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Physical Impacts of High Frequency of Ultrasound Wave on Sea, Brackish, Hot Spring and Municipal Water

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This study aims to apply the ultrasound technique in the field of clean technology to protect environment. The principle of ultrasound was conducted here to study the effect of applying high frequency of ultrasound waves. Four kinds of water namely; Seawater from Aqaba gulf, Red Sea, brackish from Maan desert southern part of Jordan, hot spring from northern part of Jordan and tap water (Amman City) were selected to study the effect of ultrasound on its physical properties. High ultrasound frequency device with 1.7 MHz was applied to study the effect of ultrasound waves. All conducted experiments were fixed at room temperature. The effect of liquid volume while applying a constant ultrasound waves on the water properties were investigated here. Exposing time of ultrasound waves was fixed at 0.5, 1.0 and 1.5 h. The experimental results showed that ultrasonic wave irradiation for different samples of water at different period of time has its significant impacts on physical and chemical properties of water such as pH, total dissolved solids and consequently the conductivity.

Key Words: High frequency ultrasound, Total dissolved solids, Water desalination, Water treatment, Environmental protection, Physical properties.

INTRODUCTION

The chemical applications of ultrasound and sonochemistry, become an exciting new field of research during the past decade. The history of sonochemistry, however, begins in the late 1800s. During field tests of the first high-speed torpedo boats in 1894, Sir John I. Thorneycroft and Sydney W. Barnaby discovered severe vibrations from and rapid erosion of the ship's propeller. They observed the formation of large bubbles (or cavities) formed on the spinning propeller and postulated that the formation and collapse of these bubbles were the source of their problems. By increasing the propeller size and reducing its rate of rotation, they could minimize this difficulty of cavitation[1,2].

The phenomenon of cavitation occurs in liquids not only during turbulent flow but also under high-intensity ultrasonic irradiation. It is responsible for both propeller erosion and for the chemical consequences of ultrasound. Alfred L. Loomis noticed the first chemical effects of ultrasound in 1927, but the field of sonochemistry lay fallow for nearly 60 years[3,4]. The renaissance of sonochemistry occurred in the 1980's, soon after the advanced of inexpensive and reliable laboratory generators of high-intensity ultrasound was noticed.

In general the acceptable phenomena in the liquid phase ultrasound wave application can be attributed to cavitation and it can take place only in liquids, chemical reactions do not generally occur during the ultrasonic irradiation of solids or solid-gas systems. High intensity sound and ultrasound are generally produced in a similar fashion, where electric energy is used to cause the motion of a solid surface, such as a speaker coil or a piezoelectric ceramic. Piezoelectric materials expand and contract when an electric field is applied. For ultrasound a high frequency alternating electric current is applied to a piezoelectric attached to the wall of a metal container.

One explanation in the field of ultrasound wave irradiation for generating mist or vapour was acceptable on to be contributed to the relatively hot spot the compression of cavities when they implode in irradiated liquids is so rapid than little heat can escape from the cavity during collapse. The surrounding liquid, however, is still cold and will quickly quench the heated cavity. Thus, one generates a short-lived, localized hot spot in an otherwise cold liquid. Such a hot spot is the source of homogeneous sonochemistry; it has a temperature of roughly 5000 ºC (9000 ºF), a pressure of about 1000 atmospheres, a lifetime considerably less than a microsecond and heating and cooling rates[5-7] above 10 billion ºC/s.

The goal of this investigation is to study the impacts of ultrasound wave on water's properties from different resources. When applying ultrasound waves to water at certain frequencies, a high intensity sound wave will produce mist (an imitation for evaporation process). This investigation will help in understanding the mechanism of ultrasound waves to produce mist in order to establish an evaporation and condensation process for further study.

This technique will be useful for applying the ultrasound technique in the field of clean technology and protect environment from consuming a high energy for water evaporation and condensation. This unique application will be a new one in the field of water purification and treatment.

EXPERIMENTAL

The experimental setup consists of ultrasound wave generator, attached to the ultrasound cell from the bottom. Fig. 1 shows the apparatus details. Electrical source was attached to the apparatus. All experiments were conducted at 24 volts and 1500 mA, according to the specified condition by manufacture. The ultrasonic vibrator is comprised of 0.020 m diameter transducer, which contains piezoceramics (sandwich) with aluminum end masses leading the face from which the ultrasonic is emitted and it is supplied by Honda Electronics Co. Ltd., of Japan, type HM-2412.

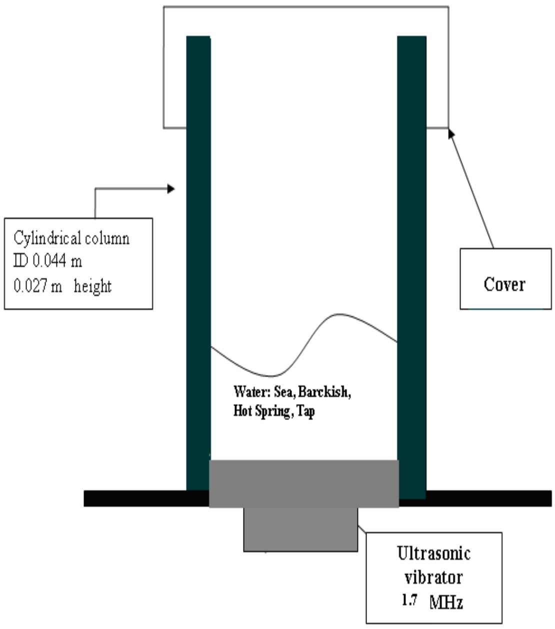

Fig. 1. Experimental apparatus

Procedure

In this experiment water from different locations was placed inside a vessel with a dimension of 0.044 m inside diameter and 0.27 m height. All the obtained water samples were used in this experimental cylindrical vessel without any further treatment. These samples were collected from Aqaba Gulf (Red Sea), underground brackish water (Maan: desert area at southern part of Jordan), Al-Himma Hot Spring Water (Northern part of Jordan) and Amman City municipal tap water (obtained from the faculty's department laboratory tap water).

The vessel filled with one of these samples, at desire and the specified volume. Before placing the sample water's volume were measured simply by using graduated cylinder. Soon after water was pouring into vessel, ultrasound device switched on and stop watch was started. When pre-specified time reached ultrasound device switched off and both temperature and volume of water were measured after every run.

The experiment was conducted using two different liquid volumes, namely 50 and 70 mL. Three different time's periods for ultrasound exposing were selected and fixed at 0.5, 1.0 and 1.5 h.

All collected samples were analyzed by measuring its pH, conductivity and TDS, using two separate devices, type Oyster-EXTECH Instrument (pH/conductivity meter), with electrode cells one for pH and other for TDS.

RESULTS AND DISCUSSION

Effect of ultrasound waves on pH for different liquid volumes

For brackish water it is clear from Fig. 2, as the exposing time increasing, the pH values also increasing. It is clear from figure that the pH values raised from 6.8 to 7.1. This behaviour is interesting, since it changed the acidity for the water from almost acid phase to neutral phase, which means for the water quality it is better to have neutral pH, if it will be used for drinking and other purposes. The increase in pH will indicate that ions had the chance to dissociate during this period of ultrasound wave exposing process, which has the responsibility to raise the pH. The figure is also indicating that the volume is another parameter that has its effect on pH, when liquid volume inside the vessel changed from 50 to 70 mL, higher pH profile observed. This behaviour may attributed to the capacity of ultrasound wave effect on the liquid quantity, as the quantity (volume) of water increased the ability for ultrasound to dissociate more ions will be increase and this will give higher pH value as shown in Fig. 2.

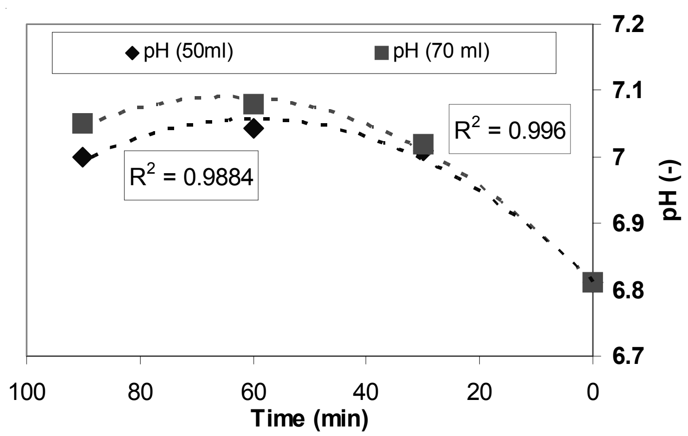

Fig. 2. Effect of ultrasound waves exposing time on brackish water pH for two different volumes

Fig. 3 shows the results obtained for collected sample of water from hot spring. The same behaviour was noticed for the water sample obtained for brackish water. The pH value increased after exposing to ultrasound wave from an initial value of 7.5 to final value of 8.2. Less water's volume inside vessel will give lower pH value rise as explained before in the case of brackish water phenomena.

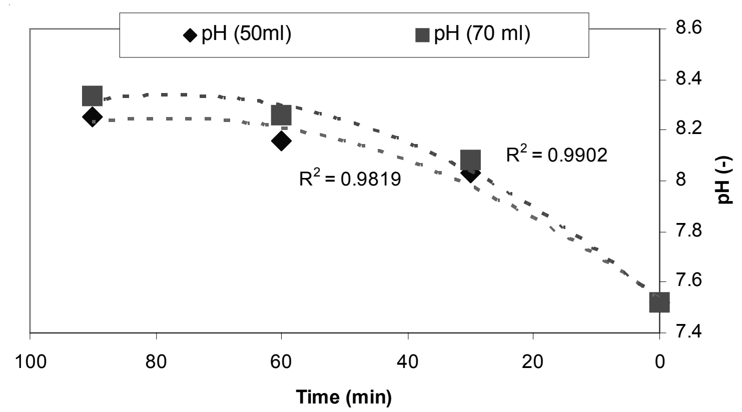

Fig. 3. Effect of ultrasound waves exposing time on hot spring water for two different volumes

Fig. 4, shows the result of pH changes with time after exposing to ultrasound waves for sea water. The pH increases as the ultrasound wave exposing time increased. The pH started at 7.65 and end up with 7.95 according to the time of exposing. Ultrasound waves had its effects on pH with water's volume. As the volume increases the pH value slightly decreases, this behaviour is different from both hot spring and brackish water types. The differences do not vary in a wide range, this may be attributed to

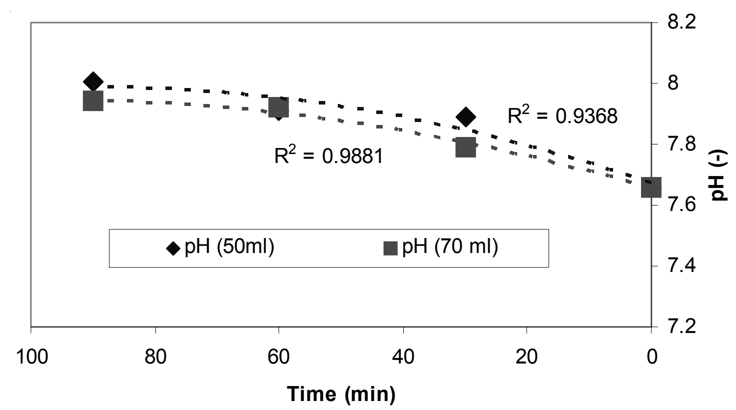

Fig. 4. Effect of ultrasound waves exposing time on sea water for two different volumes

the water type, since sea water contains more ions compare to hot and brackish water in its original state, so that when exposed to the ultrasound waves there will be less ability to liberate more ions from the sea water, these ions almost dissolved in water in a saturated phase.

Fig. 5 indicates the effect of ultrasound waves on tap water. The behaviour is almost similar to that for brackish, sea and hot spring water, as the exposing time increases the pH also increases. The pH value started at 7.5 and end up with 8.

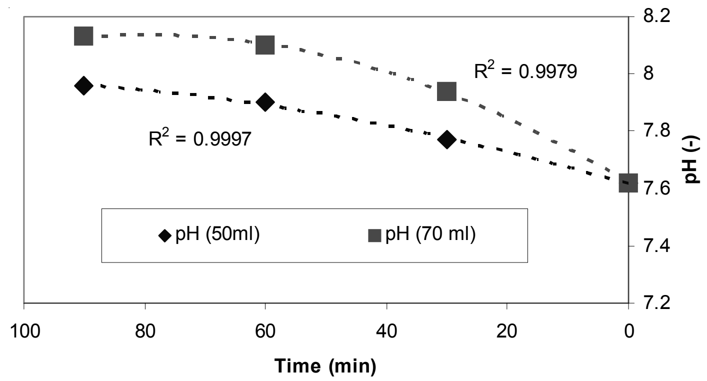

Fig. 5. Effect of ultrasound waves exposing time on tap water for two different volumes

Effect of ultrasound waves on total dissolved solids (TDS)

Fig. 6, indicates the effect of ultrasound waves on brackish water. Same behaviour for the pH was noticed here, as the exposing time increases, the TDS also increases. The TDS increased from 600 to 800 in 1.5 h. Therefore, the ultrasound gives the chance to increase the solubility of the existence dissolved solid the increasing time for exposing to ultrasound waves.

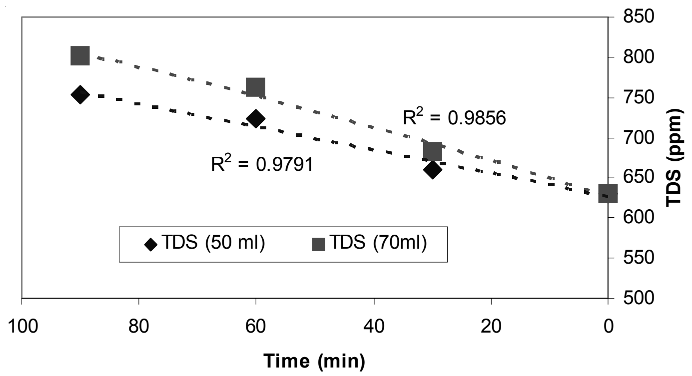

Fig. 6. Effect of ultrasound waves exposing on TDS for brackish water at two different volumes

Fig. 7 shows the results of hot spring water exposing to ultrasound and TDS values. TDS deceases as the exposing time for ultrasound waves increasing. TDS started at around 710 ppm and end up with around 600 ppm. This behaviour may be explained for hot spring water due to the existence of other dissolved solids *i.e.*, microorganism, algae, *etc.*; such dissolved solids during its exposing time to ultrasound waves these kind of dissolved solids will be degradated and hence will decrease the TDS value, due to the effect of high frequency ultrasound waves[8].

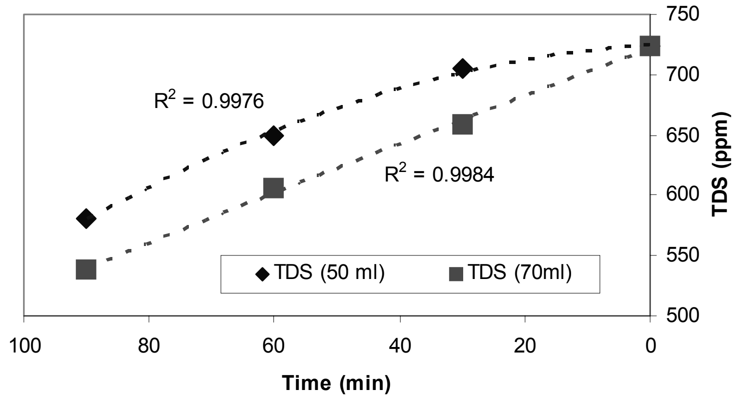

Fig. 7. Effect of ultrasound waves exposing on TDS for hot spring water for two different volumes

Fig. 8 demonstrates the effect of ultrasound wave on TDS for sea water. It is clear from this figure that the TDS increases from 1900 ppm to about 2400 ppm. The effect of liquid volumes on TDS has its significant impact on increasing the TDS way. This behaviour may be attributed to the effect of ultrasound which played a significant role on increasing the dissolved matter as the time for sea water exposes to waves.

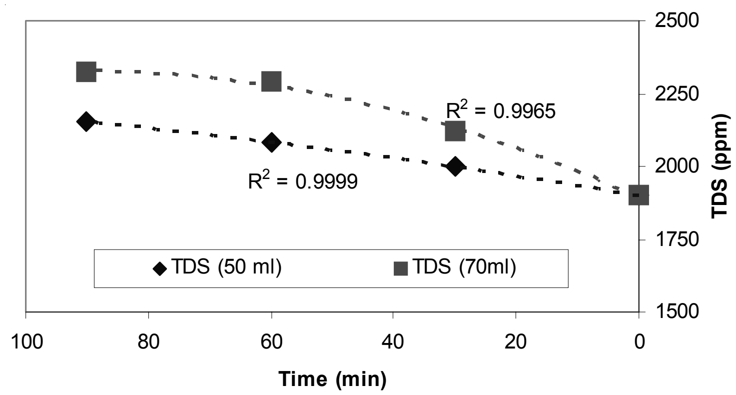

Fig. 8. Effect of ultrasound waves exposing on TDS for Sea water for two different volumes

The comparison of the sea water conductivity (which is in general equal to TDS/0.66) with the other three types of water brackish, hot spring and tap water, it is noted that the sea water has the highest value (1200 mS/cm). The highest which means more ions exist in sea water and when exposing to ultrasound waves the chance will less to produce more ions and hence lower pH and TDS profiles will be observed when changing volumes as it mentioned before in Fig. 4.

Fig. 9, indicates the effect of exposing time for ultrasound waves on tap water for TDS. As the exposing time increases the TDS increase to certain level and after 1 h it starts to decrease and falls down. The TDS starts at around 450 ppm and ends up with 400 ppm after 1.5 h. This behaviour indicates that there is a maximum value for TDS after 1 h, beyond that value it starts to fall down.

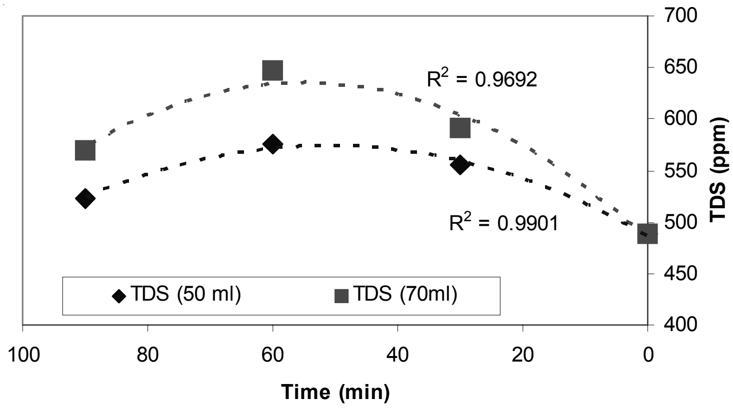

Fig. 9. Effect of ultrasound waves exposing on TDS for tap water for two different volumes

Effect of ultrasound on conductivity and volumes of different water kinds

Since the relation between TDS and conductivity is equal to the TDS value divided by 0.66, to give the conductivity. Therefore it expected for all result of conductivity will have the same trend for those of TDS. Thus the conductivity profiles will be similar to that for TDS ones in its trends except the numerical values will be decrease by 0.66 factors.

Conclusion

It was concluded that when the ultrasound applied to water the TDS and consequently the conductivity, both increased with the increased time for ultrasound waves exposing for all type of water except to hot spring and tap water types. This gives an indication that as the water sample expose to ultrasound wave the chance for the ions to dissociate and dissolve in liquid will be higher at the mean time the TDS and conductivity will also increasing.

Hot spring water and tap water indicate a different behaviour after exposing to ultrasound waves. Both show decrease in TDS, when time of ultrasound wave exposing increased. For hot spring water one explanation for this behaviour may be attributed to the microorganism and other dissolved solids that exist originally in sample and after exposing to ultrasound wave will give the chance these solids to be removed or coagulate.

The results will be a new trend in water properties exposing to high frequency of ultrasound waves, these waves impacts will be the same one as applying high source of energy to water, but here with the behaviour occurred almost at normal conditions and even at low energy source and will be a promising techniques for evaporation and purification of water with clean technology at lower energy consumption.

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