,000 mg/L doses will be expensive.	Oemcke 1999

Shipboard Use

Storage	Store in cool area (<room temperature, ideally 25-37 degrees C). Storage at elevated temperatures may shorten shelf-life.	Lubomudrov 1997
Size	Small pumps that meter the chemical into ballast water. Systems could be installed into existing vessels in addition to being integrated into new vessel design.	Lubomudrov 1997
Corrosivity	Will not permanently damage ballast piping or tank systems, nor adversely affect protective coatings on pipes when in solution.	Lubomudrov 1997
Corrosivity	Non-corrosive	Oemcke 1999
Limits	Mixing chemical in tank difficult and doses of 20,000 mg/L are expensive.	Oemcke 1999

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf

USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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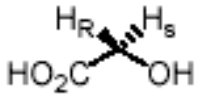
Kirkeby, S, Jacobsen, P., and D. Moe. 1987.	Glutaraldehyde pure and impure. A spectroscopic investigation of two commercial glutaraldehyde solutions and	Anal. Lett 20: 303-315
Lubomudrov, L, R Moll, M Parsons. 1997.	An Evaluation of the Feasibility and Efficacy of Biocide Application in Controlling the Release of Nonindigenous Aquatic Species from Ballast Water	Report to MI DEQ, Office of the Great Lakes : -
McGucken, PA, W. Woodside. 1973.	Studies on the mode of action of glutaraldehyde on Escherichia Coli	J. Appl. Bacteriol 36: 419-
Monsan, P, Puzo, G., and H. Mazarguil. 1975.	Ētude du mechanisme d' establissement des liaisons glutar-aldēhyde-protéines	Biochimica 57: 1281-
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Rubbo, SD, Gardner, J.F., and R.L. Webb. 1967.	Biocidal activities of glutaraldehyde and related compounds	. Appl. Bacteriol 30: 78-
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551
Scott, E, S Gorman. 1991.	Glutaraldehyde. In: Disinfection, Sterilization, and Preservation	S.S. Block (Ed) Lea & Feviger, Philadelphia : -
Stonehill, AA, Krop, S., and P.M. Borick. 1963.	Buffered glutaraldehyde, a new chemical sterilizing solution	Am. J. Hosp. Pharm 20: 458-

Glycolic Acid

$C_2H_4O_3$ **CAS_#** 79-14-1

Moist white crystalline powder



Other Names Acetic acid; hydroxy-;

Trade_Names

Environmental Acceptability

Shipboard Use

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html

NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

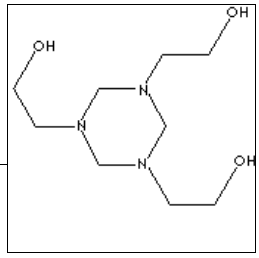
Citations

Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -

Grotan

$C_9H_{21}N_3O_3$

CAS_# 4719-04-4



Alkaline, clear to light yellow viscous liquid used in formulating bactericide and fungicide. It is used as a preservative in oil field applications

Other Names hexahydro-1,2,5-tris(2-hydroxyethyl)-s-triazine; Hexahydro- 1,3 ,5-tris(2-hydroxyethyl)-s-triazine; 1,3,5-triazine-1,3,5-(2H, 4H, 6H)-triethanol; Triazinetriethanol; Tris(2-hydroxyethyl)hexahydro-s-triazine;

Trade_Names Grotan; Triadine 3; Onyxide 200 MUP

Physiochemical Properties	Value or Comment	Citation
Physical State	clear viscous liquid	GR OShea Company 2004
pH	10.3 - 11.3 at 25 deg C	GR OShea Company 2004
Specific gravity	1.152	GR OShea Company 2004
Viscosity	250 cps	GR OShea Company 2004
Solubility in water	miscible with water in all proportions	GR OShea Company 2004
Stability	normal shelf life is a minimum of 2 years	GR OShea Company 2004

Environmental Acceptability

Shipboard Use

Storage	Store in original container for ~2 years when stored between -10 deg C and 40 deg C	GR OShea Company 2004

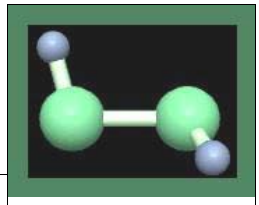
Laws and Regulations

Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

GR OShea Company, , . 2004.	Grotan	http://www.groshea.com/troy/grotan.html : -

Hydrogen Peroxide



H_2O_2 **CAS_#** 7722-84-1

Hydrogen peroxide solutions of 10-25% are used to purify drinking water; treat contaminated water supplies; sterilize spacecraft and disinfect contact lenses. Hydrogen peroxide solutions of 15-35% are used to sterilize the contact surfaces of food packaging. Available as a colorless, syrupy liquid or as a crystalline solid (below 12 deg. F).

Other Names dioxogen; Dihydrogen dioxide; Genoxide+so; Hioxyl; Hydrogen dioxide; hydroperoxide; hydrozone; Lensan A; Mirasept; Oxysept; Oxzone; Pegasyl; Percarbamid; Perhydrol; Peroxal; Peroxol; Peroxyl; Proxy; Truzone

Trade_Names Albone; Kastone; Perone; Tysu; Interox

Physiochemical Properties	Value or Comment	Citation
Physical State	colorless liquid	Hazardous Substances Data Bank 2004
pH	Ineffective throughout pH range	Sagripanti 1996
Density	1.4425 at 25 deg C	Hazardous Substances Data Bank 2004
Solubility in water	miscible with water; In water 1000000 mg/L at 25 deg C.	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
Bacillus subtillus spores	10% is ineffective (<90% inactivation) at room temperature for 30 min	Sagripanti 1996
Crustaceans	from EC50: behaviro, biochemistry, development, intoxication, mortality	PAN 2004
Daphnia magna	Minimum concentration of 18,000 ppm, maximum concentration of 32,000 ppm, and a mean concentraiton of 24,000 ppm will result in the immobility of the species less than 24 hours.	PAN 2004
Daphnia magna	Minimum concentration of 18,000 ppm, maximum concentration of 32,000 ppm, and a mean concentraiton of 24,000 ppm will result in the immobility of the species less than 24 hours.	Pesticide Ecotoxicity Database 2000
Dreissena polymorpha	minimum concentration of 29,300 ug/L, maximum concentration of 298,000 ug/L and a mean concentration of 29,600 ug/L will result in mortality in 3.5 hours.	Matisoff 1996
Fish	EC50: behavior, biochem, feeding behavior, growth, mortality	PAN 2004
Fish	LC50: not acutely toxic	PAN 2004
Fungi	EC50: population	PAN 2004
Molluscs	behavior, mortality, reproduction	PAN 2004
Oscillatoria rubescens	1,750 ug/L will cause mortality in less than 1 day	Barroin 1986
Phytoplankton	EC50: biochem, histology, mortality, physiology, population	PAN 2004
Saprolegnia sp.	100,000 ug/L is toxic to the population	Marking 1994
Zooplankton	EC50: behavior, intoxication, mortality	PAN 2004

Environmental Acceptability

Shipboard Use

Application	Product: $0.34 per lb-50% (FOB Houston, TX); Freight: $3.50 per mile (regardless of delivery volume)	U.S. Peroxide 2004
Storage	Must be stowed "on deck only" on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded. Shade material from radiant heat. Stow separated from flammable solids, permanganates, and powdered metal.	DOT 2002
Storage	Storage tanks should be constructed of high-purity aluminium; keep away from direct heat and sun and combustible materials. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.	Hazardous Substances Data Bank 2004
Handling	Oxidizer hazard class	DOT 2002
Handling	Inhalation, ingestion, or contact (skin, eye) with vapors or substance may cause severe injury, burns, or death; protective chlothing: Wear positive pressure self-contained breathing apparatus (SCBA)	Hazardous Substances Data Bank 2004
Corrosivity	hydrogen peroxide destroys residual chlorine and reduced sulfur compounds thiosulfates, sulfites, and sulfides which form corrosive acids whtn condensed onto processing equipment and oxidized	U.S. Peroxide 2004

	by air	
Ventilation	proper ventilation required	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
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Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	CERCLA section 103, codified at 40 CFR part 302, in addition to requirements of 40 CFR part 355	
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt

Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

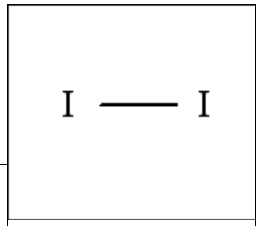
Citations

Barroin, , Feuillade. 1986.	Hydrogen Peroxide as a Potential Algicide for Oscillatoria rubescens	Water Research 20: 619-623
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Hazardous Substances Data Bank, , . 2004.	Hydrogen peroxide	National Library of Medicine Toxnet System : -
Marking, LL, JJ Rach and TM Schreier. 1994.	Evaluation of Antifungal Agents for Fish Culture	Prog Fish Cult 56: 225-231
Matisoff, G, G Brooks and BI Bourland. 1996.	Toxicity of Chlorine Dioxide to Adult Zebra Mussels	J Am Water Works Assoc 88: 93-106
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551
U.S. Peroxide, , . 2004.	Intro to H2O2	www.h2o2.com : -

Iodine

I_2 **CAS_#** 7553-56-2

Iodine is a bluish-black, lustrous solid used as a microbiocide, fungicide, or herbicide.



Other Names iodine crystals; molecular iodine

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Solubility in water	only slightly souble in water; Solubility in water is increased by alkali bromides and decreased by sulfates and nitrates. Measurements: 0.034 g/kg in water @ 25 deg C; 0.029 g/100 cc in water @ 20 deg C; 0.078 g/100 cc in water @ 50 deg C; 330 mg/l in water at 25 deg C	Hazardous Substances Data Bank 2004
Inactivation	Iodine causes chemical action and cell/protein disruption	Letcher 2003

Target Organism	Treatment Dosage	Citation
Feline Calicivirus (FCV)	Final concentration of 0-8% give a Log10 reduction of 1-25	Doultree 1999
fish	moderately toxic	PAN 2004
fungi	no LC50 but population effects from EC50	PAN 2004
Waterborne microorganisms	Iodinated resins: most waterborne microorganisms susceptible to doses up to 5 mg/L as I2	Letcher 2003
zooplankton	highly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Iodine at certain concentrations is toxic to certain fresh water and marine species. Acceptable levels for specific applications are not known.	Letcher 2003
Byproducts	Iodine: same as for bromine except resulting iodinated organics are typically much lower in concentration; reduced form of free iodine-- iodide ion, I-	Letcher 2003

Shipboard Use

Handling	Iodine vapor is irritating to the eyes	Hazardous Substances Data Bank 2004
Corrosivity	Iodine is a powerful oxidizing agent	Hazardous Substances Data Bank 2004
Power Requirements	Needs research	Letcher 2003

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	

Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
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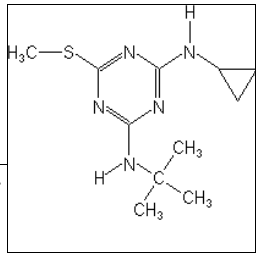
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Brion, GM, J. Silverstein. 1999.	Iodine disinfection of a model Bacteriophage, MS2, demonstrating apparent rebound	Water Research 33: 169-179
Doultree, JC, Druce, J. D., Birch, C. J., Bowsden, D. S., and J. A. Marshall. 1999.	Inactivation of feline calicivirus, a Norwalk virus surrogate	The Hospital Inspection Society : -
Hazardous Substances Data Bank, , . 2004.	Iodine	National Library of Medicine Toxnet System : -
Letcher, J, . 2003.	Telephone conversation with Jerry Letcher, Sales Manager	Pentair Water Treatment/Plymouth Products : -
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Irgarol 1051 (Cybutryne)

$C_{11}H_{19}N_5S$ **CAS_#** 28159-98-0



Microbiocide used for antifouling. Available as a white or slightly yellow powder.

Other Names 1,3,5-Triazine-2,4-diamine; N-cyclopropyl-N'-(1,1-dimethylethyl)-6-(methylthio)-; 2-(tert-Butylamino)-4-(cyclopropylamino)-6-(methylthio)-1,3,5-triazine; 2-(tert-butylamino)-4-cyclopropylamino-6-methylthio-1,3,5-triazine; Cyclopropyl-n'(1,1,dimethylethyl)-6-(methylthio)1,3,5-triazine,2,4,di=; N-Cyclopropyl-N'-(1,1-dimethylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine; s-Triazine; 2-(tert-butylamino)-4-(cyclopropylamino)-6-(methylthio)-

Trade_Names Irgarol 1051; Irgarol 1071

Physiochemical Properties	Value or Comment	Citation
Physical State	crystalline powder	Ciba Specialty Chemicals, Inc. 1999
Solubility in water	7 mg/L; Kow = 3.95; Koc = 3100 L/kg (dissolved phase), 1240 L/kg (suspended phase)	Albanis 2002
Solubility in water	Water solubility dependent on salinity values at 25 deg C and pH of 7: 0.0 Mol NaCl/L = 9mg/L; 0.3 Mon NaCl/L = 5.9 mg/L; 0.6 Mol NaCl/L = 1.8 mg/L	Ciba Specialty Chemicals, Inc. 1999
Inactivation	blocks pivotal step of electron transport	Ciba Specialty Chemicals, Inc. 1999

Target Organism	Treatment Dosage	Citation
Algae	Concentration between <1 and 1700 ng/l. Safety level of 0.4 ug/L for algae, 1.6 ug/L for other aquatic organsims.	Thomas 2001
Anthocidaris crassispina	At higher concentration of 10 mg/L, the eggs were mostly unfertilized and later showed induced cytolysis. Retarded cleavage and development were evident at 1 mg/L. The concentration of 0.01-0.1 mg/L induced cytolysis and allowed a normal state.	Kobayashi 2002
aquatic plants	EC50: accumulation, growth, physiology, population	PAN 2004
Crustacean, A. salina	For a concentration level of 40 mg/L, Irgarol caused 30% mortality of the organisms	Okamura 2000
cyanobacteria (Anabaena flos-aquae)	2 ug/L	Ciba Specialty Chemicals, Inc. 1999
D. magna	The toxicity of Irgarol 1051 was by a 48 h-EC50 value of 8.1 mg/L and a LC50 value of 0.86 mg/L.	Okamura 2000
Daphnia	LC0 is 440 ug/L	Ciba Specialty Chemicals, Inc. 1999
diatoms	0.1 to 0.4 ug/L	Ciba Specialty Chemicals, Inc. 1999
Enteromorpha intestinalis	An EC50 value of 5.4 ug/L inhibted the growth.	Okamura 2000
fish	LC50: moderately toxic	PAN 2004
green algae (Raphidocelis subcapitata)	1 ug/L	Ciba Specialty Chemicals, Inc. 1999
Hemicentrotus pulcherrimus	At higher concentration of 10 mg/L, the eggs were mostly unfertilized and later showed induced cytolysis. Retarded cleavage and development were evident at 1 mg/L. The concentration of 0.01-0.1 mg/L induced cytolysis and allowed a normal state.	Kobayashi 2002
higher plants (Lemna gibba)	2 ug/L	Ciba Specialty Chemicals, Inc. 1999
Lemma gibba	A 14-day EC50 value of 1.62 ug/L inhibited the growth.	Okamura 2000
molluscs	EC50: intoxication	PAN 2004
Mysid shrimps	LC0 is 130 ug/L	Ciba Specialty Chemicals, Inc. 1999
oyster larvae	LC50 over 48 hours was 3200 ug/L.	Ciba Specialty Chemicals, Inc. 1999
Periphyton community	At concentration levels of 63-250 ng/L in seawater, Irgarol was shown to be capable of damaging sensitive periphyton communities.	Okamura 2000
Periphyton community	Detection limit of 1-5 ng/L. Irgarol is toxic to microalgal communities of Enteromorpha intestinalis at 50 ng/L and long term effects on periphyton communities in coastal water were observable at ambient levels between 63 and 250 ng/L	Liu 1998
Periphyton community	Irgarol with concentration of 1 nM (approximately 250 ng/L) produced changes in the structure of the periphyton community.	Connelly 2001

phytoplankton	EC50: ecosystem process, physiology, population	PAN 2004
Rainbow Trout	The toxicity of Irgarol 1051 was by a 48 h-EC50 value of 8.1 mg/L and a LC50 value of 0.86 mg/L.	Okamura 2000
S. capricornutum	The phototoxicity of Irgarol has been reported as 1.26 ug/L (120 h-EC50) and 0.45 ug/L (120 h-EC50).	Okamura 2000
Sea organism	Cell density range from 0.136 ppb for Navicula pelliculosa (a freshwater diatom) to 2.07 for Anabaena flos-aquae (a freshwater blue algae). The value varies from 400 ppb for Misidopis bahia to 5300 ppb for Daphnia magna.	Voulvoulis 2000
Skeletonema costatum	The phototoxicity of Irgarol has been reported as 1.26 ug/L (120 h-EC50) and 0.45 ug/L (120 h-EC50).	Okamura 2000
V. fisheri	For a concentration level up to 50 mg/L, had little effect on the organism.	Okamura 2000
zooplankton	LC50: moderately toxic	PAN 2004
Zostera marina	An Irgarol concentration of 0.18 ug/L can reduce the growth rate of the leaves. Where the concentration was found mainly in leaves than in roots.	Scarlett 1999

Environmental Acceptability

Environmental Acceptibility	half life of 25 days; does not bioaccumulate and is of low risk to animals like oysters, curstaceans, fish or birds at concentrations designed to inhibit target organisms (e.g., photosynthetic organisms). Koc: 3100 L/kg (dissolved phase, 1240 L/kg (suspended phase).	Ciba Specialty Chemicals, Inc. 1999
Environmental Acceptibility	not readily degraded with half life of 100 days	Thomas 2000
Environmental Acceptibility	anaerobic half lifeover 226 days	Thomas 2003
Byproducts	inactive metabolites	Ciba Specialty Chemicals, Inc. 1999
Byproducts	Chemical degradation of 1051 by mercuric chloride appeared to follow the reaction of a catalyzed hydrolysis and the mech apparently involved the formation of bidentate chelation, which weakened the cyclopropylamino bond and resulted in formation of a hydrolysis product M1. M1 is the major degradation product during the biological and chemical degradation of 1051.	Liu 1998
Byproducts	iodegradation, photodegradation, and chemical hydrolysis of Irgarol 1051 as the result in n-dealkylation to yield 2-methylthio-4-tert-butylamino-6-amino-s-triazine (GS26575) as the principle of degradation product	Thomas 2000
Inhibitors	Half life: 100 or 200 days for marine or freshwater, respectively	Albanis 2002
Effectiveness Factor	As a herbicide, Irgarol 1051 is much more toxic to algae and higher plant species, mainly due to inhibition of photosynthesis.	Okamura 2000
Effectiveness Factor	When some flushing is allowed (in open tidal marinas, the runoff is quickly diluted and flushed out by the tide), 1051 concentration was found higher than non-flushing	Thomas 2001

Shipboard Use

Laws and Regulations

Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf

Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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Ciba Specialty Chemicals, Inc., , . 1999.	Part 1 General Information: Physical Information and algaecide properties, health and environmental effects, risk assessemnt and registration status	: 1-9
Connelly, DP, JW Readman, AH Knap, J Davies. 2001.	Contamination of the coastal waters of Bermuda by organotins and the triazine herbicide Irgarol 1051	Marine Pollution Bulletin 42: 409-414
Kobayashi, N, H Okamura. 2002.	Effects of new antifouling compounds on the development of sea urchin	Marine Pollution Bulletin 44: 748-751
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Okamura, H, I Aoyama, D Liu, RJ Maguire, GJ Pacepavicius, YL Lau. 2000.	Fate and ecotoxicity of the new antifouling compound Irgarol 1051 in the aquatic environment	Water Research 34: 3523-3530
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Scarlett, A, P Donkin, TW Fileman, SV Evans, ME Donkin. 1999.	Risk posed by antifouling agent Irgarol 1051 to the seagrass, Zostera marina	Aquatic Toxicology 45: 159-170
Thomas, KV, M McHugh, M Hilton, M Waldock. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution 123: 153-161
Thomas, KV, SJ Blake, MJ Waldock. 2000.	Antifouling Paint Booster Biocide Contamination in UK Marine Sediment	Marine Pollution Bulletin 40: 739-745
Thomas, KV, TW Fileman, SV Evans, ME Donkin. 2001.	Antifouling paint booster biocides in the UK coastal environment and potential risks of biological effects	Marine Pollution Bulletin 42: 677-688
Tolosa, I, Readman, J. W., Blaevoet, A. Ghilini, S., Bartocci, J., and Horvat, M. 1996.	Contamination of Mediterranean (Cote d' Azur) Coastal Waters by Organotins and Irgarol 1051 Used in Antifouling Paints	Marine Pollution Bulletin PII: S0024-326X(96)00013-6. : -

Voulvoulis, N, MD Scrimshaw, JN Lester. 2000.	Occurrence of four biocides utilized in antifouling paints as alternatives to organotin compounds in waters sediments of commercial estuary in the UK	Marine Pollution Bulletin 40: 938-946

Mexel 432 (Fatty Amines)

CAS_# 00-00-0

This mixture of aliphatic amine surfactants is an anti-fouling material that acts as a corrosion inhibitor and scale dispersant as well as having activity against freshwater and saltwater mussels and barnacles; commercial mulluscicide using 1.7 % solution of (alkylamino)-3-aminopropane. Available as a slightly milky homogeneous liquid.

Other Names chemical name = (Alkylamino)-3-aminopropane

Trade_Names Mexel 432/0

Physiochemical Properties	Value or Comment	Citation
pH	11	RTK Technologies, Inc 2004
Stability	Half life of 22 hours in river water; decreases to ~ 6 hours with aeration and agitation	RTK Technologies, Inc 2004
Inactivation	registered as a FIFRA muluscicide; effectvie in inhibiting toxic algae blooms and growth of bacteria colonies by retarding population growth by eliminating the habitat toxic to fish	RTK Technologies, Inc 2004

Environmental Acceptability

Environmental Acceptibility	contains no halogens, aromatics, quaternary amines, phosphorus, heavy metals, sulfur, cyclic hydrocarbons, zinc, or oxidizing agents	RTK Technologies, Inc 2004
Byproducts	only products of its biodegradation are carbon dioxide, water, and a trace of nitrogen	RTK Technologies, Inc 2004

Shipboard Use

Application	0.033 lbs/day per 100 sq ft of surface per day (for controlling mollusks in closed delivery systems)	RTK Technologies, Inc 2004
Storage	Store the barrels hermetically closed far of bad weather and without intense heat source (<60 deg C). Avoid oxidizing agents (peroxides, perchlorates, nitrates, etc.) strong acid and halogen-organic compounds.	RTK Technologies, Inc 2004
Handling	non-flammable, low vapor pressure -- safe to use in confined spaces	RTK Technologies, Inc 2004
Corrosivity	Used as a corrosion inhibitor	RTK Technologies, Inc 2004
Ventilation	well ventilated area	RTK Technologies, Inc 2004

Laws and Regulations

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Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or	http://www.unepmap.gr/pdf/dumping.pdf

	Incineration at Sea	
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
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Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

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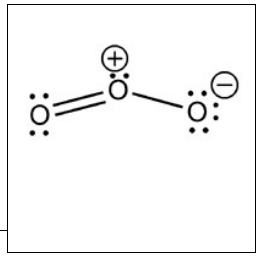
RTK Technologies, Inc, , . 2004.	About Mexel® 432/0	http://www.rtkti.com/aboutmexel.html : -

Ozone

O_3 **CAS_#** 10028-15-6



Ozone is found in the atmosphere in varying proportions as it is produced continuously in the outer layers of the atmosphere by the action of solar UV radiation on the oxygen of the air. It is also formed locally in the air from lightning and electrical sparks. In freshwater, ozone is an excellent disinfectant and in seawater, ozone is used to control bacteria and viruses. Available as in gas form, in liquid form (below its boiling point of -112 deg. C), or in solid form (below its melting point of -193 deg. C)

Other Names Triatomic oxygen, trioxygen

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	gas	U.S. EPA 1999
pH	Ozone decomposes faster as pH increases but biocidal activity not influenced by pH	U.S. EPA 1999
Specific gravity	2.144	CCOHS 2004
Solubility in water	Slightly soluble (0.11 g/100 mL or 49.4% v/v at 0 deg C ; 0.06 g/100 mL at 20 deg C)	CCOHS 2004
Solubility in water	sparingly soluble	U.S. EPA 1999
Stability	Reacts with dissolved organics, iron(II), manganese(II), and sulphite very quickly.	Oemcke 1999
Stability	decays rapidly at high pH and warm temperatures	U.S. EPA 1999
Inactivation	Cell wall rupture (lysing)	Jackson 2003
Inactivation	Production of halogens and injection of ionized air	Stewart 2003
Inactivation	attacks bacterial membranes and disrupts enzymatic activity, and may also act on the nuclear material within cell. Virus inactivation is the virion capsid, particularly the proteins. RNA may also be the target	U.S. EPA 1999

Target Organism	Treatment Dosage	Citation
All microroganisms	1 mg/L	Jackson 2003
Cryptosporidium parvum	40 mg/L effective dose for drinking water	Biswas 2003
Cryptosporidium parvum oocysts	4-10 min*mg/L can achieve 2-log (99%) reduction	Oemcke 1999
Cryptosporidium parvum oocysts	1 ppm (1 mg/L) for 5 min achieved > 90% inactivation	Korich 1990
Enterococci	~2-log reduction: 30-50 mg/L	Gehr 2003
Entrococcus seriolicida	0.111 mg/L achieves 2-log (99%) reduction or 0.123 mg*min/L; 0.177 mg/L achieves 3-log (99.9%) reduction or 0.186 mg*min/L; 0.246 mg/L achieves 4-log reduction; 0.319 mg/L achieves 5-log reduction; 0.393 mg/L achieves 6-log reduction	Sugita 1992
Escherichia coli	0.6 ug/L dissolved ozone can achieve 4-log (99.99%) reduction in less than 1 minute with a residual of 9 ug/L at 12 degrees C.	U.S. EPA 1999
fish	LC50: highly toxic	PAN 2004
Giardia cysts	To achieve 0.5-log, 1.0-log, 1.5-log, 2.0-log, 2.5-log, 3.0-log inactivation: 0.23 mg-min/L, 0.48 mg-min/L, 0.72 mg-min/L, 0.95 mg-min/L, 1.2 mg-min/L, and 1.43 mg-min/L.	Cowley 1999
Giardia muris	Inactivation at pH 8 and 15 deg C shows dependency between log kill and the initial concentration of microorganisms. The level of inactivation decreases as initial organism concentration decreases.	Hass 2003
Giardia muris cysts	2 min*mg/L can achieve 2-log (99%) reduction	Oemcke 1999
Legionella pneumophila	0.21 mg/L ozone can achieve 2-log (99%) removal within 5 min	U.S. EPA 1999
molluscs	EC50: mortality	PAN 2004
MS-2	Less resistant than enterococci	Gehr 2003
Mycobacterium tuberculosis	0.21 mg/L ozone achieves 4-log (99.99%) reduction with >30 min contact time	U.S. EPA 1999
Pasteurella piscicida	2-log removal: 0.063 mg/L or 0.057 mg*min/L; 3-log removal: 0.089 mg/L or 0.084 mg*min/L; 4-log removal: 0.115 mg/L; 5-log removal: 0.140 mg/L; 6-log removal: 0.165 mg/L	Sugita 1992
Perfringens	More resistant than enterococci	Gehr 2003
Streptococcus faecalis	0.21 mg/L ozone achieves 2-log (99%) reduction with contact time of >10 min	U.S. EPA 1999
Vibrio anguillarum	2-log removal: 0.081 mg*min/L; 3-log removal: 0.123 mg*min/L	Sugita 1992
Viruses	To achieve 2-log, 3-log, 4-log inactivation: 0.5 mg-min/L, 0.8 mg-min/L, 1.0 mg-min/L,	Cowley 1999

	respectively.	

Environmental Acceptability

Environmental Acceptibility	Brominated organics and bromate can have negative environmental impacts at low concentrations.	Oemcke 1999
Byproducts	Oxygen, brominated organics; Brominated organics are naturally biodegradable	Jackson 2003
Byproducts	Brominated organics, bromate, and bromines	Oemcke 1999
Byproducts	organic acids and aldehydes. If bromide ion is present or chlorine added, halogenated DBPs may form	U.S. EPA 1999
Effectiveness Factor	Ozone is more effective in freshwater systems.	Oemcke 1999
Effectiveness Factor	As temperature increases, ozone becomes less soluble and less stable in water.	U.S. EPA 1999

Shipboard Use

Generation	Ozone is generated on-site, at its point of use usually by dissociation of molecular oxygen electrically (silent discharge) or photochemically (ultraviolet irradiation).	CCOHS 2004
Generation	Ozone can be safely generated with on-site air.	Oemcke 1999
Generation	should be generated at the point of use. Feed gas should be clean and dry with max dewpoint of -60 deg C. Relatively complex process	U.S. EPA 1999
Storage	not easily stored	CCOHS 2004
Handling	Even very low concentrations of ozone can be harmful to the upper respiratory tract and the lungs.	CCOHS 2004
Handling	ozone is a toxic gas	U.S. EPA 1999
Corrosivity	Attacks most metals including iron and mild steel.	CCOHS 2004
Corrosivity	Hyprobromous acid will have little effect, which is what will be the result of controlled application of ozone; Oxidation of the steel if ozone application is not controlled	Jackson 2003
Corrosivity	highly corrosive	U.S. EPA 1999
Power Requirements	Usually single-phase 115/230 vac. Possibly three-phase 460 vac.	Jackson 2003
Power Requirements	rate of 8 to 17 kWhr/kg O3	U.S. EPA 1999
Maintenance	Semi-annual service if the gas supply and ozonator units. Ususally 1 day twice per year.	Jackson 2003
Maintenance	Regular visual inspections and reading the maintenance log. Annual change out of Ionz cells and chlorine generators.	Stewart 2003

Laws and Regulations

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Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
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USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
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Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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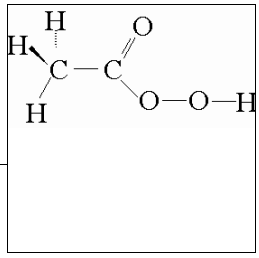
Cowley, G, . 1999.	Disinfection with Chlorine Dioxide	Sterling Pulp Chemicals : 1-9
Gehr, R, M Wagner, P Veerasubramanian, P Payment. 2003.	Disinfection efficiency acid, UV and ozone after enhanced primary treatment of municipal wastewater	Water Research 37: 4573-4586
Hass, CN, B Kaymak. 2003.	Effect of Initial Microbial Density on Inactivation of Giardia Muris by Ozone	Water Research 37: 2980-2988
Jackson, J, . 2003.	Telephone conversation with James Jackson	GDT Corporation : -
Korich, DG, JR Mead, MS Madore, NA Sinclair, CR Sterling. 1990.	Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on Cryptosporidium parvum Oocyst Viability	Applied and Environmental Microbiology 56: 1423-1428
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Stewart, J, . 2003.	Telephone conversation with Jon Stewart, Vice President of Sales	Marine Environmental Partners : -
Sugita, H, T Asai, K Hayashi, T Mitsuya, K Amanuma, Y Deguchi. 1992.	Application of Ozone Disinfection to Remove Enterococcus seriolicida, Pasteurella piscicida, and Vibrio anguillarum from Seawater	Applied Environmental Microbiology 58: 4072-4075
U.S. EPA, , . 1999.	Alternative Disinfectants and Oxidants Guidance	EPA Report 815-R-99-014 : -

Peracetic Acid (Peroxyacetic Acid)

$C_2H_4O_3$ **CAS_#** 79-21-0



Available as a liquid.

Other Names Acetic peroxide; Acetyl hydroperoxide; Ethaneperoxoic acid; Monoperacetic acid; Peroxoacetic acid; Peroxyacetic acid

Trade_Names Peraclean®

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid based on peroxy acetic acid	Fuchs 2001
pH	pH of treated sea water is recuded from 8.2 to 6.1, due to acidic properties of peraclean	Fuchs 2001
Solubility in water	very soluble in water	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
brine shrimp, Artemia salina, at four stages	levels above 350 ppm resulted in 100% mortality of all Artemia live stages.	Fuchs 2001
coliforms	Intial concentration of 0.5-4 mg/L with 8-38 min contact time. Low contact time: 8-12 min, med contatc time: 20-26 min, high contact time of 36-39 min.	Veschetti 2003
Everything down to 40 uM	With filtration, 50 ppm	Fredericks 2003
fish	no LC50; immunological, mortality from EC50	PAN 2004
Fungi	population effects based on EC50	PAN 2004
Giardia muris	90% inactivation has CT of 1.2 mg-min/L and for 99% inactiviation CT of 2.6 mg-min/L. When H2O2/O3 ratio is 0.2, 90% inactivation CT of 2.6 mg-min/L and for 99% inactivation CT of 5.2 mg-min/L	U.S. EPA 1999
poliovirus	99% inactivation requires hydrogen peroxide dose of 3,000 mg/L for 360 minutes or 15,000 mg/L for 24 minutes.	U.S. EPA 1999

Environmental Acceptability

Environmental Acceptibility	not expected to adsorb to suspended solids and sediment in water based on an estimated Koc value of 4	Hazardous Substances Data Bank 2004
Byproducts	expected to hydrolyze slowly to acetic acid and hydrogen peroxide in water	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	shelf life is at least 1 year. More than 90% of original activity present after 1 year stored at room temp. Available in 220 L drums, 1 m3 IBCs or 20 m3 bulk.	Fuchs 2001
Storage	Store in a cool, dry, well-ventilated location. Separate from acids, alkalies, organic materials, heavy metals. Normally kept refrigerated outside or detached storage is preferred	Hazardous Substances Data Bank 2004
Corrosivity	Corrosive to most metals, including aluminum	Hazardous Substances Data Bank 2004

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European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
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USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
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Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

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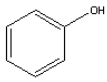
Fuchs, R, N. Steiner, I. deWilde, and M. Voigt. 2001.	Peraclean Ocean - a Potential Ballast Water Treatment Option	1st International Ballast Water Treatment R&D Symposium, IMO, London : -
Gehr, R, M Wagner, P Veerasubramanian, P Payment. 2002.	Disinfection Efficiency of Peracetic Acid, UV and Ozone after Enhanced Primary Treatment of Municipal Wastewater	Water Research 37: 4573-4586
Hazardous Substances Data Bank, , . 2004.	Peracetic Acid	National Library of Medicine Toxnet System : -
Oemcke, D, . 1999.	The Treatment of Ships' Ballast Water	EcoPorts Monograph Series 18: -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551
Veschetti, E, D. Cutili, L Bonadona, R Briancesco, C Martini, G Cecchini, P anastasi, M Ottaviani. 2003.	Pilot-plant comparative study of peracetic acid and sodium hypochlorite wastewater disinfection	Water Research 37: 78-94

Phenol

C_6H_6O **CAS_#** 108-95-2

Available commercially as a liquid, but is a colorless solid when pure.



Other Names Phenylic acid; Carbolic acid; Benzene, hydroxy-; Phenyl hydroxide; Hydroxybenzene; Oxybenzene; monohydroxy benzene; monophenol; Phenyl alcohol; Phenic Acid; phenol alcohol;

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	colorless acicular crystals or white crystal mass	Hazardous Substances Data Bank 2004
Density	1.071 g/cu cm	Hazardous Substances Data Bank 2004
Solubility in water	1 g/15 ml water	Hazardous Substances Data Bank 2004
Stability	half-life about 9 days in saltwater	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
amphibians	slightly toxic	PAN 2004
annelida	not acutely toxic	PAN 2004
aquatic plants	not acutely toxic	PAN 2004
crustaceans	slightly toxic	PAN 2004
fish	slightly toxic	PAN 2004
molluscs	not acutely toxic	PAN 2004
nematodes and flatworms	not acutely toxic	PAN 2004
phytoplankton	not acutely toxic	PAN 2004
zooplankton	slightly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	will adsorb to suspended solids and sediments with Koc of 2900 to 3100. Log Kow 1.46	Hazardous Substances Data Bank 2004

Shipboard Use

Storage	Material may be stowed "on deck" or "under deck" on cargo or passenger vessels.	DOT 2002
Storage	Phenol and its solutions are flammable. Stored in closed containers protected from light and area well-ventilated. Prevent overheating and buildup of pressure in phenol containers	Hazardous Substances Data Bank 2004
Handling	strong irritant to tissue. Vapor irritates respiratory system and eyes. Wear protective clothing, gloves, face shields, splash-proof safety goggles.	Hazardous Substances Data Bank 2004
Ventilation	Poison hazard class.	DOT 2002
Ventilation	Concentrations should not exceed 20 mg/cu m.	Hazardous Substances Data Bank 2004

Laws and Regulations

Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development	http://sedac.ciesin.org/entri/texts/mar

	of the Marine and Coastal Environment of the Eastern Africa Region	ine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Occupational Safety and Health Act	http://www4.law.cornell.edu/uscode/29/ch15.html
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Hazardous Substances Data Bank, , . 2004.	Phenol	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551

Polyhexamethylene Biguanide (PHMB)

proprietary

CAS_# 32289-58-0

Light blue liquid used as microbiocide, fungicide. Also available as a solid in tablet form.

Other Names Baquacil; Baquacil SB; poly hexamethlene biguanidine; polyhexamethylene diguanide chlorhydrate; PHMB; Poly (iminocarbonimidoyliminocarbonimidoylimino-1,6-hexanediyl), hydrochloride; Poly (iminoimidocarbonyliminoimidocarbonyliminohexamethylene) hydrochloride

Trade_Names Vantocil 1B; Baquacil SB; Baquacil; Cosmoquil CQPoly Clear Maxi Polish Swimming Pool Sanitizer and Algistat

Physiochemical Properties	Value or Comment	Citation
Physical State	20% active ingredient in water solution	Alden Leeds 2002
pH	4.5 - 6.0	Alden Leeds 2002
Specific gravity	1.04	Alden Leeds 2002
Solubility in water	Soluble	Alden Leeds 2002
Stability	stable product	Alden Leeds 2002

Target Organism	Treatment Dosage	Citation
annelida	LC50: slightly toxic	PAN 2004
fish	LC50: moderately toxic	PAN 2004
zooplankton	EC50: intoxication	PAN 2004

Environmental Acceptability

Environmental Acceptibility	Material is toxic to fish if released.	Alden Leeds 2002

Shipboard Use

Application	Dosing equipment required	Alden Leeds 2002
Storage	Store in Polyethylene, Polypropylene, Vinyl Polychloride and avoid temperatures below 43F to avoid freezing and do not store near Chlorine, Bromine, Ozone, Sodium Hydroxide, Copper, Silver, and most metals.	Alden Leeds 2002
Handling	Gloves, goggles/glasses, and long sleeves should be worn when handling.	Alden Leeds 2002
Ventilation	Local ventilation adequate	Alden Leeds 2002

Laws and Regulations

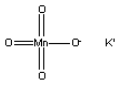
Citations

Alden Leeds, , . 2002.	Poly Clear MSDS	http://www.aldenleeds.com/html/poly_clear.html : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Potassium Permanganate

$KMnO_4$ **CAS_#** 7722-64-7

Dark green solid used as a metal stain as well as an oxidizer in a number of histological and electron microscope laboratory sample preparation procedures. Can also be made into a liquid solution.



Other Names

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	crystalline solids	U.S. EPA 1999
pH	better biocide under acidic conditions around pH of 6	U.S. EPA 1999
Density	100 lb/ft3	U.S. EPA 1999
Solubility in water	6.4 g/mL at 20 deg C	U.S. EPA 1999
Inactivation	direct oxidation of cell material or specific enzyme destruction.	U.S. EPA 1999

Target Organism	Treatment Dosage	Citation
annelida	LC50: very highly toxic	PAN 2004
asiatic clams	juvenile clam doses range from 1.1 to 4.8 mg/L	U.S. EPA 1999
coliform bacteria	doses of 1 and 2 mg/L needed contact time of 30 minutes. Doses of 3, 4, 5, and 6 mg/L needed contact time of 10 minutes.	U.S. EPA 1999
coliform bacteria	high doses required. For coliforms, 2.5 mg/L for complete inactivation	U.S. EPA 1999
crustaceans	LC50: moderately toxic	PAN 2004
fish	LC50: moderately toxic	PAN 2004
Legionella pneumophila	CT values for 99% (2-log) inactivation at pH 6 were 42.7 mg-min/L at a dose of 1 mg/L (contact time 42.7 min) and 41 mg-min/L at a dose of 5 mg/L (contact time 8.2 min).	U.S. EPA 1999
molluscs	LC50: slightly toxic	PAN 2004
MS-2 bacteriophage	0.5 to 5 mg/L capable of obtaining 2-log inactivation with E. coli as host bacterium. At pH 6 and 8, a 2-log inactivation occurred after a contact time of 52 minutes and a residual of 0.5 mg/L. At residual of 5 mg/L, approx 7 and 13 minutes required for 2-log inactivation at pHs of 8 and 6, respectively.	U.S. EPA 1999
phytoplankton	EC50: biochem, cell, mortality, population	PAN 2004
Vibrio cholerae, Salm. Typhi, and Bact. Flexner	doses of 20 mg/L and contact time of 24 hours needed	U.S. EPA 1999
viruses	50 mg/L and contact time of 2 hours required for poliovirus. Dose of 5 mg/L and contact time of 33 minutes needed for 1-log inactivation of type 1 poliovirus. Higher inactivation rate at 23 deg C than at 7 deg C.	U.S. EPA 1999
zebra mussels	continuous dosing of 0.5 to 2.5 mg/L	U.S. EPA 1999
zooplankton	LC50: highly toxic	PAN 2004

Environmental Acceptability

Environmental Acceptibility	residual levels give water a pink color.	U.S. EPA 1999
Byproducts	manganese dioxide as a precipitant. Microogranisms adsorb to these particles and settled.	U.S. EPA 1999
Inhibitors	Presence of oxidizable organics and inorganics in water reduces disinfection effectiveness.	U.S. EPA 1999
Effectiveness Factor	reaction rates depend on temperature, pH, and dosage. Better biocide under acidic conditions. Higher temperatures enhance bactericidal action. Long contact time required.	U.S. EPA 1999

Shipboard Use

Generation	generated on-site by using dry crystalline solids with makeup water. Costs ranges from $1.50 to $2.00 per pound (1997 costs). May need dry chemical feeder, storage hopper, and dust collector for large systems. Small systems may need dissolver/storage tank with mixers and a metering pump.	U.S. EPA 1999
Storage	Must be stowed "on deck only" on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded. Stow separated from ammonium compounds, cyanides, hydrogen peroxide, powdered metal, peroxides and superoxides.	DOT 2002
Storage	easy to store	U.S. EPA 1999

Handling	Oxidizer Hazard Class; medium degree of danger presented by material.	DOT 2002
Handling	can cause serious eye injury and is a skin and inhalation irritant so safety goggles and a face shield, gloves, coveralls and boots should be worn.	U.S. EPA 1999

Laws and Regulations

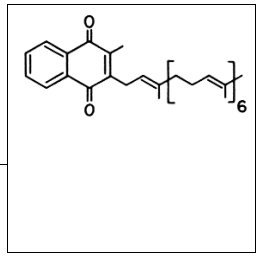
Country_Region	Regulation	Web site
	East Asian Seas Action Plan	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean Region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Anderson, WB, CI Mayfield, DG Dixon, PM Huck. 2003.	Endotoxin Inactivation by Selected Drinking Waer Treatment Oxidants	Water Research 37: 4553-4560
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
U.S. EPA, , . 1999.	Alternative Disinfectants and Oxidants Guidance Manual	EPA 815-R-99-014 : -

SeaKleen (Vitamin K)

$C_{31}H_{40}O_2$ **CAS_#** 11032-49-8



Vitamin K2. Available in powder form and used as a biocide.

Other Names Menaquinone-4; Menatetrenone

Trade_Names SeaKleen

Physiochemical Properties	Value or Comment	Citation
Physical State	powder	Hyde OptiMarin 2004
Solubility in water	soluble	Hyde OptiMarin 2004
Stability	half life in fresh and salt waer is 18-24 hours depending upon dosage	Hyde OptiMarin 2004
Stability	degrade relatively rapidly with half life of 16-30 hour. Remains in dissolved form in heavy sediment loads.	Wright 2001

Target Organism	Treatment Dosage	Citation
bivalve larvae (zebra mussels)	1 ppm	Wright 2001
dinoflagellates and dinoflagellates cysts	1 ppm. Complete chloroplast destruction within 2 hours.	Wright 2001
Eurytemora, Cyprinodon eggs, dinoflagellates	low dose (1-2 ppm)	Hyde OptiMarin 2004
fish larvae and eggs	1 ppm	Wright 2001
Isochrysis galbana, Neochloris, zebra mussel larva	very low dose (1-2 ppm)	Hyde OptiMarin 2004
Leptocheirus plumulosus	1 ppm	Wright 2001
Oyster mussel larvae, E. coli, Cholera	low dose (1-2 ppm)	Hyde OptiMarin 2004
Vibrio bacteria	1 ppm	Wright 2001

Environmental Acceptability

Environmental Acceptibility	environmental friendly compounds are discharged	Hyde OptiMarin 2004
Environmental Acceptibility	does not present toxic threat to receiving waters.	Wright 2001
Byproducts	environmentally friendly compounds	Hyde OptiMarin 2004
Byproducts	non toxic compounds in marine environment	Wright 2001

Shipboard Use

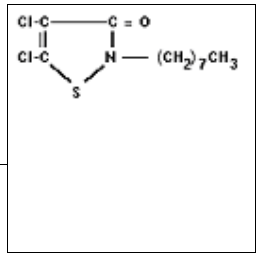
Generation	delivered as a soluble powder which is dissolved in water prior to being injected into the influent ballast water stream.	Hyde OptiMarin 2004
Application	1-2 g. per metric ton of ballast water. Retail at less than $0.2 per metric ton of ballast water treated. Dosing equipment retails at $1600.	Wright 2001
Handling	no special training needed	Hyde OptiMarin 2004
Size	complete system includes a chemical storage and handling system, mixing system, and accurate chemical metering system.	Hyde OptiMarin 2004
Corrosivity	not corrosive to piping and ballast tanks	Hyde OptiMarin 2004

Laws and Regulations

Citations

Hyde OptiMarin, , . 2004.	SeaKleen Treatment	http://www.hydeweb.com/ballast/seakleen.htm : -
Wright, D, Rodger Dawson. 2001.	SeaKleen, a Potential Natural Biocide for Ballast Water Treatment	1st International Ballast Water Treatment R&D Symposium, IMO, London : -

Sea-Nine



$C_{11}H_{17}Cl_2NOS$ **CAS_#** 64359-81-5

4,5-dichloro-2-n-octyl-4-isothiazonline-3-one (DCOI) supplied in 30% solution in xylene as commercial product

Other Names 4,5-dichloro-2-n-octyl-3(2H)-isothiazolone; 4,5-dichloro-2-octyl-3(2H)-isothiazolone

Trade_Names C-9211; DCOI; Duracide L Meldewcide; Kathon 287T; Kathon 5287; Kathon 930; Sea-Nine 211; Sea Nine 211; RH-25287

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid solution	Rohm & Hass 2003
Solubility in water	6.5 mg/L at 20 deg C; log Kow = 2.8; log Koc = 3.2	DEPA 2000
Solubility in water	4.7 g/m3	Gandrass 2001
Solubility in water	Koc = 15000 kg/L	Thomas 2003
Stability	biological half-life may be estimated at 14 hours at 12° C ; The aerobic half-life of DCOI is very short in marine systems with sediment and seawater (< 1 hour)	DEPA 2000
Stability	leaching rate = 1 (0.1-5) ug/cm2/day	Gandrass 2001
Inactivation	Similar effects whether freshwater or seawater.	DEPA 2000

Target Organism	Treatment Dosage	Citation
Algae	EC50 = 0.0139-0.036 mg/L for 4-5 days exposure	DEPA 2000
Balanus amphitrite	LC50 with active ingredient (ai) = 0.34 ppm	Rohm & Hass 2003
Bay Mussels	48-hour LC50 (embryo) = 2 ug/L; 48-hour LC50 (larvae) = 2 ug/L	Kobayashi 2002
Bluegill	96-hour static LC50 (0.5-1.1 g fish) = 19.8 - 26.7 ppb (highly toxic)	PAN 2004
Brown shrimp	juvenile shrimp 96-hour LC50 = 27 ppb highly toxic	PAN 2004
Crustaceans	EC/LC50 = 0.0047-1.312 mg/L for 2-4 days; NOEC (reproduction) = 0.0006 mg/L (21 days)	DEPA 2000
Daphnia magna	48-hour EC50 = 5.22 ppb for flow-through	PAN 2004
Diatom	96-hour EC50 = 18 ppb	PAN 2004
Ectocarpus siliculosis	(Algae) Minimum inhibitory concentration (MIC) with active ingredient (ai) = 0.2 ppm	Rohm & Hass 2003
Enteromorpha intestinalis	(Algae) Minimum inhibitory concentration (MIC) with active ingredient (ai) = 0.1 ppm	Rohm & Hass 2003
Fiddler crab	15-cm crabs: 96-hour LC50 = 1700 ppb (moderately toxic)	PAN 2004
Fish	LC50 = 0.0027-0.03 mg/L for 4 days; NOEC (early life stage) = 0.006 mg/L for 35 days exposure	DEPA 2000
Mollusca	EC/LC50 = 0.0019-0.850 mg/L for 2-4 days exposure	DEPA 2000
Opossum shrimp	96-hour LC50 = 4.70 ppb (highly toxic)	PAN 2004
Oysters	48-hour EC50 = 24 ug/L	Kobayashi 2002
Protozoa	100% effect at 5 mg/L	DEPA 2000
Sea Urchin	Higher concentrations of Sea-Nine induced cytolysis after cleavage, or produced a delay in development. Cleavage was delayed and development abnormal at medium and lower concentrations.	Kobayashi 2002

Environmental Acceptability

Environmental Acceptibility	DCOI (EC/LC50) are lower than 10 µg/LN-(n-octyl) compared to its metabolite, malomanic acid, is several orders of magnitude lower as the lowest effect concentrations (LC50) are estimated to be between 90 and 160 mg/L.	DEPA 2000
Environmental Acceptibility	More degradable and has a lower affinity to sediment as compared to TBT.	Gandrass 2001
Environmental Acceptibility	Sea-Nine undergoes rapid biodegradation with a half life of less than an hour.	Thomas 2003
Byproducts	metabolites (N-(n-octyl) malonamic acid and N-(n-octyl) acetamide) and carbon dioxide in seawater	DEPA 2000
Inhibitors	Tolerance towards DCOI was detected during a short-term concentration response of photosynthesis inhibition in the microcosms with phytoplankton communities were exposed to 3.2-10 nM DCOI. The tolerance is possible due to the changes in communityy structure (changes in taxonomic composition of phytoplankton communities). For 32 nM DCOI, the half life is 2.5 days while for the 100 nM DCOI, the half life is 2.6 days.	Larsen 2003

Shipboard Use

Storage	In a well ventilated area	Rohm & Hass 2003
Handling	30% solution is corrosive to skin and eyes and slightly toxic by oral and dermal routes of exposure; protective equipment must be worn to avoid contact with skin and eyes; respirator should be worn in areas that may have high vapor concentrations	Rohm & Hass 2003
Ventilation	Explosive-proof local exhaust needed in storage and handling area	Rohm & Hass 2003

Laws and Regulations

Country_Region	Regulation	Web site
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html

Citations

DEPA, , . 2000.	Ecotoxicological Assessment of Antifouling Biocides and Nonbiocidal Antifouling Paints	www.mst.dk/udgiv/publications/2000/87-7944-084-3/html/kap03_eng.htm : -
Gandrass, J, W Salomons (Eds). 2001.	Dredged Material in the Port of Rotterdam - Interface between Rhine Catchment Area and North Sea (http://coast.gkss.de/aos/dredged_material/)	GKSS Research Centre : -
Kobayashi, N, H Okamura. 2002.	Effects of new antifouling compounds on the development of sea urchin	Marine Pollution Bulletin : 748-751
Larsen, DK, I Wagner, K Gustavson, VE Forbes, T Lund. 2003.	Long-term effect of Sea-Nine on natural coastal phytoplankton communities assessed by pollution induced community tolerance	Aquatic Toxicology : 35-
PAN, , . 2004.	Pesticide Action Network Database	www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC35757 : -
Rohm & Hass, , . 2003.	Formulating A Coating with SEA-NINE®	http://www.rohmhaas.com/seanine/index.html : -
Thomas, KV, M McHugh, M Hilton, M Waldock. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution : 153-161

Silver Ions

Ag^+ **CAS_#** 15046-91-0

Ag+ ions in solution or as insoluble silver complexes; can be electrolytically generated; used as a bacteriostat to destroy animal pathogenic bacteria

Ag^+

Other Names

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	aqueous solution or insoluble silver complexes	Hazardous Substances Data Bank 2004
Physical State	aqueous solution	Sistecam SA 2003
pH	1.45	Sistecam SA 2003
Specific gravity	1.091	Sistecam SA 2003
Stability	Stable in solution. Light sensitive.	Sistecam SA 2003

Target Organism	Treatment Dosage	Citation
amphibians	LC50: very highly toxic	PAN 2004
Bacteria	30 ppm induces a 6-log reduction within 2 minutes	Sistecam SA 2003
crustaceans	EC50: accumulation	PAN 2004
fish	LC50: highly toxic	PAN 2004
Fungi	30 ppm induces a 6-log inactivation within 10 minutes	Sistecam SA 2003
molluscs	EC50: accumulation, behavior, biochem, growth, mortality	PAN 2004
phytoplankton	EC50: accumulation, growth, mortality, physiology, population	PAN 2004
Viruses	30 ppm induces a 6-log reduction within 10 minutes	Sistecam SA 2003
zooplankton	LC50: very highly toxic	PAN 2004

Environmental Acceptability

Effectiveness Factor	enhances disinfection properties of halogens (chlorine)	Sistecam SA 2003

Shipboard Use

Corrosivity	Not corrosive	Sistecam SA 2003
Ventilation	No irritating fumes	Sistecam SA 2003

Laws and Regulations

Citations

Abad, FX, RM Pinto, JM Diez, and A Bosch. 1994.	Disinfection of Human Enteric Viruses in Water by Copper and Silver Combination with Low Levels of Chlorine	Applied and Environmental Microbiology : 2377-2383
Hazardous Substances Data Bank, , . 2004.	Silver Compounds	National Library of Medicine Toxnet System : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -
Sistecam SA, , . 2003.	Axenohl™: Advanced Silver Ion Disinfection Technology	http://www.sistecam.com/Supportdocs/techdatasheet.PDF : -

Sodium Chlorite

$ClNaO_2$ **CAS_#** 7758-19-2

Bleaching agent as solution or solid flakes

Other Names Chlorite (sodium salt); Alcide ld; Chlorous acid, sodium salt;

Trade_Names Neo Silox D

Target Organism	Treatment Dosage	Citation
fish	EC50: mortality	PAN 2004
fish	LC50: not acutely toxic	PAN 2004
fungi	EC50: population	PAN 2004
molluscs	EC50: intoxication, mortality	PAN 2004
phytoplankton	EC50: population	PAN 2004
zooplankton	EC50: intoxication, mortality	PAN 2004
zooplankton	LC50: highly toxic	PAN 2004

Environmental Acceptability

Shipboard Use

Storage	Material may be stowed "on deck" or "under deck" on cargo or passenger vessels. Stow separated from ammonium compounds, cyanides, and powdered metal.	DOT 2002
Handling	Oxidizer hazard class; medium degree of danger presented by the material.	DOT 2002

Laws and Regulations

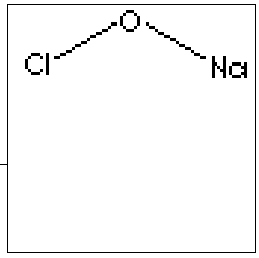
Country_Region	Regulation	Web site
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/

Citations

DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -

Sodium Hypochlorite

NaOCl **CAS_#** 7681-52-9



Industrial solutions available in water solutions containing approximately 12.5-15.75% sodium hypochlorite (12-15% available chlorine) are typically used as a disinfectant in water and wastewater systems.

Other Names Bleach; Chlorox; Hypochlorous acid, sodium salt; Javel water; Liquid bleach; Soda bleach; Sodium chloride oxide; Sodium oxychloride; Hychlorite; Sodium Chloride Oxide

Trade_Names Clorox; Javex

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid	Hill Brothers 2003
pH	12	Hill Brothers 2003
pH	Maximum efficacy near neutral	Sagripanti 1996
Specific gravity	1.07	Hill Brothers 2003
Solubility in water	29.3 g/100 g (0 deg C) in water	Hazardous Substances Data Bank 2004
Solubility in water	100% soluble	Hill Brothers 2003
Stability	Decomposition of sodium hypochlorite takes place within a few seconds with the following salts: ammonium acetate, ammonium carbonate, ammonium nitrate, ammonium oxalate, and ammonium phosphate.	Hazardous Substances Data Bank 2004
Stability	unstable above 40 deg C, in sunlight, or in contact with acid or metals	Hill Brothers 2003
Stability	Decay rate = 0.;89 +/- 0.19 per day (r = 0.85)	Sagripanti 1996
Inactivation	Bacteria and protozoa: breaches the cell wall and attacks nucleus; Viruses: attacks the DNA	Bolek 2003
Inactivation	Attacks mucous membrane (i.e. cell walls) of nitrogen-bearing organisms	Harwell 2003
Inactivation	Breaks up DNA with oxidation	Hill 2003
Inactivation	Production of halogens and injection of ionized air	Stewart 2003

Target Organism	Treatment Dosage	Citation
Bacillus subtillus spores	0.05% inactivated >99.9% upon 30 min exposure at 20 deg C	Sagripanti 1996
crustaceans	LC50: moderately toxic	PAN 2004
Cryptosporidium parvum oocyst	Viability is not affected by 1.05 - 3 % chlorine as sodium hypochlorite for up to 18 hours.	Korich 1990
Everything down to 50uM	≤ 1-2 ppm	Hill 2003
fish	LC50: highly toxic	PAN 2004
Microorganisms	Depends on what is in the water. Ranges from 0.5 ppm to 50 ppm.	Bolek 2003
molluscs	LC50: moderately toxic	PAN 2004
nematodes and flatworms	LC50: slightly toxic	PAN 2004
phytoplankton	LC50: moderately toxic	PAN 2004
VEGETATIVE BACTERIA, VIRUSES		Hazardous Substances Data Bank 2004
zooplankton	LC50: moderately toxic	PAN 2004
Zooplankton	~10 ppm residual achieves 90% reduction after 2 hours treatment compared to control	Gracki 2002
Zooplankton	~10 ppm residual for 2 hours achieved >90% reduction	MI Env Sci Brd 2002
Zooplankton, phytoplankton, viruses, larvae, bact.	Depends on level of harbor pollution. Minimum of 2 ppm and maximum of 18-20 ppm	Harwell 2003

Environmental Acceptability

Environmental Acceptibility	Residual chlorine can be toxic to aquatic organisms.	Gracki 2002
Byproducts	Chlorine; sodium chlorate	CCHOS 2002
Byproducts	Potential for leaching metals from the organic fraction of sediments. Amount of release would depend on contact time, amount of metals bound to sediments, amount of sediment, and fate of metals. Disinfection by-products (e.g., THMs) may form.	Gracki 2002

Byproducts	Sodium hypochlorite at .15% (EPA standards are 1%) and hydrogen gas below explosion level	Harwell 2003
Byproducts	Salt and water are produced (NaOCl + H2)	Hill 2003

Shipboard Use

Generation	Sodium hypochlorite can be produced directly by electrolysis of seawater or brine aboard ships	CCHOS 2002
Generation	Can be purchased or generated on site.	Gracki 2002
Application	Electrolosis and dosing equipment	CCHOS 2002
Storage	Compatible tanks for liquid	CCHOS 2002
Storage	Material may be stowed "on deck" or "under deck" on a cargo vessel or on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers, or one passenger per each 3 m of overall vessel length; "on deck only" on passenger vessels in which the number of passengers above is exceeded. Stow away from acids.	DOT 2002
Handling	Corrosive to skin and eyes	CCHOS 2002
Handling	Health: TOXIC, inhalation, ingestion, or skin contact with material may cause severe injury or death. Contact with molten substance may cause severe burns to skin and eyes. Avoid any skin contact	Hazardous Substances Data Bank 2004
Size	System is made to conform to offshore platform standards. Made of stainless steel. Footprint is 1500mm W X 2600mm L X 2100mm H	Harwell 2003
Size	Filter is modular and inline on intake (but it can be freestanding); Hypochlorite system has a footprint of 3'x5'x5'	Hill 2003
Corrosivity	Concentrated sodium hypochlorite is corrosive to most metals	CCHOS 2002
Corrosivity	Corrosive hazard class	DOT 2002
Corrosivity	None	Harwell 2003
Power Requirements	Small system: 220V AC Large system: 480V AC	Bolek 2003
Power Requirements	4 KW/kg; 3-phase power; voltage is adjusted according to vessel	Harwell 2003
Ventilation	With electrolosis, hydrogen gas must be vented	CCHOS 2002
Maintenance	Periodic preventative maintenance, loading brine tank, keeping recording logs	Bolek 2003
Maintenance	Sulfamic acid cleaning (used as a boiler descaling material); lubricate pump and motor bearings	Harwell 2003
Maintenance	Regular visual inspections and reading the maintenance log. Annual change out of Ionz cells and chlorine generators.	Stewart 2003

Laws and Regulations

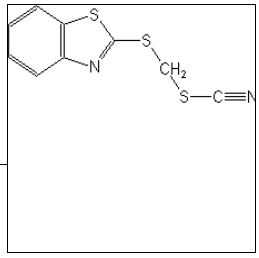
Country_Region	Regulation	Web site
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Canada Shipping Act - Part (XV): Pollutant Substances Regulations (CRC, c. 1458)	http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/050/csa052/csa52.html
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Existing Substances Regulation 793/93/EEC	http://ecb.jrc.it/Legislation/1993R0793EC.pdf
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Mediterranean Sea	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea	http://www.unepmap.gr/pdf/dumping.pdf
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html

Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	http://www4.law.cornell.edu/uscode/7/ch6.html
USA	Hazardous Materials Regulations (CFR49, Chap I, Subchap. C)	http://www.myregs.com/dotrspa/
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

Citations

Bolek, K, . 2003.	Telephone conversation with Katie Bolek, Marketing Manager	Miox Corporation : -
CCHOS, , . 2002.	Sodium hypochlorite solutions Chemical Profile	http://www.intox.org/databank/documents/chemical/sodhypoc/cie351.htm : -
DOT, , . 2002.	Hazardous Materials Table	49 CFR 172.101, http://www.myregs.com/dotrspa/ : -
Gracki, JA, RA Everett, H Hack, PF Landrum, DT Long, BJ Premo, SC Raaymakers, GA Stapleton, KG Harrison. 2002.	Critical Review of a Ballast Water Biocides Treatment Demonstration Project Using Copper and Sodium Hypochlorite	Michigan Environmental Science Board, Lansing : -
Harwell, C, . 2003.	Telephone conversation with Christopher Harwell	Electrichlor : -
Hazardous Substances Data Bank, , . 2004.	Sodium Hypochlorite	National Library of Medicine Toxnet System : -
Hill Brothers, , . 2003.	Material Safety Data Sheet	http://www.desertbrand.com/msds/shypo.htm : -
Hill, D, . 2003.	Telephone conversation with David Hill	Severn-Trent : -
Korich, DG, JR Mead, MS Madore, NA Sinclair, CR Sterling. 1990.	Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on Cryptosporidium parvum Oocyst Viability	Applied and Environmental Microbiology 56: 1423-1428
Michigan Environmental Science Board, , . 2002.	Critical Review of a Ballast Water Biocides Treatment Demonstration Project using Copper and Sodium Hypochlorite	A Science Report to Governor John Engler : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Sagripanti, J, A Bonifacino. 1996.	Comparative Sporicidal Effects of Liquid Chemical Agents	Applied Environmental Microbiology 62: 545-551
Stewart, J, . 2003.	Telephone conversation with Jon Stewart, Vice President of Sales	Marine Environmental Partners : -

TCMTB



$C_9H_6N_2S_3$ **CAS_#** 21564-17-0

reddish viscous and emulsifiable liquid commonly used as a fungicide in soil and seed treatment

Other Names 2-(Benzothiazolylthio)methyl thiocyanate; 2-(Thiocyanomethylthio)benzothiazole; 2-(Thiocyanometylthio)benzothiazole (TCMTB); mercaptobenzothiazonel;

Trade_Names Busan; Busan 30; Busan 44; Buxan 72; Busan 74; TCMTB

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid	Cornell University 1985
Solubility in water	practically insoluble in water	Cornell University 1985

Target Organism	Treatment Dosage	Citation
Bluegill sunfish	96-hour LC50 = 0.047 ppm using 60% formulation (Busan 72)	Cornell University 1985
fish	very highly toxic	PAN 2004
molluscs	slightly toxic	PAN 2004
Rainbow trout	96-hour LC50 = 0.029 ppm using 60% formulation (Busan 72)	Cornell University 1985

Environmental Acceptability

Environmental Acceptibility	Anaerobic half life of 1.5 days for TCMTB and aerobic half life of 31-36 days. TCMTB is rapidly degraded in anaerobic marine sediments when compared to seawater	Thomas 2003

Shipboard Use

Handling	Wear rubber gloves and goggles and avoid contact with this product.	Cornell University 1985

Laws and Regulations

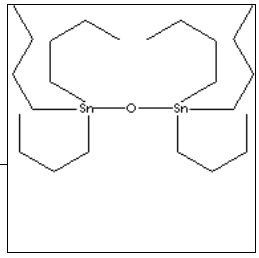
Citations

Cornell University, , . 1985.	TCMTB (Busan) Chemical Profile 2/85	http://pmep.cce.cornell.edu/profiles/ : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org/ : -
Thomas, KV, M McHugh, M Hilton, M Waldock.. 2003.	Increased persistence of antifouling paint biocides when associated with paint particles	Environmental Pollution 123: 153-161

Tributyltins (TBT)

$C_{24}H_{54}OSn_2$ **CAS_#** 56-35-9

Organotin exists in the form of monobutyltin (MBT), dibutyltin (DBT), and tributyltin (TBT). TBT degrades into DBT and DBT degrades into MBT.



Other Names bis(tributyltin) oxide [CAS_# indicated]; butinox; hexabutyldistannoxane; TBTO

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	liquid	NSC 2004
pH	strong base	NSC 2004
Solubility in water	soluble in hot water	NSC 2004
Inactivation	Chronic toxic effects of TBT such as calcification anomalies in oyster and imposex in gastropods occur at a few ng TBT/L. The toxic concentrations of TVT at embryonic and early life stages of aquatic organisms lie in the range of a few ug/L. TBT into marine environments wwas generated by washdown furing repainting of ships in dry-dock facilities. Antifouling paints applied on boats and ships and effluents from dry-dock facilities are major sources of BTs. TBT was the highest concentration. TBT accumulated in the surface microlayers poses adverse effects on intertidal organisms, particularly their larvae which are more susceptible to toxic effect.	Hong 2002

Target Organism	Treatment Dosage	Citation
Acartia Tonsa	Environmental concentrations of TBT of 20 to 100 ng/L. Acute toxicity of 0.47 ug/L at 18% salinity and 0.24 ug/L at 28% salinity. Concentrations as low as 0.6 ug/L was found to be toxic for Mercenaria mercenaria. At 0.6 ug/L inhibit growth of O. edulis for 50%	Kusk 1997
Algae	EC50 values between 1-170 nM reported as indicators, based on various approaches employing growth or photosynthesis of algal cultures or phytoplankton communities.	Dahl 1996
Anthocidaris crassispina	10 mg/L induced low rates of fertilization and cleavage, cytolisis occurred. 0.001-1 mg/L: cleavage and normal development rates increased or decreased depending on the actual concentration; development delays and abnormal developments also appeared to be similarly affected. 0.01-0.1 ng/L (low dose) increased normal development rates.	Kobayashi 2002
Hemicentrotus pulcherrimus	10 mg/L induced low rates of fertilization and cleavage, cytolisis occurred. 0.001-1 mg/L: cleavage and normal development rates increased or decreased depending on the actual concentration; development delays and abnormal developments also appeared to be similarly affected. 0.01-0.1 ug/L (low dose) increased normal development rates.	Kobayashi 2002
Mytilus edulis	TBT concentrations increased with decreasing water depth and with length of mussel living in intertidal and subsurface zones.	Hong 2002
Nucillus lapillus	TBT concentrations <0.5 ng/L have been shown to cause imposex.	Connelly 2001
Periphyton	Detected TBT values as the first effect on periphyton communities was 0.3-0.6 nM.	Dahl 1996
T. bronni	10 to 20 ng/L TBT could cause imposex.	Bech 2002
T. clavigera	10 to 20 ng/L TBT could cause imposex.	Bech 2002

Environmental Acceptability

Environmental Acceptibility	TBT degrades to DBT in sediments which is more readily desorbed from the sediments. This desorption and increased mobility would result in an increase of the DBT:TBT ratio over time.	Connelly 2001
Environmental Acceptibility	TBT interferes with energy metabolism in both chlorophlasts and mitochondria where they act either as ionophores; facilitating the halide/hydroxyl exchange across membrane or as energy transfer inhibitores binding to or in the area of the coupling factor. Both cases, ATP synthesis will be impaired. TBT can also inhibit DNA, RNA, and protein systhesis in rat thymocytes. TBT also inhibits mediated hemolysis of human erythrocytes. EC20 of photosynthesis inhibition: 4-16 nM; EC50 of photosynthesis inhibitions: 16-69 nM.	Dahl 1996
Environmental Acceptibility	half life 1 to 2 weeks	Kusk 1997
Byproducts	Reacts with inorganic and organic acids forming non-conducting, water-insoluble compounds.	NSC 2004
Effectiveness Factor	Maximum no effect concentration = 10 ng/L (for all organisms??)	Kobayashi 2002

Laws and Regulations

Country_Region	Regulation	Web site
Australia	Anti-Fouling Legislation	
Baltic area	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	http://www.helcom.fi/convention/conventionframe.html
Canada	Anti-Fouling Legislation	
Central America, Northwest South America	Northeast Pacific Action Plan	http://www.unep.ch/seas/main/nep/nepape.html
East Asian nations	East Asian Seas Action Plan	
East coastal Africa	Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region	http://sedac.ciesin.org/entri/texts/marine.coastal.east.africa.1985.html
European Union	Biocidal Products Directive 98/8/EC (Anti-fouling)	http://europa.eu.int/comm/environment/biocides/
Hong Kong	Anti-Fouling Legislation	
IMO	IMO Anti-Fouling Systems Convention	http://www.imo.org/Conventions/mainframe.asp?topic_id=529
Japan	Anti-Fouling Legislation	
Korea	Anti-Fouling Legislation	
Malta	Anti-Fouling Legislation	
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	http://www.unep.ch/seas/main/med/medconvi.html
Mediterranean Sea	Protocol Concerning Mediterranean Specially Protected Areas	http://sedac.ciesin.org/entri/texts/acrc/mspecp.txt.html
Nations bordering the Red Sea or the Gulf of Aden	Jeddah Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	http://www.unep.ch/seas/main/persga/convtext.html
Nations of the South Pacific	Noumea Convention for the Protection of Natural Resources and Environment of the South Pacific Region	
Nations surrounding Persian Gulf	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html
NE Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (Paris Convention)	http://www.ospar.org/eng/html/convention/welcome.html
Netherlands	Anti-Fouling Legislation	
New Zealand	Anti-Fouling Legislation	
North and South Korea, Japan, China, Russian Federation	Northwest Pacific Action Plan	
South Asia	South Asian Seas Action Plan	
Sweden	Anti-Fouling Legislation	
UK	Anti-Fouling Legislation	
United Nations	United Nations Convention on the Law of the Sea	http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm
USA	Anti-Fouling Legislation	http://www4.law.cornell.edu/uscode/

		33/ch37.html
USA	Clean Water Act	http://www.epa.gov/region5/water/pdf/ecwa.pdf
USA	Ocean Dumping Act (MPRSA)	http://www4.law.cornell.edu/uscode/33/ch27.html
USA	Organotin Antifouling Paint Control (33 U.S.C. 2401)	http://www4.law.cornell.edu/uscode/33/2401.html
West coastal Africa	Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	http://sedac.ciesin.org/entri/register/reg-112.rrr.html
Western coastal nations of Central and South America	Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific	http://fletcher.tufts.edu/multi/texts/bh809.txt
Wider Caribbean region	Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	http://www.cep.unep.org/pubs/legislation/cartxt.html

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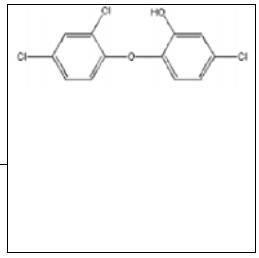
Connelly, DP, JW Readman, AH Knap, J Davies. 2001.	Contamination of the Coastal Waters of Bermuda by Organotins and the Triazine Herbicide Iragarol 1051	Marine Pollution Bulletin 42: 677-688
Dahl, B, H Blanck. 1996.	Pollution-induced community tolerance (PICT) in periphyton communities established under tri-n-butyltin (TBT) stress in marine microcosms	Aquatic Toxicology : 305-325
Hong, HK, S Takahashi, BY Min, S Tanabe. 2002.	Butyltin residues in blue mussels (Mytilus edulis) and arkshells (Scapharca brughtonii) collected from Korean coastal waters	Environmental Pollution 117: 475-486
Kobayashi, N, H Okamura. 2002.	Effects of new antifouling compounds on the development of sea urchin	Marine Pollution Bulletin : 748-751
Kusk, KO, S Petersen. 1997.	Acute and Chronic Toxicity of Tributylin and Linear Alkylbenzene Sulfonate to the Marine Copepod Acartia Tonsa	Environmental Toxicology and Chemistry 16: 1629-1633
NSC, , . 2004.	Tributyltin and Associated Chemicals Backgrounder	www.nsc.org/library/chemical/tributyl.htm : -

Triclosan



$C_{12}H_7Cl_3O_2$ **CAS_#** 3380-34-5

chlorinated phenol used as an antimicrobial agent, which is widely used in personal care products such as shampoos, soaps, cosmetics, lotions and toothpaste.

Other Names TCS, 5-chloro-2-(2,4-dichloro-phenoxy)-phenol, Phenol, 5-chloro-2-(2,4-dichlorophenoxy)-

Trade_Names Aquasept, CH-3635, Gamophen, Lexol 300, Irgasan DP-300, Irgasan, Sapoderm, SterZac

Physiochemical Properties	Value or Comment	Citation
Solubility in water	12 mg/L; log Kow = 4.8; Koc = 47,454 mL/g	Danish EPA 2003
Solubility in water	10 mg/L in distilled water at 20 C	McAvoy 2002
Stability	degradable under aerobic conditions but only little or no removal of Triclosan occurred during anaerobic sludge digestion	Danish EPA 2003
Inactivation	does not affect the treatment processes at levels up to 2 mg/L in the influent	Danish EPA 2003

Target Organism	Treatment Dosage	Citation
fish	highly toxic	PAN 2004
gram negative and gram positive bacteria	exhibits a broad-spectrum bacteriostatic activity	McAvoy 2002
zooplankton (water flea 24-hr)	48-hr EC50 intoxication at min conc of 390 ug/L and max conc of 560 ug/L and mean of 180 ug/L	PAN 2004

Environmental Acceptability

Environmental Acceptibility	auatic photolysis: 41 min. half-life at pH 7 and 25°C	Danish EPA 2003
Environmental Acceptibility	rapidly biodegradable in the soil environment half life from 15-35 days	McAvoy 2002
Byproducts	may be biotransformed to a more slowly degradable methoxy-triclosan(TCS-Ome; 5-chloro-2-[2,4-dichloro-phenoxyl]-anisole) intermediate in wastewater treatment system. Exposure concentrations of TCS and its biotransformation by-products are expected to be low in the aquatic environment.	McAvoy 2002

Shipboard Use

Laws and Regulations

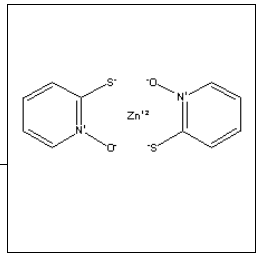
Citations

Danish EPA, , . 2003.	Fate and Effects of Triclosan	Environmental Project no. 861 http://www.mst.dk/ : -
McAvoy, D, B Schatowitz, M Jacob, A Hauk, WS Eckhoff. 2002.	Measurement of Triclosan in Wastewater Treatment Systems	Environmental Toxicology 21: 1323-1329
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -

Zinc Pyrithione

$C_{10}H_8N_2O_2S_2Zn$ **CAS_#** 013463-41-

Available as a solid.



Other Names Pyrithione zinc; Zinc 2-mercaptopyridine N-oxide; Zinc pyridine-2-thiol 1-oxide; Zinc 1-hydroxy-2-pyridinethione; 2-Mercaptopyridine-1-oxide, zinc salt; Zinc, bis(1-hydroxy-2(1H)-pyridinethionato)-(8CI)

Trade_Names

Physiochemical Properties	Value or Comment	Citation
Physical State	powder form	Hazardous Substances Data Bank 2004
Solubility in water	not soluble	Hazardous Substances Data Bank 2004

Target Organism	Treatment Dosage	Citation
Anthocidaris crassispina	Fertilization and cleavage very high at all concentrations; however, cytolisis or delay in development occurred at 1, 0.1, 0.01, 0.001 pg/L. Various abnormal plutei ocurred at concentration of 0.0001 pg/L.	Kobayashi 2002
Hemicentrotus pulcherrimus	Fertilization and cleavage very high at all concentrations; however, cytolisis or delay in development occurred at 1, 0.1, 0.01, 0.001 pg/L. Various abnormal plutei ocurred at concentration of 0.0001 pg/L.	Kobayashi 2002

Environmental Acceptability

Shipboard Use

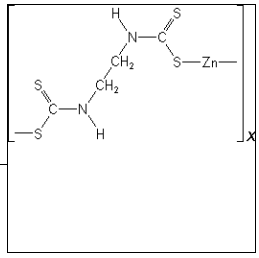
Laws and Regulations

Citations

Hazardous Substances Data Bank, , . 2004.	Pyrithione zinc	National Library of Medicine Toxnet System : -

Zineb

$C_4H_6N_2S_4Zn$ **CAS_#** 12122-67-7



fungicide; Dithiocarbamate, inorganic zinc. Available as a light-colored powder or crystal.

Other Names Carbamodithioic acid; 1,2-ethanediylbis-; zinc salt; Cineb, Dithane Z-78, Ethylenebis(dithiocarbamic acid); [Ethylene bis(dithiocarbamate)]zinc; Micide; Aaphytora; Aspor; Bercema; Blizene, Carbadine; CHEM zineb; Cineb; Dithane Z; Dithiamina; ENT 14; Novozin; Parzate C; Phytox; Tanazon; Zidan; Zebtox

Trade_Names Zineb, Zinebe, Lonacol, Aspor, Chem Zineb, Dipher, Discon Z, Zinosan

Physiochemical Properties	Value or Comment	Citation
Physical State	light-colored powder or crystal	Extension Toxicology Network 1996
Solubility in water	10mg/L at 25 deg C	Extension Toxicology Network 1996
Stability	Unstable in water, hydrolyzes rapidly. Koc is 1000 (estimated); Kow is <1.3010 at 20 deg C	Extension Toxicology Network 1996

Target Organism	Treatment Dosage	Citation
amphibians	LC50: not acutely toxic	PAN 2004
annelida	LC50: highly toxic	PAN 2004
crustaceans	LC50: slightly toxic	PAN 2004
fish	LC50: slightly toxic	PAN 2004
fish	moderately toxic. The 96-hour LC50 in perch is 2 mg/L	Extension Toxicology Network 1996
molluscs	LC50: not acutely toxic	PAN 2004
phytoplankton	EC50: growth, population	PAN 2004
zooplankton	LC50: slightly toxic	PAN 2004

Environmental Acceptability

Byproducts	ETU and other compounds	Extension Toxicology Network 1996

Shipboard Use

Generation	was available in the U.S. as wettable powder and dust formulations. Zineb is formed by combining nabam and zinc sulfate in the spray tank.	Extension Toxicology Network 1996

Laws and Regulations

Country_Region	Regulation	Web site
USA	formerly registered in the U.S. as a General Use Pesticide. All tolerances for zineb in agricultural commodities in the U.S. (except grapes used in winemaking) were revoked, effective 12/31/94. The tolerance for grapes in winemaking was revoked in 1997.	

Citations

Extension Toxicology Network, , . 1996.	Pesticide Information Profiles	Oregon State University : -
PAN, , . 2004.	Pesticide Action Network Database	http://www.pesticideinfo.org / : -