Novel Phase Change Materials, MgO Nanoparticles, and Water Based Nanofluids for Thermal Energy Storage and Biomedical Applications

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ABSTRACT

Fabrication of novel nanofluids from phase change materials, MgO nanoparticles and water for antibacterial, antifungal, thermal energy storage and release applications are also useful in a heating/cooling systems of buildings to prevent the bacterial and fungal presence in water. Also, the prepared nanofluids have high quality for thermal energy storage and release for heating/cooling. The (PVP-PEG-MgO-H_2O) nanofluids are prepared with different concentrations of (polyvinyl pyrrolidone (PVP 50 wt.%) –polyethylene glycol (PEG 50 wt.%) and magnesium oxide nanoparticles were added to polymer blend fluids with different weight percentages of (0, 4, 8 and 12) wt.%. The optical and thermal properties of (PVP-PEG-MgO-H_2O) nanofluids have been studied. The results showed that the absorbance of (PVP-PEG-H_2O) fluid increases and the transmittance decreases with increase of the MgO nanoparticles' concentrations. The thermal conductivity of (PVP-PEG-H_2O) fluid increases with increase of the MgO nanoparticles' concentrations. The antibacterial and antifungalproperties of (PVP-PEG-MgO-H_2O) nanofluids were tested against aspergillus, bacillus, lactose, streptococcus and pseudonymous organisms. Results showed that the (PVP- PEG-MgO-H_2O) nanofluids have high activities for antibacterial and antifungal. The inhibition zone diameter increases with increasing of magnesium oxide nanoparticles' concentrations. Also, the (PVP- PEG-MgO-H_2O) nanofluids tested for storage of energy and release; the results showed the time of melting and solidification are decreased with increase of the MgO nanoparticles' concentrations. The (PVP- PEG-MgO-H_2O) nanofluids have high activities for antibacterial and antifungal. The (PVP-PEG-MgO-H_2O) nanofluids have high quality for thermal energy storage and release which can be used for heating-cooling of buildings, automobile engines etc.

Key Words: Antibacterial, energy storage, nanofluids, phase change, thermal properties

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INTRODUCTION

Nanofluids can be obtained by dispersing different nanoparticles in public fluids (such as water) for enhancing thermal properties. Nanofluids are capable to upgrade the stability, thermal conductivity, coefficient of heat transfe
r, and decrease the costs power consumed. All these benefits made arising capability in the use of

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nanofluids in different kinds of heat transfer exchangers; accordingly, revealing appropriate nanofluids with amended properties of heat transfer and high thermal conductivity [1]. Great efforts have been done to enhance the performance of systems such as heat transfer process. The modern heat transfer technology meets the challenges on the increasing requirement of higher applied heat fluxes at one side and the system minimizing at the other side. If nanofluidis used as an alternative heat transfer fluid, they offer great abilities to have those challenges. Nanofluids can be produced by dispersing 1-100 nm sized metallic or nonmetallic particles into conventional base fluids (for example water, oil, ethylene glycol, etc.). This modern heat transfer fluid beats the problems found in the use of the fluid including larger suspended particles (particles in mm or µm sized), such as rapid sedimentation, clogging, abrasion, and fouling. Thermal conductivity is one of the properties that has been paid attention in the nanofluids' researches. Enormous researches have presented that the thermal conductivities of nanofluids are higher than those of their base fluids [2]. PCM (Phase Change Materials) have been used in storage of energy systems due to their high storage density and little temperature change from storage to retrieval in many applications. PCMs can be found in many groups such as storage of energy for heating-cooling for example buildings, food industries, medical, waste heat recovery etc. The storage systems materials should have a high thermal diffusivity to sponsor the stored energy's re-distribution [3]. Related to the convection heat transfer, modern global researches have obviously pretend the useful effect on the enhancement of heat transfer by using nanofluids in certain confined flow condition [4]; for instance, because of nanosmall size particles, minimum drop of pressure, the high nanoparticle thermal conductivity will increase the heat transfer rate, and gaining certain nanofluid will cause lighter and smaller heat exchanger. Zhan Shu et al. [6] prepared a discovered antimicrobial nanocomposite incorporating hallo site nanotubes (HNTs) and silver (Ag) into zinc oxide (ZnO) nanoparticles by integrating HNTs and embossing Ag nanoparticles. HNTs simplified the squandering and stability of ZnO NPs and transported them for contact with bacteria, but Ag NPs could enhance the season of photo generated electron hole pairs and enhance the activity of antibacterial forZnO NPs. Through approaching contact with membrane of cell, the nanoparticles can give the raised concentration for species of reactive oxygen and the ions of metal to perform into the cytoplasm, then induce a fast death of bacteria, indicating that Ag-ZnO/HNTs nanocomposite of antibacterial is a favorable nominee in the antibacterial fields as shown in figure (1).

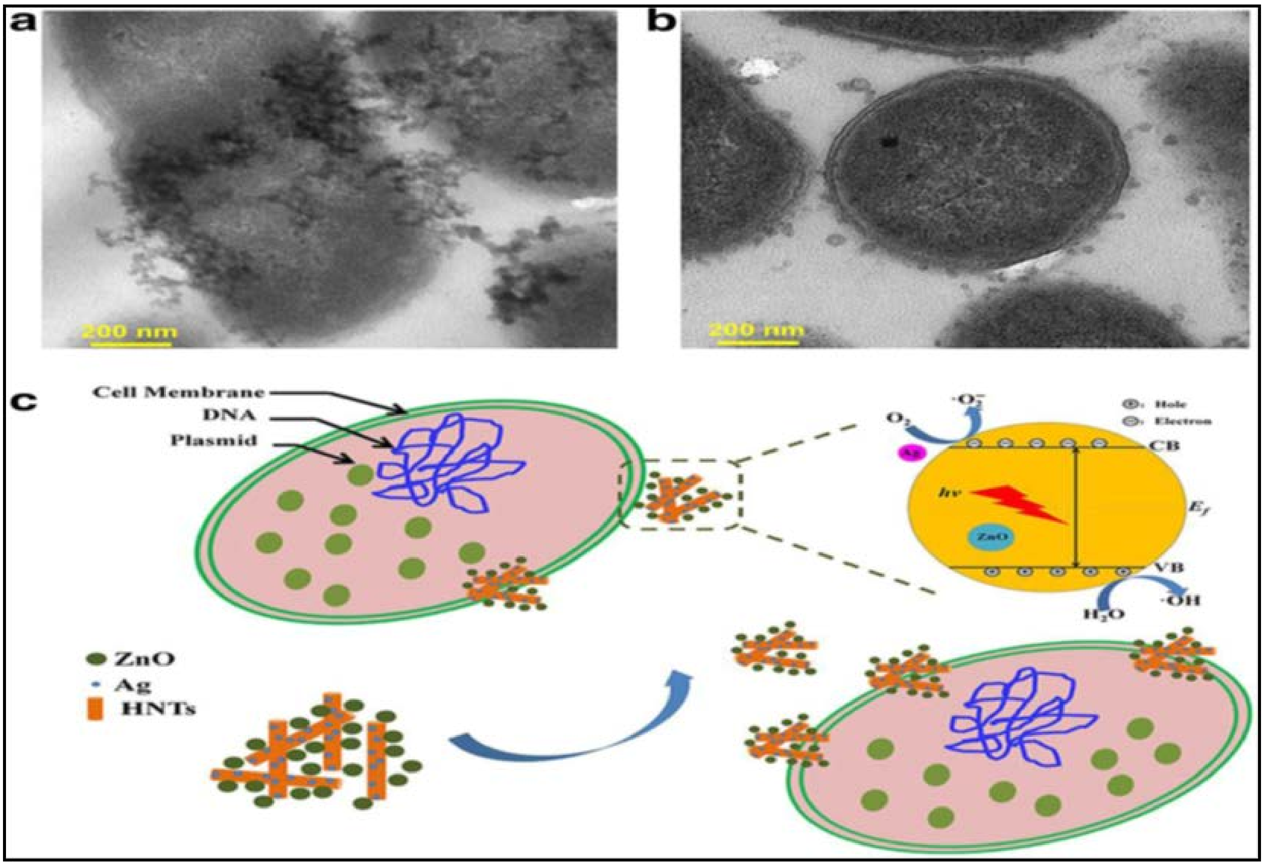

Fig 1. a and b are TEM oversight of Ag-ZnO/HNTs absorption of nanocomposites in E. coli bacteria and c represents diagram for enhanced activity of antibacterial [6].

Nowadays, sciences and technology of the nanoparticles is considered essential to the technological upheaval, which is attentive with significant materials' illusion and amended physical, chemical and biological properties. Nanosciences are known as antibacterial agents because of their structure, size, and surface properties. Thus, nanotechnology gives a way to get better the inorganic antibacterial agents activity. Nanoparticles of metal oxide like toMgO, ZnO and CaO were inspected as agents of inorganic antibacterial. MgO is an example of important inorganic material having a wide bandgap. It was used in different applications including catalysis, catalyst supports, refractory materials, adsorbents, etc. In the field of medicine, MgO is used for the heart burn relief and for regeneration of bone. Recently, MgO nanoparticles have shown promise for application in tumor treatment. MgO nanoparticles also have considerable potential as an antibacterial agent. Nanostructured materials promise fruitful development for applications in the aerospace sector due to their low density, high strength and thermal stability [7,8]. Different antimicrobial agents have different effects on different organisms [9] due to which nanoscience best act as antibacterial agents because of their structure, size, and surface properties. Nanotechnology has attracted the interest of numerous research groups around the world due to its potential for application in various industries [10]. Polymeric materials have unique properties such as low density, light weight, and high flexibility and are widely used in various industrial sectors [11,12]. Polymers are considered a good choice as host materials, because they normally exhibit long-term stability and possess flexible reprocessability and they can be designed to yield a variety of bulk physical properties [8].

Experimental part

The materials used in the present work are polyvinyl pyrrolidone, polyethylene glycol, and magnesium oxide nanoparticles. The (polyvinyl pyrrolidone (PVP 50 wt.%) –polyethylene glycol (PEG 50 wt.%) - magnesium oxide) nanofluids PCMs are prepared by dissolving 0.5 gm of two polymers in 30 ml of distilled water by using magnetic stirrer to obtain more homogeneous solution. The magnesium oxide nanoparticles were added to polymer blend fluids with different concentrations (0, 4, 8 and 12 wt.%). The nanofluids optical properties were measured by the double beam spectrophotometer (shimadzu, UV-1800^{0}A) in wavelength (200-800) nm. The thermal energy storage and release include measuring the characteristics of melting and solidification of nanofluids during the processes of heating and cooling. The water and nanofluids PCMs were used as maximizing of heat transfer, their temperature ranged (30to 100°C) by using stirrer and measuring the temperature of nanofluids during the heating and cooling processes by digital device. The antibacterial and antifungal of nanofluids PCMs tested samples were investigated using a disc diffusion method. The antibacterial and antifungalactivities of (PVP-PEG-MgO-H_2O) nanofluids were done by using fungus organisms, gram positive organisms and gram negative organisms including aspergillus, bacillus, lactose, streptococcus and pseudonymous organisms. The fungus organisms, gram positive organisms and gram negative organisms were cultured in Muller-Hinton medium. The nanofluids were placed over the media and incubated at 37°C for 24 hours. The inhibition zone diameter of the (PVP-PEG-MgO-H_2O) nanofluids was measured.

RESULTS AND DISCUSSION

The absorption spectroscopy of UV-Visible is a powerful tool for the optical properties' investigation of material. Optical absorption spectra of (PVP-PEG-MgO-H_2O) nanofluids is shown in figure 2. The absorption edge was around 225 nm for (PVP-PEG) fluid and this sharp absorption edge for (PVP-PEG-H_2O) fluid indicates the semi crystalline nature. The (PVP-PEG-H_2O) fluid has very limited UV absorbance, and it is enhanced with the addition of MgO nanoparticles due to its high-energy gap. After incorporation of MgO nanoparticles, the sharp absorption edges intensity increases and its position gets little shifted across higher wavelength/lower frequency. Sharp absorption edges and well developed excitonic peaks further indicate that incorporated MgO nanoparticles are rather mono dispersed. The UV wavelengths' range is always divided into UV-A (400 to 315 nm), UV-B (315 to 290 nm), and UV-C (290 to 200 nm). MgO nanoparticles incorporated in (PVP-PEG) blend increases the absorption of UV light over the entire characteristics. Higher UV-absorbance values were got in the zone between 280 to 380 nm when MgO nanoparticles content is increased up to 12 wt.%. Thus MgO nanoparticles with (PVP-PEG-H_2O) nanofluids can be used to block the UV-A radiation. The results behold that the shielding effectiveness of UV radiation is due to the UV absorption capacity of MgO nanoparticles present in the bulk of (PVP-PEG) blend [13], this behavior of absorbance is consistent with the results of papers [14-15]. The UV-Visible transmittance spectra of (PVP-PEG-MgO-H_2O) nanofluids are shown in figure 3. The ultraviolet transmittance of light was decreased with increasing of MgO nanoparticles contents in (PVP-PEG) blend. Lower transmittance observed is resulted in increase of surface roughness. There is a decrease in transmittance which is observed for nanocomposite material which is due to Rayleigh scattering caused by MgO nanoparticles. For polymer nanocomposites, nanoparticles dispersion, particle size, polymer–interface, surface roughness and refractive index significantly affect the transmittance [10].

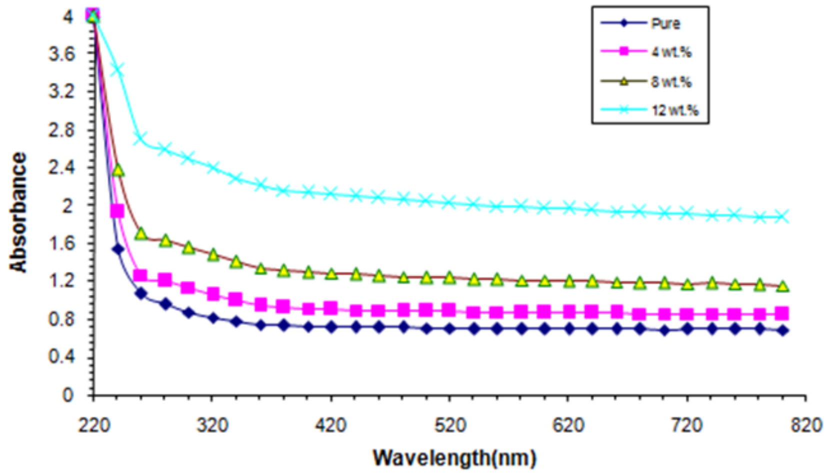

Figure 2. optical absorption spectra of (PVP-PEG–MgO-H_2O) nanofluids

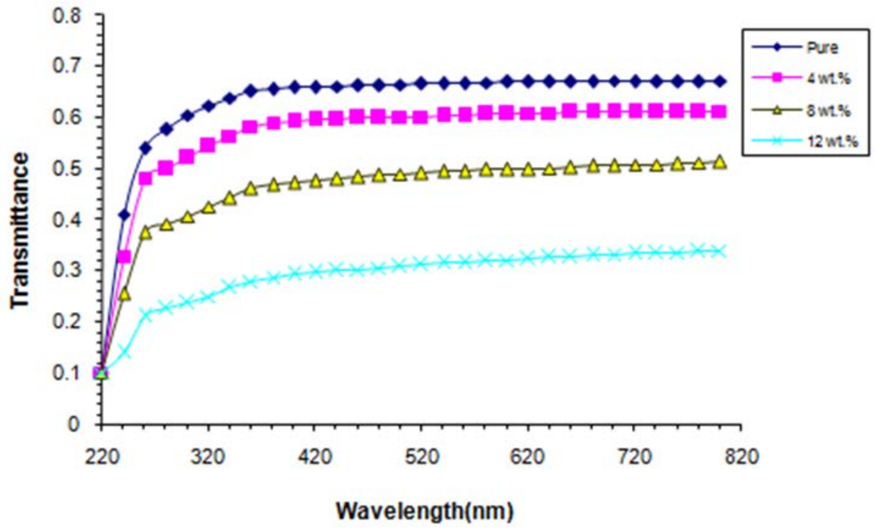

Figure 3. UV-Visible transmittance spectra of (PVP-PEG-MgO-H_2O) nanofluids

Figure 4: shows photo images of fungus and bacteria organisms were used in this paper. Figure 5 shows the antibacterial and antifungalactivities of (PVP-PEG-MgO-H_2O) nanofluids against fungus organisms and gram-positive organisms and gram-negative organisms' activities (aspergillus, bacillus, lactose, streptococcus and pseudonymous organisms). As shown in the figure, the inhibition zone diameter for aspergillus, bacillus, lactose, streptococcus and pseudonymous organisms increases with increasing of magnesium oxide nanoparticles concentrations as shown in figures (6-10). Researchers explained that nanoparticles having well attached to the bacteria membrane, can give elevated level of reactive oxygen species (ROS) [16].

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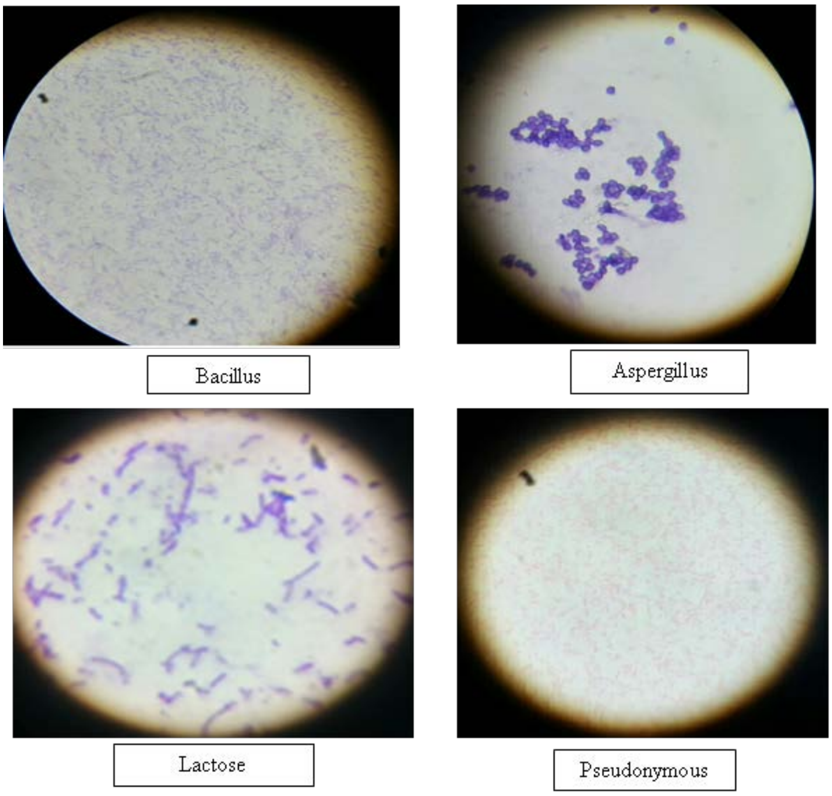

Figure 4. Images of bacteria and fungus organisms

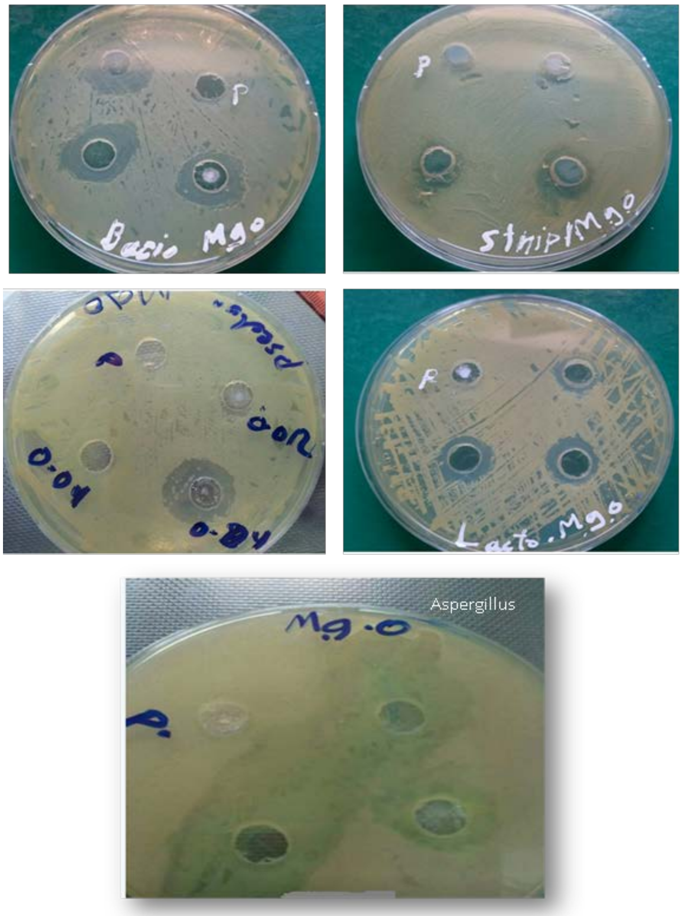

Figure 5. Antibacterial and antifungal of (PVP-PEG-MgO-H_2O) nanofluids

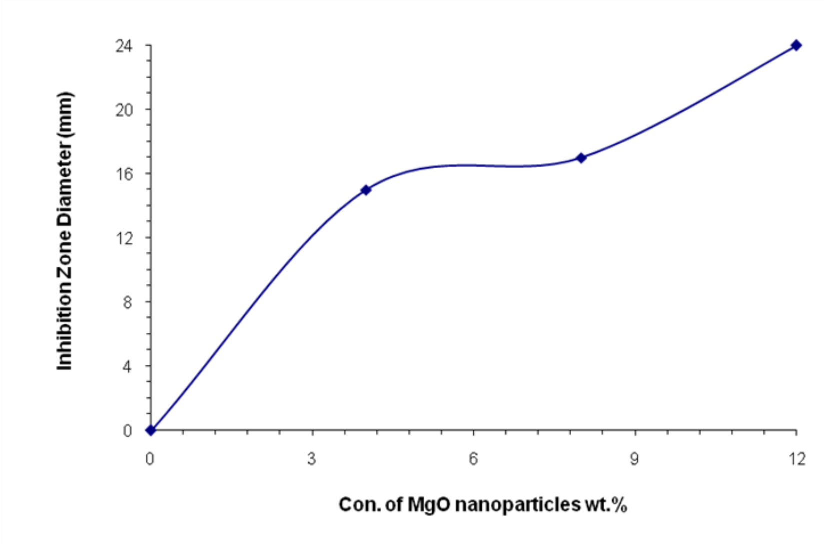

Figure 6. Antifungal activity of (PVP-PEG-MgO-H_2O) nanofluids against Aspergillus organisms

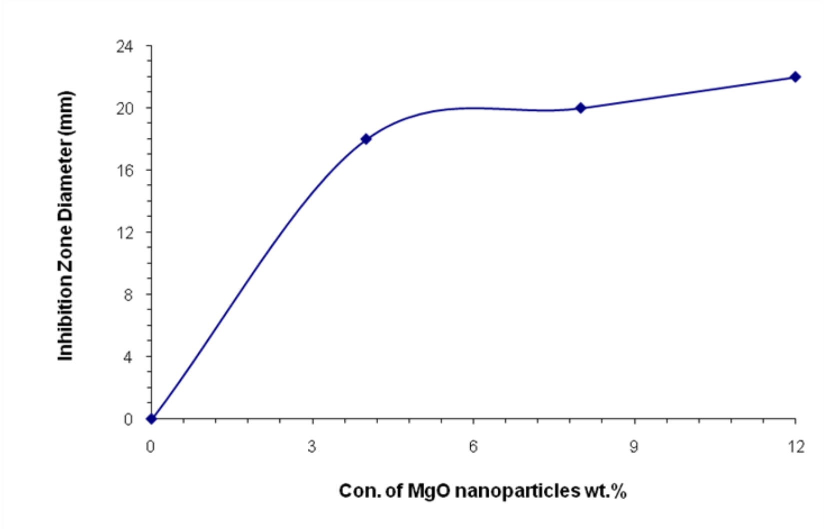

Figure7. Antibacterial activity of (PVP- PEG -MgO-H_2O) nanofluids against bacillus organisms

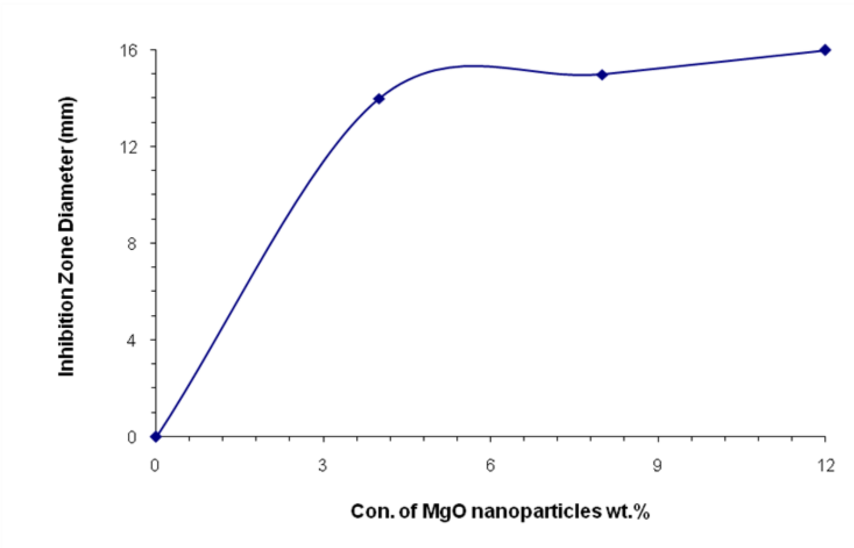

Figure 8. Antibacterial activity of (PVP-PEG-MgO-H_2O) nanofluids against lactose organisms

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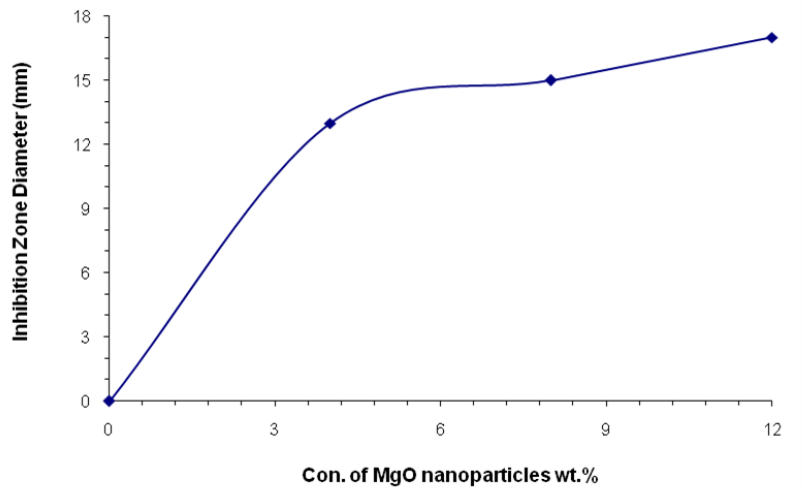

Figure 9. Antibacterial activity of (PVP-PEG-MgO-H_2O) nanofluids against streptococcus organisms

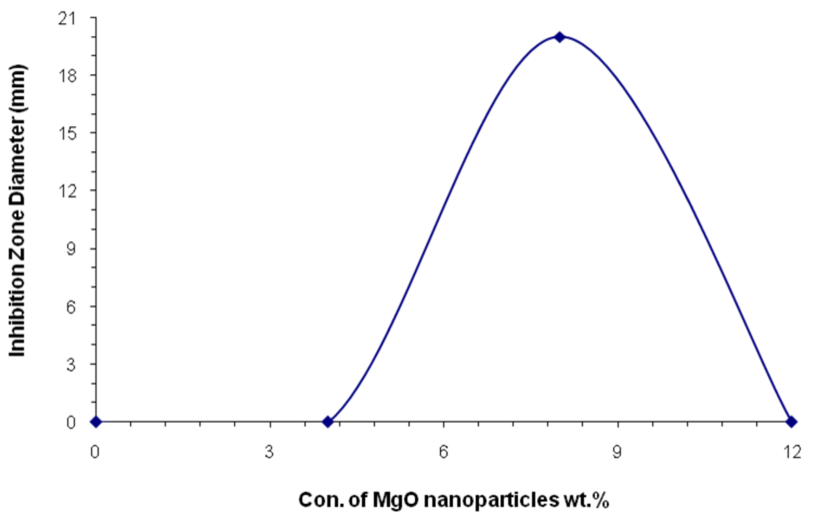

Figure 10. Antibacterial activity of (PVP- PEG-MgO-H_2O) nanofluids against pseudonymous organisms

A lot of researches showed that MgO nanoparticles have a good activity to gram-positive bacteria than to gram negative bacteria. This is because of the difference probably in the structure of cell membrane (Fig. 11). The cell wall of gram-positive bacteria includes primarily thin lipid layers of A, lipopolysaccharide, and peptidoglycan, but that of gram-negative bacteria includes only a peptidoglycan layer. Functions of membrane, enzymes activity associated with the membrane, and cell integrity maintenance depends on the cell surface structure [7].

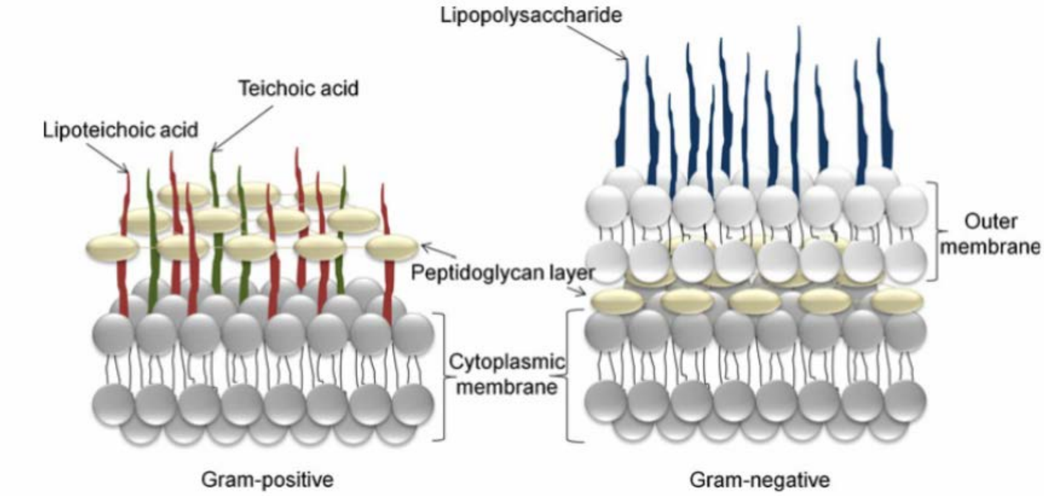

Figure 11. Membrane structure of gram-positive and gram-negative bacteria (reproduced with permission [7]

Figure 12 shows the thermal conductivity of (PVP-PEG-MgO-H_2O) nanofluids at room temperature. From the figure, the thermal conductivity increases with increase of the MgO nanoparticles' concentrations. The irregularity in enhancement is observed. This may be attributed to orthokinetic aggregation effect. Thus, the thermal conductivity is attributed to orthokinetic aggregation effect. This type of nanofluids is fit for heat exchanger application, where heat transfer rate plays a crucial role [17].

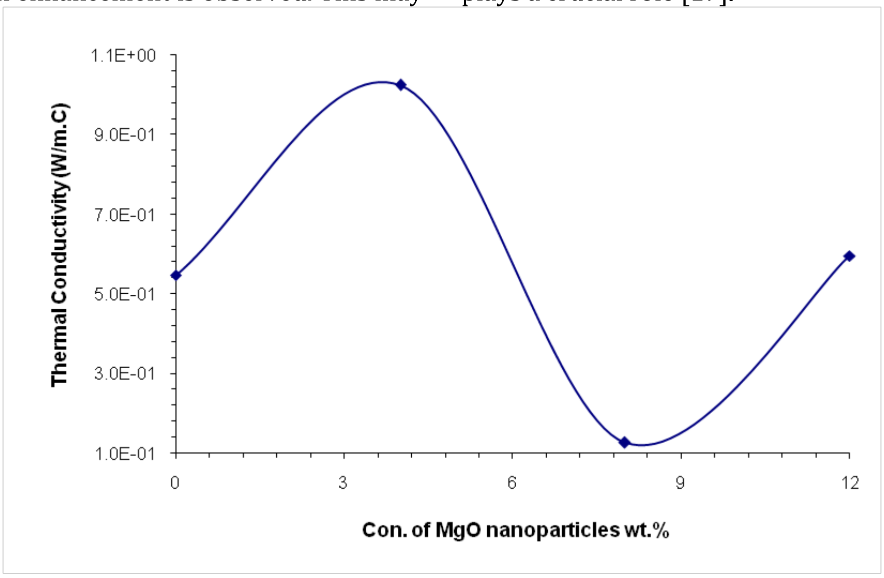

Figure 12. Thermal conductivity of (PVP-PEG-MgO-H_2O) nanofluids

The heat transfer of (PVP-PEG-MgO-H_2O) nanofluids was investigated during the processes of melting and solidification as shown in figures 13 and 14. The time of melting and solidification decreases with increasing of MgO nanoparticles' concentrations. Effective dispersion of MgO nanoparticles into base fluid were accelerated the conductive heat transfer during the process of solidification. The (PVP-PEG-MgO-H_2O) nanofluids could be considered efficient (PVP-PEG-MgO-H_2O) for solar water heating system due to their characteristics of enhanced heat transfer [18], which is consistent with the results of papers [19-21].

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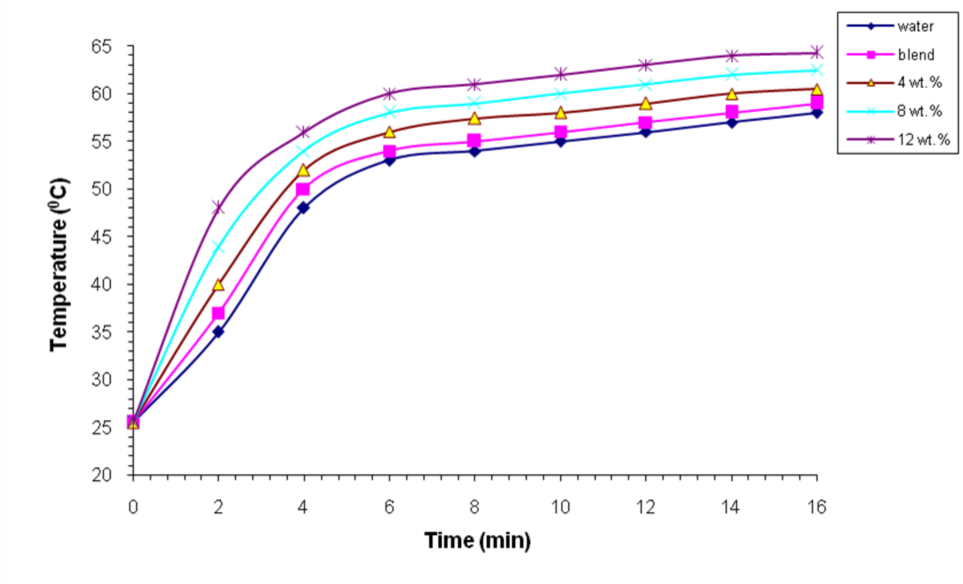

Figure 13. Melting curves of (PVP-PEG-MgO-H_2O) nanofluids

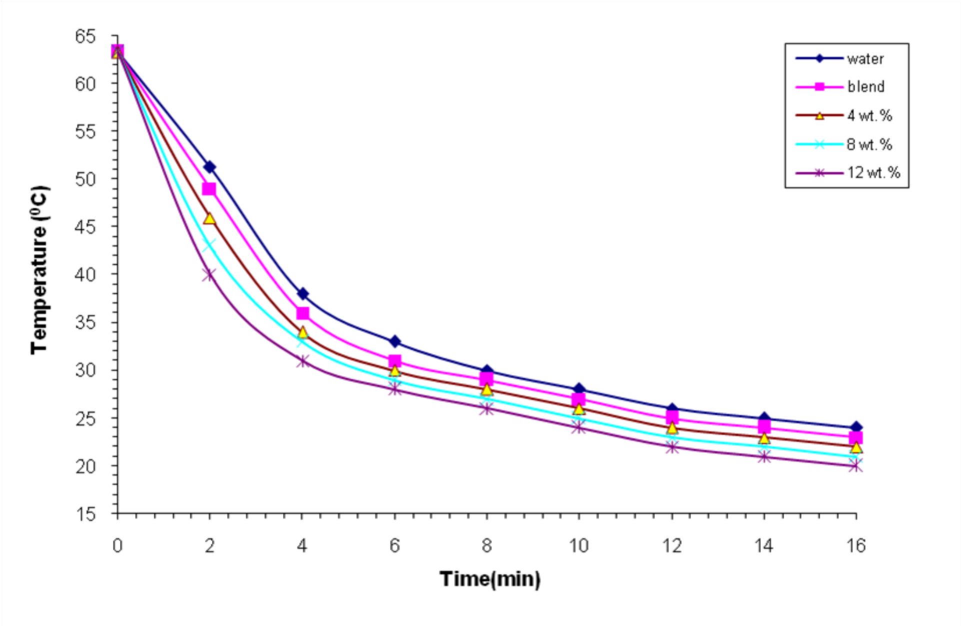

Figure 14. Solidification curves of (PVP-PEG-MgO-H_2O) nanofluids

CONCLUSIONS

1- The absorbance increases and transmittance decreases with regard to (PVP- PEG) nanofluid with increasing of MgO nanoparticles' concentrations.
2- The thermal conductivity of (PVP-PEG-MgO-H_2O) nanofluids increases with increasing of magnesium oxide nanoparticles' concentrations.
3- The (PVP- PEG-MgO-H_2O) nanofluids have high activity for antibacterial and antifungal which are useful in heating/cooling of buildings because the (PVP- PEG-MgO-H_2O) nanofluids cause bacterial and fungal disorganizations and prevent the bacterial and fungal presence in water tubes for heating/cooling systems. Also, they are useful in cold storages, waste heat recovery, automobile engines, electronic goods, food and medical industries.
4- The inhibition zone diameter for aspergillus, bacillus, lactose, streptococcus and pseudonymous organisms increases with increasing of magnesium oxide nanoparticles' concentrations.
5- The (PVP-PEG-MgO-H_2O) nanofluids have high quality for thermal energy storage and release which can be used for heating-cooling of buildings, automobile engines, etc.
6- The melting and solidification time for thermal energy storage and release application are decreased with increase of the MgO nanoparticles' concentrations.

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