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Design, Construction and Application of a Solar Water Distiller

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ABSTRACT
This work reported the design, construction and application of solar water still this simple equipment can purify contaminated water from any source. This solar still is an airtight basin, constructed out of mildstainless steel with a top pyramid cover of transparent 5mm thickness glass, the pyramid is made up of four equal triangular parts each of area 0.29msq. The inner surface of the rectangular basin is blackened to efficiently absorb the solar radiation incident at the surface, on it is a blue rubber chlorinated marine coat for bacterial control and enhance purity against corrosion. The basin has a capacity to take eight litres of water for purification. After the absorption of the sun radiation energy, by conduction, the water gets heated leading to an increased difference between water and glass cover temperature. The water evaporated gets condensedon the inner surface of the glass cover. The condensed water trickles into the trough provided at the lower end of the glass cover under gravity. The collected distillate in the trough is taken out of the system into a glass container. This equipment was used to purify water collected from a nearby river. The results showed that the pH was reduced from 5.8 to7.1. Total Dissolved Solid from 173mg/l to 48mg/l. Electrical Conductivity from 245 µS/cm-to- 72µ/cm and Total Hardness from 47mg/l to 14mg/l. The physico-chemical parameters of the purified water were within the World Health Organisation (W.H.O) standards for portable water. This equipment is a cheap source of water purification for small laboratories, health centres especially for rural dwellers because it uses no electricity as source of power.

Keywords: Solar, WHO, River, Physico-Chemical and Portable water.

I. INTRODUCTION

Water is a basic necessity of man along with Food, and Air. Fresh water resources usually available are Rivers, Lakes and underground water reservoirs. About 71% of the planet is covered in water, yet of all that 96.5% of planet water is found in ocean, 1.7% in ground water, 1.7% in glaciers and the ice caps and 0.001% in the air as vapour and clouds. Only 2.5% of the earth's water is freshwater and 98.8% of that water is in ice and ground water. Less than 1% of all freshwater is in rivers, lakes and the atmosphere. "There is almost no water left on Earth that is safe to drink without purification" W.H.O (2012).Distillation is one of many processes that can be used for water purification. This requires energy inputas heat or electricity and solar radiation can be the source of energy. When solar energy is used for this purpose, it is known as "Solar water Distillation". Solar distillation is an attractive process to produce portable water using free of cost solar energy. This energy is used directly for evaporating water inside a device usually termed a "Solar Still". Solar stills are used in cases where rain, piped or well water is impractical such as in remote homes or during power outages.

Solar distillation is an attractive alternative because of its simple technology, non-requirement of highly skilled labour for maintenance work and low energy consumption, (Dunkle R.V, 2012). Solar distillation is a tried-and-true technology. It is by far the most reliable, least costly method of 99.9% true purification of most types of contaminated water especially in developing nations where fuel (fossil derived) is scarce or too expensive. Expensive filtration and deionising systems are even more expensive to purchase and use and will not totally purify the water by removing all the contaminants. No additional heat or electrical energy is required in our still and even after the sun set, distillation continues at a slower pace into the night, (Bird, J 2008).It is a technology that is not only capable of removing a very wide variety of contaminants in just one step, but is simple, cost-effective, and environmentally friendly, that is the use of solar energy, (Safianu, B. D. 2014)

Solar reduces environmental pollution. Harmful carbon-dioxide and methane emissions from fossil fuels, our traditional energy sources, are leading contributors to global warming and decreased air quality. Hence, going solar ensures a greener tomorrow and helps save a lot on cost and also benefits the environment as well.The solar still is a passive solar distiller that only needs sunshine to operate. There are no moving parts to wear out. The distilled water from a solar still does not acquire the “flat” taste of commercially distilled water, since the water is not boiled (which lowers pH). Solar stills use natural evaporation and condensation, which is the rainwater process. This allows for natural pH buffering that produces excellent taste as compared to steam distillation. Solar stills can easily provide enough water for family drinking and cooking needs.

Benefits of Solar Distillation includes the following: It produces water of high quality, maintenance is almost negligible, any type of water can be purified into portable water by means of this process, the system will not involve any moving parts and will not require electricity to operate, wastage of will be minimum, and finally the provision of clean useful drinking water without the need for external energy source, (Armstrong C, 2010)

The aim of this studyis to design solar water still that will produce portable water for use and to evaluate the performanceof the solar water still constructed from locally sourced materials.

II. MATERIALS AND METHODS

The materials used for this solar still have following characteristics:

- Materials have a long lifespan under exposed conditions
- Inexpensive enough to be replaced upon degradation
- Be non-toxic
- They are of a size and weight that can be easily packaged and transported
- They are able to resist corrosion from saline and distilled water
- They are not instil unpleasant taste and odour to the water
- Be sturdy enough to resist wind damage.

Factors to consider in selecting materials for basin still include:

- It must be able to contain water without leaking
- It must absorb solar energy
- It must be structurally supported to hold the water
- It must be insulated against heat loss from bottom and edges

Choosing materials for the components in contact with water represents a serious problem. Many plastics will give off a substance which can be tasted or smelled in the product water, for periods of anywhere from hours to years.

The Table1 below shows the various materials used for still basin and their properties. It should be noted that the basin consists of the following basic components; basin, support structures, glazing, a distillate trough and insulators.

Table.1: Materials for Still’s Basin and their Properties.

Material	Durability	Cost	Availability	Skill Needed	Cleaning	Portability	Toxicity
Mild Steel	High	High	Low	Low	High	Medium	Low
Rubber	High	High	Low	Low	High	High	Low
Asbestos Cement	High	Medium	Low	Medium	Medium	Medium	High
Polyethylene	Medium	Low	Low	Low	Medium	High	Low
Wood	Low	(a)	(a)	Medium	Medium	Medium	Low
Fibreglass	Medium	Medium	Low	Low	High	Medium	Low

Science Direct: 2016

(a) unknown or depends upon local conditions

The basin contains the saline (or brackish) water that will undergo distillation. As such, it must be waterproof and black so that it will better absorb the sunlight and convert it to heat.It should also have a relatively smooth surface to make it easier to clean any sediment from it.

Selecting a suitable material basing construction is the biggest problem in the solar still industry. Materials such as Concrete and Asbestos, Plastics and Fibre glass have their short comings,

such as imparting to the water taste, absorption there by reducing the volume of water produced.
Hence the best suitable alternative is ordinary or mild steel coated with silicone rubber, or anti-corrosive material. The durability of basins made with these materials increased from (10-to-15) years.

Glazing cover:

After the basin, the glazing cover is the most critical component of any sola still. It is mounted above the basin and must be able to transmit alot of light in the visible spectrum yet keep the heat generated by that light from escaping from the basin.

Water droplets restrict the amount of light entering the still because they act as small mirrors and reflect it back.
Ideally, the glazing material should be strong enough to resist high winds, rain, hail, and small earth movements, and prevent the intrusion of insects and animals. Moreover, it must be "wettable". This is the ability of the glazing material to allow condensing vapour to form as sheets of water on the underside of a glazing material rather than as water droplets.

The table 2 below compares various glazing materials based on some properties. Of these materials, tempered glass is the best choice in terms of wettablity and its capacity to withstand high temperatures.

It is also 3-times stronger than ordinary window glass and much safer to work with. It's disadvantage is it's high cost and it cannot be cut since it has been tempered.

Ordinary window glass is the next best choice, except that it has an oily film when it comes from the factory, and must be cleaned carefully with detergent and/or ammonia. If you choose glass as a glazing material, double-strength thickness (i.e, one-eight of an inch, or about 0.5m) is satisfactory. While some plastics are cheaper than either window glass or tempered glass, they deteriorate under high temperatures and have poor wet ability.

Table.2: Materials for Still's Glazier cover and their properties.

Material	Cost	Weight	Lifespan	Max. Temperature	Solar Transmittance	Impact Resistance	Wettability	Availability
Tempered Glass	High	High	50yrs+	204-316^{o}C	91	Low	Excellent	No
Ordinary Glass	Medium	High	50yrs+	204^{o}C	86	Low	Excellent	Yes
Fibreglass	Medium	Low	8-12yrs	93^{o}c	72-87	Medium	Treatable	No
Polyethylene	Low	Low	8months	71^{o}c	90	Low	Possibly Treatable	Yes

Science Direct: 2016

OPERATION/METHODS

Different designs of solar still have emerged over time. In spite of the wide variety of distillation system and various forms of energy used they all have certain features in common which allows a systematic approach to their design. In most cases the distillation system is based on evaporation and condensation.
The completed solar still Fig.3.4 below shows the home size solar water distiller. It contains basically the following parts:

- Still Basin
- Side Walls
- Glazing Cover
- Channel
- Collector

The still basin is covered with the side walls which is insulated to reduce heat loss and covered with transparent top cover through which the sun rays pass into the surface of the still basin in the form of radiation and convention to heat up impure water to evaporation which then condenses on the inner surface of the inner cover. Close to the lower end of the top cover there is a trough where the condensate which slides on the inner surface of the top cover passes into a collector for further usage, First Solar 2011.

PRINCIPLE OF OPERATION.

The home size solar water distiller is an airtight basin, constructed out of mild steel with a top cover of transparent material (5mm glass). The inner surface of the rectangular base is blackened to

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efficiently absorb the solar radiation incident at the surface, and gently layered with a chlorinated blue rubber coat of utmost purity.

Solar radiation after reflection and absorption by the glass cover is transmitted inside an enclosure of the distiller unit. This transmitted radiation is further partially reflected and absorbed by the water mass. The solar radiation finally reaches the blackened surface where it is mostly absorbed. After the absorption of solar radiation at the basin liner, most of the thermal energy is converted to water mass and a small quantity is lost to the atmosphere, by conduction, consequently the water gets heated, leading to an increased difference between water and glass cover temperature.

The evaporated gets condensed on the inner surface of the glass cover after releasing the latent heat of evaporation. The condensed water trickles into the trough provided at the lower end of the glass cover under gravity. The collected water in the trough is taken out of the system through the channel into the collector, McCracken H. (2016)

The solar distillation process is as shown below.

- Solar energy passing through a glass heats up the brine, sea water or water from any other source in the pan, this causes the water to vaporize.
- The vapour rises and condenses on the underside of the cover and runs down into the distillate troughs to a collector.
- This process is carried out in the solar basin still.

DISTILATION EQUIPMENT COMPONENTS

- A basin
- Supply tanks.
- A support structure
- A transparent glazing cover
- A distillate trough (water channel)
- Insulation (usually under the basin)
- Sealants piping and Valves
- Storage tank

Figure:1. Tetrahedral Glass top Under Construction

Figure:2. Completed Section of the Glazing

Figure 3. Completed Solar Still.

JUSTIFICATION FOR THIS MODEL OF SOLAR STILL

Below are reasons for the pyramid solar still model is better and preferable to other design models:

- The model is completely unique; its glazingcover is designed in a way to permit efficient transmission of the sun's radiant energy no matter the position and angle of inclination of the sun.
- This model is designed to have a still basin with depth relatively lesser than the existing trend. This makes provision for accelerated evaporation, hence higher efficiency.
- The model is designed from or rather can be produced from cheap and locally available materials.

III. RESULTS AND DISCUSSION

The construction involved the fabrication of the various parts that bade up this solar still system, coupling them together to operate as a composite single product.

After this assemblage the equipment was tested using water sample from Argbarho River, in Delta State Nigeria. The result obtained from the laboratory analysis is as shown in the table below.

Table 3: Laboratory Analysis of Post & Pre- Treatment of River Water Sample in Comparison with the World Health Organisation (W.H.O) Limit

Parameters	Unit	River Water (Pre-Treated)	Distilled Water (Post- Treated)	W.H.O Limit
pH		6.26	7.21	6.50-8.50
TDS	mg/l	172.63	48.27	500.00
Electrical Conductivity	µS/cm	245.48	72.41	400.00
Turbidity	NTU	10.56	0.31	5.00
TSS	mg/l	30.00	1.00	10.00
Total Hardness	mg/l as for Calcium Carbonate	46.00	14.00	500.00

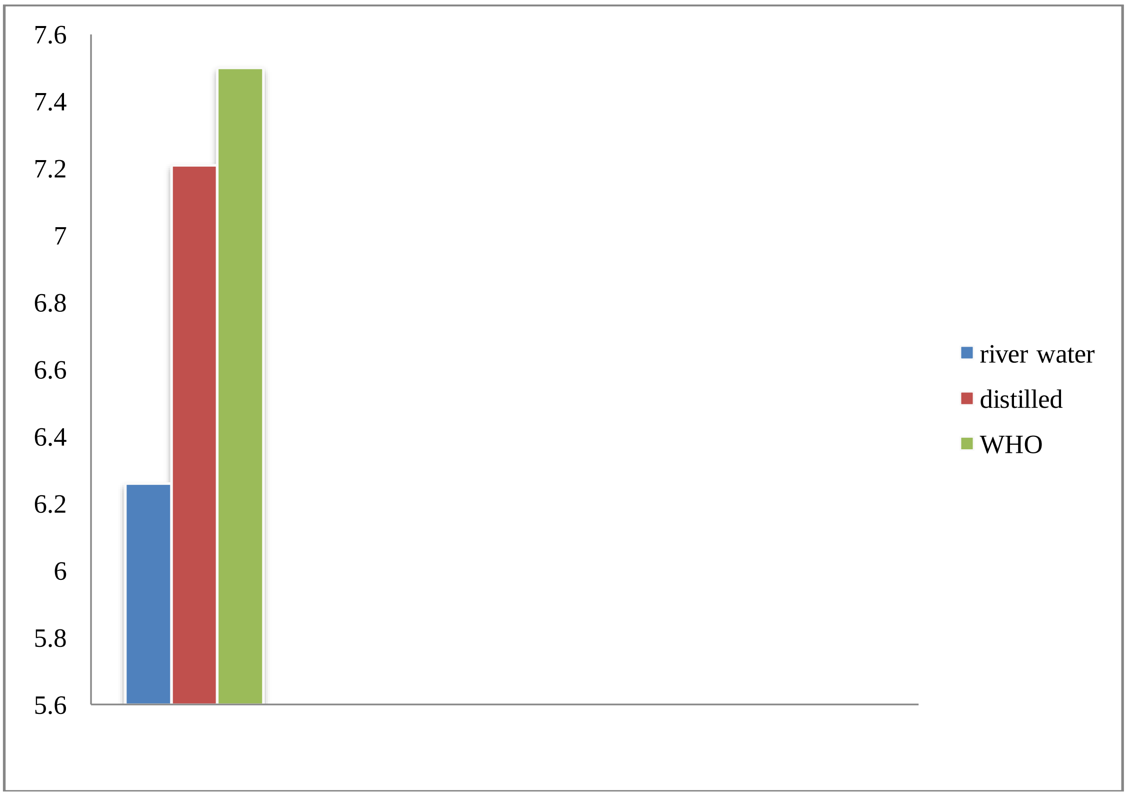

Figure 4: pH values for Post andPre-treatment of River Water Sample.

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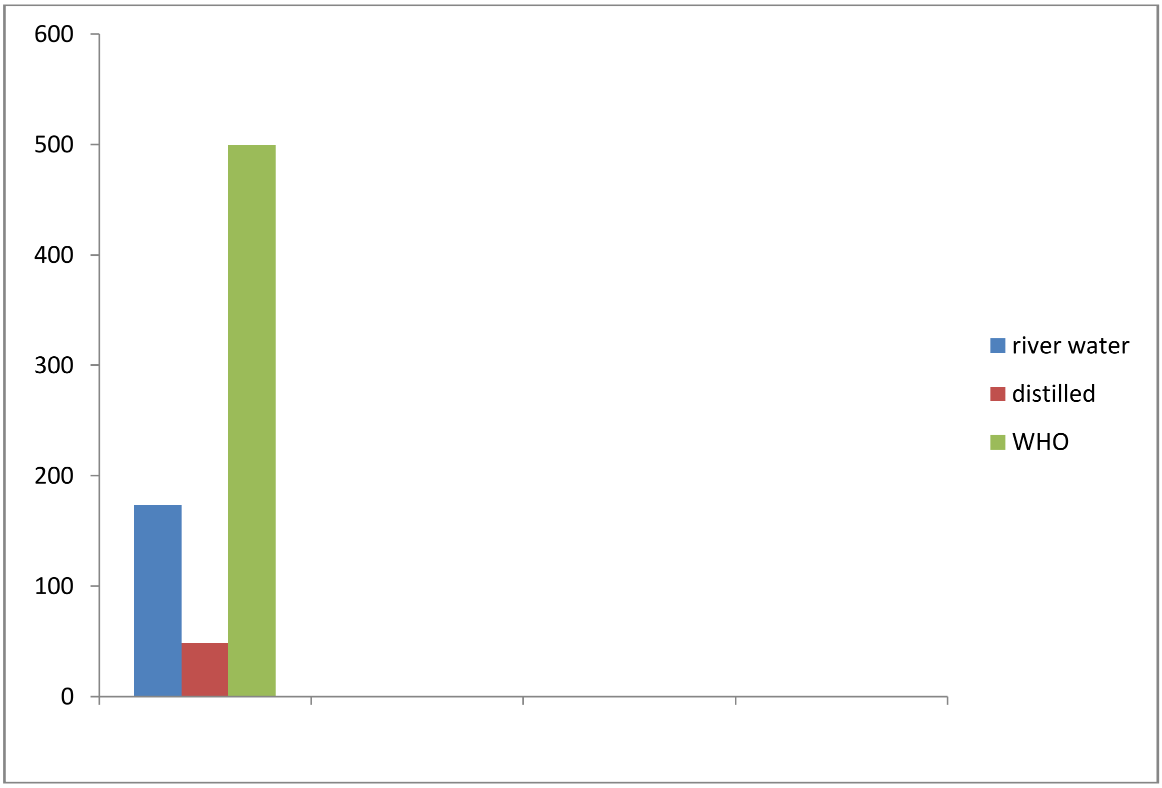

Figure 5: TDS values for Post and Pre-treatment of River Water Sample.

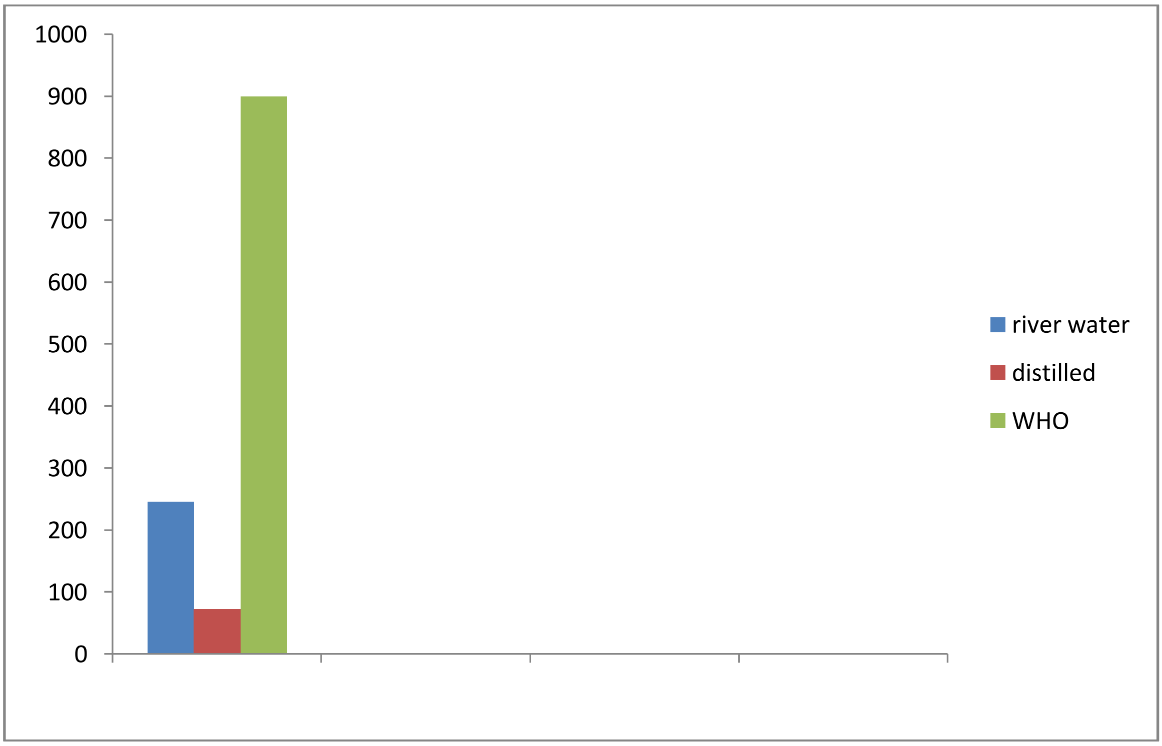

Figure 6: Electrical conductivity values for Post & Pre-treatment of Surface Water Sample.

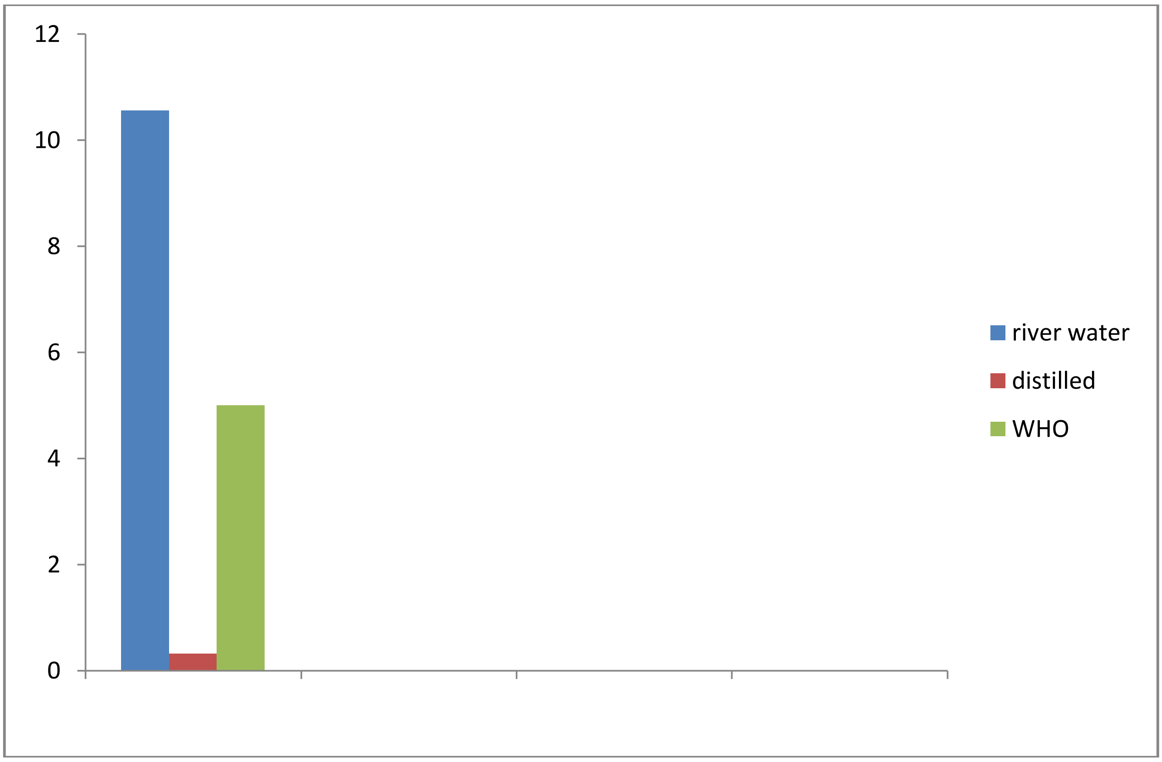

Figure 7: Turbidity values for Post andPre-treatment of River WaterSample.

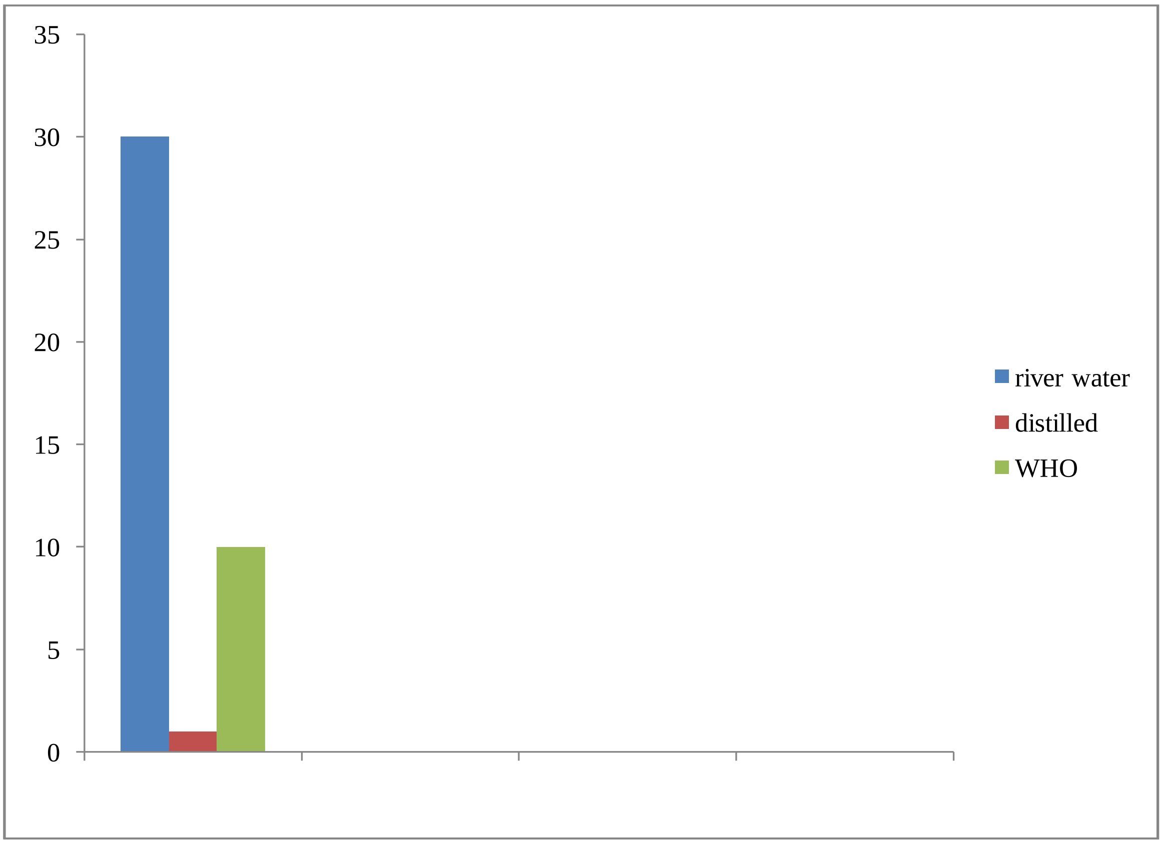

Figure 8: Total suspended solid (TSS) values for Post and Pre-treatment of Surface Water Sample.

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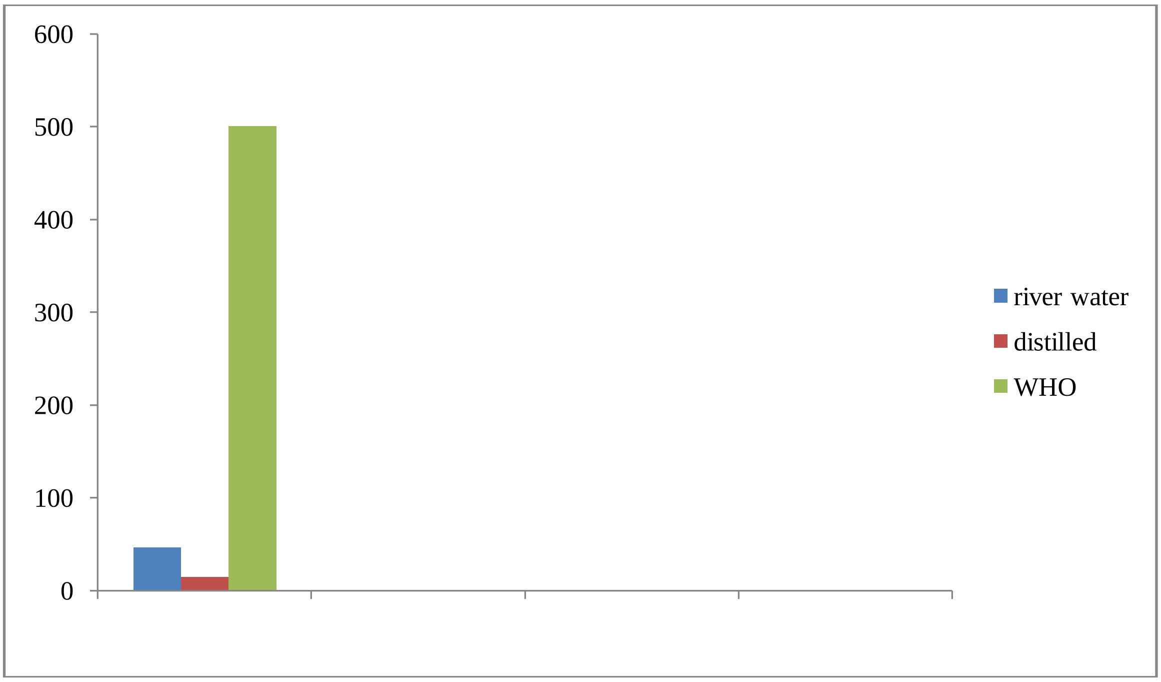

Figure 9:Total hardness values for Post and Pre-treatment of River Water Sample.

In figure 4, pH values for Post and Pre-treated River Water Sample is shown, in comparison with the World Health Organisation (W.H.O) limit for water pH. It was observed that the pH value for the pre-treated water is 6.26 which is slightly acidic and that of the distilled water is 7.21 which is almost neutral. The post treated water pH value was within the W.H.O standard range. The post treated water distillate showed an improvement of 15.17% above the river water.

Figure 5, shows TDS values of River Water Sample in comparison with the World Health Organisation (W.H.O) limit for TDS. The TDS for pre-treated water is 172.63mg/l, while that of distilled water is 48.27mg/l; both values are less than the WHO limit of 500mg/l. If one compare the TDS of the structural and pre-treated water samples post treated water samples gave improved of over 300%.

Figure 6, Illustrate the electrical conductivity values for Post and Pre-treatment of Surface Water Sample in comparison with the World Health Organisation (W.H.O) limit for water electrical conductivity. The values gotten shows that the pre-treated value is 242.48µS/cm, 72.41µS/cm, while the WHO limit is 400.00µS/cm. It can be concluded that the pre-treated water electrical conductivity is high, which means more concentration of ions than that found in the distilled water which is very small when compared with the WHO limit.

Figure 7, shows the turbidity values for Post and Pre-treated of Surface Water Sample, in comparison with the World Health Organisation (W.H.O) limit for water turbidity. From the values obtained, the pre-treated water has a value of 10.56NTU, distilled water has a value of 0.31 NTU and the WHO limit is 5.00 NTU. This shows that the distilled water is less turbid than that of the pre-treated water by the WHO limit. Therefore, the distilled water is clearer and good for domestic use. The comparative value is, −97.06%, which implies that the post- heated water sample from the solar water still is very clear in observation.

Figure 8 showed the Total Suspended Solid (TSS) values for Post and Pre-treated of River Water Sample in comparison with the World Health Organisation (W.H.O) limit for water TSS. The pre-treated water has a value of 30.00mg/l, distilled water has 1.00mg/l with a WHO limit of 10.00mg/l. It can be observed that the distilled water has very little or no suspended solid. The comparative analysis showed a TSS of, −96.67%, which means that the post- treated water from the water still has little or no suspended solid present in it.

Figure 9: Total hardness parameter values for Post and Pre- Treatment of River Water Sample in comparison with the World Health Organisation (W.H.O) limit for water hardness. Total Hardness obtained is as follows 45.00 mg/l for pre-treated water, 14.00 mg/l for distilled water with 500.00 mg/l as the WHO limit. Though the distilled water

has a value of 14.00 mg/l, it is lower than that of the river water and the WHO limit respectively.
From the table and graphs, (Fig.4-9), it was observed that the distilled water from the solar still has parameter values in the acceptable range of the World Health Organisation, (W.H.O), standards.

This implies that the water obtained from the solar still distiller is suitable for domestic use especially in areas where portable clean water is lacking. The solar still can be used to provide distilled water for student's practical uses in physical and biological sciences also in rural areas for uses in Primary Health care century.

IV. CONCLUSION

This work designed and constructed solar water still from locally sourced materials. The constructed water still has the ability to purify contaminated water; this was tested by using it to purify collected river water samples from a nearby flowing river. The physico-chemical properties of the distillate showed significant improvement over the raw river water sample.

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