FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 3, September, 2020, pp 601 – 608
DOI: https://doi.org/10.33003/fjs-2020-0403-334

OLIGODYNAMIC EFFECT OF PRECIOUS METALS ON SKIN BACTERIA

***Obafunmi, T. I., Ocheme, J. J. and Gajere, B. E.**

Department of Applied Biology, College of Science and Technology, Kaduna Polytechnic, Kaduna State, Nigeria.

*Corresponding Author's Email: dunniobafunmi@gmail.com, +2349084160101

ABSTRACT

The oligodynamic hold of gold and silver is extant and extremely relevant as a proactive measure against infections. The antimicrobial effect of gold and silver jewelries was determined on skin bacteria by introducing them into culture plates already inoculated with bacterial isolates; *Staphylococcus aureus, Staphylococcus epidermidis* and *Pseudomonas aeruginosa* from the wrist, neck and ear regions of the skin. Samples were collected by swab sampling and isolates were identified by their cultural morphology and biochemical characterization. Results showed that both precious metals were able to inhibit all three bacteria with silver jewelries giving wider zones of inhibition measuring between 3 mm to 7 mm while gold jewelries gave zones of inhibition between 1 mm to 4 mm. The culture plates containing *Pseudomonas aeruginosa* recorded the highest zone of inhibition while the least was observed in the culture plates that contained *Staphylococcus epidermidis.* No zone of inhibition was observed with ordinary golden-coloured and silver-coloured jewelries which served as negative control. This study showed that gold and silver are oligodynamic with silver having a higher oligodynamic efficacy on the skin bacteria tested.

Keywords: Oligodynamic activity, Silver, Gold, Bacteria.

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 Hambidge (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-spore-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 Iperirido 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.

A

B

C

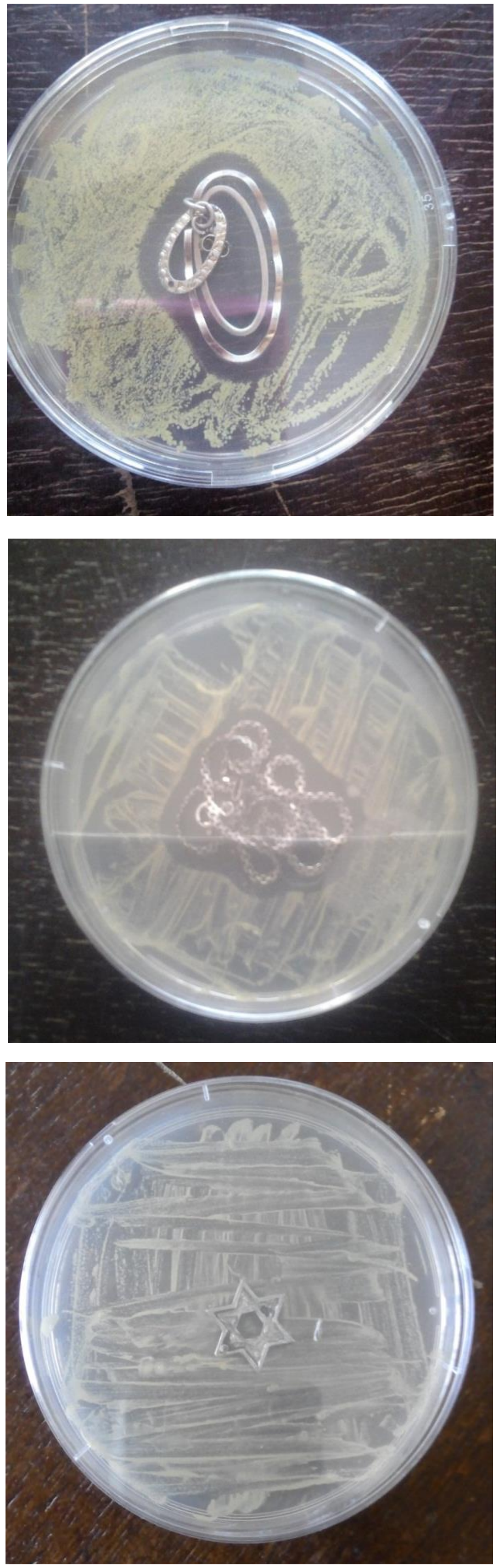

Plate 1: Oligodynamic activity of silver jewelry on skin bacteria isolates. A-Silver earring, B- silver necklace and C- silver coloured earring (control)

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. *Staphyloccocus 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 jewelleries 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 Ca^{2+} and Zn^{2+} 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 bacterium 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 tracts infections rates have been minimized with the use of silver-alloy catheters (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 jewelleries have no oligodynamic effect thus, may not offer any health benefit.

REFERENCES

Benson, H.J. (2002). *Microbiological applications: Laboratory manual in general microbiology*. 8th Edition. McGraw Hill: New York.

Chiller, K., Selkin, B.A. and Murakawa, G.J. (2001). "Skin Microflora and Bacterial Infections of the Skin". *The Society for Investigative Dermatology, Inc*.1087-0024/01/

Cogen, A., Nizet, V., and Gallo, R.L. (2008). "Skin microbiota: a source of disease or defence?" *The Journal of Dermatology*, 158 (3): 442-55.

Cowan, M.K. (2012). Microbiology: A systems Approach. 3rd Ed. Pp.320-321. ISBN 978-0-07-352252-4.

Darouiche, R.O., Raad, I. I., Heard, S.O., Thornby, J. I., Wenker, O. C., and Gabrielli, A. (1999). A comparison of two antimicrobial-impregnated central venous catheters. Catheter Study Group. *New England Journal of Medicine*. (340): 1.

Dean, J. (2016). Filling vs. inlay vs. onlay vs. crown: what's the difference and which is the right one for you? *Rancho Santafe Cosmetic and Family Dentistry.* https://www.rsfdentist.com/about-us

Dowling, D.P., Dounnelly, K., McConnell, M.L., Eloy, R., and Amaud, M.N. (2001). Deposition of antibacterial silver coatings on polymeric substrates. *Thin Solid Films.* 398:602-606.

Duran, N., Marcarto, P.D., De Souza, G. I. H., Alves O. L., and Esposito, E. (2007).Antibacterial Effect of Silver Nanoparticles Produced by Fungal Process on Textile Fabrics and their Effluent Treatment. *Journal of Biomedical Nanotechnology.* (3): 203.

Finelib.com (2017). About Nigeria natural resources, silver (Ag) mineral deposits in Nigeria and its applications. www.finelib.com

Furst, D.E., Gottlieb, N.L. and Small, R.E. (2002).Gold as a remedy in disease. *Arthritis Foundation Brochure.* Washington/Alaska chapter. https://orthop.washington.edu/patient-care/articles/arthritis/gold-treatment.html#

Hambidge, A. (2001). "Reviewing efficacy of alternative water treatment techniques." *Health Estate,* 55: 23–25.

Harke, H. (2007). Disinfectants. *Ullmann's Encyclopedia of Industrial Chemistry (7th Ed.), Wiley.* Pp.1-17. ISBN 978-3527306732

Leong, H.N., Kurup, A., Tan, M., Hoon Kwa, A.L., Liau, K.H. and Wilcox, M.H. (2018). Management of complicated skin and soft tissue infections with a special focus on the role of newer antibiotics. *Infection and Drug resistant-Dove press.* 11:1959-1974.

Loukas, M., Lanteri, A., Ferrauiola, J., Tubbs, R.S., Maharaja, G., Shaja, M.M. Yadav, A. and Rao, V.C. (2010). Anatomy in ancient India: a focus on the Susruta Samhita. *Journal of Anatomy.* 217 (6):646-650.

Mindart.org (2020). Kishesha lead silver mine, Jos Plateau, Plateau Nigeria. *Hudson Institute of Mineralogy.* https://www.mindar.org/loc-289955.html

Otto, M. (2009). *Staphylococcus epidermidis*- the accidental pathogen. *Nature Reviews Microbiology*. 7:555-567.

Politano, A.D., Campbell, K.T., Rosenberger, L.H. and Sawyer, R.G. (2013). Use of silver in the prevention and treatment of infections: Silver Review. *Surgical Infection (Larchmt)*. 14(1): 8-20

Qureshi, S. (2020). *Pseudomonas aeruginosa* Infections. *Medscape Article*. https://emedicine.medscape.com/article/226748-overview

Robert, B. T., Gerba, C.P. and Gabriel, B. (1989): The molecular mechanisms of copper and silver ion disinfection of bacteria and viruses, Critical Reviews in Environmental Control, 18:4, 295-315

Sanosil (2020). Disinfectant against coronavirus like covid-19. *Sanosil Disinfectants for Life (Switzerland)*. https://www.sanosil.com/en/disinfectant-against-coronavirus-china-2019-ncov/

SBS. (2015). Is the Gold in My Jewelry Real?. *Science Buddies Staff*. Retrieved October 3, 2016from http://www.sciencebuddies.org/science-fair projects/project_ideas/MicroBio_p026.shtml

Semikina, A. L. and Skulacher. V. P. (1990). "Submicromolar Ag+ increases passive Na+ permeability and inhibits the respiration supported formation of Na+ gradient in Bacillus FTU vesicles." *FEBS* 269 (1):69–72

Sharma, K. (2007). Isolation, Purification and Identification of Bacteria. *Manual of Microbiology Tools and Techniques (2nd Ed.)*. Ane Books: New Delhi. Pp 179-80

Shrestha, R., Joshi, D.R., Gopali, J., and Piya S. (2009). "Oligodynamic Action of Silver, Copper and Brass on Enteric Bacteria Isolated from Water of Kathmandu Valley". *Nepal Journal of Science and Technology*. 10: 189-193

Sondi, I. and Salopek, B.S. (2004).Silver nanoparticles as Antimicrobial Agent: A case study on E. coli as a model for Gram-Negative Bacteria*. Journal of Colloid interface Science*. 275:177-182.

Tdmu. (2014). Main Methods, Principles and Steps of isolating bacteria's pure cultures. Retrieved December 3, 2016 from http://intranet.tdmu.edu.ua

The Daily Crisp (2019). 3 surprising health benefits of wearing silver or gold mother's day. https://thedailycrisp.com/3-surprising-surprising-health-benefits-of-wearing-silver-or-gold-mother's-day/

Totora, G.J., Funke, B.R. and Case, C.L. (2010). Microbiology: An Introduction. *Benjamin Cummings*. (10th Ed). Pp 300-301. ISBN 978-0-321-55007-1

Valiathan, M.S. (2007). The legacy of Susruta. *Orient Longman*. ISBN 9188125031505 OCLC 137222991.

Vlab. (2011). "Gram Stain Technique". Virtual Amrita Laboratories Universalizing Education. Retrieved November 13, 2016 from http://www.vlab.amrita.edu

Wesley, F. (2013).The oligodynamic effect: how some metals kill off bacteria. *Adam Sava Tested.* http://www.tested.com/science/life/453961-oligodynamic-effect-how-some- metals-kill-bacteria/

Wilcox, M., Kite P., and Dobbins B. (1998). Antimicrobial intravascular catheters-which surface to coat?. *Journal of Hospital Infection.* (40): 322.