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Research Article

Design and Fabrication of an Integrated Solar Still and UV/Pasteurization System for Domestic Use

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ABSTRACT

Water, that miraculous liquid, is the fundamental foundation upon which life on Earth is based. The first human civilizations were founded on water, and wherever water is found, civilization is found. Given the increasing population, rising living standards, and developments that have led to increased water pollution and limited water resources, and given the expected rise in fuel and electricity prices in the future, and to rationalize electricity consumption, the use of solar energy is an effective solution for desalination and sterilization of water.In this research, a solar-powered desalination and sterilization system was designed and manufactured to make water potable. This system operates using river, well, and surface water, meeting the needs of homes in remote, desert, and rural areas, as well as homes within cities. This system consists of three filters (polypropylene, a block carbon filter, and a granular activated carbon filter) with an 8-watt solar-powered UV system. The system's production capacity is 20 liters/hour for well and river water, increasing to 60 liters/hour when used with tap water inside homes.The system was operated on water from a 10-meter-deep well in the Al-Jadriya area of Baghdad, and the well water was tested. It was salty and polluted, but the results of the examination after desalination and sterilization were good and within the required specifications.

1. INTRODUCTION

Water is life for every human being, and eliminating its pollutants is one of the most important tasks preoccupying the inhabitants of planet Earth, especially the poor. Without purifying water from these pollutants, it will become a source of numerous diseases, the severity of which varies depending on the source of the pollution, whether nuclear, microbial, or chemical. Indeed, some of the materials used for purification, such as chlorine, can be fatal in themselves. Therefore, it is necessary to consider safe and inexpensive methods for purifying water to make it suitable for human consumption. Given the blessing of bright sunshine throughout the day, which God Almighty has bestowed upon the countries of the region, it is imperative to utilize it to sterilize drinking water [1].There are numerous water sources on planet Earth, which can be summarized in three forms:

1. Rainwater: This can be used directly or indirectly by citizens, and its quantities depend on the intensity of rainfall, the timing of its fall, the influencing climatic factors, and the method of collecting and storing water.
2. Surface water: This constitutes the largest proportion of water resources and includes rivers, lakes, ponds, streams, and seas. The quantity and quality of this water depend on the type of source, the amount of surface runoff, the topography, geology, and geography of the area, and the surrounding climatic conditions. The use of this water is also governed by the type of water, the degree of contamination present, and the possibility of purifying it using available local resources and capabilities.
3. Groundwater: Groundwater is considered a better source for consumption than surface water, especially in the absence of pollutants and when sufficient quantities are available.

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The process of selecting a source depends on several factors, including the degree of acceptance of the source by consumers, the quantity and type of source water, the means of using the source, the cost of production and distribution, the proximity of the source to the consumption area, the quality of the technology used, the availability of labor, and the requirements for operation and maintenance. In general, the process of desalination and sterilization of water can be defined as the process of converting salty and polluted water into pure, salt-free water suitable for human consumption [2]. The process of purifying and sterilizing water using solar energy involves two basic methods. One is using plastic (PET) containers as containers for polluted water and leaving them in the sun inside metal reflectors to increase the effectiveness of solar radiation for two days (6 hours per day). Another, more effective method is using ultraviolet (UV) light waves with a wavelength of 100-280 nm. This light source can be powered by photovoltaic solar panels instead of electrical energy [3]. The increasing demand for water in most parts of the world, due to population growth and climate change, which has led to droughts, could lead to conflicts in many countries. Our region and country are among the countries most likely to be exposed to such risks. It is well known that 70% of Iraq's water resources come from abroad, and this, if it indicates anything, indicates the seriousness of our water situation. Signs of importing mineral water for drinking have begun. Therefore, we must pause and review, for fear that the land of the two rivers will become a net importer of water [4]. For the purpose of rationalizing the use of electrical energy and the rising prices of fuel, which is likely to lead to an increase in the prices of electricity generation and distribution in the near future, and in view of the expansion of residential complexes resulting from the increase in population, in addition to the significant shortage of electrical energy, the use of solar energy to desalinate and sterilize water is the ideal alternative, given that Iraq enjoys an estimated 3,700 hours of sunshine throughout the year. These systems operate solely on solar energy, without the need for traditional electrical energy, and for various water sources (wells, rivers, ponds, streams, etc.) [5].

2. THEORETICAL ASPECT

The desalination process for drinking water is carried out by passing raw water through a set of filters, the number and type of which depend on the water source and salinity. The sterilization process is carried out by passing the desalinated water through a lamp that generates ultraviolet rays with a wavelength of 254 nm and a dose of 40,000 μm/m2, according to the international standard (NSF/ANSI). This dose of ultraviolet rays destroys the DNA of bacteria. Therefore, this system requires a small amount of electrical power, which can be provided by solar energy via photovoltaic panels [6].To operate a solar-powered water desalination and sterilization device with a capacity of 20-60 liters/hour, an 8-watt ultraviolet lamp can be used, receiving electricity from the solar panel system and a battery with a capacity of 11 watts for the solar panel and 24 ampere-hours for the battery, which is obtained from equations (1, 2) below:

$$PV = \frac{1.1\ x\ Hr\ x\ PL}{I} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (1)\ [\mathbf{8}]$$

$$AH = \frac{PL\ x\ Hr}{V\ x\ B\ x\ DD} \quad \ldots\ldots\ldots\ldots\ldots\ldots. (2)\ [\mathbf{8}]$$

PV: Solar Panel Power (Watts)
Hr: Number of Operating Hours
PL: Device Power (Watts)
I: Average Daily Solar Irradiance for Central Iraq: 5.5 Kw/m2/day
AH: Battery Capacity (Ampere-hours)
V: Device Voltage (System)
B: Battery Efficiency
DD: Depth of Discharge (DDR).

3. PRACTICAL ASPECT

A solar-powered home drinking water desalination and sterilization system was manufactured in four stages:

1. Polyprolene filter
2. Carbon block filter
3. Granular activated carbon filter
4. UV lamp

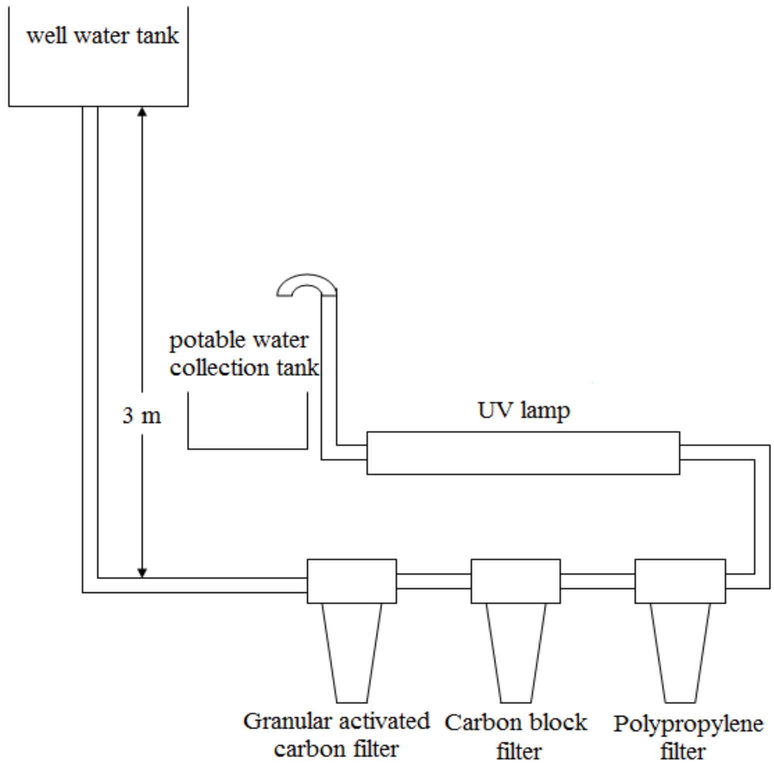

Fig. 1. Shows a Diagram of The Desalination System.

As shown in Figure (1), the entire system is installed inside a portable box, enabling it to be used anywhere and anytime. In addition to the components above, the system is equipped with an 11-watt solar panel, a 24-ampere-hour battery, and a high-frequency inverter (ballast). Figure (2) shows the system's electrical circuit. The lamp's wavelength is 253.7 nm, which is within the C-band, the effective wavelength required to eliminate bacteria. The system is also equipped with two openings for the inlet of raw water and the outlet of potable water. Figure (3) illustrates the complete system.

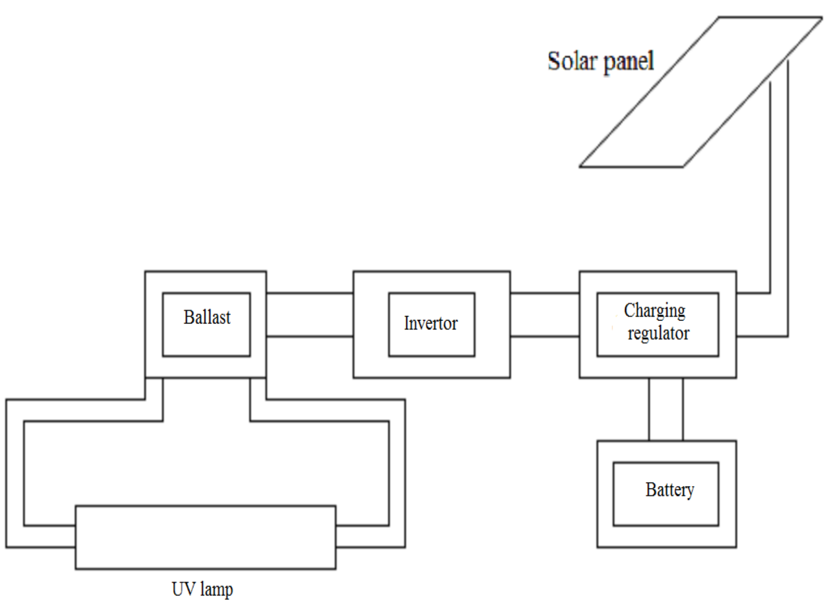

Fig. 2. Solar Electrical System

Fig. 3. Solar Desalination and Sterilization System

4. RESULTS AND DISCUSSION

Using equations (1, 2), the solar panel power (11 watts) and battery capacity (24 ampere-hours), in addition to the 30-watt inverter and charge controller (12 volts, 4 amperes), were sufficient to operate the system for (6) continuous hours, producing (20 liters per hour) of potable water from raw water. This quantity reaches (60 liters per hour) for domestic tap water (due to citizens' lack of confidence in tap water). Note that Table (I), which shows the chemical and biological analyses of the water before desalination and sterilization, contained numerous colonies of bacteria, suspended and dissolved substances, and salts. After desalination and sterilization, the results were within the required limits (Iraqi Specification 417 of 1974). The advantages of this system include:

1. The system operates in all locations and conditions and does not require power lines.
2. Easy installation, operation, and maintenance.
3. It is considered economically feasible, as the selling price is approximately $400, and the solar panel's lifespan is more than 25 years. To explain this, we explain: (One aspect of the feasibility study is cost, as the provision of potable water and human health are not subject to feasibility. However, the price of the system is $400, in addition to the price of the filter set, which is less than $10 per year. Therefore, the price of a system with a lifespan of 25 years becomes $650, which produces 1,460,000 liters during its operating period. Thus, the price per liter becomes $0.00044, which is significantly lower than the price of bottled water and even tap water.
4. High reliability
5. Environmentally friendly and non-polluting.
6. Providing potable water to homes in rural, desert, and remote areas, thus preserving citizens' health.

TABLE I. CHEMICAL AND BIOLOGICAL ANALYSES OF WATER WITH THE SPECIFICATIONS OF IRAQI SPECIFICATION NO. 417

	Test name	**Unit**	**Before desalination and sterilization**	**After desalination and sterilization**	**Maximum acceptable mg/L**	**Maximum allowable when a better source cannot be found mg/L**
1	Total Bacteria Count Test		Dense growth (pollutant)	No pollution	Less than 10 colonies/ml	Less than 10 colonies/ml
2	Most Probable Bacteria Count Test (MPM)		Discoloration + gas (pollutant)	No pollution	Less than 10 colonies/ml	Less than 10 colonies/ml
3	Total Suspended Matter (TSS)	ppm	140	20	-	-
4	Total Dissolved Matter (TDS)	ppm	2010	520	1000	1500
5	Chemical Oxygen Demand (COD)	ppm	360	120	-	-
6	Sulfates	ppm	291.59	240.78	250	400
7	Chlorides	ppm	170.691	158	250	600
8	Phosphates	ppm	0.082	0.042	-	-
9	Calcium	ppm	1.98	0.81	75	200

10	Magnesium	ppm	2.03	1.15	50	150

5. CONCLUSION

domestic solar water desalination systems represent a compelling, sustainable, and decentralized solution to the critical challenge of freshwater scarcity, particularly in remote, arid, and sun-rich coastal regions. Their core value lies in their elegant simplicity: they harness abundant solar energy to directly address the lack of clean drinking water, offering a degree of water independence to individual households and small communities.

The advantages of these systems are undeniable:

1. Sustainability and Eco-Friendliness: They operate on clean, renewable solar energy, producing zero greenhouse gas emissions and having a minimal environmental footprint compared to fossil-fuel-powered desalination.
2. Energy Independence and Off-Grid Capability: They are ideal for remote locations without access to the electrical grid or centralized water infrastructure, empowering communities to produce their own vital resource.
3. Low Operational Costs: After the initial investment, the "fuel" from the sun is free, leading to very low ongoing expenses, primarily for basic maintenance.
4. Simplicity and Low-Tech Options: Technologies like solar stills are mechanically simple, easy to understand, build, and maintain with local materials and skills, making them accessible in developing regions.
5. High Purity: The distillation process effectively removes salts, minerals, heavy metals, and most biological contaminants, producing water of very high purity.

Domestic solar water desalination is not a silver bullet that can replace large-scale municipal water infrastructure for urban centers. Its true niche is in decentralized, off-grid applications where conventional solutions are impractical or too expensive. It stands as a powerful testament to appropriate technology—using a local resource (sunlight) to solve a local problem (water scarcity). While current systems are best viewed as a crucial source for potable water rather than for full household consumption, ongoing advancements promise to boost their efficiency and reliability. Ultimately, for millions living in water-stressed regions, this technology offers not just a source of water, but a symbol of resilience, self-sufficiency, and hope for a more sustainable future.

Recommendations

1. Approach government departments (municipalities and public works) regarding the need to provide such systems to villages and rural areas.
2. Study the system's potential for desalination and sterilization of various types of well and lake water.
3. Study the various capacities of these systems and compare them with the quality of the water produced.
4. Efficiency Enhancements: Research is focused on increasing the yield of solar stills through advanced materials (e.g., nano-coated surfaces for better light absorption and heat localization), multi-effect designs that reuse latent heat, and improved condensation techniques.
5. Hybrid Systems: Combining solar thermal with small-scale photovoltaic (PV)-powered Reverse Osmosis (RO) or Electrodialysis (ED) systems can offer a balance between reliability and sustainability, using battery storage to allow for some evening operation.

Conflicts of Interest

The authors declare no conflicts of interest.

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