2020-03-28

Corrigendum to "Manufacturing silver nano-coating currencies to prevent the bacteria growing on the surface of currency" [Gene Rep. Volume 19, June 2020, 100648]

A-Kadmy, IMS

<http://hdl.handle.net/10026.1/16016>

10.1016/j.genrep.2020.100663

Gene Reports

Elsevier BV

All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.

Manufacturing Silver Nano-coating currencies to prevent the bacteria growing on the surface of currency

Abstract

This study evaluated the level of contamination and pattern of organisms found on local currencies of Iraq and the antibacterial effects of silver nanoparticle (AgNPs) coating currencies *in vitro*. Local currencies and US dollar notes were collected and individually placed in a sterile petri plates containing Todd hewit broth incubated at 37° C in a rotary shaker for 2 hours. All the individual bacterial colonies were identified using PCR for amplifying the 16S rRNA genes. Green synthesis of AgNPs was followed as described earlier and in a dish containing a solution of AgNPs and ammonia; AgNPs was impregnated in the cellulose matrix of notes. All sterilized coated or uncoated notes were subjected for contamination of pathogens such as MRSA, VRE, ESBL *E. coli*, and MDRAB counting colony-forming units. A total number of 17 different bacteria were isolated from currencies of Iraq and dollars. The percent of contamination was high in local Iraqi notes than dollars notes. Many of these Iraqi notes (n=22) showed growth of at least two bacterial species. Gram positive organisms dominated the bacterial population. Coating of notes with AgNO₃ led to a less counts of organisms. Coating of nanoparticle was more effective on control of MRSA, VRE and to a lower extent *E. coli*. Silver which is commonly used in health products including eatable can be an alternative as a coating agent. We recommend further studies with diverse microbial contamination to enrich the information on the subject. A variety of other nanoparticles can be tested to establish a cheap and proper material which can be used for this purpose.

Key Words: Silver Nano-coated currencies, Infection control, Surface of currency

Highlights

- A total number of 17 different bacteria were isolated from currencies of Iraq and dollars. The percent of contamination was high in local Iraqi notes than dollars notes.
- Many of these Iraqi notes (n=22) showed growth of at least two bacterial species. Gram positive organism dominated the bacterial population.
- Coated notes with AgNO₃ showed a less counts of organism. Coating of nanoparticle was more effective on control of MRSA, VRE and somewhat *E. coli*.
- Silver which is commonly used in health products including eatable can be an alternative as a coating agent.
- A variety of other nanoparticle can be tested to establish a cheap and widely accepted material which can be used for this purpose.

Introduction

Microorganism are rapidly spread through environment and/or environmental agents. Many environmental agents acts as reservoir and also serve as vehicles (Kuria et al. 2009). Currency and coins are one of few important tools which connect the wide range of population with in no time and frequently passed from hand to hand (Angelakis et al. 2014). While getting in hand of so many hands it tends to get contaminate and due to its exchange it spread the contamination. Contamination not only contain normal flora but also are reservoir for pathogens from skin, respiratory secretions, water, soil and aerosols (Thiruvengadam et al. 2014). The place like hospital, transports and markets are place where these currency are exchanged vigorously (Butt & Malik 2015). At such place people do not care how dirty their hands are and **thus** unknowingly contaminate the currency, causing spread of microbes to others hands and transmitting pathogenic organisms becomes a process (Kuria et al. 2009). Due to globalization and worldwide migration of different ethnic people, this problem is become worldwide. Many a literature from Turkey (Göktaş & Oktay 1992), United States (Pope et al. 2002) Australia (Food Science Australia 2005), Egypt (El-Dars et al. 2005), China (Xu et al. 2005), Myanmar (Khin et al. 1989) have investigated the presence of pathogens on coins and currency notes proving the carriage from these circulation. These implicate that money is a source vehicle for pathogens transmission (Angelakis et al. 2014). Such information is necessary to facilitate infection control strategies. While a variety of groups such as society hygiene levels, and antimicrobial resistance rates at community level clearly have effect on the transmission of resistant microorganisms, the type of banknote-paper may be an additional changing to theorize (Butt & Malik 2015).

Nanotechnology is considering a modern science that solves many problems in manufacturing, agriculture and health as well, including elimination of diseases (Saravanan et al., 2011). The goal of this research is to manufacture a Nano coating deposited on the surface on local currencies for killing or prevent growing any microorganism so that this process can reduce the spread of diseases between people and countries, AgNPs have showed different mechanisms of antimicrobial action in the nanoparticles which make it the most appropriate promising candidate to overcome bacteria and fungus and different microorganisms (Agarwal et al., 2010).

We also aimed to ascertain the survival status and rate of bacteria including *E. coli*, *Staphylococcus aureus* and (VRE) Vancomycin-Resistant Enterococci on banknotes and the transmission of bacteria to volunteers getting in contact with contaminated banknotes under tentative conditions, which included the coating of these currencies with nanoparticle

Methods and materials

Collection of Samples and microbiological contamination of currencies

To fulfill first objective of the study, local currencies of Iraq were collected, which included a total of 41dinar notes from markets. We also included the 15 different denominations dollar notes collected from markets to compare the notes surface infection. This study did not require any ethical board permission however permission from local authority was obtained before the study. The collected samples notes were individually placed in a sterile petri plates containing Todd hewitt broth (Hi-Media, Mumbai, India) and incubated at 37° C, at rotary shaker for up to 2 hours. The plates were secured with rubber band. After two hours of incubation a 100µL of each incubated sample was cultured on were streaked on petri plates poured with Nutrient agar, Mac Conkey agar and Blood agar for selective isolation of Gram positive and Gram negative organisms following standard techniques (13, REF). The Plates were incubated for 24 hours at 37° C. All the individual bacterial colonies grown plates were subjected to DNA extraction using Quigen bacterial DNA isolation KIT (REF) and pure DNA was used for PCRs for amplifying the 16S rRNA genes. In order to amplify this gene, primers pairs F: 5'- ATGGAAATGCTGAAATTCGGC-3' and R: 5'- CTTCTTCAGCTCGACGCGACG-3' were used for detection *E.coli*, the *recA* gene (F: 5'- CCTGAATCTTCYGGTAAAAC/ R: 5'- GTTTCTGGGCTGCCAAACATTAC; amplified size 240 bp) for identification *A. baumannii* (AL-Kadmy *et al.*, 2017, Alyousef and Al-Kadmy 2017), for detection *E. faecium* were used F: TTGAGGCAGACCAGATTGACG and R: TATGACAGCGACTCCGATTCC (amplified size 600 bp), While *mecA* for detection MRAS F- GTA GAAATGACTGAACGTCCGATAA \ R- CCAATTCCACATTGTTTCGGTCTAA (amplified size 800 bp) and *16S rRNA* gene was used to identify *P. aeruginosa* and primers pairs F: 5' ATGGAAATGCTGAAATTCGGC-3' and R: 5'- CTTCTTCAGCTCGACGCGACG-3' with amplified size 711bp. 16srRNA for detection *Klebsiella pneumoniae* F: GTGAAGATATACCAAGTGATT\ R: ATGCGCTATAGATTGAAAGGA with amplification size 500pb

PCR amplification of *16S rRNA* genes was performed in an Applied Biosystems Veriti™ Thermal Cycler (Thermo Fischer Scientific, USA) using the 16S Barcoding Kit (Oxford Nanopore Technologies, Oxford, UK) and LongAmp™ Taq 2× Master Mix (New England Biolabs, USA). Amplified gene sequences were subjected to sequencer (Thermo Fischer Scientific, USA) and

obtained sequence were BLAST in Pubmed database to identify the bacterial species with matching sequence.

Bacterial strain and Banknotes used in the study

Well characterized and pure colonies of clinical isolates which includes methicillin-resistant *S.aureus* (MRSA), Vancomycin-resistant *Enterococcus faecium* (VRE), extended spectrum of beta lactamases (ESBL) producing *E. coli*, and multidrug resistant *Acinetobacter baumannii* (MDRAB) strains were cultured into 5 ml of lauria bertani borth medium in tubes, which were incubated at 37° C for overnight. The 1,000 & 5,000 denomination of Dinar and, 1, 5 denomination US Dollar were used in this study. These noted were previously been sterilized by ultraviolet light radiation before using in study. After the study was completed, all of these banknotes were sterilized by ultraviolet light radiation again and made sure to bring back in re-circulation.

Chemical reduction reaction for Ag NPs preparation and characterization

The production steps of cellulose paper coating with silver nanoparticles achieved by the chemical reduction method by used sodium borohydride and silver nitrate. The cellulose filter papers (10 cm 5 cm 2.5 cm) were obscure in different concentration of silver nitrate solutions of 0.025, 0.05, and 0.10 M with the competent immersion time of 1, 2, and 3 h. Next, cellulose filter paper was wash with ethanol for 1 min in order to flush the unabsorbed silver nitrate on the filter paper. silver nitrate ratios of 2, 5, and 10 for an inundation time of 1 h. Finally, the cellulose filter paper was rainsed in ultrapure water for 30 min, while the spare water was removed by drying the sheet in a drying oven at 60° C for 2.5 h (Tang et al. 2009; Praveena and Aris 2015).

Silver nanoparticle (AgNPs) were prepared using chemical synthesis method outlined (Agnihotri et al. 2014) In brief, aqueous solution of equal volume of sodium borohydride and trisodium citrate were heated at 60° C for up to half an hour in dark. Silver nitrate solution (1/20th part of aqueous solution) was then added to the aqueous solution, and heated up to 90° C for an additional 20 min and cooled down to room temperature. The AgNPs solution was observed under UV-vis spectral analysis to confirm the silver ion in to nanoparticles in solution. This AgNPs were diluted further to get a light colored solution of AgNPs (Ismail et al. 2019). The bank note in study were merged

into a dish containing a solution of AgNPs and ammonia. Ammonia was introduced so that notes get easily impregnated of AgNPs. Next the notes were fumed with formaldehyde gas, which enhanced the penetration through notes texture and impregnated AgNPs in the cellulose matrix of notes (Cheng et al. 2011; Pinto et al. 2013). Notes were quickly dried off and the nanoscale size range, metallic nature of the particles of formed particles were confirmed through transmission electron microscope (TEM) images and X-ray diffraction methods (XRD) measurement was performed for the dried notes from the concentrated suspension.

Experiment design

All the experiment mentioned below were done in triplicate and results are the mean of triplicates. After isolation and detection microorganisms from different paper bank notes and diagnosis by phenotype and genotype methods according to different genes specific to bacterial species. The original inoculum of MRSA, VRE, ESBL *E. coli*, and MDRAB which was grown overnight and adjusted to obtain 1.0 unit of McFarland standard. In the first set up, all sterilized bank notes (uncoated) were inoculated with 10 times dilutions of a serial dilution from the original inoculum, by spreading 100 µl from each tube onto previously sterilized banknotes. A sample of 100 µl of dilutions were also inoculated onto LB agar plate as a positive control. These notes were incubated overnight at 37° C, and later on next day all colony-forming units were counted. All banknotes were dried in surrounded conditions for couple of hours and colonies from the banknotes were picked by a moistened swab (0.9% saline) after 3-h, 6-h, 12-h and 24-h after drying. Swabs were inoculated into LB broth. 100 µl from each tube were spread onto LB agar. In the second part, coated bank notes were inoculated with organism inoculum in similar fashion as described above.

Results

A total number of 17 different bacteria were isolated from currencies of Iraq and dollars which includes 41 dinar notes circulating in markets and hospitals. The percent of contamination was higher in local Iraqi notes (27/41; 65.38%) than dollars notes (5/15; 55.5%). Many of these Iraqi notes (n=22) showed growth of at least two bacterial species, whereas, dollars showed less numbers of notes having two or more organisms. Gram positive organisms dominated (87%) the bacterial population isolated from currencies and Diptheroids, staphylococcus, *E. feacalis*, Micrococcus and Bacillus were the top three species isolates from currency (**Figure 1**). Gram negative isolates were only 13% of the total and *E. coli* and *E. feacalis* were among the top two organisms. In all case the frequency of isolation of bacterial species was more from notes. Few such as *C. freundii*, *E. feacalis*, and *P. mirabilis* were isolated in equal frequency from both types of currencies (**Figure 2**). All the samples had more than one strain including the normal flora. In the case of currencies collected from hospital, there were all 17 different species of microbes present, of which *S. penumoniae*, *K. oxytoca*, *A. baumannii*, *K. pneumonia* and *P. aeuroginosa* were identified only from hospital originated notes. *E. faecium* and *Bacillus* were more from markets environmental notes (**Figure 3**). Though the non-pathogenic bacteria occur in higher frequencies were from gram positive group, highly pathogenic species such as *S. aureus*, *P. aeuroginosa*, *K. pneumonaie* and *E. coli* were also found in small numbers. Thus the chance of transmitting infections caused by the pathogenic organisms which were found in lower hesitation cannot be ruled out.

Figure 1. Distribution of organism from notes collected from circulation

Figure 2. Distribution of organism in comparison to surface of notes

Figure 3. Distribution of organism in comparison to origin (from only Iraqi Notes)

Notes were coated with AgNO₃ nanoparticles and the survival rate was analyzed. Solution of silver nitrate turned dark brown indicating formation of AgNPs. In the UV-Vis spectrum. Synthesized AgNPs in aqueous solution had absorption spectra in a range of wavelength (300-700) nm (**Figure. 4**). The UV-Vis showed a single peak around 414 nm confirming AgNPs. Notes were coated with AgNO₃ nanoparticles and the survival rate was analyzed. TEM analysis confirmed the spherical nature of the AgNPs with average diameter ranging 22-30 nm. The results of XRD suggests the polygonal crystal structure of nanoparticles (**Figure 5**).

Figure 4. UV-Vis analysis of synthesized AgNPs.

Figure 5. A: TEM analysis of synthesized AgNPs. **B:**XRD analysis of synthesized AgNPs

All results were agreeing on the Dinar was more contaminated than dollar. Coated notes with AgNO_3 showed lower counts of organisms. Coating of nanoparticles was more effective on control of MRSA, VRE and somewhat *E. coli*. Coating did not show much control on *A. baumannii*. The effect of coating was up to 24 hours (**Table 1**). It is not sure that the coating effect continues for longer as the notes were not in circulation while this experiment was continue.

Table 1. Survival (semi-quantitative measuring counts) of ESBL <i>E.coli</i> , MRSA, VRE, MDRA B on different international banknotes, over time									
Time	Currency	MRSA		VRE		ESBL <i>E coli</i>		MDRAB	
Hour		Coated	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated
		Notes	notes	Notes	notes	Notes	notes	Notes	notes
3 Hour	Dinar 1000	0	2+	0	0	1+	1+	0	1+
	Dinar 1000	0	2+	0	0	0	1+	0	1+
	US Dollar								
	1	0	1+	0	0	0	0	0	0
	US Dollar								
6 Hour	5	0	1+	0	0	0	0	0	0
	Dinar 1000	1+	2+	1+	1+	1+	1+	1+	1+
	Dinar 1000	1+	2+	0	1+	1+	1+	1+	1+
	US Dollar								
	1	0	1+	0	1+	0	0	1+	1+
12 Hour	US Dollar								
	5	0	1+	0	1+	0	0	1+	1+
	Dinar 1000	1+	2+	1+	1+	1+	1+	1+	2+
	Dinar 1000	1+	2+	1+	1+	0	1+	1+	2+
	US Dollar								
	1	0	1+	0	1+	0	1+	1+	1+

24 Hour									
	US Dollar								
	5	0	1+	0	1+	0	1+	1+	1+
	Dinar 1000	0	1+	0	1+	1+	1+	1+	2+
	Dinar 1000	0	1+	0	1+	0	1+	1+	2+
	US Dollar								
	1	0	0	0	1+	0	1+	1+	1+
	US Dollar								
	5	0	0	0	1+	0	1+	1+	1+
3+ (Confluent growth; >100 colonies), 2+ (multiple segments; 10-100 colonies), 1+ (single colonies; 1-10 colonies), 0 (no growth)									

Discussion

System runs with the circulation of different items among the people within society and banknotes are most adored, cherished, way to trade the items between hands of citizens. Fast and frequent circulation of currencies between traders of different origin with various grade of personal hygiene are prone to get contaminated with different types of microorganism. Microorganisms do not only contain bacteria but a number of studies showed presence of fungal contamination too (Alemu 2014; Thiruvengadam et al. 2014). These contaminations of notes in circulation act as reservoir as well as vehicle to carry infectious agents incriminated as major disseminator of many diseases particularly skin, and respiratory (Kuria et al. 2009). The main area where notes are in circulation is markets and hospitals, where notes goes in and around in various hands with different health status and prone to get contaminated by droplets during coughing, sneezing, touching with previously contaminated hands, dirty surface or materials (Angelakis et al. 2014; Thiruvengadam et al. 2014).

In our first experiment we assess the levels of infection and nature of organism. Of collected 41 currencies of Iraq and 15 US dollar, 32 of them showed growth of microorganism indicating high contamination of circulating notes in our region. It was naturally due to made up, notes were more contaminated and more number of organism were isolated. At the same time note showed isolation of multiple organism from same sample. Gram-negative and positive bacteria, including bacilli, staphylococci, and various *Enterobacteriaceae*, have been found on banknotes in multiple countries, like Iran (Rashed et al. 2006) and Turkey (Alemu 2014; Göktaş & Oktay 1992). A number of studies have pointed multidrug-resistant and virulent strains on banknotes, these have the prospect to cause grave infections that are cruel to treat, to spread in health care and community settings, and to spread antimicrobial resistant determinants to other bacteria (Alemu 2014; Thiruvengadam et al. 2014; Al-Kadmy et al, 2018).

In the present study all experiments were performed using previously sterilized banknotes (Kuria et al. 2009). It was very evident that coating of AgNO₃ was able to protect the growth of organism but if this would be successful in real time cannot be assured; the NPs had a better penetration ability through the cell wall of microorganisms and more effective compared to antibiotics. The NPs easily enter into bacterial cell and lead to kill those (Kim et al., 2007; Abdulkadir et al., 2015). Up to 24 hours the growth or organism was in control and colonies were reduced. If this continues in same manner even when notes are in circulation is yet to be verified. The growth and survival

of microorganisms on banknotes depends not only microorganisms nature, but also their type of materials that were used for making of banknotes (Angelakis et al. 2014). Most of currencies in world are manufactured using cotton fiber, mixed with linen, or other textile fibers which provides strength, and durability (DeLaRue: online resources). Unlike printing paper, banknotes are supplied with polyvinyl alcohol or gelatin to give it extra strength. Polymer (or plastic) banknotes are also in use to improve durability and are extremely difficult to reproduce (Banknote: Wikipedia resources). The content of banknotes is also a factor that affects the survival of bacteria on the banknotes.

In conclusion, currencies are circulated among different classes of people tends to contaminate the paper made currencies which then act as vehicle for spreading organisms. A general awareness towards good personal hygiene might help to reduce the contamination of circulating currencies but it cannot totally bring down the infection causing through such notes.

The universal method is to use some kind of coating to this notes which can not only protect the notes from contamination but also do not cause harm to health. Silver, which is commonly used in health products including eatable, can be an alternative as a coating agent because of specific properties such as the good stability (physical and chemical), non-toxicity, low cost. We recommend further studies with diverse microbial contamination to enrich the information on the subject. A variety of other nanoparticle can be tested to establish a cheap and widely accepted material which can be used for this purpose.

References

- [1] Angelakis E, Azhar EI, Bibi F, Yasir M, Al-Ghamdi AK, Ashshi AM, Elshemi AG, Raoult D. Paper money and coins as potential vectors of transmissible disease. *Future microbiology*. 2014 Feb; 9(2):249-61.
- [2] Kuria JK, Wahome RG, Jobalamin M, Kariuki SM. Profile of bacteria and fungi on money coins. *East African medical journal*. 2009; 86(4).
- [3] Alemu A. Microbial contamination of currency notes and coins in circulation: A potential public health hazard. *Biomedicine and Biotechnology*. 2014 Jan 23; 2(3):46-53.
- [4] Butt A, Malik S. Microbial and parasitic contamination on circulating Pakistani Currency. *Advancements in Life Sciences*. 2015 Aug 25; 2(4):150-7.
- [5] Thiruvengadam S, Shreenidhi KS, Vidhyalakshmi H, Ramya M, Kamala T, Sundararaman TR, Selvi R. A study of bacterial profiling on coins and currencies under circulation and identifying the virulence gene in Chennai (TN). *International Journal of ChemTech Research*. 2014;6(9):4108-14.
- [6] Rashed T, Ghanaat J, Ghazvini K, Rashed E: Bacterial contamination of current banknotes and coins. *Med J Tab Univ Med Scien* 2006, 28(2):67–69.
- [7] DeLaRue: The Banknote Lifecycle – from Design to Destruction.
<http://www.delarue.com/ProductsSolutions/BanknoteProduction/TheBanknoteLifecyc>.
- [8] Banknote: Wikipedia Free Encyclopedia. <http://en.wikipedia.org/wiki/Banknote>.
- [9] Göktaş P, Oktay G: Bacteriological examination of the currency notes. *Mikrobiyol Bult* 1992, 26:344–348.
- [10] Pope,T.M., Ender,P.T., Woelk,W.K., Koroscil,M.A., Koroscil,T.M., Bacterial contamination of paper currency. *Southern Med. Journal.*, 2002, 95: 1408-1410.
- [11] Food Science Australia.,Money handling in food service operations.,Food Safety and Hygiene., (<http://www.foodscience.csiro.au/fshbull/fshbull20c.html>).,Retrieved May 5, 2005.
- [12] El-Dars, F.M.,Hassan W.M., A preliminary bacterial study of Egyptian paper money., *International Journal of Environmental Health Research.*, 2005, 15:235-239
- [13] Xu, J., Moore, J.E., Millar, B.C., Ribosomal DNA (rDNA) identification of the culturable bacterial flora on monetary coinage from 17 currencies., *Journal of Environmental Health.*, 2005,67(7): 51-55.

- [14] Khin, N.O., Phyu, P.W., Aung MH, Aye T. Contamination of currency notes with enteric bacterial pathogens. *Journal of Diarrhoeal Disease Research*. 1989, 7: 92-94
- [15] Agnihotri, S.; Mukherji, S.; Mukherji, S. Size-controlled silver nanoparticles synthesized over the range 5–100 nm using the same protocol and their antibacterial efficacy. *RSC Adv*. 2014, 4, 3974–3983.
- [16] Cheng ML, Tsai BC, Yang J. Silver nanoparticle-treated filter paper as a highly sensitive surface-enhanced Raman scattering (SERS) substrate for detection of tyrosine in aqueous solution. *Analytica chimica acta*. 2011 Dec 5;708(1-2):89-96.
- [17] Al-Kadmy, I.M.S., Ali, A.N.M., Salman, I.M.A. and Khazaal, S.S., 2018. Molecular characterization of *Acinetobacter baumannii* isolated from Iraqi hospital environment. *New microbes and new infections*, 21, pp.51-57.
- [18] Ismail, R. A., Abid, S, A. & Taha, A. A. Preparation and Characterization of CeO₂@Ag Core/Shell Nanoparticles by Pulsed Laser Ablation in Water. 2019. *Lasers in Manufacturing and Materials Processing*.
- [19] Alyousef, A.A., Al-Kadmy, I.M.S. (2017). The effect of immune modulation of *Streptococcus constellatus* SC10 strain upon *Acinetobacter baumannii* infection. *Microbial Pathogenesis*, 111; 370-374.
- [20] J.S. Kim, M.S.E. Kuk, J.H. Yu, S.J Kim, Antimicrobial effects of silver nanoparticles, *Nanomed. Nanotechnol. Biol. Med.*, 3 (2007) 95-101.
- [21] Abdulkadir, A. R., Zawawi, D. D., & Jahan, M. S. (2015). DPPH antioxidant activity, total phenolic and total flavonoid content of different part of Drumstic tree (*Moringa oleifera* Lam.). *Journal of Chemical and Pharmaceutical Research*, 7(4), 1423-1428.
- [22] Agarwal A; Weis TL; Schurr MJ; Faith NG; Czuprynski CJ; McAnulty JF; Murphy CJ; and Abbott NL.(2010)Surfaces modified withnanometer-thick silver-impregnated polymeric films that kill bacteria but support growth of mammalian cells. *Biomaterials*. 31(4):680-90. PubMed. DOI:10.1016/j.biomaterials.2009.09.092.
- [23] Saravanan M; Vemu AK; and Barik SK.(2011) Rapid biosynthesis of silver nanoparticles from *Bacillus megaterium* (NCIM 2326) and their antibacterial activity on

multi drug resistant clinical pathogens. *Colloids Surf B Biointerfaces*; 88(1):325-31.
PubMed. doi: 10.1016/j.colsurfb.2011.07.009. Epub 2011 Jul 12.