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Solar Desalination Technology: Physicochemical Parameters Estimation of Contaminated & Treated Water of Gomti River, Lucknow (U.P.), India

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***Abstract:** In the present research article, physicochemical parameters of raw and distilled water of the Gomti River are estimated and compared with standards of drinking water quality by using a modified double slope solar distillation unit. The raw water as five different samples collected from different locations of Gomti River (Lucknow, Uttar Pradesh, India) was treated. Total number of 16 physiological and biochemical characteristics and parameters of raw and distilled water are estimated such as electrical conductivity (3.62 ± 0.176 to 3.21 ± 0.52), TDS (837 ± 49.65 to 682 ± 15.73), pH (8.7 ± 0.18 to 8.9 ± 0.50), alkalinity (223 ± 9.23 to 215 ± 3.36), total hardness (347 ± 19.82 to 313 ± 11.2), DO (5.79 ± 0.36 to 3.29 ± 0.67), chloride (104 ± 3.4 to 108 ± 4.9), nitrate (7.21 ± 0.29 to 7.93 ± 0.83), BOD (3.27 ± 0.79 to 2.24 ± 0.27), TSS (403.27 ± 0.19 to 214.07 ± 0.32), COD (39.56 ± 0.76 to 33.2 9± 0.17), sulphate (452 ± 0.63 to 321 ± 1.67) and Ecoliform (3100 ± 3.93 to 2750 ± 2.45) which were within the range of World Health Organization & Bureau of Indian Standers approved standards. It is observed that this fabricated modified double slope solar still is producing drinkable water as per the requirement for solving the water scarcity problems in especially coastal & arid areas due to shortage of electricity. Experimental results show that solar still is producing 8-9 liters in the summer & 4-5 liters in the winter seasons.*

***Keywords:** Physico-chemical, Solar distillation, Gomti river,Water quality, Solar energy.*

I. INTRODUCTION

The development in the world is going on at a very fast rate. All the nations are running for the security of life in terms of basic needs such as clean water, food, clothes, the shelter of human being along with energy and technology. The clean water has the highest priority because of the well-known fact that the human body consists of 57 % of water and its deficiency definitely affects the cell activity which results in chronic dehydration and can subsequently leads to symptoms such as nervousness, dizziness, weakness, headache, irritability, fatigue and even death [1].

Water is an essential requirement of human beings, animals and plants and purity of water is becoming a challenging mission now a days. Therefore, the quality of water plays a vital role in their survival. Indian rivers are being polluted day-by-day due to inputs of untreated industrial effluents, domestic and sewage water along with agricultural wastes and decaying materials of humans, animals, and plants. Water pollution sources (especially the river flowing within the Lucknow city) are outlet drainages. Which carry industrial effluents, domestic wastes sewage and medicinal waste [2].

The water quality can be affected by both biological and chemical contaminants. The injudicious disposal of waste effluents may contaminate the water as translocation of toxic chemicals and may lead to adverse effects on living organisms [3].Water pollution has a direct relationship with physicochemical parameters if they are found beyond permissible limits [4]. Some of these parameters such as amounts of nitrate, fluoride, hardness, alkalinity, heavy metals, chloride and variables such as temperature, pH etc. are toxic and impose a much deleterious effect on public health and environment [5]. Fine suspended particles or colloidal substances make water turbid. Water temperature directly acts on the gametogenesis and responsiveness of hormonal stimulation. Oxygen is the most important constituent of water activities in the respiration of biological, decomposition of organic matter, an inflow of oxygen ingredient in water [6]. The presence of ions and a rise in temperature remove oxygen from the natural water. CO_2 directly affects the pH of water [7]. The quantity of total alkalinity is also an important factor for measuring the strong acidic nature of water to neutralize. The total alkalinity is also the main affecting parameter for productivity. The quantity of chloride present in the freshwater and then the possibility of salt decomposition in soil [8, 9].

Another reason of the water pollution is the use of polluted water for survival. The polluted water contains a large quantity of salts, solids matters, and hazardous elements and compounds, etc., which is not suitable to use in any application without its treatment [10].

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On the other side, a rapid development has led to many water purification technologies (such as reverse osmosis, electro dialysis, and solar distillation, *etc*.,) but most of these are high-grade energy-intensive processes. The world is also facing the crisis of energy resources because of limited use of technology.

Among many techniques, the solar distillation technique is cost-effective and economical process as compared to other processes for the production of potable water by using non-conventional resources [11]. Evaporation and condensation of the water vapor are the key factors of this technology and this process is used for removing impurities and salts present in the water [12].

World Health Organization (WHO) and all nations have given guidelines for the permissible limit of salt content in drinking water according to the available quality of water and technology in a locality [13].

Table. 1 Level of total dissolved solids in drinking water

Total dissolved solids (ppm)	Recommendation level	Available in countries (due to their economic status)
0 - 500	Satisfactory	Developed, Developing
500 - 1500	Less than desirable	Developing
1000 - 1500	Undesirable	
> 1500	Unsatisfactory	

As per the world health organization (WHO), 65% population from rural India is consuming contaminated water (above permissible limit), which was obtained from the rivers. Therefore we studied physic-chemical parameters of Gomti river water in Lucknow district (Uttar Pradesh, India) which affected by sewage water, domestic wastes, agricultural waste and industrial effluents [14].

In this article, we are using cost-effective technology which needs approximately Rs. 13,000 for fabrication and installation purposes with negligible operating cost. Moreover solar energy harvesting technology has been used to get the drinking water due to long durablity[15]. In our case, the maximum production capacity was found 4.0 to 6.0 liter per day in the summer season. In repeated experimentation, we found that the contamination in treated water present in the traces amount and it was found in the permissible limit of standard drinking water quality parameters [16].

For the characterization of this treated water, we analyzed various water quality parameters. BOD_5 (std. 3 ppm), COD (std. 50 ppm), alkalinity (std. 600 ppm), pH (std. 6.5-8.5), DO (std. 6 ppm), TSS (std. 500 ppm), TDS (std. 600 ppm), total hardness (std. 600 ppm), electrical conductivity (std. 3 ds/m), chloride (std. 150 ppm), nitrate (std. 12 ppm), sulfate (std. 400 ppm) and *E. Coli* (std. 2000 ppm) are the standard values and these were also compared with the values of treated water. These dictated values were found in good agreement with the standard limits [17]-[18].

II. MATERIAL AND METHODS

2.1. Study area and Collection of the Sample

Gomti river flowing in the path of Lucknow city (capital of Uttar Pradesh) which is associated with a population of about 3.5 million. We have selected five different places of Gomati River, Lucknow (Uttar Pradesh) India for the collection of water samples. The sterilized polythene bottles are used for water sample collection. The experiment was done from December 2017 to April 2018 (Summer & Winter Season) between 07:00 to 19:00 hrs.

For experimental work, total five different samples (Sample 1,2,3,4,5) were collected at the different locations such as Sample 1 (Gaughat), Sample 2 (Mohan Meakin), Sample 3 (Hanumansetu), Sample 4 (Kukrail) and Sample 5 (Barrage) and examine to period from December 2017 to April 2018 from various locations of the Gomti river. The sampling point location was specially designed to cover key sites, which reasonably represent the pollution station of the river system exerting an impact on river hydrochemistry.

2.2. Experimental Setup

This solar still (distillation unit) has assembled with material fiber reinforced plastic (FRP) as mention below in Figure 1. The total inner surface area of the still is 200 cm x 100 cm x10 cm. For good absorptivity, black dye with resin was painted over the bottom surface. For the good performance of this still, it has been installed in East-West direction to receive more radiation for maximum sunshine and also increasing the heat addition into solar still. The depth of the solar still wall is 12 cm at the East-West ends and 48 cm at the center. The base surface and North surface wall are made of FRP material with 5 mm thickness in place of the acrylic sheet with 3 mm thickness [19]. The top surface of the still is covered with two transparent glasses with thickness 4 mm and for better absorptivity and two simple window glasses are used with dimensions of 1.03 x 1.06 x 0.004 m^3 designed over the surface of the wall of the still with an inclined angle at 15° on both sides using FRP frame [20].

Fig. 1: (A) Pictorial diagram of solar distillation system (B) Mode of condensation

The thermocouple device is used for measuring the temperature of the basin water surface, still water surface and condensate water temperature which are inserting in the sidewall of the still through a hole. To avoid heat loss, we use an insulating material around the hole. A thermocouple is also used for measuring the atmospheric temperature. The flow rate and mass of water are maintaining always constantly in the still basin [21].

The experimental setup was situated in the Department of Chemical Engineering, Institute of Engineering and Technology, Lucknow, Sitapur Road, Uttar Pradesh, India.

2.3.Thermal Efficiency Analysis

The experiment was conducted in the solar still with and without nanofluid and the various observations and reading were concluded. The observation and reading in the result show the increase in the thermal conductivity of the water when Al_2O_3 water nanofluid was used [22].

The overall efficiency of the solar still is calculated by:

$$\eta = \frac{\sum M_{W}.L}{\sum A_s\,.\,I_{rad}.\,3600} \tag{1}$$

Where, M_w = summation of hourly condensate production of distilled water (kg), A_s = surface area of the glass cover in solar still (m^2), I_{rad} = daily average solar radiation with time (W/m^2) and L = latent heat of vaporization (kJ/kg).

As per experimental work, the overall efficiency of the solar still is 55%.

2.4. Error analysis

The experimental error has been found in terms of percent uncertainty (internal +external) for the most sensitive parameter like distillate water. Experimental percentage uncertainty (U) is calculated by [23]

$$U = \frac{\sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \cdots + \sigma_n^2}}{N} \tag{2}$$

Where σ is the standard deviation expressed as:

$$\sigma = \frac{\sqrt{\Sigma(X_i - \overline{X})^2}}{N_0} \tag{3}$$

Where $(X_i - \overline{X})$ is the deviation from the mean and N is the number of sets and N_0 is the number of observation in each set.

$$\%\ \text{Internal Uncertainity} = \frac{U_i}{\text{Mean of total observation}} \tag{4}$$

The external uncertainty is taken as the least count of the various measuring instruments. The observed data for yield (distilled water) were found to be within the percent uncertainty of 11.08 and 12.04 for modified double slope solar still before and after solar distillation process respectively [24].

2.5. Economic analysis

The payback period of the modified double slope solar still set up depends on the various cost analysis such as overall cost of fabrication, maintenance cost, operating cost and cost of feed water, hence these calculations are done for the present modified system.

The overall fabrication cost = Rs. 12,350

The maintenance cost, operating cost and cost of feed water are considered negligible because very less values.

Daily production yield is 0.36

Cost of water per liter production is Rs. 1

Cost of water produced per day = Daily production yield × Cost of water per liter = 0.36 × Rs. 1 = 0.36 paisa.

The total expenditure description are:- Capital expenditure (Iron stand = Rs. 1100, Tin sheet = Rs. 1000, still glass Rs. 600, Measuring Jar & Collection Tank Rs. 350, Thermocouple Rs. 800, Solar power meter Rs. 6350, Fabrication Charges Rs. 1000) and Running Expenditure (Thermacoal Rs. 150, Overhead Charges Rs. 1000).

III. RESULT AND DISCUSSION

The physicochemical parameters of water samples like pH value, electrical conductivity, alkalinity, DO, TDS, BOD, COD, salinity, total hardness of water sample were analyzed before and after distillation from the Gomati River, Lucknow through modified double slope solar still. These parameters were taken at the five different locations site of the Gomti river according to the winter season (December 2017) and summer season (April 2018).

From Table 2, it is clear that the various physicochemical parameters are studied for different samples at different locations. The parametric values have been obtained for two cases:- Before distillation and After distillation, through modified double slope solar still. The difference was found between the values before and after treatment by using this technology in terms of some deductive values.

In the case of hardness, the parametric values of different samples are 725, 712, 493, 691, and 791 ppm, respectively. After the distillation process, we found some new values such as 400, 502,471, 500, and 520 ppm, respectively for different samples. If we compare both values, there is a huge difference between these values (Values of BD and AD) and these analyzed values also compared with standard drinking water quality parameters (WHO). They found within acceptable limits and gave satisfactory results. From this analysis, it is clear that this modified double solar distillation unit is suitable for the reduction of hardness of Gomti river water.

3.1. Analysis of Physicochemical Parameters

All the parameters like temperature, electrical conductivity, pH value, and dissolved oxygen are measured

Fig. 2: Diagram of analytical steps

at the sample site location and other parameters such as total hardness, total alkalinity, BOD, TSS, COD, TDS, colour, salinity, chlorides, nitrate, sulphate, acidity and E-coliform are analyzed in the laboratory (Figure 2). These obtained parameters were compared with standard values [25, 26].

Table. 2 Analysis of physicochemical parameters in the River water from December 2017 to April 2018

S. No.	Parameters	Units	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
			Experimental Values		Experimental Values		Experimental Values		Experimental Values		Experimental Values	
			BD	AD	BD	AD	BD	AD	BD	AD	BD	AD
1	Colour	Hazen	CL	CL	DY	CL	CL	CL	CL	CL	turbid	CL
2	Odour	ou/m^3	OL	OL	FS	OL	OL	OL	OL	OL	OL	OL
3	Temperature	^0C	30	29.6	30.1	29.7	30	29.6	30	29.6	28.9	28.6
4	pH	U pH	8.9	7.02	8.87	7.04	8.6	7.01	8.7	7.1	8.75	7.07
5	Alkalinity	ppm	490	447.5	510	439.29	432	408.5	501	473.5	454	432
6	Hardness	ppm	725	400	712	502	493	471	691	500	751	520
7	DO	ppm	3.65	5.12	3.31	3.43	3.37	3.41	3.25	3.92	3.03	3.42
8	EC	ds/m	3.07	3.05	3.41	3.17	3.21	3.18	3.27	3.15	3.32	3.20
9	TDS	ppm	830	702	853	735	798	753	931	788	880	690
10	TSS	ppm	360	66	376	197.5	450	73	334	71	410	68
11	BOD_5	ppm	3.23	2.15	3.23	2.15	3.41	2.35	3.03	2.45	3.53	2.75
12	COD	ppm	43.5	37	41.5	34.8	47.5	34.6	33.5	29.7	41.65	35.7
13	Chloride	ppm	104	108	102.5	103.7	102	103.6	110	112.5	106	109.6
14	Nitrates	ppm	7.2	7.9	7.15	7.96	7.01	7.34	7.05	7.97	6.37	7.21
15	Sulphte	ppm	500	280	470	381	460	301	436	370	469	370
16	*E. coliform*	MPN/100ml	2900	1750	3300	2650	3000	2160	3100	2550	3500	2950

*CL = Color less, OL= odor less, DY= Dirty Yellow, FS= Foul smell, BD= Before Distillation, AD= After Distillation, Sample 1 = Gaughat, Sample 2 = Mohan Meakin, Sample 3 = Hanumansetu, Sample 4 = Kukrail, Sample 5 = Barrage

3.1.1. pH Value

The pH value was found in the range from 6.4 to 7.9 during the study period. Each sampling location has almost the same pH, but sample-4 (Kukrail) denoted low pH (6.4). WHO recommended the pH value from 6.5 to 8.5 for drinking water. Therefore, the pH of all five sampling locations reached within acceptable limit after use of solar distillation technology. The pH value was very low in the summer season due to decreasing the water levels as well as the concentration of nutrients present in the water. The pH value rapidly rises in the day period due to the effect of photosynthesis phenomena with solar radiation and slowly decreases during night period due to respiratory activity.

3.1.2. Electrical Conductivity (EC)

Conductivity is a property for expressing the water's ability to conduct an electric charge and its value depends on ions present in the total concentration, valence ions and the temperature of the water sample. It was analyzed using a digital conductivity meter as microsiemens/centimetre and observed EC values for the water sample of the Gomti river ranged between 2.15 to 3.47 Ω/cm. In the winter season, the value of electrical conductivity is higher (i.e. 3.47 Ω/cm) because the more addition of domestic wastage into the river as compared in the summer season.

3.1.3. Total Dissolved Solids (TDS)

The TDS value of water was estimated by using the standard measuring kit by weighing various samples and measuring volumes of various samples. The general range of the TDS value is about 1008 to 1224 mg/L. In the winter season, the highest TDS obtained (i.e. 1224 ppm) because the presence of more organic matter solid waste into the river as compared to the summer season. In our case is TDS the values range was 800 to 900 ppm for raw water at different locations of the Gomti river. After the distillation process, the values come to the 700 ppm limit means that product water has low TDS in comparison to the raw water.

3.1.4. Dissolved Oxygen (DO)

The higher value of DO is better for aquatic life. DO indicate the biological, physical & chemical changes in the water system. In the present study, the DO value ranged from 3.15 - 5.89 ppm. The maximum DO value was obtained in the rainy season as 5.89 ppm because of the eddies of water facilitating. It can be estimated by measuring volumes and normalities values of various samples of water. The rate of diffusion varies with atmospheric oxygen and increased the solubility of oxygen due to decreasing temperature.

3.1.5. Total Alkalinity

The main application of alkalinity, to measure the ability of water for neutralizes the strongest acid solution. Its general range varies from 204 to 224 ppm. Its maximum value obtained during the winter season is about 224 ppm because of the highest nutrients present in the water body.

3.1.6. Biochemical Oxygen Demand (BOD)

It is the quantity of oxygen required for surviving of aquatic life of microorganisms present in the water body.

For normal water, the BOD general range varies from 1.78 - 3.22 ppm.

Its maximum value obtained during rainy season is about 3.22 ppm because of the possibility of the addition of high amounts of waste like soil erosion and solid waste in the water. During the experimentation for BOD calculation, the sample is filling in an airtight bottle and placed in BOD incubator for 5 days at a specified temperature.

3.1.7. Chemical Oxygen Demand (COD)

It indicates the quantity of oxygen which is equal to the organic content present in the water body. During the experimentation, the potassium dichromate is used for oxidizing the organic matter due to the presence of concentrated sulphuric acid in the solution and it produces CO_2 and water content. The COD value can be determined by titration of ferrous ammonium sulfate (FAS) using ferroin indicator with the remaining amount of potassium dichromate after the reaction [27].

3.1.8. Colour & Odor

The major portion of water is colorless except for industrial wastewater. Due to the presence of some acid like humic acids, metallic ions suspended matter, and industrial effluents are changing the color value of the water. This impurity can be determined by visual comparison of the sample with distilled water. All the samples were odorless, except sample 2, which was found to smell foul.

3.1.9. Total hardness (TH)

The general range of hardness was from 310 - 348 ppm. The maximum value of hardness obtained in the rainy season is about 348 ppm while the permissible limit is reported as600 ppm. EDTA solution and $CaCO_3$ were used as base reagents to estimate the total hardness in various samples of raw water as well as treated water.

3.1.10. Total Suspended Solids (TSS)

The gravimetric method is basically used for the estimation of TSS. During experiment, the higher value of total (if suspended) solids was found at Mohan Meakin sample due to the presence of high organic matter like bicarbonates, carbonates, chlorides, nitrates and phosphates of magnesium, sodium, calcium, potassium, and manganese, etc.

3.1.11. Nitrate (NO_3^-)

The concentration of nitrate was found on all five sampling locations ranging from 6.37 to 7.97 ppm which was relatively low because it is highly related to the small number of human activities. The permissible value of nitrate according to WHO has to be $\leq$ 45 ppm, therefore nitrate at five sampling locations was within the acceptable limit after solar distillation.

3.1.12. Chlorides (Cl^-)

It indices the amount of chloride in water from sewage and drains. According to WHO standards, HDL and MPL of chloride is 45-150 ppm. Sample 4 was having more value and sample 2 showed the result of chloride being present less in that. Chloride content was measured by argentometric titration.

3.1.13. Sulfate (SO_4^{-2})

The sulfate concentration was found with ranged between 300 to 500 ppm before the solar distillation but after solar distillation, its values were found on all sampling location within an acceptable limit. For domestic purposes, the limit of high sulfate concentrations is 250 ppm as per WHO. Sulfates are present in nearly all flowing water and it derived due to the presence of sulfides of heavy metals in the water like iron, nickel, copper, and lead. The excess amount of sulfate in water may be responsible for damaging the concrete sewer pipes.

3.1.14. E. Coliform

E. Coli. (*Escherichia coli* or *Klebsiella pneumonae*) is bacteria, comes from animal and human waste and its indicator of the potential danger of health risks those fecal passes. This test can be done by a lactose fermentation process using brilliant green lactose bile (BGLB) medium for better results. As per standard water quality data for freshwater, the MPN (Most Probable Number) of total coliform/100 ml observed to the much higher value at all the sampling locations site and this also reveals the bacteriological quality of river water is not so good for aquatic life [25]. In the present study, the values of *E. Coli.* were found 2900, 3300, 3000, 3100, and 3500 MPN index /100 ml for different raw water samples. After processing this raw water with modified solar still, the colonies of this *E. Coli.* bacteria may be decreased up to permissible limit as per WHO standards such as 1750, 2650, 2160, 2550, and 2950 MPN index / 100 ml respectively for distilled water [28].

From figure 3, It was found that the temperature was maximum around 14:00 hrs. During experimental work, it is observed that difference in the temperatures of the water and glass surface has increased and due to this, the rate of production is increased due to the bulk movement of the air mixture inside the solar distillation unit basin and also raises the rate of evaporation and rate of the condensation process. The productivity is maximum found when the temperature of water is reached around 50°C - 60°C during temperature rise but for certain period of time the rate of water production increases with decrease in the difference of temperature, between the water and glass surface and also decreases the basin water temperature in the solar still. When the still reached the highest water temperature in still than the rate of production is lesser as compared to maximum value was found.

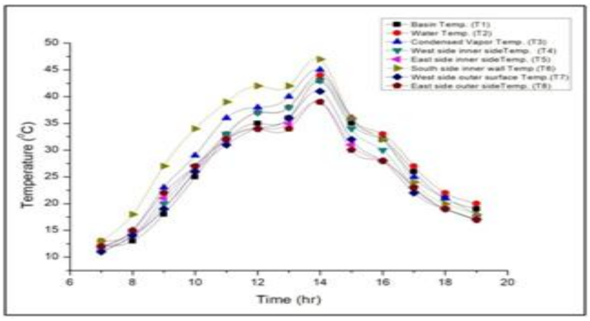

Fig. 3: Effect of various temperatures along with solar time in the solar distillation system.

Figure 4 depicts that the yield of production rate varies with respect to time in hours especially for all three directions except north direction. Eastside direction has maximum production rate up to 170 gm/ lit/ day due to the higher radiation absorption from the sun (13:00 hr) while in case of the west direction the production rate was found as 140 gm/ lit/day (13:00 o'clock).

The minimum value of water production rate found for south direction i.e. 20 gm/lit/day (14:00 o'clock) due to less availability of sunlight. Some other factors affect the production rate of water such as wind velocity, glass temperatures as well as basin coated material for better absorptivity of the solar radiation, etc.

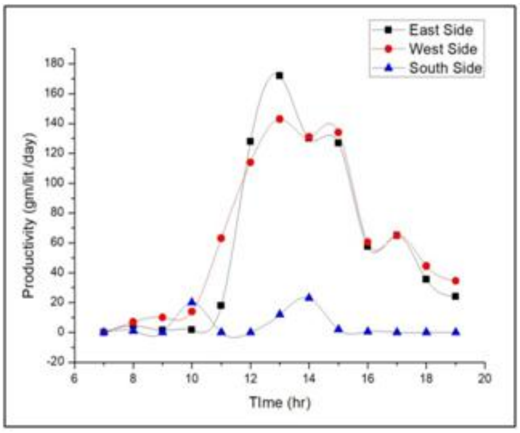

Fig. 4: Total productivity along with solar time

IV. CONCLUSION

In the present research work, the water purification by solar energy harvesting is applied as a clean, sustainable and environmental friendly technology. For fulfilling this purpose, a fabricated model of the distillation unit has been developed to produce pure water having a negligible amount of contaminations. Although, by cascading the solar distillation units, we can produce the required amount of treated water by using Gomti river water. The water quality parameters in terms of water quality of raw water and treated water, many experiments have been performed. It was found that values of parameters were changed significantly for treated water in comparison with raw water. Further, the electrical conductivity has been reduced up to 3.21ds/m from its initial value of 3.62 ds/m. Total dissolved solids were found 682ppm while in original contaminated water, it was 837 ppm. The pH value of the treated water remained same found to be basic in nature (8.7) while the initial basicity was a little bit higher (8.9), the alkalinity was also reduced from 223 ppm to 215 ppm. Total hardness and DO were also minimized from 347 ppm to 313 ppm and 5.79 ppm to 3.29 ppm, respectively.

Furthermore, the increase in chloride value from 104 ppm to 108 ppm and nitrate value from 7.21 ppm to 7.93 ppm was found. In BOD analysis, a decrement was observed from 3.27 ppm to 2.24 ppm, in TSS analysis it was found as 403.27 ppm to 214.07 ppm. In COD value estimation, the reduction was observed from 39.56 ppm to 33.29 ppm, in sulfate estimation, it was reduced from 452 ppm to 321 ppm while *E. coliform* estimation, the significant reduction has been found from 3100 MPN/100ml to 2750 MPN/100ml [29].

On the basis of the aforementioned experimental results, it has been observed that this technology can be used in water-stressed areas where the water contains a lot of impurities and the people lack the method to purify it. This technique will be a great success in the remote areas having no ease of access to the electricity and the devices based on the electricity to purify water.

APPENDIX

FRP	Fibrereinforced plastics
WHO	World Health Organization
η	Solar Efficiency
M_w	Summation of hourly condensate production of distilled water (kg)
m	Mass of water (kg)
A_s	Surface area of the glass cover in solar still (m^2)
I_{rad}	Daily average solar radiation with time (W/m^2)
L	Latent heat of vaporization (kJ/kg)
U	Experimental percentage uncertainty
σ	Standard deviation
$(X_i - \overline{X})$	Deviation from the mean
N	Number of sets
N_0	Number of observation in each set
U_i	Percentage internal uncertainty

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REFERENCES

1. H. Moungar, A. Azzi, Y. Sahli, A. Mediani and A. Haida, "Physicochemical parameter influences on distilled water production for a simple and modified hot box solar still", International Journal of Scientific & Engineering Resources, vol. 7 (6), pp.846-850, (2016).
2. P.K. Pandey and R. Upadhyay, "Desalination of Brackish Water using Solar Energy", International Journal of Renewable Energy Research, vol. 6(2), pp. 1-5, (2016).
3. H. Soonmin, A. Lomi, E. Okoroigwe and L.R. Urrego, "Investigation of Solar Energy: The Case Study in Malaysia, Indonesia, Colombia and Nigeria", International Journal of Renewable Energy Research, 9(1), pp.1-10. (2019).
4. D. Kumar, A. Verma, N. Dhusia and N. More, "Water Quality Assessment of River Gomti in Lucknow", Universal Journal of Environmental Research and Technology, vol. 3(3), pp. 337-344, (2013).
5. S. Chandra and S.K. Garg, "Pre and Post-monsoon Seasonal Variation of some Heavy Metal Pollution in Sediments of river Gomti in the Vicinity of Lucknow City, India", Journal of Applied Science Environment Management, vol. 21(3), pp. 593-599, (2017).
6. A. Srivastava, M. Lohani, S.K. Kar and D.D. Upreti, "Physicochemical Characteristics of inorganic constituent in Alluvium of Gomti basin and its health effects- A case study from Lucknow and Unnao district, Uttar Pradesh", International Journal of Geomatics and Geosciences, vol. 6(2), pp. 1-14, (2015).

7. G. Wisz, L. Nykyruy, V. Yakubiv, I. Hryhoruk and R. Yavorskyi, "Impact of Advanced Research on Development of Renewable Energy Policy: Case of Ukraine", International Journal of Renewable Energy Research, vol. 8(4), pp. 1-18, (2018).
8. K. Dutta, and A.R. Ghosh, "Analysis of physic-chemical characteristics and metals in water sources of chromite mining in Sukinda Valley, Odisha, India", Journal of Environmental Biology, vol. 34, pp. 783-788, (2013).
9. P. Pal, and R. Dev, "Experimental study on modified double slope solar still and modified basin type double slope multiwick solar still", International Journal of Civil and Environmental Engineering, vol. 10 (1), pp. 70-75, (2016).
10. S.D. Bondage, R.S. Khan and J.D. Shaikh, "Comparative study of physicochemical parameter between marathwada and western Maharashtra's water body", International Journal for Research in Applied Science & Engineering Technology, vol. 5(2) pp. 218-225, (2017).
11. N. Parveen and S.K. Singh, "Physicochemical characteristics of Gomti river at Lucknow stretch, India", International Journal of Advanced Research, vol. 4 (7), pp. 749-759, (2016).
12. M. Chandrashekara and A. Yadav, "Water desalination system using solar heat: A review", Renewable and Sustainable Energy Resources, vol. 67 pp. 1308-1330, (2017).
13. S. Umar, U.K. Muhammad, A. Yakubu, M. Musa and S.B. Muhammad, "Experimental Investigation and Performance Analysis of Single Slope Solar Still", International Journal of Renewable Energy Research, vol. 7(4), pp. 1-8, (2017).
14. R.S. Divya and K.M. Kani, "Water quality assessment of Sasthamcotta Lake, kollam, kerala", International Journal of Engineering and Advanced Technology, vol. 7(3), pp. 119-129, (2018).
15. P.G. Smith, K. Byrappa and S.N. Ramaswamy, "Physico-chemical characteristics of water samples of Bantwal Taluk, south-western Karnataka, India", Journal of Environmental Biology, vol. 28 (3), pp. 591-595, (2007).
16. A.A. Hafizurrahman, M. Khan and Z. Ali, "Evaluation of physicochemical characteristics of Gomti River water at Uttar Pradesh, India", International Journal of Advanced Research, vol. 4 (12), pp. 1408-1414, (2016).
17. U.M. Qureshimatva, R.R. Maurya, S.B. Gamit, R.D. Patel and H.A. Solanki, "Determination of physicochemical parameters and water quality index (wqi) of Chandlodia Lake, Ahmedabad, Gujarat, India", Journal of Environmental anal Toxicology, vol. 5 (4), pp. 1-9, (2015).
18. T.Ganesh, A.Ravinthiran, S.Santhosh, M.Kannan, B.Dinesh Kumar, "Experiments for calculating Properties of Distilled Water from Solar Still and Potable water from Reverse Osmosis Process" International Journal of Recent Technology and Engineering, Vol.8 (4), 1780-1785 (2019).
19. G.N. Tiwari, J.M. Thomas, E. Khan, "Optimisation of glass cover inclination for maximum yield in a solar still", Heat Recovery System CHP, vol. 14, pp. 447–455 (1995)..
20. N. Rahmanian, S.H.B. Ali, M. Homayoonfard, N.J. Ali, M. Rehan, Y. Sadef and A.S. Nizami, "Analysis of physicochemical parameters to evaluate the drinking water quality in the State of Perak Malaysia", Journal of Chemistry, vol. 37, pp. 1-10, (2015).
21. S.K. Patel, D. Singh, R. Dev, and G.L. Devnani, "Experimental investigation for drinking water production through double slope solar still", International Journal of Scientific and Technical Advance, vol. 2 (1), pp. 45-47, (2016).
22. P. Sivamanikandan and J.S. Ahmed, "Assessing the impact of physicochemical and bacteriological analysis of mullaiperiyar river water in Theni district, Tamilnadu, India", Imperial Journal of Interdisciplinary Research, vol. 3 (2), pp. 727-734, (2017).
23. Ath Singhal, Tejas Raval, Anand Bhatt, " Experimental Optimization of a Solar Distillation Unit", International Journal of Recent Technology and Engineering, Vol.8 (2), 6238-6243 (2019).
24. D.B. Singh. J.K. Yadav, V.K. Dwivedi, S. Kumar, G.N. Tiwari, I.M. Al-Helal, "Experimental studies of active solar still integrated with two hybrid PVT collectors", Solar Energy, vol. 130, pp.207-223, (2016).
25. J. Aishwarya and S.S. Ranchani, "Enhanced Design of Automated Solar Still Based on Light-Harvesting Nanoparticles", International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol.5(3), pp.1-6, (2017).
26. H. Soonmin, A. Lomi, E. Okoroigwe, L.R. Urrego, "Investigation of Solar Energy: The Case Study in Malaysia, Indonesia, Colombia and Nigeria", International Journal of Renewable Energy Research, vol. 9(1), pp.1-10, (2019).
27. Renu, M. Agarwal, K. Singh, "Heavy metal removal from wastewater using various adsorbents", Journal of Water reuse and desalination, vol.7 (4), pp. 1-33, (2017).
28. R. Tripathi, G.N. Tiwari, "Thermal modelling of passive and active solar stills for different depths of water by using the concept of solar fraction", Solar Energy, vol. 80, pp. 956-967, (2006).
29. Hafizullah Shafaq, Milind R. Gidde, "Water Resource Issue and Solution in Helmand-Afghanistan", International Journal of Recent Technology and Engineering, Vol.8 (2), 4338-4341 (2019).

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