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Prospects of incorporation of nanoparticles in molten salt for water purification

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ABSTRACT

The potential of solar energy is very promising. This type of energy is clean and derived from a sustainable source. The only significant disadvantage of this source of energy is its absence during the night. A potential solution would be to create a heat reservoir to be used once the sun has set. This principle is already being applied in solar power plants with the help of molten salt. The molten salt's beneficial thermal characteristics allow power production to continue even past the normal operating hours. In this paper, this principle along with others will be used to create a theoretical method of water purification utilizing molten salt. Additionally, the thermal characteristics of molten salt will be established and a link between stored energy and the maximum possible output of water will be recognized. Different nanoparticle additives (SiO_2, Al_2O_3, TiO_2, SiO_2-Al_2O_3) at different concentrations (0.5 wt, 1 wt, 1.5 wt) will also be examined and compared to clarify if they have any effect on the output yield during water purification. It will be seen that some specific mixtures possess thermal properties with more potential compared to others when contrasted with the base mixture of molten salt [$NaNO_3$(60%)-KNO_3(40%)]. These results show promise and will hopefully help address the issue of the severe deficiency of clean drinking water in many countries with the enhancement of the thermal capabilities of molten salt.

1. Introduction

Contaminated water possesses many different water- borne pathogens. These pathogens can cause an assortment of crippling diseases. An enormous amount of people are affected by these diseases where the main cause is due to impure drinking water. According to the World Health Organization, 2.2 million people perish from these diseases, of which most are children from developing countries [12]. These deaths could easily be avoided if a clean drinking water supply could be consistently maintained.

This particular method of water purification has many advantages over traditional methods such as boiling. In the case of boiling, we know that this method involves the combustion of fossil fuels which is a fuel that is not sustainable. Furthermore, it cannot remove any of the solid impurities, of which in some cases, may be toxic. Groundwater is a major source of drinking water for many countries such as Bangladesh. This water is sometimes contaminated with extremely harmful material causing the precious resource to become completely useless. An example would be the contamination of arsenic in many bodies of groundwater in Bangladesh [13]. India is also struggling and has been investigating desalination processes, which provided great insight on the potential of these processes [7].

Molten salt is the main material under investigation in this article, but what exactly is molten salt [14]? Molten salt is a eutectic mixture of sodium nitrate and potassium nitrate. This combination produces a substance with a lower melting point than its constituents. This incredible substance was originally used with fertilizers before its beneficial thermal characteristics were fully understood. It is now used in solar power plants to continue power production during the night, such as the Andasol 1 located in Spain [15]. Is there a way to improve its thermal characteristics with the addition of nanoparticles? Research is being done on this topic and can be seen in references [1,8–11]. In particular, reference [1] has explored the prospects of nanoparticles with the intention of reducing the storage material by improving the specific heat of molten salt. This paper expands mostly upon their research by applying the new thermal properties with water purification.

In this paper, a theoretical water purification system harnessing the energy stored within molten salt will be presented where its working principle will be briefly explained. Following this will be the main significance of the paper, where the possible improvements in the

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Fig. 1. Heating mechanism for molten salt, where magnifying lenses are used to focus sunlight at one point to heat the molten salt [3–7,11,17,18].

thermal characteristics of molten salt will be highlighted through the addition of different concentrations of nanoparticle additives with the base mixture.

2. Theoretical water purification system

2.1. Molten salt heat reservoir

The method the molten salt is heated is very similar to the working principle of a heliostat solar tower, [2] where reflective surfaces focus sunlight at one point to heat water and produce steam. This steam is then used for power generation [16].

In the case of Fig. 1, sunlight is converging at one point with the help of magnifying lenses. This will allow the molten salt to be heated at a much faster rate compared to sunlight just incident on the molten salt tank. The flexible supports allow manual adjustments of the position of the lenses to be made to compensate for the movement of the sun.

2.2. The evaporation chamber

The evaporation chamber is where the impure water is delivered and where the main purification steps occur. In this metal container, the contaminated water is boiled to produce steam. This steam moves from the evaporation chamber to the condenser where pure water will be produced. For this to happen, heat from the molten salt must be transferred to the contaminated water. Inspiration from thermosiphons [24] was taken as they do not require the assistance of a water pump to circulate water. Heated water possesses a lower density compared to cooled water which causes the water to rise and circulate throughout the tank. This process, shown in Fig. 2, will continue until steam is produced where it can move toward the condenser and continue the purification process.

2.3. Condenser

The condenser is where the steam is conditioned to revert back to its liquid state. This is done through heat exchange with a substance that has a high heat capacity, such as water. A significant benefit of using water within the condenser would be that it can be reused in the evaporation chamber once it has absorbed sufficient heat. As a result, not much time is needed to elapse to produce the required steam.

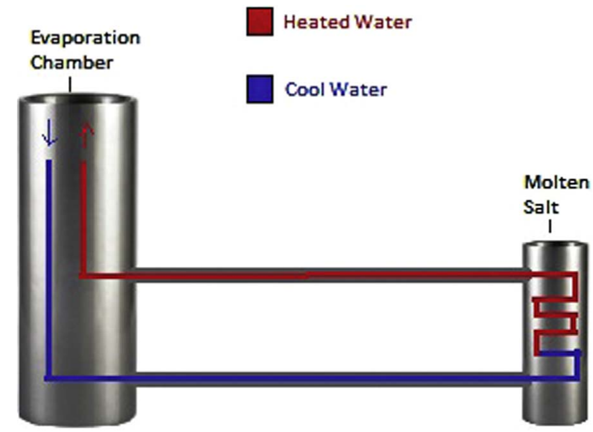

Fig. 2. Operation of evaporation chamber with molten salt heating tank, where the red path indicates the course of heated water and the blue path indicates the course of cooled water. The magnifying lenses have been omitted in this figure [3–7,11,17].

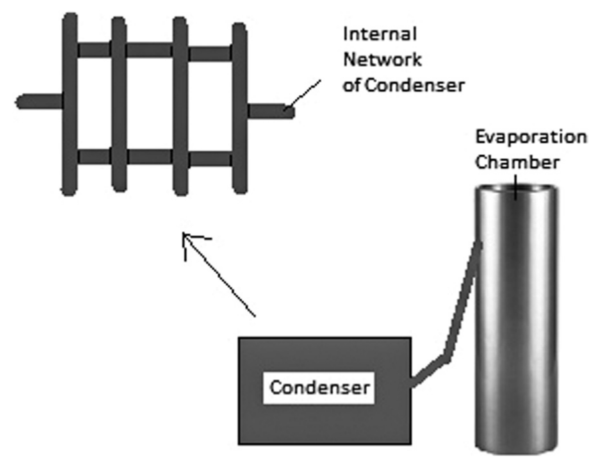

Fig. 3. Theoretical structure of condenser, where the internal component is shown separately. The molten salt tank has been removed for this figure to emphasize the condenser [3–7,11,17].

The internal network of the condenser, displayed in Fig. 3, is submerged in the heat absorbing liquid. As the steam passes, heat is extracted from the steam and transferred to the heat absorbing fluid. This eventually creates a state change and the resultant clean water. The internal network is shaped as such to maintain the pressure of the steam and allow adequate time for condensation.

2.4. Potential backup supply design and operation

This backup supply is needed so that purified water can be continued to be produced even under unfavorable weather conditions. The key way molten salt will be heated is through energy transfer with sunlight, but weather conditions are difficult to predict. To make sure production can meet demand regardless of the overall weather conditions, a backup supply is essential. If weather conditions remain unfavorable, then at least time can be allocated to utilize other sources to meet demand. The backup supply system is very straightforward in design and operation. A potential design can be seen in Fig. 4.

3. Data and analysis

3.1. Base calculation

This calculation displays the required energy to convert 1 kg of water into steam. The values of Specific Heat Capacity and Latent Heat