INTRODUCTION

The word oligodynamic originates from two Greek words; oligos, which means "few," and dynamis, which means "force". The concept of oligodynamic effect of metals originated more than 150 years back and refers to its biocidal effect on microorganisms, even at extremely low doses (Sanosil, 2020). Metals which exhibit the oligodynamic effect include mercury, silver, gold, copper, brass, bronze, tin, iron, lead and bismuth. Silver is one, among the metals that exert the strongest oligodynamic effect (Sanosil, 2020). Silver and gold, are antimicrobial agents that fight off infection (Leong et al., 2018; The Daily Crisp, 2019). Some reports suggest that the metal ions kill or inhibit target cells by; disrupting their protein (Benson, 2002; Harke, 2007; Wesley, 2013), affecting cell membrane permeability (Sanosil, 2020) and by inhibiting enzyme activities (Robert et al., 1989; Semikina and Skulacher, 1990; Wesley, 2013). A study by Hambridge (2001) suggests that silver ion distorts cell wall. Also, silver ions can bind to DNA and RNA genetic material disrupting reproduction resulting in cell damage and death (Sanosil, 2020).

The skin microbiome includes both Gram positive and Gram negative bacteria (Chiller et al., 2001). Skin micro flora is usually non-pathogenic and is either commensal or mutualistic. However, resident microbes have been reported to cause, particularly in immunosuppressed individuals, nosocomial infections, skin diseases and life-threatening diseases, if they gain access into the blood stream (Cogen et al., 2008; Otto, 2009; Leong et al., 2018 and Qureshi, 2020). Precious metal jewelries do not cause skin allergies and no matter how long it is used, it has no known side effects (The Daily Crisp, 2019). The oligodynamic property of these precious metal jewelries is the scientific basis for fewer occurrences of skin allergies and a number of health pros.

Susruta Samhita’s medical text intensified the use of specific metals in surgical procedures as a measure to prevent infection (Valiathan, 2007; Loukas et al., 2010). Gold is reportedly used in dental inlays for restoration of extensive tooth decay or fracture and it offers superior treatment to direct fillings (Dean, 2016). Rheumatoid symptoms is said to be relieved with gold treatment (Furst et al., 2002). The Daily Crisp (2019) claims wearing high quality silver and gold jewelry improves mood which bear a direct relationship in relaxing the blood vessels hence, help in the regulation of body temperature and blood circulation. It further stated that silver jewelries owe its health benefits to its electrical and thermal conductivity. Silver is also incorporated into medical implants and devices such as catheters to prevent infection (Wilcox et al., 1998; Darouiche et al., 1999 and Politano et al., 2013). Silver sulfadiazine is reportedly proven useful against antibiotic resistant bacteria when used as antiseptic ointment for extensive burns and wound dressings (Duran et al., 2007 and Cowan, 2012).

Objects that are coated with silver like the silver coins have a bactericidal effect. One advantage of silver ware for example silver spoons is that they self-sanitize due to their oligodynamic effect. Harke (2007) also reported that in order to prevent diseases during expeditions by military commanders silver drinking vessels were used. Therefore, it is recommended that silver is incorporated onto objects and frequently touched surfaces especially in public places. Tortora et al., (2010) stated that silver ions are increasingly being incorporated into plastics (including plastic food containers), steel, toilet seats, stethoscopes, refrigerator doors and even athletic shirts and socks are silver-infused with claim to minimize odors.
The metabolism of bacteria is adversely affected by silver ions at concentrations of 0.01-0.1 mg/L therefore even less soluble silver compounds such as silver chloride, also act as bactericides or germicides (Sanosil, 2020). Also, the concentrations of silver required for a disinfectant is at extremely low toxic level to mammalian life (Wesley, 2013). Oligodynamic metals, such as silver and copper, have long been utilized as disinfectants for non-sporo-forming bacteria and viruses (Robert et al., 1989; Shrestha et al., 2009). Silver, primarily exerts a long-lasting preservative, bacteriostatic effect regardless of dosage. The biocidal effect of silver has therefore been enhanced by using it in combination with other substances such as hydrogen peroxide. The effects are synergistic, producing highly effective biocidal complex and long lasting effect (Sanosil, 2020).

Nigeria is one of the few West African countries with silver although it is sparsely deposited and predominant in Northern Nigeria, it is present as very high grade lead silver (Pb-Ag) (Mindar.org, 2020), as an alloy with gold, as by-product of copper, lead and Zinc refining and in its pure form (Finelib.com, 2017). Gold (Au) deposit is also prominently located in Ipeririido in Osun state with smaller deposits in 13 other states. Despite the numerous benefits that can be accrued from these precious metals, they seem neglected. This study tested on skin bacteria, the oligodynamic potential of precious metal jewelries (silver and gold) and ordinary painted metal jewelries.

MATERIALS AND METHOD

Sample Collection
Sterile swab sticks were used to collect samples from the wrist, ear and neck region of five female human subjects. The swabs were placed immediately into the swab stick jacket, labeled appropriately and taken to the laboratory in the Department of Applied Science, Kaduna Polytechnic for further analysis. A total of fifty (50) samples of gold and silver jewelries were collected at random from female staff and students of the Department of Applied Science, Kaduna Polytechnic. A total of 25 gold jewelries were collected; seven (7) earrings, labeled A-G, six (6) bracelets, labeled A-F, six (6) pendants, labeled A-F and six (6) necklaces labeled A-F.

A total of twenty-five (25) silver jewelries were also collected; seven (7) earrings, labeled A-G, six (6) bracelets, labeled A-F, six (6) pendants, labeled A-F and six (6) necklaces labeled A-F.

Isolation of Bacteria from Skin Swabs
Each of the swab stick was used to inoculate on already solidified nutrient agar plates and labeled appropriately. The plates were incubated at 37°C in inverted position for 48 hours (Vlab, 2011). Pure cultures were obtained from growth of distinct colonies after 48 hours incubation.

Identification of Bacterial Isolates from Skin Swabs
Bacteria isolates were identified based on their colonial and morphological appearance on cultural plates such as shape, margin, elevation, size and texture (Tdmu, 2014) and biochemical characterization by subjecting the isolates to biochemical tests such as grams reaction, catalase, coagulase and indole tests according to the procedures described by Sharma (2007).

Determination of the Oligodynamic Activity of Silver and Gold Jewelries on the Isolated Skin Bacteria
A sterile wire loop was used to pick a small portion of each identified test organisms and aseptically spread uniformly throughout different solidified nutrient agar plates. Using a fresh pair of disposable gloves each gold-painted and silver-painted jewelries were placed separately into the respective Gold Control and Silver Control plates. Each of the corresponding pieces of Gold and Silver jewelries were also placed singly onto each of the plates that contained the test organisms. Each piece of the jewelry was arranged in a manner that the maximum amount of jewelry surface area was in contact with the agar plate. The plates were incubated at 37°C for 48 hours. The zones of inhibitions were measured in millimeters using a measuring rule and results obtained were appropriately recorded (SBS, 2015).

RESULTS

Cultural Morphology and Biochemical Characteristics of Skin Bacteria Isolates
A total of Three (3) bacteria were isolated from the skin swab samples collected and identified as Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa. The cultural, morphological and biochemical characteristics of the skin bacterial isolates is as shown in Table 1.

The Oligodynamic Activity of Silver and Gold Jewelries on the Isolated Skin Bacteria
The oligodynamic activity of silver earrings (7), bracelets (6), pendants (6) and necklaces (6) was tested against Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa from skin swabs. A demonstration of oligodynamic activity of silver earring and necklace is as shown in Plate 1. After 48 hours incubation, an average of zones of inhibition in (mm) was obtained. The highest zone of inhibition of 7 mm was observed in Pseudomonas aeruginosa while Staphylococcus epidermidis had the least zone of inhibition of 3 mm. Staphylococcus aureus had an average zone of inhibition of 5 mm. No zones of inhibition were observed with ordinary silver-coloured jewelries as shown in Plate 1. The oligodynamic activity of silver on the skin bacterial isolates is represented in Table 2.

The oligodynamic activity of Gold earrings (7), bracelets (6), pendants (6) and necklaces (6) was tested against Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa from skin swabs. An average of zones of inhibition (mm) was obtained. Gold gave the highest zone of inhibition of 4 mm on Pseudomonas aeruginosa while Staphylococcus epidermidis had the least zone of inhibition of 1 mm. No zones of inhibition were observed with ordinary golden-coloured jewelries. Staphylococcus aureus had an average zone of inhibition of 3 mm. The oligodynamic activity of gold on the skin bacterial isolates is represented in Table 3.
Plate 1: Oligodynamic activity of silver jewelry on skin bacteria isolates. A-Silver earring, B- silver necklace and C- silver coloured earring (control)
## Table 1: Cultural, Morphological and Biochemical Characteristics of the Skin Bacterial Isolates

| Characteristics          | Isolate A    | Isolate B    | Isolate C     |
|--------------------------|--------------|--------------|---------------|
| Shape of Colony          | Circular     | Circular     | Irregular     |
| Margin of Colony         | Entire       | Entire       | Entire        |
| Elevation of Colony      | Convex       | Convex       | Umbonate      |
| Surface of Colony        | Smooth       | Smooth       | Mucoid        |
| Size of Colony           | Small        | Small        | Small         |
| Colour of Colony         | Yellow       | White        | Milky         |
| Gram’s Reaction          | Positive     | Positive     | Negative      |
| Catalase Test            | Positive     | Positive     | Positive      |
| Coagulase Test           | Positive     | Negative     | Negative      |
| Indole Test              | Negative     | Negative     | Negative      |
| Oxidase Test             | Negative     | Negative     | Positive      |
| Citrate Test             | Positive     | Negative     | Positive      |
| Methyl Red Test          | Positive     | Negative     | Negative      |
| Inference                | *Staphylococcus aureus* | *Staphylococcus epidermidis* | *Pseudomonas aeruginosa* |
Table 2: Oligodynamic Activity of Silver on the Skin Bacterial Isolates

| Precious Metal Sample | Staphylococcus aureus | Staphylococcus epidermidis | Pseudomonas aeruginosa |
|-----------------------|-----------------------|---------------------------|------------------------|
|                       | (Zones of inhibition (mm) on skin bacterial isolates) | | |
| Earrings              |                       |                           |                        |
| A                     | 6.0                   | 3.5                       | 8.0                    |
| B                     | 6.0                   | 3.0                       | 8.0                    |
| C                     | 6.0                   | 2.5                       | 8.0                    |
| D                     | 5.5                   | 4.0                       | 8.0                    |
| E                     | 7.0                   | 2.5                       | 8.0                    |
| F                     | 6.5                   | 3.0                       | 7.5                    |
| G                     | 5.0                   | 4.0                       | 7.5                    |
| Control (Silver coloured earring) | 0       | 0                         | 0                      |
| Bracelets             |                       |                           |                        |
| A                     | 4.0                   | 2.5                       | 7.0                    |
| B                     | 4.0                   | 3.5                       | 6.5                    |
| C                     | 4.0                   | 3.0                       | 6.5                    |
| D                     | 5.0                   | 3.0                       | 7.0                    |
| E                     | 5.0                   | 3.0                       | 7.5                    |
| F                     | 5.0                   | 3.0                       | 7.5                    |
| Control (Silver coloured bracelet) | 0       | 0                         | 0                      |
| Pendants              |                       |                           |                        |
| A                     | 6.0                   | 3.0                       | 6.5                    |
| B                     | 3.5                   | 3.0                       | 6.5                    |
| C                     | 6.0                   | 3.0                       | 7.0                    |
| D                     | 5.0                   | 3.0                       | 7.5                    |
| E                     | 4.0                   | 2.0                       | 7.0                    |
| F                     | 5.0                   | 3.5                       | 7.0                    |
| Control (Silver coloured pendant) | 0       | 0                         | 0                      |
| Necklaces             |                       |                           |                        |
| A                     | 4.0                   | 3.0                       | 7.0                    |
| B                     | 5.5                   | 3.0                       | 6.5                    |
| C                     | 3.0                   | 3.0                       | 7.0                    |
| D                     | 5.0                   | 2.0                       | 7.0                    |
| E                     | 5.0                   | 3.0                       | 7.0                    |
| F                     | 4.0                   | 3.0                       | 7.0                    |
| Control (Silver coloured necklace) | 0       | 0                         | 0                      |
| Average Zone of inhibition (mm) | 5       | 3                         | 7                      |
Table 3: Oligodynamic Activity of Gold on the Skin Bacterial Isolates

| Precious Metal | Zones of Inhibition (mm) on the skin bacterial isolates |       |       |       |
|----------------|---------------------------------------------------------|-------|-------|-------|
|                | Staphylococcus aureus | Staphylococcus epidermidis | Pseudomonas aeruginosa |
| Earrings       |                                                         |       |       |       |
| A              | 3.5                                                     | 1.5   | 4.5   |
| B              | 3.0                                                     | 1.0   | 4.0   |
| C              | 2.5                                                     | 1.5   | 3.5   |
| D              | 3.0                                                     | 1.0   | 5.0   |
| E              | 2.5                                                     | 1.0   | 3.5   |
| F              | 3.0                                                     | 1.0   | 4.0   |
| G              | 3.0                                                     | 1.0   | 4.0   |
| Control (Gold coloured earring) | 0 | 0 | 0 |
| Bracelets      |                                                         |       |       |       |
| A              | 2.5                                                     | 1.0   | 3.5   |
| B              | 3.5                                                     | 1.0   | 4.5   |
| C              | 3.0                                                     | 1.0   | 4.0   |
| D              | 3.0                                                     | 1.0   | 4.0   |
| E              | 3.0                                                     | 1.0   | 4.0   |
| F              | 3.0                                                     | 1.0   | 4.0   |
| Control (Gold coloured Bracelet) | 0 | 0 | 0 |
| Pendants       |                                                         |       |       |       |
| A              | 3.0                                                     | 1.0   | 4.0   |
| B              | 3.0                                                     | 1.0   | 4.0   |
| C              | 3.5                                                     | 1.0   | 4.0   |
| D              | 3.0                                                     | 1.0   | 4.0   |
| E              | 3.5                                                     | 1.0   | 4.5   |
| F              | 2.5                                                     | 0.5   | 3.5   |
| Control (Gold coloured pendant) | 0 | 0 | 0 |
| Necklaces      |                                                         |       |       |       |
| A              | 3.0                                                     | 1.0   | 4.0   |
| B              | 3.0                                                     | 1.0   | 4.0   |
| C              | 3.5                                                     | 1.0   | 4.0   |
| D              | 2.5                                                     | 0.5   | 3.5   |
| E              | 3.0                                                     | 1.0   | 4.0   |
| F              | 3.0                                                     | 1.0   | 4.0   |
| Control (Gold coloured necklace) | 0 | 0 | 0 |
| Average Zone of inhibition (mm) | 3 | 1 | 4 |

DISCUSSION

This study evaluates the oligodynamic activity of precious metals on skin bacteria with a view to determine the ability of precious metal to inhibit the skin bacteria most often implicated in skin allergies and other infections (Cogen et al., 2008; Otto, 2009; Leong et al., 2018 and Qureshi, 2020). Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa were the bacteria isolated from the ear, neck and wrist of the skin, this agrees with Cogen (2008). Although Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa are natural inhabitants of a healthy human skin, they have reportedly been associated with some clinical infections most especially in individuals with compromised immunity, Staphylococcus aureus for example, is associated with abscess, cellulitis resulting from injection use, surgical site infections, necrotizing fasciitis and diabetic foot ulcers (Leong et al., 2018). Qureshi (2020) also noted that pseudomonal infection is mostly nosocomial, complicated and can be life-threatening especially with blood stream infections. Otto (2009) referred Staphylococcus epidermidis as an accidental pathogen associated with nosocomial infection from indwelling medical devices.

In this study, it was observed that both gold and silver jewelries demonstrated oligodynamic effect on Staphylococcus aureus, Staphylococcus epidermidis and Pseudomonas aeruginosa although in unequal measures. This result resonates with reports that the measure of oligodynamic effect exhibited by precious metals is not same for all microorganisms (Shrestha et al., 2009).

Silver jewelries demonstrated higher oligodynamic effect on all the isolated skin bacteria having average zones of inhibition between 3 mm to 7 mm as compared to that of gold jewelries that gave average zones of inhibition between 1 mm to 4 mm. The comparatively higher oligodynamic activity of silver metal
jewelry over gold metal jewelry may be explained by the stable +1 valency of silver over the valency of gold which may be -1. This reasoning is supported by the review of Robert et al., (1989) which concluded that the capacity of a metal ion to inactivate a bacteria or virus is due their oxidation potential. Also, the distinct three step oligodynamic mechanism of silver on bacteria which involves the damage of bacterial cell membrane, the displacement of Ca²⁺ and Zn²⁺ ions and interaction with sulphur, oxygen or nitrogen (Semikina and Skulacher, 1990; Dowling, 2001; Sondi, 2004) may be considered.

_Pseudomonas aeruginosa_ was the most susceptible to both silver and gold jewelries. This finding could probably be due to the cell wall composition of the gram negative bacterium, it is thin with no teichoic acid and may enable the gold and silver ions attack the intracellular bacteria cell contents. On the contrary, _Staphylococcus aureus _and _Staphylococcus epidermidis _are both Gram positive bacteria with thick peptidoglycan layer (Sharma, 2007).

Silver play a crucial role in prevention and treatment of infections relating to the skin bacteria isolates identified in this study. Leong et al. (2018), reviewed that where silver was topically applied on the skin, reduced infection rate, fewer dressing changes, better wound healing and skin graft adherence was observed in burns and then in ulcer wounds; reduction in wound size, less pain, less odour and less exudate was observed. The study also recorded fewer surgical cite infections and shorter time for wound closure of skin graft in surgical incisions. In addition, blood stream and urinary tract infections rates have been minimized with the use of silver-alloy catheter (Politano et al., 2013 and Leong et al., 2018)

This study showed the oligodynamic activity of gold and silver jewelry on test bacteria isolates and revealed that the inhibitory activity of these precious metals on bacteria can be explored to confirm the presence of bacteriostatic metal ions in silver and gold jewelries when realness is in doubt, as ordinary gold and silver painted jewelries are not capable of inhibiting bacterial growth.

**CONCLUSION**

Gold and silver jewelries are precious metals capable of exhibiting oligodynamic effect on _Staphylococcus aureus, Staphylococcus epidermidis _and _Pseudomonas aeruginosa_. These precious metals have antibacterial property that can be exploited in the prevention and treatment of infections that results from the identified skin bacterial isolates. Gold-coloured and silver-coloured jewellery have no oligodynamic effect thus, may not offer any health benefit.

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