Brussels, Belgium, 6 June 2000

Antibacterial Properties of Copper and Brass Combat Toxic E. coliO157 Bacteria

A recent study by Dr. Bill Keevil[1] at the Centre for Applied Microbiology & Research (CAMR) in the UK found that the highly toxic E. coli O157:H7 strain of bacteria survive for much shorter periods of time on copper and brass surfaces than on stainless steel. This finding has wide-ranging implications for reducing outbreaks from cross contamination of E. coli in the food processing industry.

The study also found that copper has significant antibacterial advantages over polybutylene plastic and stainless steel in cool potable "soft" waters. This finding indicates that copper water piping systems may help to reduce the risk of human infection from waterborne E. coliO157 bacteria in many drinking water systems around the world.

Copper and brass surfaces may reduce E. coliO157 outbreaks in food processing.

The results obtained at CAMR indicate that copper and brass food preparation surfaces have the potential to combat deadly E. coliO157 quickly and efficiently. Therefore, food preparation materials made from copper and brass may reduce the incidence of cross contamination of food products with toxic E. coliO157 bacteria.

The work carried out by team member Dr. Andrew Maule found that at room temperatures it takes 34 days for E. coliO157 bacteria to die on stainless steel tiles, 4 days to die on brass tiles, and just 4 hours to die on copper tiles. At chill temperatures typical of food storage, the study found that ten percent of the bacteria were still alive on stainless steel tiles after 34 days, whereas bacteria were completely eradicated on brass tiles within 12 days and on copper tiles in just 14 hours.

These results prompted the International Copper Association to commission CAMR researchers to further investigate the bactericidal properties of copper, brass, and stainless steel surfaces in various conditions found in the food preparation industry. For example, in acidic environments representative of fruit juice processing, E. coli O157 survived for as little as 45 minutes on copper, versus 2 days on stainless steel. And in environments containing animal feces with anaerobic E. coliO157 bacteria, copper and brass tiles were found to exhibit superior bactericidal effects to stainless steel tiles.

"It may be possible to achieve important public health benefits just by changing the surface material commonly used in food processing," said Dr. Keevil. "Stainless steel is the most widely used surface in food preparation, but this material can remain a source of microbial food contamination for a very long period of time." Since copper- bearing materials have such strong antibacterial properties, the researchers believe that foods most amenable for processing on copper surfaces should be determined in order to reduce E. coliO157 occurrences and outbreaks.

"Our findings point to the potential use of copper and brass as hygienically beneficial surfaces in the food processing industry," said Keevil. "We now have a preliminary understanding of the bactericidal benefits of copper and brass over stainless steel in combating cross contamination from E. coliO157." Plans are under consideration to investigate the antibacterial effect of copper and brass on Salmonella enteritidisPT4, Campylobacter jejuni, S. typhimuriumDT104, and other highly toxic bacteria.

Antibacterial properties of copper may reduce E. coliO157 in copper water pipes.

Dr. James Walker at CAMR determined that three independent factors (i.e., water temperature, water hardness, and type of piping material) affect the survivability of E. coliO157 in potable water systems. Regarding material selection, the CAMR researchers concluded that copper water pipes may have significant antibacterial advantages over polybutylene plastic and stainless steel.

In every temperature range and water hardness condition studied, copper demonstrated significant antibacterial advantages over plastic. And in all of the conditions studied, copper demonstrated either stronger or equivalent antibacterial properties compared to stainless steel.

In soft water systems at 10^{0}C, the concentration of toxic E. coliO157 was 100 times lower on copper substrates than on steel and plastic substrates. "These temperature and water hardness conditions are typical of many residential wells and potable surface water supplies around the world," said Keevil. "Our experiments indicate that when used with cool soft drinking water resources, copper water piping systems have the potential to reduce the risk of human infection from E. coliO157 bacteria."

The study also found that copper has strong anti-biofouling characteristics (i.e., copper inhibits the deposition of bacteria and other organic matter) in cool (100C) soft waters. However, biofouling was very significant on plastic and steel. After being submerged for seven days in cool soft waters, little biofilm was detected on the copper substrates. However, nearly 80% of the steel substrates and 90% of the plastic substrates were covered with biofilms. "Biofilms are harbingers of E. coliO157 and other microbial pathogens and they pose a significant risk to human health," said Keevil. "Copper was the only piping system examined that exhibits strong anti- biofouling characteristics for cool (10^{0}C) soft water drinking supplies."

For potable systems with moderately hard water, copper imparts very strong anti- biofouling advantages over plastic at 10^{0}C (cool water), 20^{0}C (warm water), and 40^{0}C (hot water). Biofilm coverage in moderately hard water ranged from 25-43% on plastic substrates whereas biofilm coverage on copper substrates at all water temperatures was less than 2%.

For potable systems with hard water, piping materials seem to play a much lesser role in preventing biofouling, presumably because the calcium carbonate deposits in the materials from the water prevent copper from contacting the bacteria directly.

E. coliO157 is a highly infectious ACDP Hazard Group 3 foodborne and waterborne pathogen that has created a serious public health challenge for the food processing industry. This strain of bacteria produces potent verocytotoxins, which can cause hemolytic colitis, hemolytic uremic syndrome (kidney disease), and even death.

E. coliO157 bacteria infect tens of thousands of people around the world every year. An outbreak in Japan caused 9,000 people to become sick. A 1997 outbreak in Scotland was responsible for 500 infections and 20 deaths. And in the U.S., over 500 people became ill and three children died after eating undercooked hamburgers infected with E. coliO157.

The largest waterborne outbreak of E. coli 0157 occurred at the Washington County Fairground near Albany, New York State in 1999. Over 1000 people were infected, 65 were hospitalized and two died. Nine children developed hemolytic uremic syndrome and required long-term dialysis.

It is believed that just ten to fifty highly toxic E. coliO157 organisms are sufficient to infect humans with illness. The infections are difficult to treat and antibiotics may prompt the bacteria to release even more verocytotoxins. In healthy individuals, E. coliO157 infections usually last three to five days. However, the bacteria can victimize children under 14 years of age, the elderly, and immunocompromised individuals with serious complications.

[1]Dr Keevil is currently Scientific Leader at CBD Porton Down

ABOUT ICA & ECI:

The following study was funded by the International Copper Association (ICA). ICA is responsible for communicating the benefits of copper and promoting worldwide copper initiatives in the power, information, plumbing and architectural markets, as well as in other applications. ICA operates in 28 locations worldwide. Its members represent 80% of the world's refined copper output.

ICA is represented in Europe by the European Copper Institute (ECI). ECI is a joint venture between the International Copper Association and the International Wrought Copper Council, representing the world's leading copper fabricators.

For additional information, please contact:
Catherine Bolton, ICA (New York)
Tel: +1-212 251-7240. Fax: +1-212 251-7245
e-mail: cbolton@copper.org

Isabelle Adam, ECI (Brussels)
Tel: +32-2-777-7070Fax: +32-2-777-7079 e-mail:iaa@eurocopper.org

FACT SHEET
Antibacterial Properties of Copper
and Brass Combat Toxic E. coliO157 Bacteria

1. Background on E. coliO157

What is E. coliO157?
E. coliO157 is a highly infectious ACDP Hazard Group 3 foodborne and waterborne pathogen that has become a serious public health problem in the past three decades. E. coliO157 bacteria produce potent toxins which cause diarrhea, severe aches, and nausea in infected persons, and the bacteria may cause hemolytic colitis (bloody diarrhea), kidney disease (hemolytic uremic syndrome), and even death. Children up to 14 years of age, the elderly, and immunocompromised individuals are at the greatest risk of contracting severe symptoms.

How prevalent are E. coliO157 infections?
Very prevalent. It is estimated that hundreds of thousands of people become ill worldwide and hundreds of people die each year due to E. coliO157 infections.

How does E. coliO157 infect the population?
Contaminated meat, water, dairy products, and unpasteurized juices are the most common pathways for contracting E. coliO157 bacteria. Direct contact with an infected person is also a means for infection.

How does E. coliO157 infect food supplies?
Fecal contamination from the intestines of cattle and sheep during slaughter is one of the most prevalent pathways for infection. In 1993, 500 people became ill and three children died in the state of Washington after eating undercooked hamburgers infected with E. coliO157. Similar outbreaks have been reported in Japan and the United Kingdom.

What is cross contamination?
A carcass that is infected with E. colifrom its own intestines is said to be "contaminated." However, a carcass that is not infected with E. colifrom its own intestines may accidentally contact a contaminated carcass or come in contact with a contaminated surface. When this happens, the carcass becomes "cross contaminated."

2. The protective properties of copper and brass surfaces in food preparation

What is the potential role of food preparation surfaces in reducing the risk of E. coliO157 infections?
Researchers have found that some food preparation surfaces, such as copper and brass, have a bactericidal effect on E. coliO157 bacteria. Since infected carcasses in food preparation can contaminate work surfaces, the risk of cross contamination of non-infected carcasses can be reduced by using a surface that exhibits a bactericidal effect on the microbes. Copper and brass surfaces may reduce the potential for cross- contamination of food by pathogenic organisms, such as E. coliO157, and hence play a hygienic role in the food processing industry.

What is the most prevalent surface material in the food preparation industry?
Stainless steel is the most widely used surface material in food processing. It is nontoxic and easy to clean. However, stainless steel scratches, harbors microbes if not disinfected frequently, and does not exhibit the bactericidal properties of copper and brass.

What are the potential advantages of copper and brass to stainless steel?
CAMR researchers found that bacteria can survive on stainless steel surfaces for a very long time (e.g., several months). This means that the surface itself can become a source of

cross contamination. Other workers have shown that carcasses that were not directly contaminated with E. coliO157-infected feces, for example, can become cross contaminated by contacting infected stainless steel surfaces.

CAMR researchers also found that E. coliO157 dies off much more quickly on copper and brass surfaces than on stainless steel surfaces. Their study suggested that copper and brass are much more hygienic as a food preparation surface material than stainless steel. Furthermore, copper and brass are much less expensive than stainless steel.

How much better are copper-bearing surfaces than stainless steel as bactericides?
Much better. At room temperature (20^{0}C), all of the E. coliO157 bacteria died on copper tiles within just 4 hours. Alternatively, it took 34 days for all of the bacteria to die on the stainless steel tiles. Survival rates on brass were 4 days.

At chill temperatures typical of food storage (4^{0}C), all of the E. coliO157 bacteria died on the copper tiles within 14 hours. Alternatively, after 34 days, 10% of the bacteria were still alive on the stainless steel tiles. Survival rates on brass were 12 days.

What variables in food processing conditions were studied in the research?
The antimicrobial effects of brass were dramatically accelerated with anaerobically- grown microbes (i.e., microbes that thrive in the absence of oxygen, such as in the gut of animals). The antimicrobial effects of copper were delayed slightly for anaerobically-grown microbes. Low pH conditions typical in the manufacturing of fruit juice increased the mortality rate of E. coliO157 on copper surfaces to just 45 minutes. The microbes died in two days on stainless steel surfaces.

When human and animal feces containing the anaerobic form of the bacteria were studied, the antimicrobial effects of copper and brass remained significant. On stainless steel, the mortality rates of the bacteria decreased, but to a still unacceptable level of several weeks. Highly humid conditions were found to reduce the antimicrobial effect of brass surfaces. Mortality of the microbes in UHT milk (representative of dairy environments) was reduced to 24 hours on brass, but increased slightly on copper.

Where do we go from here?
Copper and brass have the potential to become more hygienic surface materials than stainless steel in the food processing industry. Therefore, it is worthwhile to study the bactericidal effects of these three surfaces on other highly toxic bacteria, such as Salmonella enteritidisPT4, Campylobacter jejuni(poultry); and the multiple antibiotic resistant S. typhimuriumDT104 (beef).

Furthermore, it is worthwhile to: 1) investigate the potential leaching characteristics of copper-bearing food preparation surfaces, 2) explore copper alloys for use in food preparation when a material is required that is harder than copper, and 3) study the potential toxicological effects of leached copper in various types of processed foods.

3. The Antibacterial Properties of Copper

What are the most common types of materials used in piping potable water for human consumption?
Copper has a long history of use as a piping material for potable water supplies. During the 20th century, stainless steel began to compete with copper for piping usage. Towards the end of the 20th Century, polybutylene plastic materials became very common piping materials because of their lighter weight and lower cost.

Do any of these piping materials exhibit desirable antibacterial properties to combat E. coliO157?
Yes, only copper. After allowing E. coliO157 bacteria to grow on substrates of copper, stain-

less steel, and plastic for seven days in soft water systems at 100C, the concentration of E. coliO157 was found to be 100 times lower on copper substrates than on steel or plastic substrates. The antibacterial properties of copper are significant for these water conditions, which are typical of many residential wells and potable surface water supplies around the world.

Do the antibacterial benefits of copper extend to hard and medium hard waters?
The precipitation of calcium carbonate from medium and hard waters creates a coating on all three of the piping materials, thereby preventing the materials from directly contacting the E. coliO157 bacteria. Nevertheless, copper still has antimicrobial benefits over plastic in cool and warm moderately hard waters, and copper has antimicrobial benefits over plastic and stainless steel in cool and warm hard waters.

What other factors are important in reducing E. coliO157?
High temperature has a dramatic effect in killing E. coliO157 bacteria. At hot water temperatures (40^0C), E. coliO157 were not detected on any of the substrates in soft or moderately hard waters (however, in hard waters, significant quantities of E. coliO157 were found on plastic substrates, whereas only trace concentrations were detected on the copper and stainless steel substrates).

Which water piping material demonstrates the best antifouling properties?
Copper has strong anti-fouling benefits over stainless steel and plastic in cool (100C) soft waters. After being submerged in these waters for 7 days, biofouling was completely absent on the copper substrates, whereas nearly 80% of the stainless steel substrate and 90% of the plastic substrates were coated with biofilms. As temperatures were increased to 40^0C, biofouling was significantly lower on copper substrates than on stainless steel or plastic substrates.

Copper has strong anti-fouling benefits to plastic in moderately hard water systems at 10^0C (cool water), 20^0C (warm water), and 40^0C (hot water). Biofilm coverage in moderately hard water ranged from 25-43% on plastic substrates whereas biofilm coverage at all water temperatures was less than 2% on copper substrates.