Quantifying Antimicrobial Properties of Copper

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ABSTRACT

Copper is one of the most essential and widely used metals in the world. The uses of the metal are noticeable as early as the time of Ancient Egypt. At the time it was used to make weapons, kitchenware, jewelry, tools, and they had also discovered other benefits. Including the metal's ability to kill bacteria. This affect was incomprehensible for the people of Ancient Egypt, but to-day we can understand the reason behind it.

The purpose of this research was to find out if copper has antimicrobial properties. The hypothesis was that Copper can interfere with the biological processes of bacteria, which gives copper antimicrobial processes.

Escherichia coli was used as the bacterial agent. All copper materials were placed in petri dishes with agar nutrient. The bacteria were streaked closed to the copper materials. They were incubated at 37^{0}C for 20 hours. After that, zones of inhibition were measured in mm.

The result shows that copper pennies had the largest (best) Zone of Inhibition, followed by Copper 110 Alloy. Since these were both better than the Zone of Inhibition of the ampicillin antibiotic, my hypothesis was accepted.

BACKGROUND RESEARCH

Copper is one of the most essential and widely used metals in the world. A reddish and ductile element, it is part of group eleven on the periodic table. The use of the element can be visible every day, which is why most times we take it in vain. The uses of the metal are noticeable as early as the time of Ancient Egypt. At the time it was used to make weapons, kitchenware, jewelry, tools, and they had also discovered other benefits. Including the metal's ability to kill bacteria. This affect was incomprehensible for the people of Ancient Egypt, but to-day we can understand the reason behind it. In the present day, it is commonly known to be in electrical equipment such as wiring and motors. This is because it can be formed into wires and it is strangely one of the best conductors of electricity and thermal, just second behind steel. It can also be used in construction for projects related to roofing and plumbing. It is also found in industrial machinery like heat exchangers, for instance. In agriculture, copper sulfate is widely used as an agricultural poison and as an algicide in water purification. The compounds of copper are also found to be used in chemical tests for sugar detection.

Copper can be found in different areas of the world. It generally comes from copper ore but at times small amounts can be discovered in cubic crystal chunks that are called native copper. Keweenaw Península near Lake Superior in Michigan is the most likely place to find native copper. Copper ore is first mined then is put into different processes to purify the copper. The United States is a large producer of copper. It has mines in Utah, Michigan, New Mexico, Arizona, and Montana. In South America. Chile and Peru are both crucial producers of copper.

There can also be other large producers of copper in China, Indonesia, parts of Africa, The Democratic Republic of Congo, and in the Ural Mountains of Russia.

The mining of this mineral is a lengthy process that begins with ore mining that contains less than one percent of copper and at the end it produces cathodes. Cathodes are sheets that contain ninety-nine-point ninety-nine percent pure copper. Due to the differing chemistries of the ore, the most prevalent forms of ore, copper oxide and copper sulfide, are put into two different processes called hydrometallurgy and pyrometallurgy. Copper oxides, which are more abundant at the surface but have a lower copper concentration are termed low-grade ore. Although more ore must be removed and processed, the method is less expensive, allowing oxides to be mined profitably. Copper sulfide ores, on the other hand, are less common but have higher copper content. Despite the greater processing costs, more copper can be gained in the end. Since each mine site has its own mineral concentration and amounts, mine planners must decide the most cost effective and profitable ore processing. A mine may extract both forms of copper minerals when it is economically feasible. When it is not, mines either process copper oxides or copper sulfides.

There are numerous disadvantages that come with mining copper. There has been the failure of controlling the escape of contaminated mine seepage which has affected the water sources. Water from the surface and underground can both be affected from the rocks used in copper mines. Tailings from the copper mines can also carry pollutants and have an impact on the environment, including the quality of the surface and underground water. The extraction process of copper also creates acidic mists that stay in the air and cause health problems for people. It also impacts crops, reduces the quality of land, and damages nearby buildings.

Like the Ancient Egyptians had discovered, copper can be used a way to kill bacteria. This is due to copper’s antimicrobial attributes, that disturb the protective layers of certain microorganisms and disrupt their essential processes. The atom of copper is composed of a stable nucleus and less stable cloud of electrons. It uses the process of redux, which is the transfer of one or more electrons from one atom to another. When copper loses electrons, it creates cuprous oxide (Cu_2O). In this state, the redox combines copper atoms with oxygen atoms, which creates a condition in which there is a continuous exchange of electrons. This soon makes cuprous oxide sufficiently unstable to interfere with organisms at a microscopic level. Bacteria can be killed when the process of creating rusting organisms is happening. When this occurs oxidizing copper atoms gather electrons from the atoms that belong to the cell wall. After the atoms that make up the cell wall are taken, the wall eventually breaks. In retaliation, the bacteria attempts to adapt to the new environment by taking in the details of its surroundings and pushing out unwanted elements. As the copper ions then begin to go into the cell and since copper is toxic to the cell, it kills the bacteria.

Prices of copper can be largely induced by the health of the global economy. This is because of its crucial role in all areas of the economy. For instance, power transmission and generation, construction, and factory equipment and electronics. Copper has been known to be a reliable indicator of a healthy economy or the opposite. The demand and order for copper represents a healthy economy if otherwise then the opposite is to happen. Recently, copper has been in demand for electric vehicles, since they require more copper than other types of vehicles.

It is mostly needed for electrical batteries and semiconductor wiring. The push for a greener infrastructure will likely increase the demand and the cost of copper.

Escherichia coli, a diverse and common group of bacteria. Generally discovered in food, environment, and in the intestines of people and specific warm-blooded animals. Most strains of Escherichia coli are deemed harmless, and some are also claimed to be beneficial for health. Escherichia coli can produce vitamin B twelves, vitamin K, and it can also maintain a protective space in the gut for other useful bacteria. Other stains of this bacteria can induce infections that give you urinary tract infections, respiratory illness, pneumonia, diarrhea, and other ailments. Enterotoxigenic E. coli and Shiga toxin-producing E. coli are both the two most frequent strains of Escherichia coli that cause diarrheal illness. Shiga toxin-producing E. coli produces a toxin that disrupts the lining of the small intestine, which causes nausea, watery diarrhea, acute stomach cramps, and other symptoms. Other than the bacteria thriving in a freezer or refrigerator, they can also multiply in temperatures as low as forty-four degrees Fahrenheit. Being infected by harmful strains of Escherichia coli can either be minor or fatal. Those with a weakened immune system or children five years below can be at most risk. People with vulnerable immune systems are more likely to have kidney failure. There is no remedy or vaccine to prevent suffering from this bacterium. E. Coli is the most recurrent inducement of food poisoning in the United States of America.

RESEARCH QUESTION

Do different types of copper have antimicrobial properties?

HYPOTHESIS

Copper can interfere with the biological processes of bacteria, which gives copper antimicrobial processes?

MATERIALS

Copper 110 Alloy Plates	Copper Pennies
Copper BBs	Inoculating Loop Agar Nutrient
E. Coli Bacteria	
Ampicillin Antibiotic	Sterile Petri Dishes
Autoclave	Gloves
70% Alcohol	Bleach
Graduated Cylinder	Balance

Bio-Bag Bunsen Burner

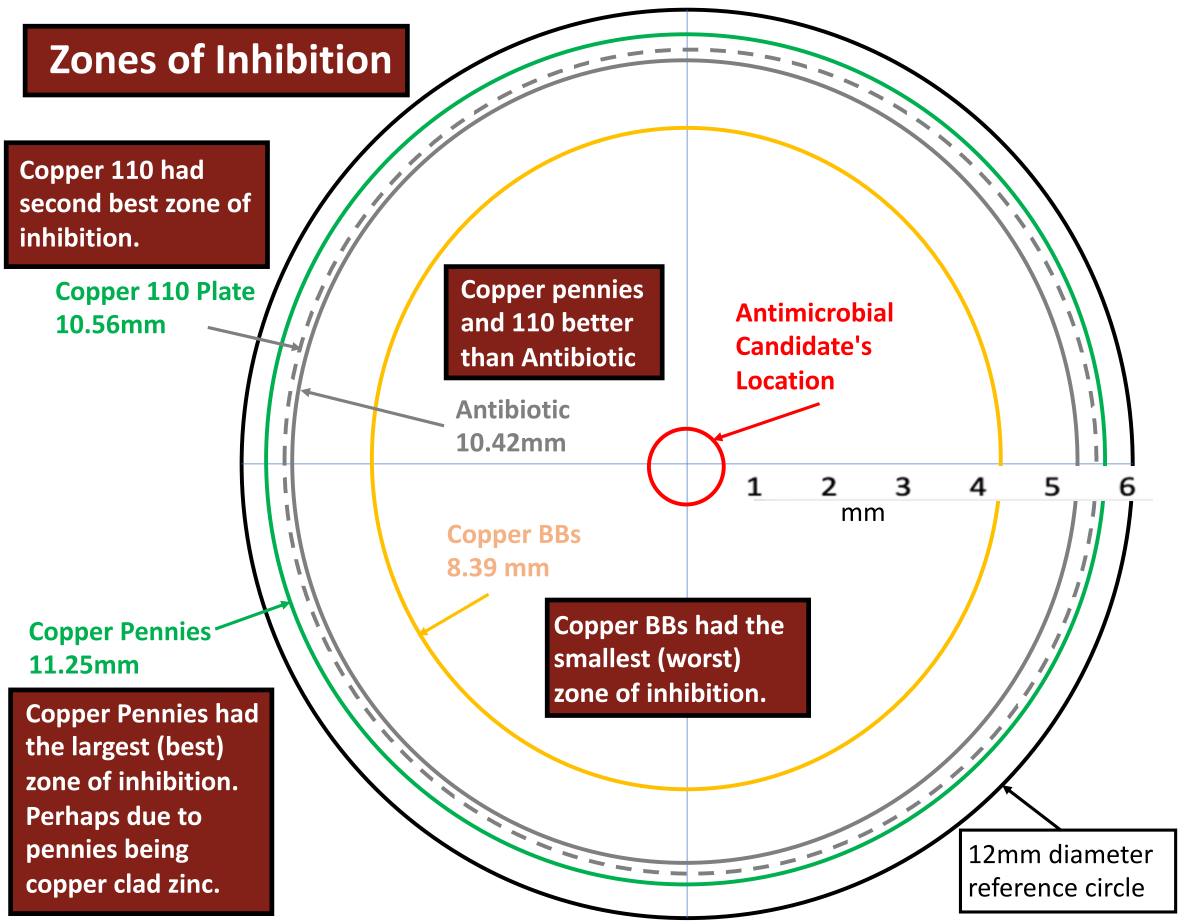
Incubator

EXPERIMENTAL PROCEDURES

1. Obtain three pieces each of copper plate, copper BB's, and copper pennies.
2. Remove all tarnish down to bare metal. Lightly sand the outer surface to create a textured surface rather than a smooth one.
3. Begin by sterilizing the petri dishes. This is done by placing them in a bath of boiling water and allowing them to dry upside down on a sanitized drying rack or lab work bench.
4. Use a permanent marker to label the bottom of each agar plate with the type of copper used and three trials and the control (no copper) and control 2-with ampicillin. A total of 15 plates.
5. Prepare agar powder by placing it in the microwave with the appropriate amount of water. 6.9 grams of agar was added to 500 ml of water and boiled to completely dissolve the agar.
6. The final mixture should be clear with no particles floating around in the solution. Let the mixture cool for 3 to 5 minutes before proceeding to the next step.
7. Separate the Petri dish into two pieces, a top and a bottom. Carefully fill the bottom half with warm agar nutrient solution. Use the top half to loosely cover the bottom portion; place the lid ajar so moisture can escape. Let the solution cool and harden for at least 1 hour.
8. Place the plates in a plastic bag and label the bag with the media type and the date and store it upside down in a refrigerator.
9. Grab one plate with agar and put one copper plate metal in the middle. Do the same for the other two more copper plates and put one in each agar plate.
10. Repeat No. 1 using copper BB's, and then copper pennies.
11. In the next three plates, copper will be put as Control 1.
12. The next three plates, put one ampicillin in one agar plate, do the same in the two agar plates.
13. Sterilize inoculating loop in Bunsen Burner
14. Use loop to capture Escherichia Coli
15. Perform these streaks on "targets:" Copper 110 plates, Pennies, and BBs:
16. Streak 1: Glide inoculating loop tip back and forth across the agar surface to make a streak.
17. Streak 2: Reignite inoculating loop and cool by stabbing it into the agar away from the first (primary) streak. Draw loop tip through the end of the primary streak and, without lifting loop, make a zigzag streak across one quarter of the agar surface.
18. Streak 3: Reignite loop and cool in the agar as above. Draw loop tip through the end of the secondary streak and make another zigzag streak in the adjacent quarter of the plate without touching the previous streak.
19. Streak 4: Reignite loop and cool it as above. Draw tip through the end of the tertiary streak and make a final zigzag streak in remaining quarter of plate.

20. Place targets upside-down in $37^{\circ}C$ incubator for 15-20 hours. (Inverted to prevent condensation).
21. Measure Zones of Inhibition. Average 3 trials. Sterilize all targets in Bunsen Burner.
22. After experimentation, all plates were autoclaved at $121^{0}C$ for 20 minutes, then 10% bleach was sprayed all over then placed in the incinerator.
23. Cleanup with disinfectant. Wash hands.

Table 1: Average Zone of Inhibition (mm)				
SAMPLES	Trial 1	Trial 2	Trial 3	Average
Control 1 - Antibiotic	12.50	7.50	11.25	10.42
Copper Pennies	12.50	15.67	14.83	11.25
Copper BB's	8.33	7.50	9.33	8.39
Copper 110 Plate	6.67	11.67	13.33	10.56



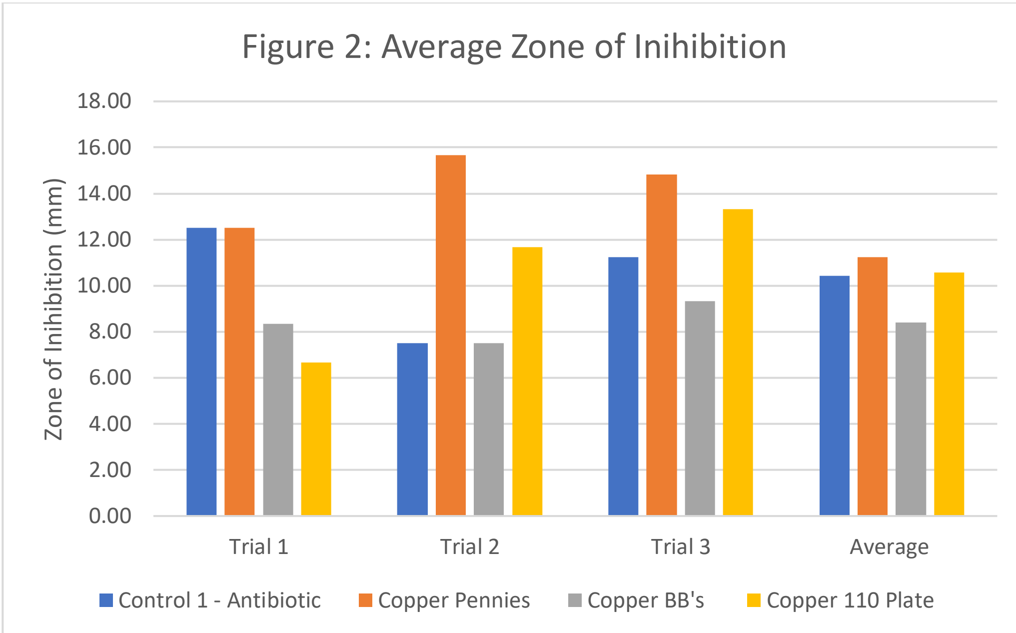


Figure 2: Average Zone of Inihibition
Zone of Inihibition (mm)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Trial 1
Trial 2
Trial 3
Average
Control 1 - Antibiotic
Copper Pennies
Copper BB's
Copper 110 Plate

TABLE 2: Raw Scores for Zone of Inhibition (mm)				
	Trial 1	Trial 2	Trial 3	Average
Control 1- with Antibiotic				
1	15.00	10.00	17.50	14.17
2	10.00	5.00	5.00	6.67
Average	12.50	7.50	11.25	10.42
Copper Penny Plates				
1	15.00	15.00	17.50	12.13
2	12.50	20.00	15.00	12.38
3	10.00	12.00	12.00	9.25
Average	12.50	15.67	14.83	11.25
Copper BB's Plates				
1	10.00	5.00	8.00	7.67
2	10.00	7.50	10.00	9.17
3	5.00	10.00	10.00	8.33
Average	8.33	7.50	9.33	8.39
Copper Metal Plate				
1	10.00	10.00	15.00	11.67
2	5.00	15.00	10.00	10.00
3	5.00	10.00	15.00	10.00
Average	6.67	11.67	13.33	10.56

CONCLUSIONS

Table 1 and Figure 1 and 2 shows that copper pennies had the largest (best) Zone of Inhibition, followed by Copper 110 Alloy. Since these were both better than the Zone of Inhibition of the ampicillin antibiotic, my hypothesis was accepted.

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