MICHIGAN ENVIRONMENTAL SCIENCE BOARD

BALLAST WATER BIOCIDES INVESTIGATION PANEL
MEETING SUMMARY
MAY 29, 2002
HOLIDAY INN SOUTH
6820 SOUTH CEDAR
LANSING, MICHIGAN

PANEL MEMBERS PRESENT
Dr. John Gracki, Chair
Dr. Bette J. Premo
Dr. Harvey Hack
Dr. David T. Long
Dr. Richard A. Everett
Dr. Peter F. Landrum
Mr. Stephen C. Raaymakers
Mr. Gregory A. Stapleton
Mr. Keith G. Harrison, Executive Director

MDEQ/OSEP SUPPORT STAFF PRESENT
Mr. Jesse Harrold, Environmental Officer
Ms. Sharon Picard, State Sites Analyst

I. CALL TO ORDER

Dr. John Gracki, Chair, called the meeting of the Michigan Environmental Science Board (MESB) Ballast Water Biocides Investigation Panel (Panel) to order at 9:20 am. He asked the Panel members to introduce themselves:

> Dr. Harvey Hack stated that he was a metallurgist and corrosion engineer with Northrop Grumman Corporation.
>
> Dr. Richard Everett stated that he was a marine ecologist with the U.S. Coast Guard Aquatic Species Program.
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> Dr. David Long stated that he was a MESB member and a Michigan State University professor specializing in aqueous and environmental geochemistry.
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> Dr. Peter Landrum stated that he was an aquatic toxicologist with the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory.
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> Mr. Stephen Raaymakers stated that he was the technical advisor to the Ballast Water Program for the International Maritime Organization.
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> Mr. Gregory Stapleton stated that he was an engineer with the U.S Environmental Protection Agency (USEPA) currently working on Uniform National Discharge Standards, which the USEPA and the U.S. Department of Defense are working on to control discharges from Armed Forces vessels.
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> Dr. Betty Premo stated that she was a limnologist with White Water Associates, a private consulting firm, and a member of the MESB.
>
> Mr. Keith Harrison stated that he was an ecologist and the Executive Director of the MESB.

Dr. Gracki stated that he was a member of the MESB and a professor of chemistry at Grand Valley State University.

II. GOVERNOR'S CHARGE AND BACKGROUND

Dr. Gracki discussed the Governor's charge to the MESB. The Governor recently signed into law Public Act 114, which requires, among other things, that the Michigan Department of Environmental Quality (MDEQ) determine whether one or more ballast water treatment methods can be used in ocean-going vessels to prevent the introduction of invasive aquatic species into the Great Lakes, while also protecting the safety of vessels, crews, and passengers. The charge to the MESB is to review a report that was prepared for the MDEQ by consultants entitled, *Ballast Water Treatment Evaluation Using Copper and Sodium Hypochlorite as Ballast Water Biocides,* and to evaluate the scientific validity of its conclusions regarding the efficacy of the biocides evaluated, the corrosiveness of those biocides to ballast tanks, and whether the discharge concentrations for each biocide meet water quality regulatory standards.

III. PRESENTATION (Mr. William McCracken, MDEQ)

Mr. William McCracken, MDEQ, provided the background and an overview ballast water demonstration project. In January 2000, the first ballast water bill was introduced in the Michigan Senate. It required sterilization of ballast water and a discharge permit for every ballast water discharge. Governor Engler, however, was concerned that the Michigan-only approach would be ineffective and would lead to a patchwork of individual regulatory requirements from various Great Lakes jurisdictions. He proposed that the Council of Great Lakes Governors convene a ballast water task force to deal with the issue on a regional basis. The Council of Great Lakes Governors began deliberations in January 2002.

Mr. McCracken stated that the MDEQ established a ballast water work group (BWWG), consisting of technical experts, including people from the shipping industry, to find the best way currently available to stop the introduction of invasive aquatic species. The BWWG focused on what was currently available and practical, and could be put into use as an interim measure while other related research continued. In April 2000, the BWWG concluded that the only currently available methods for dealing with the problem were management practices and biocides. The BWWG defined a *currently available method* as (1) not needing extensive research to establish the efficacy of the biocide, (2) not needing extensive ship retrofitting, and (3) not requiring any shore side facilities.

In May 2000, the BWWG recommended that there were two potential biocides available, glutaraldehyde and sodium hypochlorite. It also recommended that management practices be improved to minimize sediment in ballast water, because it interferes with biocides. In June 2000, the BWWG recommended biocide-testing plans, and in February 2001, copper ion was added to the list of potential biocides. FedNav, a major shipping company plying the Great Lakes, agreed to provide a ship for the experimental work. In May 2001, Michigan issued a request for proposals for biocide testing of hypochlorite and copper ion while a test of glutaraldehyde was proceeding under a separate grant. Fleet Technology Ltd. (FTL) of Kanata, Ontario, was selected as the prime contractor. The subcontractor was ESG International (ESG) of Guelph, Ontario.

The experimental protocol was finalized in October 2001. Shipboard testing was conducted during the period October through December of that year. The laboratory work on corrosion and efficacy was completed in February 2002, and the draft final report presented in March 2002. In April 2002, the Governor requested that the MESB review the final draft report. Michigan Public Act 114 (Act) was signed into law in August 2001. The Act required that the MDEQ determine whether ballast water Best Management Practices (BMPs) are being complied with by both ocean going and Great Lakes-only ships and to determine whether practical ballast water treatment methods exist for ocean-going vessels. Pursuant to the Act, the MDEQ must determine whether ballast water is being treated according to any existing BMP by March 2003. The MDEQ must also maintain public lists of vessels complying with BMPs. Additionally, vessel owners, operators, and their customers are not eligible for any grants, loans, or awards from the MDEQ unless they are on a list of BMP compliers maintained by the MDEQ.

Mr. McCracken emphasized that although biocides and management practices have been determined to be the only currently available methods for dealing with the ballast water problem, ongoing research may find methods that are superior. However, the on-going environmental danger of invasive aquatic species necessitates a need to identify interim measures essential.

Dr. Long asked how glutaraldehyde, copper ion, and hypochlorite were chosen as possible biocides for treatment of ballast water. Mr. McCracken responded that the BWWG based the selection on currently available information regarding the use of hypochlorite as a widely used disinfectant of wastewater and water supplies, the use of glutaraldehyde as a disinfectant of medical instruments, and the use of copper ion as an anti-foulant in the shipping industry. The research on glutaraldehyde is on-going. Dr. Landrum stated that the Fisheries Trust funded the glutaraldehyde investigation, on which he is a collaborator. The work is complete and has been sent to the Fisheries Trust. The research is being extended at this time because there is some evidence that glutaraldehyde's toxicity can be enhanced by the addition of surfactants.

IV. PRESENTATION (Fleet Technologies Limited and ESG International)

Mr. David Stocks, FTL, and Mr. Martin O'Reilly, ESG, presented a summary of the biocides investigation and demonstration project (Attachment 1). Mr. Stocks indicated that the BWWG asked FTL to evaluate two currently available biocides and to carry out the on-board testing. FTL was specifically charged with answering:

1. Are copper ion and sodium hypochlorite biocides effective in killing a broad range of ballast-borne biota?
2. Can they be safely handled?
3. Are the ultimate discharge concentrations environmentally acceptable to regulatory agencies?
4. Do they damage ballast tanks?
5. Do they work with sediment present?
6. Are they economical and readily available?
7. Are there any other practical considerations regarding their use?

There were three experimental components to the project. Shipboard biocide trials were carried out on board the FedNav ship, *Federal Yukon*, a typical international bulk carrier coming into the Great Lakes. Laboratory biological toxicity work was carried out by ESG International and tank coating and corrosion testing done in the FTL labs.

The FedNav ship went through two ballast cycles, saltwater and freshwater. The first was from Montreal, Canada to Lisbon, Portugal in late October, where saltwater ballast was added. That was discharged in Antwerp, Belgium, where cargo was taken on. The ship was then in a condition referred to as NOBOB (no ballast on board). The water and sediment that remains in the bottom of tanks in a NOBOB condition is the primary medium by which invasive biota enter the Great Lakes. From Belgium, it went to Burns Harbor, Indiana, where cargo was discharged and freshwater ballast taken on, and from there to Superior, Wisconsin, where the freshwater ballast was discharged. The cycle lasted 69 days, 20 of which the ship was carrying ballast, a typical duration. During this time, the hypochlorite was tested on board, but only in decant tanks and test barrels, due to the fact that the ship-owner was concerned about safety problems and would not allow hypochlorite in ballast tanks. The copper ion was tested in the ballast tanks, using a biomatic ion generator installed on the ship, and extracted to test barrels.

During the NOBOB portion of the cycle, actual tank residuals of sediment were collected to dose and load some of the toxicity experiments on board and for use in the laboratory. However, in both the seawater and freshwater cycles, an inadequate amount of biota was found and biota had to be collected through a more extensive filtering process than originally planned.

Chlorinated ballast water was dechlorinated to meet environmental requirements prior to discharge from the ship. Copper, which had been applied to the first 20 to 50 tons of water that went into the ballast tank, was diluted before discharge.

For the laboratory tests of corrosion, four different paint systems were used. The paints were typical of most ship ballast tanks (Slide 5, Attachment 1). The paints were used on bare metal, coated intact metal, and coated and scribed metal, in four environmental conditions - humid, constant submersion, sporadic splashing, and buried in inert sand. Two levels of both biocides were tested, with a control, in both freshwater and saltwater. The results are presented in Slide 5 (Attachment 1). In an aggressive saltwater environment, FTL estimates a loss in the range of three millimeters a year, and in freshwater, about one millimeter a year. These figures are comparable to losses reported by the Tanker Forum, which does most of the reported corrosion research.

Martin O'Reilly, ESG International, reported on the toxicity tests. Part of the shipboard testing was the addition of one percent sediment in the test containers to examine the effect of sediment on biocide levels as well as to provide a potential refuge for organisms that are found in ballast water. The results of shipboard testing are presented in Slide 6 (Attachment 1). Shipboard testing demonstrated that the copper ion dosed at 0.2 milligrams per liter (mg/l) is of limited effectiveness in killing organisms in ballast water, with only 33 percent of the zooplankton killed and the bacteria unaffected. The hypochlorite tests, which took place in barrels and decant tanks, showed an increase in bacterial re-growth in the freshwater test. This was probably due to suspended sediment and the additional turbidity found in the decant tanks because of their shape. In general, hypochlorite was more than 90 percent effective in reducing bacteria and zooplankton at concentrations of about 10 mg/l.

Since the shipboard tests were completed in the fall, the number of available organisms was lower. Consequently, there were problems collecting an adequate range and number for testing with the biocides. In the more controlled laboratory experiments using algae, invertebrates, bacteria, mollusks, and fish, it was found that hypochlorite is more than 99 percent effective in killing most organism types at a concentration of 10 mg/l, in both fresh and sea water, with the exception of resting life stages, such as eggs and cysts, which required much higher doses. Copper was more than 99 percent effective in killing most organism types at 20 mg/l, but even higher doses were not effective against organisms in resting life stages. Both biocides are made less effective by sediments in ballast water. Mr. O'Reilly noted that it is difficult to ascertain exactly how much copper was actually available in the laboratory water as biocide. He thought it likely that the amount of pH in water determined how much of the copper bound with calcium and precipitated out, which may account for the copper not being effective against biota in resting stages even at higher levels. The researchers could not say what the actual level of active copper was in the water when 99 percent of the organisms were killed.

The relative costs of using a copper ion generator, on board chlorine generation, or purchasing commercial sodium hypochlorite are presented in Slide 14 (Attachment 1). FTL estimated that installing and operating an ion generator on board would raise shipping costs about 0.53 percent; on board chlorine generation would raise it about 2.31 percent; buying and storing hypochlorite on board would raise it about 1.16 percent; and having hypochlorite delivered to ships as required would raise the cost about 0.67 percent. However, having hypochlorite on board will require ships to meet additional regulatory requirements for chemical cargoes.

Mr. Stocks summarized the FTL report findings by stating that copper ion biocide can be safely handled, is relatively low cost, and requires no special handling or safety precautions. There are no quantifiable detrimental effects on the structural integrity of the ship. However, discharge rates are unlikely to meet environmental regulatory standards if applied at effective dosages. Hypochlorite can be safely handled if proper accommodations are in place for the hypochlorite and the neutralizing solution (sodium bisulfate). Bulk hypochlorite is readily available at ports or may be generated on board from common salt. Over a typical lifetime, exposure to hypochlorite at a concentration of 10 mg/l Total Residual Chlorine will not significantly increase ballast tank corrosion, but at higher levels corrosion is more significant. Hypochlorite discharge levels can be achieved by the addition of a neutralizing agent, but crew training is required for dosing and neutralizing. In order to answer questions about the efficacy and practicality of hypochlorite and copper ion with sediment present, further testing should be done in actual ballast tanks and various harbor water quality situations. The dose necessary to effectively kill biota increases for both biocides in ballast water containing high amounts of sediment and the minimum amount of either biocide needed has not been determined. Sediments can be minimized through Best Management Practices (BMPs).

V. QUESTIONS AND COMMENTS

Dr. Long asked Mr. O'Reilly if he knew the actual concentration of copper at the time the experiments showed a 99 percent mortality rate. Mr. O'Reilly responded that he did not. It is difficult to determine that unless a steady state can be assumed, and with biological activity in the water, it is unlikely to be in a steady state. Consequently, they could not tell how much copper remained available as a biocide.

Dr. Landrum asked how Mr. Stocks could say that corrosion would not be a problem in the bottom of the tanks with the residual hypochlorite biocide in water and sediment sitting there for the whole life of the ship; the bottom would always be in a corrosion environment. Mr. Stocks responded that the amount of water left after emptying ballast is small and the chlorine content is continually dropping.

Dr. Hack asked whether Mr. Stocks knew the length of time it took for the hypochlorite or copper ion to penetrate coatings and get to the interface where the coating bonds with the metal. He also asked if the results of the test showed any indication of linearity, since with a short test extrapolated to a long period of time, linearity has to be assumed. Mr. Stocks replied that that linearity was assumed and that in the area of aggressive conditions, corrosion products would be continually removed, but later there are fewer corrosion products, so over a period of 30 days it averages out to a linear solution.

Dr. Hack asked whether FTL has looked at the systems U.S. Navy submarines use to dose their once-through piping systems. The U.S. Navy makes hypochlorite directly from seawater as it goes through the system. Mr. Stocks said that they did, but the problem was that ships on the Great Lakes would only have seawater half the time, that seawater is unstable and differs from place to place, and that these systems are too slow to deliver the necessary dosage to 11,000 gallons of water in eight hours.

Dr. Everett asked Mr. Stocks to expand on his earlier cost comparison statement regarding shipside delivery of commercial sodium hypochlorite. Mr. Stocks responded that that might be an option for many ships, requiring that the water be dosed as it comes on the ship at whatever port it was in prior to the Great Lakes. However, not all ports have suppliers available. In addition, a Canadian researcher found that the vast majority of ships coming into the Great Lakes reported carrying cargo rather than ballast. Mr. Raaymakers noted that aside from those issues, other research and development projects have shown that if water is treated upon ballasting, voyage time will allow re-populaton. So treatment just prior to discharge would still be necessary.

Dr. Premo asked about the prescribed BMP for removing sediment. Mr. Stocks answered that it consisted only of cleaning the tanks as well as possible. Most international shippers do ballast water exchange by going into deep water, letting out old ballast water and bringing in the deeper offshore water. Most Great Lakes shippers do a “rinse and spit;” that is, partially filling the ballast tanks, rolling around to wash the tank, and then throwing away that water. It seems to get rid of some, but not all, of the sediment. However, another problem is that new sediment is entering when new ballast water is taken on, and that sediment is what causes the load on the hypochlorite. Mr. Raaymakers added that international BMPs also include practices to minimize uptake of organisms and sediment when ballasting. One such practice is to avoid taking on ballast in shallow water to avoid sucking up seabed sediments. Another practice is to avoid taking on ballast at night because plankton migrate vertically at night and are more likely to be taken in. However, ships are usually being unloaded and ballasted in ports that are necessarily shallow, and for economic reasons, vessels are under pressure to load 24 hours a day, and cannot wait out an unproductive night to take on ballast. Another sediment BMP is filtration. Sediment is a major inhibitor of any kind of treatment. There is a consensus that the primary treatment needs to be some sort of filtering system followed by a secondary treatment such as biocides.

Dr. Hack asked whether the researchers compared their study results with other toxicity studies (e.g., from anti-fouling paint manufacturers or the U.S. Navy). He also inquired if the literature suggests any specific adequate levels toxic to most organisms. Mr. Stocks replied that the anti-fouling paints were meant to discourage things from sticking, and were not related to lethal concentrations. Mr. O'Reilly said that the studies that he has seen have been based on the LC_{50} value, rather than LC_{99}, and so were not directly comparable.

Dr. Premo requested further clarification regarding copper dilution. Mr. Stocks responded that they dosed the first 20 to 50 tons in the tank at a high level, which was intended to treat the existing sediment load, the NOBOB tank residuals. As the tanks were filled the rest of the way, the initial fill was diluted. The upper portion of the tanks was never exposed to the higher doses of copper. Dr. Premo commented that the treatment would be ineffective as a biocide at the upper levels. Mr. Stocks said that they are trying to prove that the treatment was effective in the NOBOB condition for the residual sediment and water. Dr. Premo noted that in the process of taking on the dilution water, they were taking on the organisms they were intending to kill into an ineffective concentration of biocide. Mr. Stocks said that was correct, but in the Great Lakes situation they are diluting with Great Lakes water that is just taken to another Great Lakes port. Dr. Everett affirmed that that was the standard practice, but there is an increasing amount of dissatisfaction with the existing approaches to the ballast water problem focusing entirely on ships coming in from outside, when the movement of water within the Great Lakes may be just as problematic, since once an organism gets established in one place, the ballast discharge process just hastens the spread. There is a movement to get a treatment that will deal with the entire spectrum of vessel voyage patterns, whether international or intra-coastal.

Dr. Landrum asked for additional information regarding concentrations of copper used in the laboratory tests. Mr. O'Reilly answered that the invertebrate *daphnia* and some of the algal species were affected at under 0.2 parts per million (ppm), and from 0.2 to 2 ppm, fish, algae, and bacteria were affected. They could not go higher than that on shipboard, because of discharge requirements. Copper at this level was only about 33 percent effective. It was thought that reengineering of the treatment system would enable them to dose a smaller amount of water with a higher concentration and still dilute it enough, but there was a problem with assuring that the entire bottom surface of the tank was covered in that case.

Mr. McCracken commented that the discharge problem was a serious drawback to copper. Copper cannot be neutralized like hypochlorite. Dr. Hack stated that there are also other considerations. Copper, even at 10 parts per billion, will pit aluminum immediately, penetrating even a quarter inch plate of aluminum within a few months, through a process called heavy metal ion corrosion. Discharges, even at low levels, could cause considerable property damage.

Mr. Stapleton asked whether there is a general discharge permit for ballast water. Mr. McCracken answered that there is no specific permitting requirement and that ballast water discharges are exempted from even point-source discharge regulations. But they still have to comply with water quality standards in the states. For this study, the MDEQ and FTL consulted the various Great Lakes jurisdictions about water quality standards for point-source discharges and applied those. Dr. Premo asked Mr. McCracken whether there had been any testing of common untreated ballast water to determine whether it met water quality standards coming out of the ship. Mr. McCracken said that no.

Mr. Stocks discussed concerns for ship operators if hypochlorite was used. These included the need for storage tanks, piping, pumps, and metering systems that would need to go on board. Also, involvement of several regulatory agencies would become necessary to get approvals. For example, the U.S. Coast Guard and Transport Canada have stated that they could envision that these ships would fall under regulations for ships carrying chemicals. It also would require a significant training effort for the crew. Bulk hypochlorite is available at nearly every port in the Great Lakes, but it may be more difficult to obtain in other places. The use of hypochlorite will increase both coating damage and corrosion rates. It is not clear whether the damage will be significant over the life of the ship. Mr. Jerry Saalfield, MDEQ, stated that the MDEQ ran a GCMS scan on the ballast water discharge after dechlorination and found all of the chemicals analyzed were well below current Great Lakes water quality standards.

Dr. Premo asked what contact time was recommended for the ballast water to have 10 ppm of hypochlorite. Mr. Stocks answered that their test time of 48 hours was the typical period necessary for going from one port to another, during which time they dosed once.

Mr. O'Reilly discussed the deterioration levels of chlorine during the 48-hour period. In an aggressive sediment condition, about 90 percent of the hypochlorite was consumed by the sediment within 12 hours. It is likely that in normal harbor conditions the actual residual concentration would be around longer. Dr. Premo questioned how practical that would be because of the unavailability of hypochlorite in some ports, to treat ballast water only as it enters the Great Lakes. She speculated that it could it be treated for 12 hours and then discharged. Mr. Stocks said that it would be too expensive for shippers to sit in port for that period. It is more practical to use an on-board chlorine generator so it could be done anywhere in the world. Repeated treatments would sterilize the entire system over time.

Dr. Long noted that he used sodium hypochlorite in his research to strip metals off sediment. Mr. McCracken agreed that there was a potential concern, but that he had never heard of this issue at, for instance, sewage treatment plants where hypochlorite is used in the presence of sediment. Dr. Long stated that, in fact, he did not know the ultimate fate of the metals that were stripped off sediments and that some may be reabsorbed into the sediments. Mr. Stapleton asked if there had been any reports comparing the two types of sediments, ballast and sewage. Mr. McCracken said there were none that he knew of, but the ballast sediments would contain more inorganic material than sewage plant sediment. Mr. Stocks stated that there has been considerable work done characterizing ballast water from a biological perspective, but he does not know of any chemical characterizations.

Dr. Long requested additional clarification regarding the effectiveness of the biocides. He indicated that, based on the report, it is his understanding that neither biocide was very effective. Dr. Landrum agreed that neither is effective at the levels that were tested on shipboard, but said they could be if higher concentrations were used. In some cases organisms required 1,000 ppm of hypochlorite. With the complicating factor of sediment, effectiveness becomes questionable. In addition, serious corrosion probably begins at about a 1,000 ppm concentration.

Mr. Raaymakers asked what the criteria were for selecting the organisms used in the study and how representative were the organisms. Mr. O'Reilly responded that the chosen organisms were those that existed not only in the water column itself, but those that existed in the sediment, and for which the sediment might act as a protective barrier. They also considered life stages, especially encysted stages. They tried to cover the broadest range of organisms.

Dr. Long asked whether either biocide would have been effective against the zebra mussel. Mr. O'Reilly said that the zebra mussel was indeed tested and 1 to 10 ppm of hypochlorite was effective against it. The free-floating non-attached life stage was used since this is the form that generally gets taken up in the water and could get inside a ballast tank. Dr. Landrum noted that even if a lower concentration of a biocide did not kill off resistant stages, continually killing the sensitive stages would ultimately result in sterilization.

Mr. Stocks restated some of the issues that remain to be resolved. He stated that further testing should be done in actual ballast tanks and in various harbor water quality situations. Also, the minimum level of biocide needed has not yet been determined; and while it is clear that sediment has a negative effect on biocidal action, it is not known what the magnitude of that effect is.

Dr. Everett agreed that the issues remaining to be resolved had been well laid out, but questioned whether any of the questions posed to the Panel could be definitively addressed based on the information presented in the report. For example, it is known that chlorine is an effective biocide, but since it was not tested in the ballast tanks, it is not known whether it will work on an operational vessel. Also, dose-response relationships for an agreed upon suite of organisms acting as indicators under varying parameters, such as sediments or salinities, should have been studied in the laboratory. The shipboard part of the study should have concentrated on whether the required doses can be achieved in actual ballast tanks.

Dr. Hack discussed issues related to corrosion. He agreed with the conclusions of the report but did not think the data reported supported the conclusions. The 15 days of testing the coating panels was too short a time to extrapolate to a 20-year service life. Corrosion is not necessarily a linear process. The issue is with coatings, and there are a number of relevant questions that need long-term studies. It takes a long time for the corrosive species to diffuse through the coating systems and start to attack the bonds. It is important to look at bond strength measurements after extended periods of exposure and not just peel-back from a scribe. Coating manufacturers also need to be consulted about how to do the tests and many specimens are required since there is a great deal of variability in the test specimens. No definitive conclusion about corrosivity can be drawn without this testing.

Dr. Everett asked Dr. Hack about the issue of linearity. As minerals weather, different shaped surfaces become exposed, and he does not think the corrosion process will be linear, as was assumed in this research. He also stated that the galvanic effect, which would be important in boats, was not addressed in the report. Dr. Hack stated that galvanic corrosion would be controlled in space that does not have cathodic protection by means of coatings. If the coated surfaces deteriorate in the painted tanks, there will be galvanic corrosion. With regard to linearity, there are a number of things that effect corrosion rate as a function of time. Surface roughness is one. Another is the effect of corrosion products and their degree of porosity and adhesion to the surface.

VI. DISCUSSION

In response to concerns about whether related issues that were not addressed in the research should be included in the MESB report, Mr. Harrison stated the Panel's primary charge from the Governor was to evaluate the scientific validity of the conclusions reached by the FTL report regarding the efficacy of the biocides evaluated, the corrosiveness of those biocides to ballast tanks, and whether the discharge concentrations for each biocide could meet regulatory standards. However, it was important for the MESB report to include as much information as the Panel deems necessary to clearly indicate to the Governor the usefulness of this demonstration project to address the issue of the effectiveness and practicality of the two biocides investigated.

Dr. Gracki began the discussion of the substance of the report by stating that if he understood the general comments of the Panel, the members might agree with the conclusions of the report, but that those conclusions were not supported by the data.

Dr. Landrum agreed, saying that the shipboard data are not defensible, although the laboratory toxicology data may be. The general methodology employed in this study is faulty and the data do not support the summary information. The Panel decided to consider and address each chemical separately.

Dr. Long stated that based on the report and information from the Panel members, he would conclude that copper is not an effective biocide for this use. Dr. Premo said that at certain concentrations it is, but the real issue is that it is not dischargeable. Dr. Everett suggested that the Panel look at the limiting step: the toxicity data as a whole suggests the level that might be required for effectiveness; however, that level is far too high to be discharged into the Great Lakes. Given this, and in the absence of any known neutralizing agent that would allow copper to be safely discharge into the Great Lakes, it can be concluded that copper is not worth any further study at this time.

In terms of sodium hypochlorite, Dr. Long said the Panel could conclude that sodium hypochlorite is a possibility, but needs further study, especially in terms of whether necessary levels can be obtained in ballast tanks and how its efficacy is affected by sediment. Dr. Premo stated that sodium hypochlorite is in widespread use, especially for wastewater treatment plant discharge. Consequently, considerable data exist on dosages needed to control bacteria. Dr. Premo asked whether there had been any toxicity testing data from facilities that take in Great Lakes water that could be looked at. Mr. O'Reilly answered that there has been since the zebra mussel invasion. But in those cases, sodium hypochlorite is used at low levels to irritate and prevent implantation of the organism inside the pipes. There is, however, other information available on lethal concentrations. Dr. Gracki observed that evidently hypochlorite can be handled safely since other places use it regularly, though there might be some special problems on ships.

Dr. Landrum stated that the FTL write up on the laboratory toxicity testing was not clear about what protocol was used for what organism. Also, the method of analysis does not discuss the uncertainty around the observed values. His educated guess is that the right concentration for hypochlorite is between 10 and 20 ppm. The biota tested in the report are the ones that can be handled and cultured best, and they will account for 90 percent of the species expected in ballast tanks. It is clear from this and other studies that there are some resistant forms. Consequently, it does not matter which biocide is used, since neither will kill 100 percent. Another concern is the need to be able to get to and maintain the right residual or free-chlorine concentrations to ensure an effective kill of the organisms. New sediments taken on, residual sediments in the bottom, or other reactive surfaces of the ballast tanks will use up chlorine and would need to be taken into consideration and adjustments made.

Dr. Gracki asked if it would be possible to know if the hypochlorite solution was well mixed. Mr. Stocks answered that it would be possible to do measurement adjustments on board and that the intake water could be dosed before it goes to the intake pump. Dr. Long noted that hypochlorite demand would be based on how much sediment gets pulled in. The demand would vary from place to place, making it difficult to calibrate doses on intake as well as discharge. Dr. Everett thought that this problem could be circumvented through the use of safety factors since no one can expect the shippers to know the chemical composition of the different port waters. Mr. Stocks pointed out, however, that if the water is overdosed, resulting in a high residual, there could be more damage to the ballast tanks. Dr. Long stated that fiber optics could be used to measure the chemical composition in the tanks.

Dr. Everett asked Mr. Stocks if it was fair to state that one of the conclusions of the study was that hypochlorite has a high degree of efficacy when treating the suite of organisms that was tested with but the range at which it is effective is quite variable depending on the taxonomic group or life stage. Mr. Stocks answered that is was, but it could be restated to say that the study showed that hypochlorite could be effective over a wide range of taxonomic groups in ballast waters provided that there was sufficient information about the demand as it was dosed.

Dr. Everett commented that disinfection byproducts were not found to be present above water quality standards in this case, but that disinfection byproducts will also depend on the specific organic constituents of the water being treated. Since this study was limited in terms of the range of beginning waters that could be tested, it may not be possible to conclude that disinfection byproducts are not going to be a problem. Dr. Landrum suggested that this issue might be resolved by a review of the literature on disinfection byproducts.

Mr. McCracken commented that ballast water is a temporary, not continuous discharge. Other places are discharging daily for years at a time and there is no problem with byproducts. He agreed that byproducts depend on their precursors, but what is going into sewage treatment and paper mills may have more serious precursors than ballast water. He stated that the MDEQ would not consider a one-time discharge is a serious problem.

Drs. Long and Landrum discussed the necessity for measuring the sodium hypochlorite to know how much sodium bisulfide must be added for neutralization, since the excess would be a problem in the water. There needs to be a protocol for measuring the exact amount of neutralization needed.

Dr. Everett stated that he would have trouble stating that the use of hypochlorite is ready for implementation across the fleet, but it would be easier to say it is promising enough to warrant additional work.

The Panel discussed which sections of its response each member would work on. It was decided that Drs. Landrum and Everett will address the efficacy of sodium hypochlorite, specifically addressing the methodological issues. Dr. Everett will focus on the experimental design. Drs. Long and Gracki will address copper as a biocide and discuss how sodium hypochlorite can leach chemicals out of sediments.

Dr. Premo and Mr. Raaymakers will prepare a segment on sediment, and Dr. Hack will write a section on corrosion in relation to copper and hypochlorite. Mr. Harrison will prepare the introduction and serve as the overall editor for the document.

Mr. Stocks agreed to provide some additional information to the Panel on safety regulations, standards, implementation timelines and training, based on his knowledge and experience.

VI. PUBLIC COMMENT

There was no public comment.

VII ADJOURNMENT

The meeting was adjourned at 2:45 pm.

Keith G. Harrison, M.A., R.S., Cert. Ecol.
Executive Director
Michigan Environmental Science Board

Attachment