Characters and Applications of Green Disinfectant During Hajj

Osama A. Atallah

The Custodian of the Two Holy Mosques Institute for Hajj and Umrah Research, Umm Al Qura University

Abstract

Microbial contamination is one of the common problems in high populations and mass gathering such as Hajj and Umraa seasons. So applicable solutions are in need such as finding of new formula of a powerful and effective disinfectants and sanitizers. So that this review article suggested the mixing of two disinfectants, Poly hexamethylene hydrochloride guanidine and French clay, to form a unique, safe and effective new product known as green disinfectant. The new product has the chemical and antiseptic characters of both substances. According to the previous researches; the green disinfectant can be environmental friendly and can be used in various purposes. It is a new formula of disinfectant with a wide scope of applications in food processing plants, logistics, kitchens, swimming pool sanitizers, cosmetics, leather preservatives, fibers and textiles. It can be used also as disinfectant for abattoirs, air conditions, and contact surfaces. Green disinfectant has unique characters; it is free of heavy metal and phenol compounds, and any other harmful, toxic or irritant compounds. This new product highly soluble in water, odorless, non-toxic and has no side effects on public health and hygiene. Finally, this paper suggests that mixing of the two compounds in different concentrations, then to be evaluated for its effectiveness to be applied as general disinfectant during seasons of hajj and Umraa.

Key words:PHMG, French clay, Disinfectant, Antiseptic, Hajj and Umraa

Introduction

It has been proven that Poly hexamethylene biguanide hydrochloride (PHMG) is a powerful bactericide. In recent years the resistance of microorganisms has increased (Ouahiba et al., 2010). To reduce food poisoning with the resulting epidemic diseases, the development and use of new bioactive molecules that can act more effectively on new resistant microorganism generations is essential (Ouahiba et al., 2010). PHMG is a cationic biocide marketed worldwide, due to its excellent antimicrobial activity, chemical stability, low toxicity and reasonable cost (Gustavo et al., 2011; Vitt et al., 2015). Effectiveness against cellular organisms is due to the very basic biguanide group attached to a flexible spacer, a hexamethylene group. Maximal biocidal efficiency is obtained when six methylene groups are used as spacer between biguanide groups. It was concluded that PHMG was the most widely used antiseptic when prolonged use is needed and/or when prolonged contact is feasible (Kaehn, 2010). PHMG binds to the negatively charged phosphate head groups of phospholipids at bacteria cell wall, causing increased rigidity, sinking non-polar segments into hydrophobic domains, disrupting the membrane with subsequent cytoplasmic shedding culminating in cell death. PHMG can be found in swimming pool sanitizers, cosmetics, leather preservatives, contact lens disinfectants, cleanser in agriculture and food handling, in treatment of hatching eggs, fibers and textiles and technical fluids like cutting oils and glues (Kaehn, 2010).

PHMG disinfectant known to be a biocide, odorless, non-corrosive, non-irrigative and nontoxic to humans and animals, fast at low concentrations and with a broad spectrum of action (Oulé et al., 2008). It was demonstrated that PHMG is an effective sporicidal disinfectant with great potential for use in hospitals, laboratories, food industries and households (Oulé et al., 2012). It was found that PHMG killed MRSA (methicillin-resistant Staphylococcus aureus) and E. coli at concentrations as low as 0.04 and 0.005 % (w/v), respectively, within 1.5 min (Oulé et al., 2008; 2012). PHMGH has been proved to be bactericidal and fungicidal. Hence, it could probably serve as a fungicidal disinfectant for the treatment of cocoa beans after harvesting (Mathurin et al., 2012).

PHMG showed bactericidal advantages over chlorhexidine digluconate against ESKAPE pathogens Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumanii, Pseudomonas aeruginosa, and Enterobacter species). Some study support the further development of covalently bound PHMG in sterile-surface materials and the incorporation of PHMG in novel disinfectant formulas (Zhou et al., 2015).

French clay is a natural bioorganic material and contains a compounds of valuable elements with several important include calcium, silicium, several important mineral oxides, magnesium, potassium, dolomite, silicium, manganese, phosporous, copper, and selenium. Green Illite and Montmorillonite clays are the best known of the clays for overall well being. Their main properties are the following: absorbent, adsorbent, purifying, and calming. French Green Clay is a potent remedy with highly absorbent properties (Dextreit et al., 1987). French green clay belongs to a subcategory of clay minerals known as illite clays, the other two major groups being kaolinite and smectite clays. Illite clays are usually formed by weathering or by changes produced in aluminum-rich minerals by heat and acidic ground water.

Chemical and physical specification

Its chemical name is Poly hexamethylene biguanide hydrochloride (PHMG); IUPAC Name is Homo-polymer of N-(3-Aminopropyl)-Imidodi-carbonimidi-cdiamide. Its empirical formula is (C8H17N5)n.nHCl (where n=1-40). It has off-white to pale yellow powder as physical form with strong ammonia smell at 20° C and 101.3 kPa and/or very pale yellow to pale yellow, lumpy solid; no obvious odor, and/or Pale-yellow glass-like solid (technical grade PHMG) (ANSES, 2013). The molecular weight of PHMG is higher than 700 g/mol (submission), 2670 – 2960 (weight average molecular weight), and 3686 – 4216 (weight average molecular weight). It contain impurities/accompanying contaminants such as: water content (3 – 5 %) and trace metal contents (in ppm, w/w) in PHMG (Cd (< 0.25), Cr (< 0.25– 0.7), Co (< 0.25), Fe (14 – 40), Pb (< 2), Zn (370 – 540), As (< 2), and Hg (< 0.2)) (Oule´ et al., 2012; SCCS, 2015).

The French clay was not sensitizing. Its chemical formula was given as (KH3O)(AlMgFe)2(SiAl)4O10[(OH)2(H2O)], but there is considerable ion substitution. It occurs as aggregates of small monoclinic grey to white crystals (Pough, 1988). Due to the small size, positive identification usually requires x-ray diffraction analysis. Illite occurs as an alteration product of muscovite and feldspar in weathering and hydrothermal environments. The cation exchange capacity (CEC) of illite is smaller than that of smectite but higher than that of kaolinite typically around 20 – 30 meq/100 g. Illite is highly absorbent clay (30% - it absorbs 30% of water) and has a relatively low re-mineralization power (12%). Cationic (ionic) exchange rate, alongside their sorptive properties, is one of the most important factors of clays. In fact, each type of clay exchanges mineral elements with the environment they are in and has a certain coefficient of absorption which varies from one clay to another (Elmore, 2003).

Synthesis and mechanism

PHMB can be synthesized by different routes, but usually is obtained by poly condensation of sodium dicyanamide and hexamethylenediamine in two steps Roth and Brill, 2010).

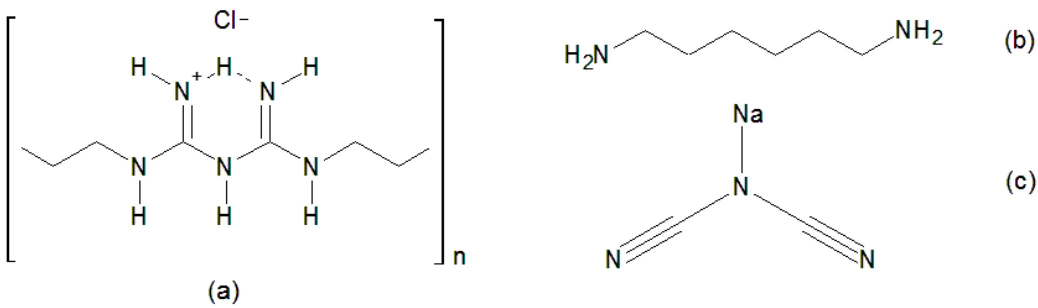
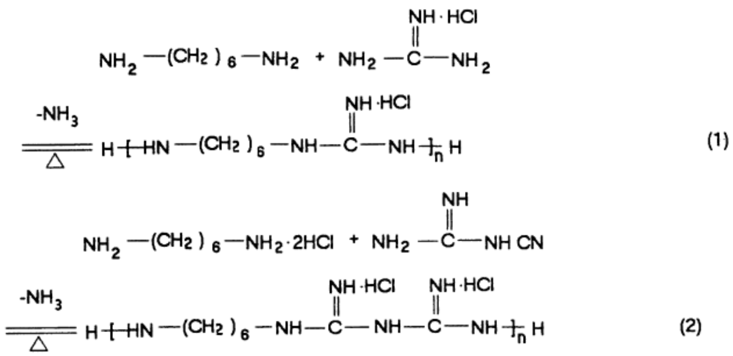


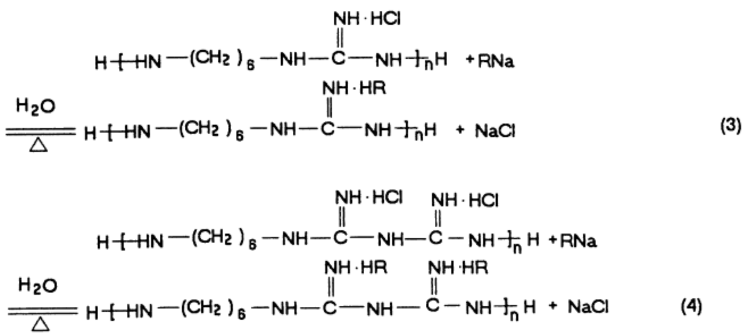
Figure . Schematic structure of mono-protonated PHMB with chloride as counter-ion (a) and monomers: Hexamethylenediamine (b) and sodium dicyanamide (c).

In addition, PHMB can be synthesized by mixing equimolar amounts of hexamethylenediamine and guanidine hydrochloride in a round-bottomed three-necked flask, which is equipped with a mechanical stirrer and vacuum system. The mixture reacted at 100 °C for 60 min, and then at 170 °C for a certain time. During the reaction, by-product ammonia is neutralized by bubbling through aqueous HCl. Thereafter the reaction continued on the condition of removing ammonia by vacuum system. At the end of reaction, the slightly yellow, viscous liquid solidifies upon cooling giving PHMG samples (Wei et al., 2009).



Scheme 1. Scheme of the polycondensation.

Finally, PHMB can be synthesized by cooligomerize equimolar amounts of guanidine hydrochloride and 1,6- hexamethylenediamine for 2h at 1208 ºC until liberation of NH_3 was completed, and then polymerized at 1608 ºC for 4, 5, 6 and 8h to prepare poly hexamethylene guanidine hydrochloride in the form of viscous mass which solidified after cooling. Equamolar amounts of dicyandiamide and hexamethylene diamine hydrochloride were poly condensated at 1808 ºC for 6, 8, 10 and 12h in the melt of monomers and poly hexamethylene biguanidine hydrochloride was obtained (Zhang et al., 1999).



where, R=$CH_3(CH_2)_{16}COO$

Scheme 2. Scheme of the precipitation reaction.

Mode of action

The mode of action of PHMG antimicrobial biocide was elucidated by transmission electron microscopy: the cell envelope was broken, resulting in cell content leakage into the medium (Oulé et al., 2008; Zhou et al., 2010). It was shown that PHMG derivatives strongly affected dehydrogenases activity in *S. aureus* than in *E. coli* (Walezak et al., 2014). Polymer C4, C6, and C8 displayed gradually increased biocidal activity with the increased alkyl chain length of the repeat unit of the polymer, and Polymer C8 had higher activity than Polymer C8 (benzene). The novel Polymer C8 also exhibited higher biocidal activity than Polymer C6 (PHMG) against Gram-negative and Gram-positive clinical strains and reference bacteria for disinfectant.

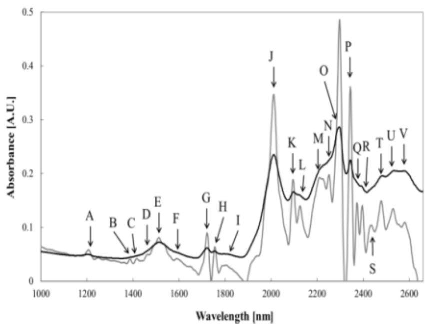
Infrared absorption spectrum of PHMG was obtained by near-infrared spectroscopy (NIR). The most important are those located at 2,000–2,400 nm range, corresponding to nitrogen-related vibrations, including combination bands due to nitrogen-carbon bonds in the biguanide pseudo-aromatic ring (Table). Remaining bonds are due to methylene groups and residual hydration water. Bands associated to chlorine ion are not present, but the —bonded behavior of some vibrations may be due to chloride interference on –N–H vibrations (Workman and Weyer, 2008; Gustavo et al., 2011).

French green clay has anti-inflammatory as well as antiseptic or bactericidal properties. It is interesting that a group of Italian researchers reported in 2002 that French green clay powder is as effective as salicylic sugar powder in preventing infection of the umbilical stump in newborns. The clay powder was found to be superior to powders containing colloidal silver, antibiotics, or fuchsine (Elmore, 2003). It is claimed that French green clay absorbs toxins from the stomach and intestines as well as neutralizing radioactivity in the body (Katsumata et al., 2003).

The absorbent power of this clay is extraordinary. Clay has the power to attract and either absorb or stimulate the evacuation of toxic and non-useful elements. Its absorbent power has contributed to the elimination of the chemical taste of chloride in Paris water. Clay considerably reduces the toxicity of harmful substances.

Table 4. Peak assignment for near-infrared spectrum of pure PHMB [20].

Peak	Wavelength (nm)	Bond (Vibration)	Remarks
A	1,206	C–H (3ν)	Methylene
B	1,388	SiOH	Quartz subtrate
C	1,416	C–H	Methylene combinations
D	1,436	N–H (2ν)/C–H	Primary amine/methylene combination
E	1,464	N–H (2ν)	Secondary amine
F	1,590	O–H (2ν)	Water, bonded
G	1,722	C–H (2ν)	Methylene
H	1,756	C–H ($2\nu_s$)	Methylene
I	1,804	O–H	Combination from water, bonded
J	2,012	N–H/C–N	Combination from $-[N(H)]_2-C=N-$
K	2,096	O–H (3δ)	Water
L	2,126	N–H/C=N	Combination from $-[N(H)]_2-C=N-$
M	2,210	N–H/C–N/C=N	Combination from $-[N(H)]_2-C=N-$
N	2,252	N–H	Bonded, from amides
O	2,298	N–H	Bonded, from amides
P	2,344	C–H (2ν) & C–H (δ)	Combination, from methylene
Q	2,372	C–H ($2\nu_s$) & C–H (δ) & C–C (ν)	Combination, from methylene
R	2,396	C–H (ν)/C–C (ν)/C–H (δ)/C–C (δ)	Aromatic biguanide ring
S	2,434	C–H (ν)/C–C (ν)/C–H (δ)/C–C (δ)	Aromatic biguanide ring
T	2,478	C–H (3δ)	Aromatic biguanide ring
U	2,530	C–N ($2\nu_a$)	C–N–C from biguanide
V	2,580	C–H (ν)/C–H (ω)/C–C (ω)	Aromatic biguanide ring



Safety

It is a new generation of disinfectant with a wide scope of applications in agriculture and food processing plants, logistics, kitchens and so on. Its ability to give long-lasting protection puts it in the top position as a unique disinfectant in providing long-lasting, total bio safety to the user. PHMG is free of heavy metal and phenol compounds, and any other harmful, toxic or irritant compounds. Because of these features, PHMB is an environmentally friendly product. PHMG has outstanding bactericide, fungicide and virucide properties (Roth and Brill, 2010). Its performance and extremely low toxicity make it the best option in Bio-safety for chicken houses, livestock farming, feed stocks, slaughterhouses, food and feed storage facilities, transport vehicles, food processing units, kitchens and so on, in addition it can work at low concentrations very fast with a broad spectrum of action because of its relatively safe status, its wide acceptance and its exploitation for potential multi-purpose functional use (Oulé et al., 2008). Several studies have been done in Côte d’Ivoire on Papaya regarding viral diseases (Diallo et al., 2007), maturation of the fruit (Yao et al., 2011). For wound dressings, Wright et al., 2003 compared the effectiveness of a silver dressing to a dry gauze dressing containing PHMG (Kerlix AMD). Results demonstrated reduction in bioburden with both dressings when tested in an in-vitro bactericidal assay. Using a Kirby-Bauer zone of inhibition study, the gauze was not as effective. This was believed to be due to a tight bond between the dressing and PHMG, which was not released and therefore did not result in killing beyond the edge of the dressing (Wright et la., 2003). It was suggested that the PHMG in the gauze resulted in a decrease in the number of organisms present in the wound (Motta et al., 2004). Also, improve the preservation of fruit and vegetables such as papaya (Koffi-Nevry et al., 2011). PHMG behaves as a low-foaming surfactant, with a critical micellar concentration near 5×10^{-2} mol dm^{-3} in water at 293 K. It is easily processable to films, but water balance is crucial to mechanical stability since water is a plasticizer: High water contents led to sticky, mechanically unstable films; completely anhydrous film is very brittle and hygroscopic (De Paula et al., 2011).

French clay hasn’t particular risk. It was stable and inert product with none hazardous decomposition, no carcinogenic, mutagenic, teratogenic, neurotoxic effects. Where it doesn't decompose itself. Also, it hasn’t irritating skin. It hasn’t other precaution for the protection of the environment. The clay will remove any bacterial infection and impurities from the site through absorption (Pezzati et al., 2002).

Recent research indicates that French Green clays have an ability to bind mycotoxins in the digestive system of animals as well as several bacteria in-vitro. "In experiments, the clay killed up to 99 per cent of superbug colonies within 24 hours. Control samples of MRSA (methicillin-resistant *Staphylococcus aureus*) grew 45-fold in the same period. The clay has a similar effect on other deadly bacteria tested, including *Salmonella*, *E. coli*, and a flesh-eating disease called buruli, a relative of leprosy which disfigures children across central and western Africa. It has been classed as "an emerging public health threat" by the World Health Organization (WHO)." The effectiveness of the French green clays, which are mostly made of minerals called smectite and illite.

Conclusion and Recomendations

Both PHMG and French clay have a powerful bactericidal activity. This review article suggested a new noval formula with different concentrations of substances, PHMG and French clay. The new product expect to be one of the most effective disinfectant that can be applied in the food processing plants in Makkah Al-Mukaramah and Madina Al-Monaurah especially during hajj and Omrah seasons.

Reference

- ANSES (2013) CLH report, Proposal for harmonised classification and labelling, Polyaminopropyl biguanide or Poly (hexamethylene) biguanide hydrochloride or PHMB, CAS No. 27083-27-8 or 32289-58-0, ANSES (on behalf of the French MSCA), Maison- Alfort, France, May 2013.
- De Paula G F , Netto G I, Mattoso L H C (2011). Physical and Chemical Characterization of Poly(hexamethylene biguanide) Hydrochloride. Polymers, 3, 928-941.
- Dextreit, Raymond. L'argile qui guérit. Memento de médecine naturelle. Paris: éditions de la revue Vivre en harmonie, 1976. Translated into English as The Healing Power of Clay. Geneva, Switzerland: Editions Aquarius, S. A., 1987.
- Diallo HA, Monger W, Kouassi N, Yoro DT, Jones P (2007). First report of Papaya ringspot virus infecting papaya in Côte d'Ivoire. Plant Pathol., 56: 718.
- Elmore, A. R.; Cosmetic Ingredient Review Expert Panel. "Final report on the safety assessment of aluminum silicate, calcium silicate, magnesium aluminum silicate, magnesium silicate, magnesium trisilicate, sodium magnesium silicate, zirconium silicate, attapulgite, bentonite, Fuller's earth, hectorite, kaolin, lithium magnesium silicate, lithium magnesium sodium silicate, montmorillonite, pyrophyllite, and zeolite." International Journal of Toxicology 22 (2003, Supplement 1): 37–102.
- Gustavo, F. P; Germano, N. L. and Henrique, C. M. (2011). Physical and Chemical Characterization of Poly (hexamethylene biguanide) Hydrochloride. Polymers 2011, 3, 928-941; doi:10.3390/polym3020928.
- Kaehn, K. Polihexanide: A safe and highly effective biocide. Skin Pharmacol. Physiol. 2010, 23 (suppl. 1), 7–16.
- Katsumata, H., S. Kaneco, K. Inomata, et al. "Removal of Heavy Metals in Rinsing Wastewater from Plating Factory by Adsorption with Economical Viable Materials." Journal of Environmental Management 69 (October 2003): 187–191.
- Koffi-Nevry R, Manizan A L , Tano K , Clément Y B Y , Oulé M K, Koussémon M (2011). Assessment of the antifungal activities of polyhexamethylene-guanidine hydrochloride (PHMGH)- based disinfectant against fungi isolated from papaya (Carica papaya L.) fruit. Afr. J. Microbiol. Res.5(24);4162-4169.
- Mathurin YK, Koffi-Nevry R, Guéhi ST, Tano K, Oulé MK (2012): Antimicrobial activities of polyhexamethylene guanidine hydrochloride-based disinfectant against fungi isolated from cocoa beans and reference strains of bacteria. J Food Prot.,75(6):1167-1171. doi: 10.4315/0362-028X.JFP-11-361.
- Motta GJ, Milne CT, Corbett LQ (2004). Impact of antimicrobial gauze on bacterial colonies in wounds that require packing. Ostomy Wound Manage.50(8):48-62.
- Ouahiba F, Tarek C, Abouricha S, Lamzira Z, Benchat NE, Abdeslam AA (2010). Synthèse et activité antimicrobienne de nouveaux dérives pyridaziniques n-alkyles (synthesis and antimicrobial activities of news products derived from pyridaziniques nalkyles) Revue Microbiol. Indust. Sanit. Environ., 4(1): 114-128.

- Oulé MK, Richard A, Anne-Marie B, Tano K, Anne-Marie M, Stephanie M, Rose KN, Korami D, Lorraine F, Lamine D (2008). Polyhexamethylene guanidine hydrochloride-based disinfectant: a novel tool to fight meticillin-resistant Staphylococcus aureus and nosocomial infections. J. Med. Microbiol., 57: 1523-1528.
- Oule, M. K., Quinn, K., Dickman, M., Bernier, A.-M., Rondeau, S., De Moissac, D., Boisvert, A. & Diop, L. (2012). Akwaton, polyhexamethylene-guanidine hydrochloride-based sporicidal disinfectant: a novel tool to fight bacterial spores and nosocomial infections. J Med Microbiol 61, 1421-1427.
- Pezzati, M., E. C. Biagioli, E. Martelli, et al. "Umbilical Cord Care: The Effect of Eight Different Cord-Care Regimens on Cord Separation Time and Other Outcomes." Biology of the Neonate 81 (January 2002): 38–44.
- Pough, Frederick H. A Field Guide to Rocks and Minerals. Boston: Houghton Mifflin Company, 1988.
- Roth, B. Brill, F.H.H (2010). Polihexanide for wound treatment—how it began. Skin Pharmacol. Physiol., 23 (1), 4–6
- SCCS (2015) (Scientific Committee on Consumer Safety). 2nd Revision of the opinion on the safety of poly (hexamethylene) biguanide hydrochloride or polyaminopropyl biguanide (PHMB) in cosmetic products. 13 July 2015.
- Vitt A, Sofrata A, Slizen V, Sugars RV, Gustafsson A, Gudkova EI, Kazeko LA, Ramberg P, Buhlin K. (2015): Antimicrobial activity of polyhexamethylene guanidine phosphate in comparison to chlorhexidine using the quantitative suspension method. Ann Clin Microbiol Antimicrob.;14:36. doi: 10.1186/s12941-015-0097-x.
- Walczak m., Richert A. & Burkowska‑But A. (2014): The effect of polyhexamethylene guanidine hydrochloride (PHMG) derivatives introduced into polylactide (PLA) on the activity of bacterial enzymes. J Ind Microbiol Biotechnol.; 41:1719–1724. DOI 10.1007/s10295-014-1505-5
- Wei, D; Ma, Q; Guan, Y; Hu, F; Zheng, A; Zhang, X; Teng, Z and Jiang, H. (2009). Structural characterization and antibacterial activity of oligoguanidine (polyhexamethylene guanidine hydrochloride). Materials Science and Engineering C 29 (2009) 1776–1780.
- Workman, J., Jr.; Weyer, L. Practical Guide to Interpretative Near-Infrared Spectroscopy; CRC Press: Boca Raton, FL, USA, 2008; pp. 240–262.
- Wright JB, Lam K, Olson ME, Burrell RE (2003). Is antimicrobial efficacy sufficient? A question concerning the benefits of new dressings. WOUNDS.15(5):133-142.
- Yao BN, Tano K, Assemand EF, Koffi-Nevry R, Bédié GK, Amani, G (2011). Effect of the Maturity Stage and Storage Temperature on the Postharvest Quality of Carica papaya L. Variety Solo 8. Fresh Prod., 5(1): 15-21.
- Zhang, Y; Jiang, J and Chen, Y. (1999). Synthesis and antimicrobial activity of polymeric guanidine and biguanidine salts. Polymer 40 (1999) 6189–6198.
- Zhou Z, Wei D & Lu Y. (2015): Polyhexamethylene guanidine hydrochloride shows bactericidal advantages over chlorhexidine digluconate against ESKAPE bacteria.Biotechnol Appl Biochem.; 62(2):268-74. doi: 10.1002/bab.1255.

- Zhou Z.X., Wei D.F., Guan Y., Zheng A.N. & Zhong J.J. (2010): Damage of Escherichia coli membrane by bactericidal agent polyhexamethylene guanidine hydrochloride: micrographic evidences. Journal of Applied Microbiology, March, 2010. 10.1111/j.1365-2672.2009.04482.x