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# Overcoming Water Scarcity Through Solar – Driven Distillation: A Sustainable Solution for Home use

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**Abstract:** Water demand from the municipal sector experienced a considerable increase and will continue growing as populations urbanize. In developing countries, poor water quality is due to the lack of water treatment facilities. As of 2022, 2.2 billion people were without access to safely managed drinking water (SDG Target 6.1) (Statistics | UN World Water Development Report, 2024.). The research addresses the pressing concern of clean drinking water scarcity, driven by industrial contamination and the insignificant upkeep of existing water filtration plants for urban households. The methodology presents research and development of a sequential schematic process to address the problem. To identify current condition of drinking water availability, testing and analysis of samples collected from different areas of Lahore, Pakistan was conducted. Thereafter, the design optimization for the development of a portable water purification system powered by solar energy was performed. It integrates a parabolic sunlight concentrator with a solar tracking system which maximizes efficiency to distillate brackish groundwater, reducing contaminants while minimizing energy consumption by employing renewable energy. The study will not only provide a framework to improve water quality and public health but also align with the sustainable development goals (SDG 3, SDG 6, SDG 7) ultimately contributing towards worldwide sustainable water management practices.

**Introduction:** Pakistan, the under developing country, has the most pressing problem which is thepollution of water used for drinking (S. Ali, 2023). As the developing nations will face the greatest impact, with poor water quality and limited access contributing to 80% of infections in these regions (HELAIMIA, 2023). Due to growing population, excessive use of chemical fertilizers is degrading the quality of groundwater (Sadasivuni et al., 2022). According to the 2017 Census, Lahore has a population of **11.13 million** growing at the rate of 3% on yearly basis (Shah et al., 2021). For water supply in Lahore, there is a high dependency on groundwater as around 7 millionpeople of the city use groundwater for drinking as well as for domestic use (Abbas et al., 2015).

Therefore, it is imperative to develop innovative solutions to ensure sustainable water and sanitation (Pusch et al., 2005). Groundwater quality is severely stressed due to unregulated and unsustainable abstraction (Rasheed et al., 2021.). There are **480 tube wells** for drinking water supply that were installed by WASA in Lahore (*Environmental-Issues-and-Concerns*, n.d.). It is necessary to focus on the major reason for the shortage of fresh drinking groundwater. The significant reasons are **seepage** contamination, **brackishness** and **salinity** of available groundwater which makes thegroundwater available but not suitable for drinking. The major risk to groundwater quality is the disposal of solid waste. A landfill leachate containing thousands of intricate components seeps intothe groundwater table (Muhammad & Zhonghua, 2014). The groundwater is predominantly saline andunsuitable for both drinking and agricultural purposes (Sabir Hussain & Abbas, 2019). On segregatinggroundwater contamination factors with respect to rural and urban areas, following are the main factors affecting groundwater quality in both areas:

1. Rural areas: The primary reasons for groundwater pollution stem from the application of pesticides and fertilizers on agricultural lands (Bhubaneswar Pradhan, 2023).
2. Urban areas: The main cause for groundwater contamination is the inclusion of toxic chemical substances and dangerous microbes inaugurating from home and industrial waste,as well as urban expansion (Bhubaneswar Pradhan, 2023).

Moving on to groundwater extraction sources, as nearly all of the population depends on groundwater supplies for their nutritional needs. Given below are the groundwater resources available in Lahore (Sajid Rashid, 2012):

1. Tube wells
2. Shallow wells
3. Canals (groundwater recharge source)

The shallow wells having depth of **45-50 feet** has the most **toxic agents** dissolved (Malik Muhammad Akhtar, 2013). In addition to that, shallow wells of which are **120-150 Feet** deep contain **sewage waste** trespass so, for obtaining clean groundwater for drinking the groundwater extraction wells should be 400 to 700 feet deep (Sajid Rashid, 2012). Although, **water filtration plants** exit in Lahore district for filtering brackish groundwater. As the main drinking water supplyto Lahore city goes from WASA but the clean water demands of Lahore metropolitan city are notfulfilled by WASA due to **improper ground water capital management** (Mirza et al., 2018a).

The capital is not sufficient for training staff, bacteria control, monitoring and record keeping, equipment and maintenance (Membracon, 2023).

Whereas the **cost of digging** 150 feet deep well is $3,800 to $15,300 on average. Including the well system's cost, the total cost per foot ranges from $25 to $65 (Campbell, 2024).

**Literature Review:** In Lahore, the primary supply of drinking water is through **groundwater** wells. The groundwater is constantly combined with contaminated materials therefore, it needs to be cleansed before being used for drinking and household use. Sewage water gets entered in fresh water supply pipelines due to aged and cracked water supply pipelines (Mirza et al., 2018b). According to AWQI (Averaged Water Quality Index), the locations with comparatively higher turbidity levels are (Shahid & Iqbal, 2016):

- Anarkali
- Baghbanpura
- Allama Iqbal Town
- Mughalpura
- Mozang

Moreover, groundwater faces multiple threats, with the most significant being the pervasive risk of contamination leading to the low quality of this vital water resource. Each year, **0.2 million** people die from the diarrhea disease which they get from drinking contaminated water (Majeed etal., 2023). Pollutant transmission brought on by closely spaced industrial and water supply pipelines, the dumping of raw sewage and industrial effluents, and insufficient service providers' technical capability. Furthermore, the quality of groundwater is under tremendous stress due to unregulated and unsustainable groundwater abstraction (Rasheed et al., 2021.). The quality controlis getting difficult due to lack of financial resources available to country therefore access to safe and clean water is getting difficult day by day (Hussain et al., 2019). As Pakistan's power industry depends heavily on costly imported fuel, straining the national treasury and contributing to the depreciation of the Pakistani Rupee against the US Dollar (STATE OF INDUSTRY REPORT CONTENTS, 2022.), a reason for high electricity bills whereas the average salary of Pakistani ranges from 50k to 75k (Profit, 2022). Consequently, the government faces an energy crisis due to transmission losses, insufficient power generation, and a lack of demand management policies (Ahmad et al., 2019) so as WASA reduced regular water supply durations from 14-18 hours in 2013 to 10-11 hours in 2020 due to budget constraints (Tamkinat Rauf, 2009), (Tubewell Timings, 2022). It does not have the desired amount for maintaining the outdated filtration plants such that in Data Ganj Bakhsh there are 39 filtration plants out of which only 4 are functional (Dozens of WaterPlants in Disrepair, n.d.).

Several, in demand water filtration systems just like RO systems exhibit waste-to-clean water ratios of **3:1** or even up to **6:1** causing major water loss (Shook, 2024). In case of chemical disinfection, primarily, chlorine act as a disinfectant to kill the micro-organisms present in groundwater (Groundwater Filtration Basics, 2016), (AOS Treatment Solutions, 2023). Another suitable purification technique is solar still which can be integrated into water supply systems of moderate capacity, ensuring self-sufficiency (Hancock, 2023). Harnessing the solar energy directlyto evaporate freshwater from seawater or brackish water is termed as solar distillation which eliminates arsenic, fluorides, and chlorides (Kapadia et al., 2021). Distillation is capable of eliminating almost all contaminants from water, including sodium, calcium, magnesium, and otherdissolved solids like iron and manganese, as well as fluoride and nitrate (Skipton, 2013). The following are the STEPS for purifying the groundwater by distillation:

- **Boiling:** The process of boiling is straightforward and involves heating water in a containerto temperatures exceeding **212 °F** or **100 °C** the boiling point of water. When the water reaches this temperature, it starts to evaporate, taking the contaminants with it (Sensorex, 2021).
- **Condensation and Collection:** As steam generated during the boiling process ascends, itexits the container and enters a tube. As the steam travels through the tube, its temperature decreases, leading to condensation (Sensorex, 2021). As the vapor's temperature drops causing it to turn back into pure liquid water, which is then collected and stored in a separate tank (Saidur et al., 2011).

This technique has been utilized for numerous years, typically on a small scale (Tzen et al., 2022). By utilizing solar power (heating source), a solar distillation apparatus separates minerals and saltfrom brine via the mechanisms of evaporation and condensation (Samuel et al., 2022). As the significant disadvantage faced by the distillation systems and needs to be solved is high cost of process and equipment (DRINKPRIME, 2023) as heat is provided by burning fossil fuels which are nonrenewable energy sources will be depleted, given their restricted supply (Cong, n.d.). Solar water heating systems (SWH) use solar thermal collectors to convert sunlight into heat for water heating. Various setups, designed for different latitudes and weather conditions, are available at varying price points (Solar, n.d.).

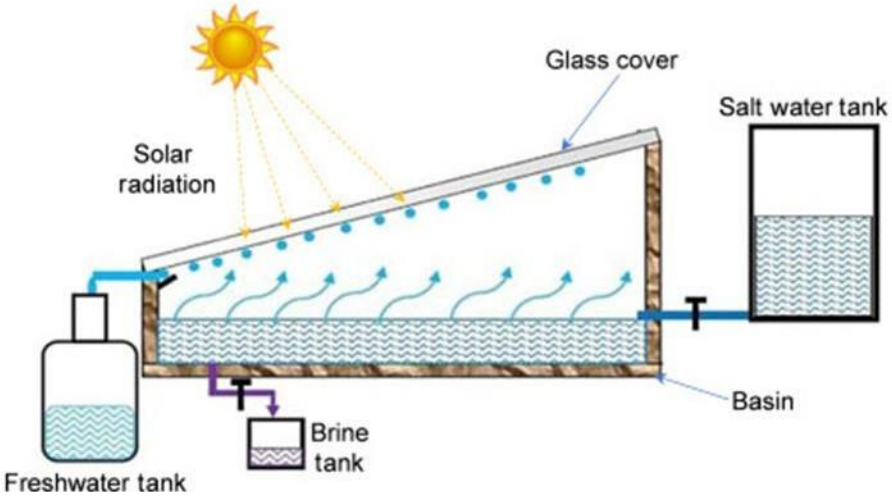
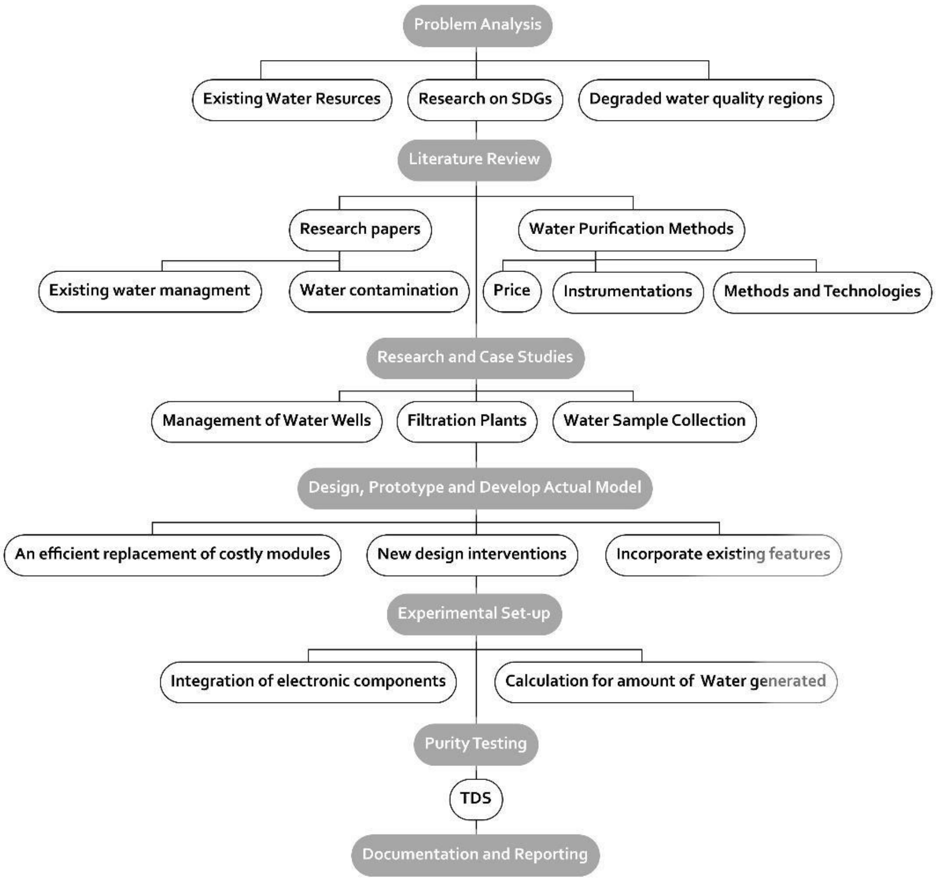



***Figure 1. Solar Water Distillation (Panchal et al., 2021)***

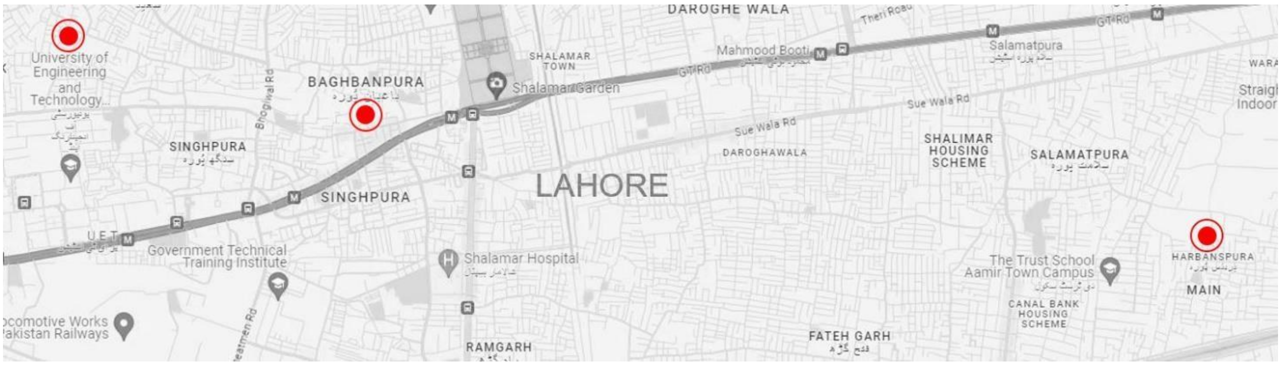
In recent times, scientists have delved into solar concentrator collectors as a viable method to capture and intensify solar energy for application in high-temperature scenarios (Mohammed et al., 2023). Solar stills can be integrated into water supply systems of moderate capacity, ensuring self-sufficiency (Hancock, 2023).. While active solar stills require several equipment, Passive solarstills do not require power consumption and do not have wear and tear problems because they do not have any moving parts (A. Babalola, 2015).

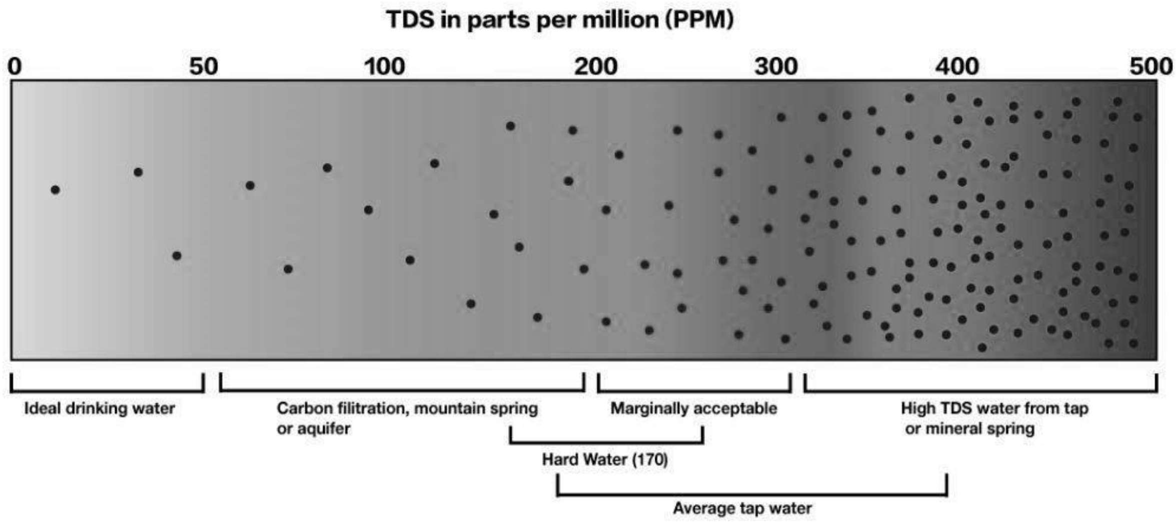
**Methodology:** The project addresses water purification challenges in Lahore through solar- thermal desalination, integrating sun-based concentration for efficient desalination. Solar thermal collectors are employed by solar water heating systems (SWH) to transform solar radiation into thermal energy for water heating purposes (Solar, n.d.).
Beginning with a literature review, it explores existing technologies and designs a system with parabolic concentrators and condenser chambers. Then proceeds with different case studies for assessing water quality of Lahore, evaluating solar-powered water filtration then developing a working prototype by harnessing local market components to ensure accessibility. The system undergoes continuous testing and optimization. Data on water quality, energy use, and economic feasibility are collected, culminating in comprehensive documentation and reporting, aimed at sustainable water solutions in Lahore.



**Research Objectives:** This project focuses on purifying brackish groundwater by reducing its salinity and contaminants, making it safe for drinking. The proposed solution is a solar-powered water distillation system that utilizes a parabolic sunlight concentrator and a solar tracking system to ensure sustainable purification. Designed with readily available market components, the systemaims to be both affordable and accessible to a wide range of users, particularly in Lahore.

**Observational study:** Water samples were collected from different sites of Lahore including GT Road, Baghbanpura and Harbanspura. The groundwater taken from these sites had increased levels of TDS (Total dissolved Solids) as it is the fundamental indicator of bad water quality. Because of things like nearby pollution sources, land use patterns, and geological formations, groundwater quality may change in different parts of the city. Gathering samples from multiple locations enables a thorough evaluation of groundwater quality and pinpoints regions withparticular pollution problems.




High TDS in water can cause a bitter or briny taste, elevated lead or copper levels can lead toillness (Bisleri, 2020). A TDS safe and unsafe zones are shown in figure 2.

***Figure 2. TDS Safe and Unsafe Zones (Yida, 2020) Table 1. Water Sample Data***

| Sr no. | Location | Coordinates | TDS (ppm) |
|---|---|---|---|
| 1 | Baghbanpura | 31.5850° N, 74.3749° E | 467 |
| 2 | UET Lahore GT Road | 31.5802° N, 74.3570° E | 395 |
| 3 | Harbanspura | 31.5761° N, 74.4262° E | 325 |


1- Baghbanpura 2- UET Housing Society GT Road 3- Harbanspura

***Figure 3. TDS Meter Readings***

As figure 3 indicates, the water sample from UET Lahore Bhola Cafeteria showed a TDS of 467 PPM, indicating a high concentration of dissolved solids like salts and minerals, with the water appearing yellowish and containing suspended contaminants. Another sample from a water filter near UET Housing Society recorded a TDS of 395 PPM, suggesting hard water that may be unsafe for daily consumption due to its high salt and metal content. Additionally, a third sample from a 345-feet deep borewell had a TDS of 325 PPM, indicating a moderately high level of dissolved solids, which can affect the water's taste and safety, prompting the need for treatment before humanconsumption.

**Experimental procedure and set-up:** The project sun-driven water purifier is focused on utilizing renewable energy resources available on the planet. Sun, a natural heating source, is taken as a **primary heating element** in the proposed product. The project incorporates the distillation process powered by sunlight. Working principle begins when solar radiation falls on the water containing body, resulting in heating up that body, raising the water temperature and triggering evaporation. The resulting water vapor condenses on the sloped glass cover (in our project, it will be replaced by tubes and the condensed pure water will then flow through these tubes into anothertank) due to pressure and temperature differences and is then collected at the bottom through an appropriate mechanism (M. & Yadav, 2017).

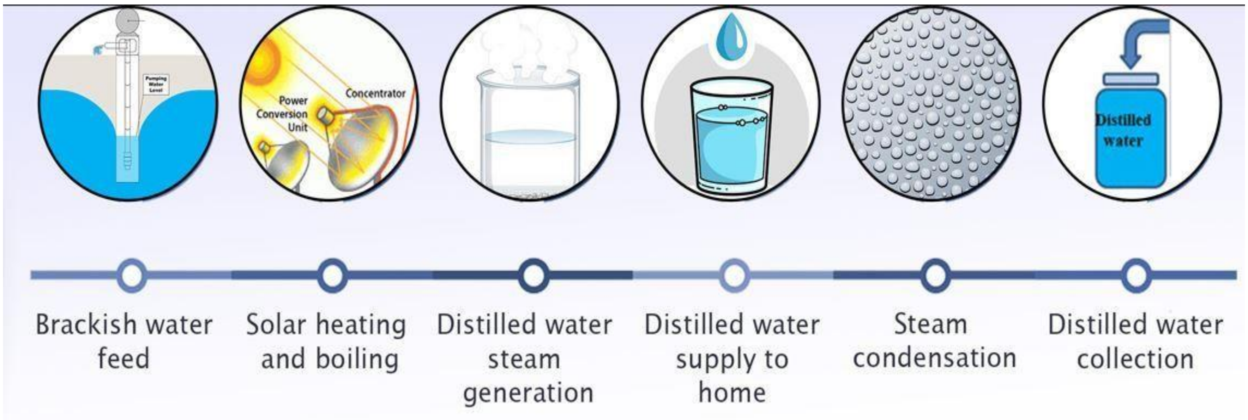



*Figure 4. Stages of Solar Water Distillation*

The purification process which is initiated by sun focused heat driven by parabolic concentrator has further optimized to provide excellent sun light tracking and portability. The project is an integration of parabolic concentrator, solar tracker and water flow system. Parabolic concentrator is considered vital as it must direct the sun rays to a single point where the low-quality groundwater is heated. The water is supplied to this receiver profile on which all the sunlight must be focused through a water flow system. The receiver should be in the focus of the sun with the help of a solartracker. See the figure 5.

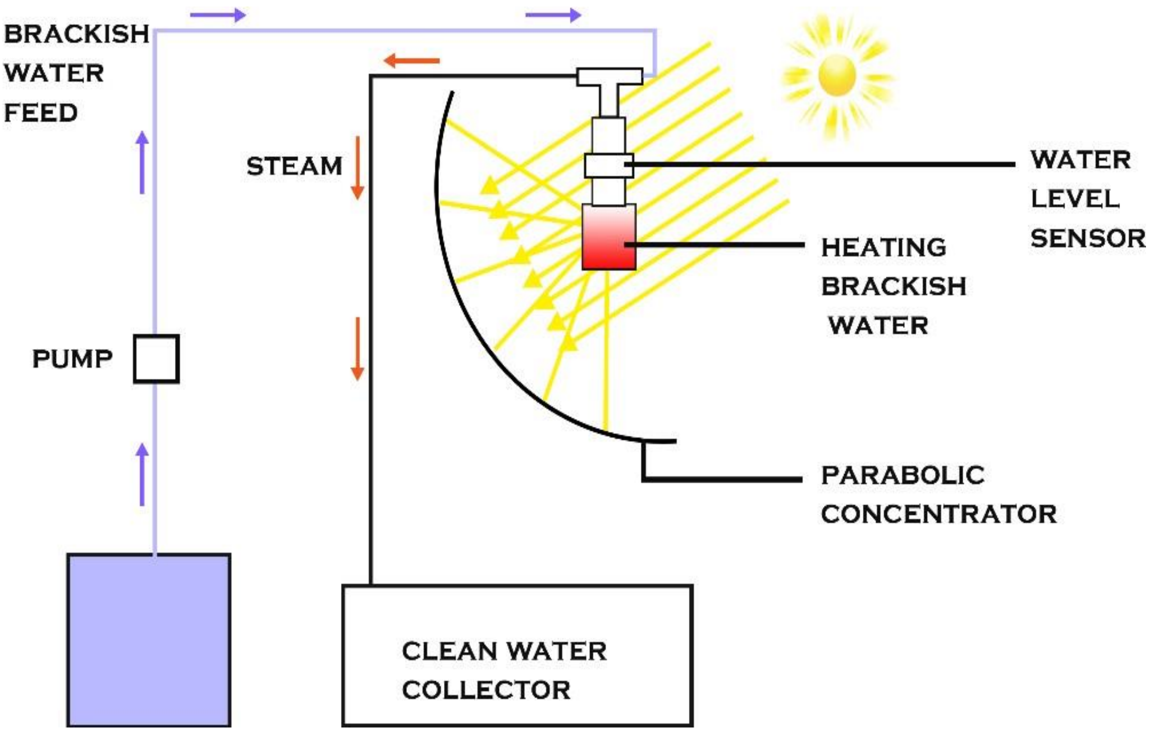



*Figure 5. Working Principle*

Following diagram illustrates the complete integration of the purification unit containing all elements configured together:

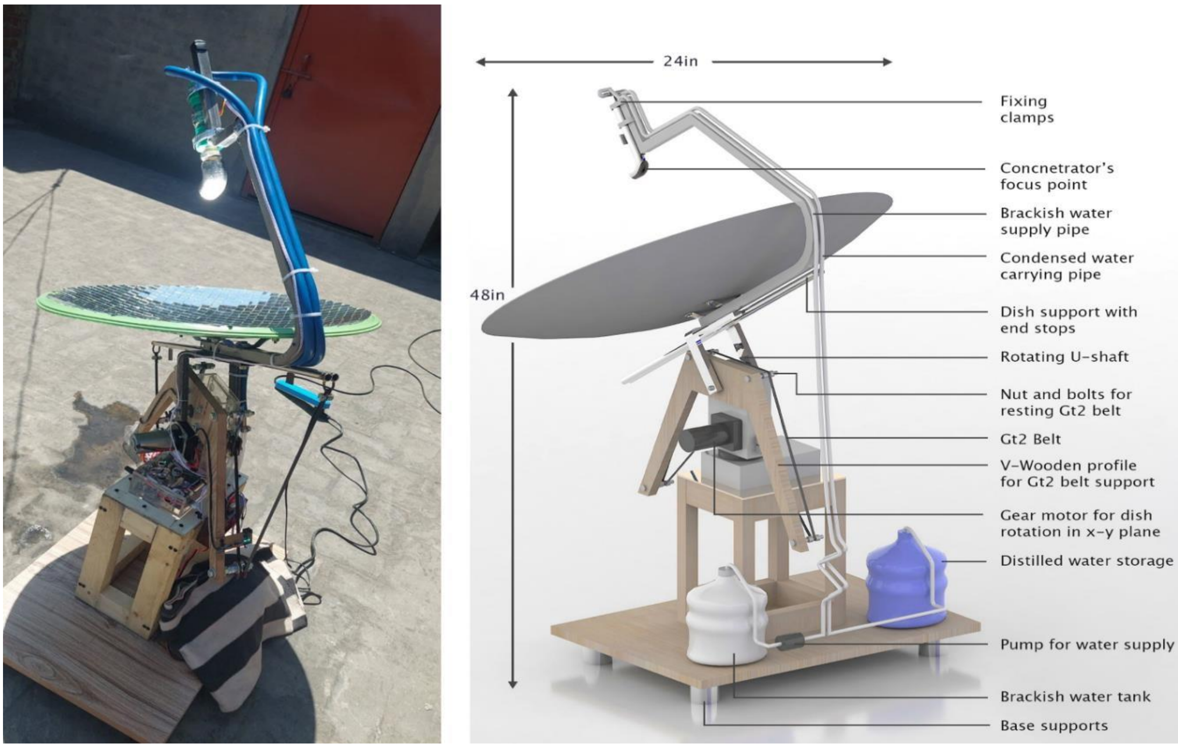



***Figure 6. Solar Water Distillation System***

Given below are the step by step working details of the purification unit. The project consists ofTHREE major parts: 1- Waterflow system, 2- Parabolic Concentrator, 3- Solar Tracker

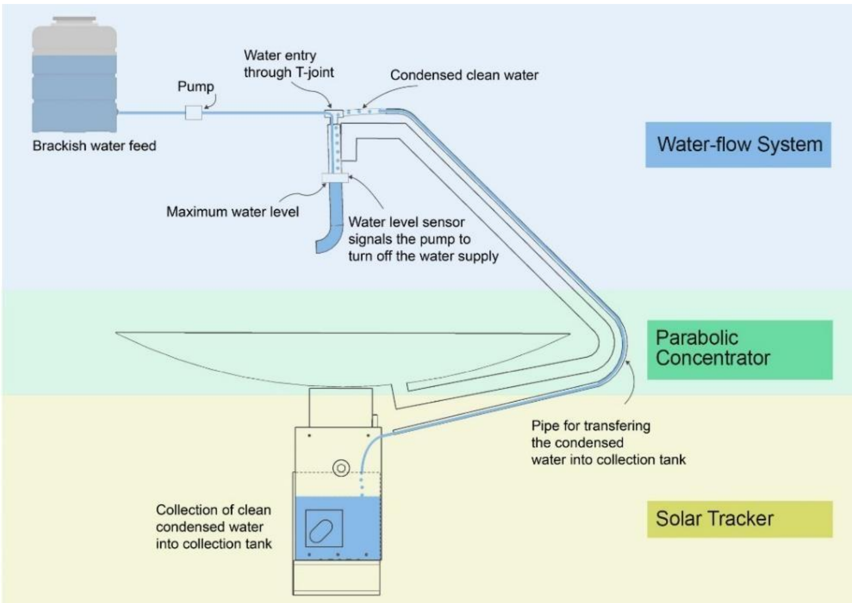



***Figure 7. Water Intake and Distillation Process***

**1. Parabolic Concentrator:**

The parabolic dish, a key component of the parabolic concentrator, features a 2 ft diameter steel curved dish with tiny mirrors on its surface. A steel elbow at the focus point tests the sunlight's intensity. The dish reflects sunlight to a single point, heating water to boiling, converting it to steam, and then condensing it back into pure water droplets.

*Figure 8. Parabolic Concentrator*

**2. Water Flow System:**

Water is supplied to the receiver profile where sunlight is concentrated. The system includes a steel elbow-shaped water receiver integrated with threaded PVC pipes and a T-joint steel pipe. Water flows through the T-joint into the steel elbow at the focal point of the parabolic concentrator.The T-joint's second route collects steam from boiled water, all connected to a steel rectangular profile.

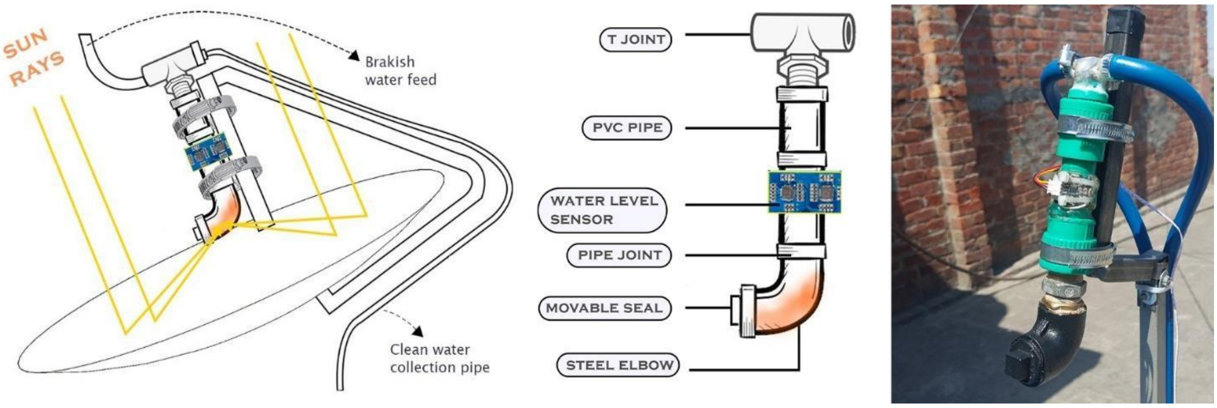



*Figure 9. Water Flow System*

**3. Solar Tracker:**

The tracker facilitates movement in the xy-plane using two gear motors. One motor, located at the base, moves the dish along the x-axis, while the other motor, mounted vertically, adjusts movement along the y-axis. A pulley belt mechanism, featuring a GT2 belt, connects the gear motor rotor to a larger pulley wheel, ensuring precise adjustments.

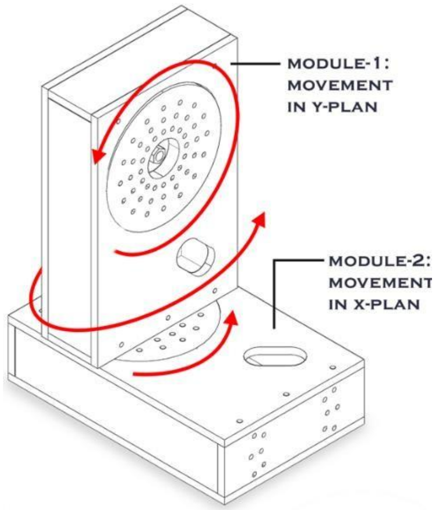



*Figure 10. Solar Tracker Isometric View*

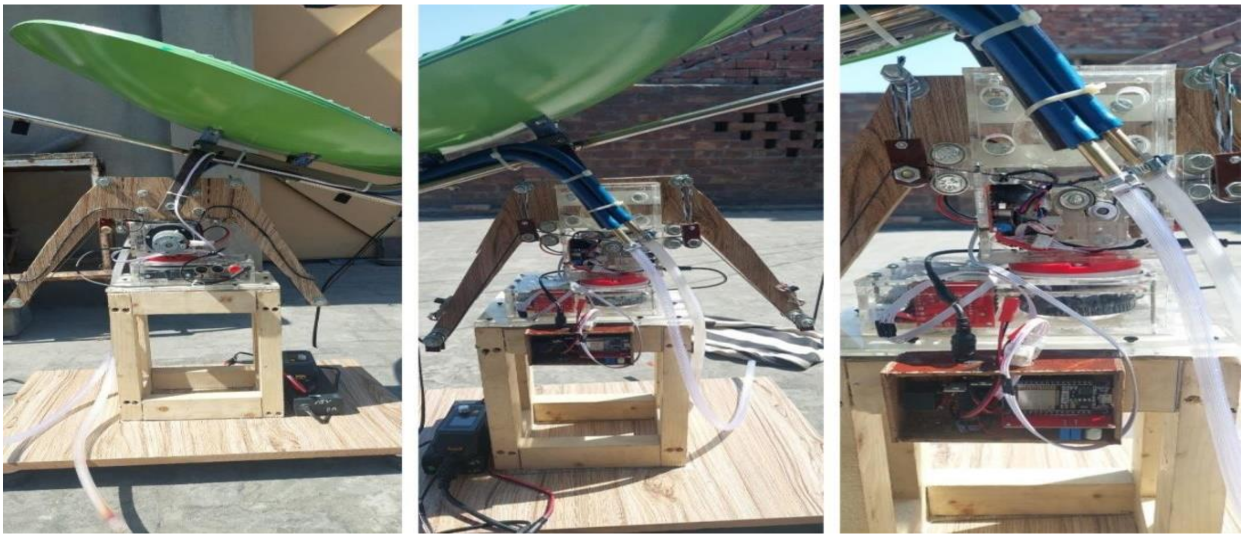


***Figure 11. Solar Tracker***

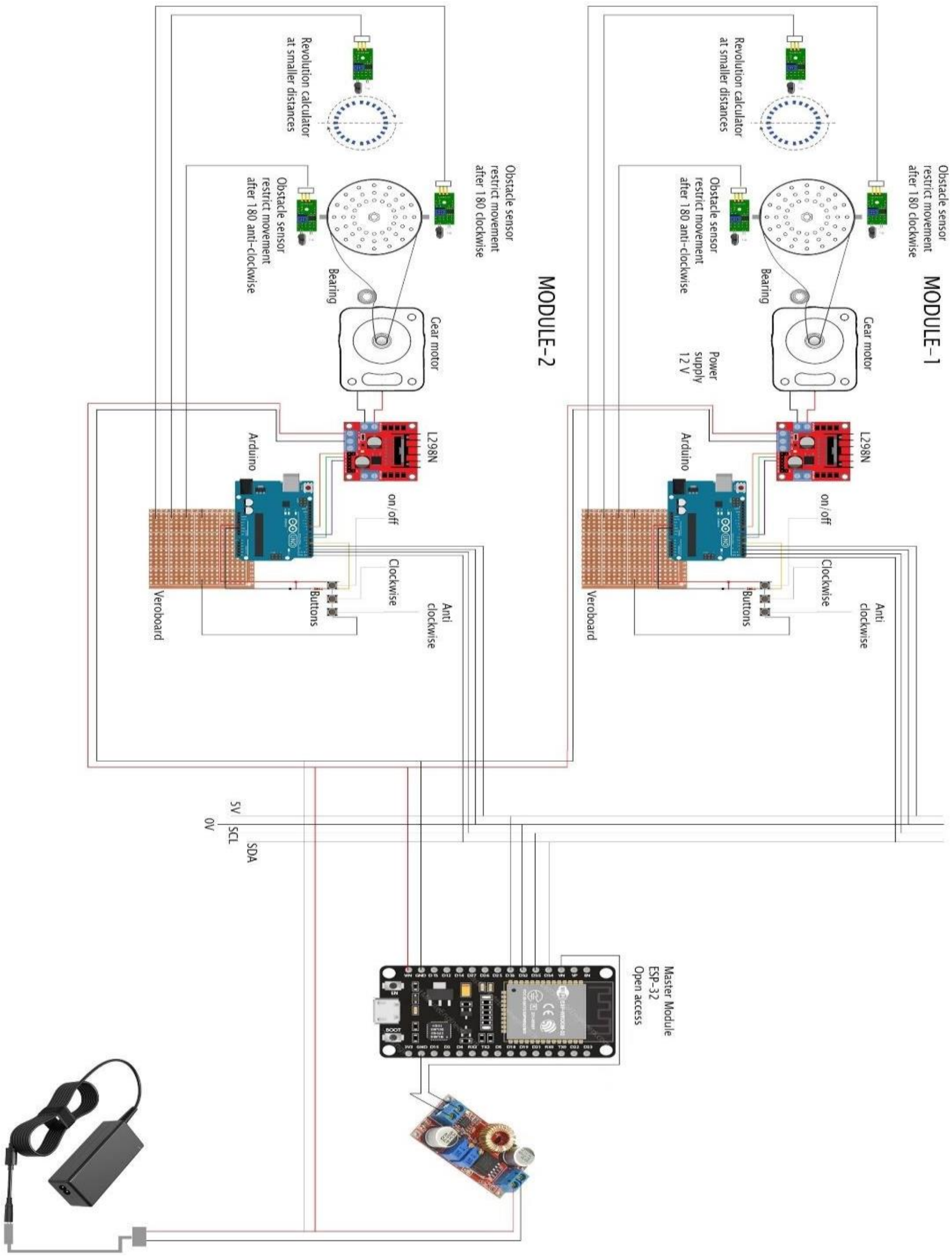



***Figure 12. Circuit Diagram of Solar Tracker***

**Experiment**

***Figure 13. Prototype***
***Figure 14. Water Boiling***

The first experiment was done on **17 April, 2024 at 8:00am to 8:20am.** The water was inserted into the elbow. The water inside the hot steel elbow started boiling in just **10 minutes,** validating the experiment and the solar concentrating system. The evidence of boiling water is shown in figure 14.

**Table 2. Ambient temperature and total distillate output.**

| Date | Max./Min. Temperature (°C) | Time (24-H format) | Duration (Minutes) | Total Output (mL) | Avg Output (Per Minute) | Solar Intensity w/m$^2$ |
|---|---|---|---|---|---|---|
| 17 April, 2024 | 33 - 20 | 8:00 to 8:20 | 20 | 64 | 3.33 | 297 |
| 21 April, 2024 | 35 - 22 | 11:00 to 13:00 | 65 | 230 | 3.54 | 732 |
| 5 May, 2024 | 36 - 24 | 11:30 to 12:30 | 60 | 390 | 6.5 | 745 |

The three experiments were performed in both morning and afternoon timings as demonstrated bytabular values in Table 2. The efficiency of the water purification process in this project is directlylinked to solar intensity. As the intensity of sunlight increases, more energy is absorbed by the steel profile, which serves as the heat conductor. High-intensity solar rays allow the steel profile to heat up rapidly, thus transferring heat to the water inside at a faster rate. This results in quickerboiling of the water, speeding up the evaporation process and, consequently, the rate of water purification. The higher the solar intensity, the faster the system can operate, making sunlight a crucial factor in determining the overall performance of the solar-powered distillation process. Asindicated by Table 2. When the intensity was 732-745 w/m$^2$, it producsed larger mLs of pure waterthan the water purified with solar intensity of 297 w/m$^2$ . Samples collected from experimentationof our design's working prototype were tested in the TDS Testing Lab of Environmental Engineering Department of UET Lahore. Samples which were collected from filters of different sites in Lahore along with prototype produced water were tested from the Lab's precise TDS meters. The TDS rating of the experimental water which was obtained is ranging from **50-80 MPL.** A Total Dissolved Solids (TDS) level of 50-80 MPL (Milligrams per Liter) categorizes water as exceptionally pure. This low TDS count indicates that the water contains minimal amounts of dissolved substances such as salts, minerals, metals, and other inorganic and organic compounds.

***Table 3. Lab Experiment Data***

| Prototype Experimental Data | | | |
|---|---|---|---|
| **Source** | **Output** | **TDS (MPL)** | **Turbidity** |
| Experiment-1 | Sample 1 | 80 | <10 |
| Experiment-2 | Sample 2 | 60 | <5 |
| Experiment-3 | Sample 3 | 50 | <5 |

**Figure 15. Sample Testing from Environmental Engineering Department, UET Lahore**


**Figure 16. TDS Meter Reading of Distilled Water Samples**

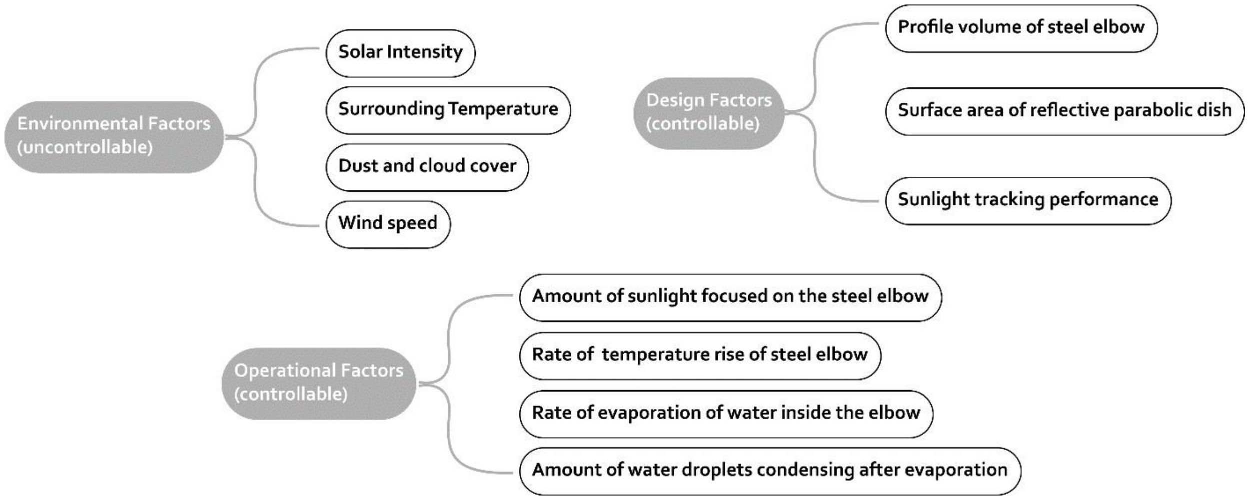



***Figure 17. Factors affecting the overall performance of the solar water distillation system***

**Results & Conclusion:** The testing results from the Environmental Engineering Lab reveal significant improvements in the Total Dissolved Solids (TDS) levels of the experimental water samples, though some challenges related to turbidity still persist. Turbidity, which refers to the cloudiness or haziness of water caused by the presence of suspended particles, is an important measure of water quality and visibility. Ideally, drinking water in houses should have turbidity below 1 NTU, but in many cases, home water treatment is necessary to ensure safe drinking water.In such scenarios, the target should be to keep turbidity levels at or below 5 NTU (Nephelometric Turbidity Units) but water seems cloudy when it has turbidity level beyond 4 NTU (WATER QUALITY AND HEALTH-REVIEW OF TURBIDITY: Information for Regulators and Water Suppliers, 2017.). Water with turbidity levels below 5 NTU is considered clear and suitable for consumption (Lenntech, 2024). However, the one tested sample exhibited turbidity levels higher than 5 NTU, indicating that further improvement is necessary to achieve optimal clarity. This can be accomplished through additional settling and decanting processes, which help remove suspended particles and reduce turbidity.

In terms of TDS, the experimental results showed promising numbers, with TDS levels ranging from a minimum of 50 milligrams per liter (mg/L) to a maximum of 80 mg/L. TDS is a crucial indicator of water quality, representing the concentration of dissolved solids, such as salts, minerals, and metals, in water. Distillation processes are highly effective at reducing TDS, and purified water typically has TDS levels between 1 to 100 mg/L, which aligns with the results obtained in this study (What Is TDS?, 2024.). However, while low TDS levels indicate high purity, water that is too pure lacking essential minerals like calcium, magnesium, and potassium may notbe ideal for human consumption. Drinking water with extremely low mineral content can lead to mineral deficiencies over time, potentially affecting health by depriving the body of vital nutrients.Also, the low TDS water can be unsuitable for drinking due to its dull and bland flavor (Faysal etal., 2017.).
Despite this concern, water with lower TDS levels has specialized uses. For example, in certain industrial applications, such as in batteries, low-mineral, low-TDS water is preferred. High TDS water can damage the internal components of batteries by causing scaling and mineral buildup. Therefore, the water purified through the distillation process, with TDS levels between 50 to 80 mg/L, can serve multiple purposes beyond human consumption, such as in technical applicationsrequiring low-mineral water.
Overall, while the distillation process has proven effective at significantly reducing TDS and improving water purity, addressing turbidity remains a priority for optimizing water clarity. Additionally, balancing the mineral content of purified water is important to ensure that it is both safe for drinking and suitable for various industrial applications. Further refinement of thepurification process can help achieve both goals.

**References**


*1.* AOS Treatment Solutions. (2023, 7). Disinfection of Groundwater and Wastewater. Retrieved from aosts.com: https://aosts.com/municipal-groundwater-treatment-solutions/disinfection/#:~:text=Sodium%20Hypochlorite%20(Bleach)%20%E2%80%94%20This,up%20a%20resistance%20to%20it.
*2.* Bhubaneswar Pradhan, S. C. (2023). Emerging groundwater contaminants: A comprehensive review on their health hazards and remediation technologies. Groundwater for Sustainable Development.
*3.* Bisleri. (2020, July 24). Understanding TDS and its Role in Drinking Water. Retrieved from Bisleri.com: https://www.bisleri.com/blog-detail/understanding-tds-and-its-role-in-drinking-water?city_id=8
*4.* Campbell, B. (2024, 1 22). How Much Does a Well Cost? (2024 Well Drilling Cost Guide). Retrieved from waterfilterguru.com: https://waterfilterguru.com/how-much-does-a-well-cost/
*5.* DRINKPRIME. (2023, July 20). Water Purification And Its Advantages And Disadvantages. Retrieved from drinkprime.in: https://drinkprime.in/blog/water-purification/
*6.* Hancock. (2023, May 21). Solar Water Distillation. Retrieved from Safe Drinking Water Foundation: https://www.safewater.org/fact-sheets-1/2016/12/8/solar-water-distillation
*7.* Lenntech. (2024, July Monday). Turbidity. Retrieved from lenntech.com:

https://www.lenntech.com/turbidity.htm#:~:text=The%20WHO%20(World%20Health%20Organization,ideally%20be%20below%201%20NTU.

8. Malik Muhammad Akhtar, Z. B. (2013). Contamination Potential Assessment of Potable Groundwater in Lahore, Pakistan. Polish Journal of Environmental Studies, 1905-1916.
9. Membracon. (2023, October 17). The 5 Most Common Problems In Water Treatment. Retrieved from membracon.co.uk: https://www.membracon.co.uk/blog/5-common-problems-water- treatment/
10. Profit. (2022, 12 Monday). Income, culture, and inequality — who are Pakistan's middle-classes?Retrieved from Profit Pakistan Today: https://profit.pakistantoday.com.pk/2022/12/04/income- culture-and-inequality-who-are-pakistans-middle-classes/
11. Programme, U. W. (2018, March 19). World Water Development Report 2018. Retrieved from unwater.org: https://www.unwater.org/publications/world-water-development-report-2018
12. Sajid Rashid, M. S. (2012). Sewage Water Intrusion in the Groundwater of Lahore, its Causes andProtections. Pakistan Journal of Nutrition, 5.
13. Sensorex. (2021, 11 10). How Does the Water Distillation Process Work? Retrieved from Sensorex: https://sensorex.com/how-does-the-water-distillation-process-work/
14. Shook. (2024, 3 Tuesday). Advantages and Disadvantages of Reverse Osmosis (RO) Water. Retrieved from NEWater: https://www.newater.com/reverse-osmosis-water-pros-cons/
15. Skipton, B. I. (2013, 12 Monday). Drinking Water Treatment: Distillation. Retrieved from Extension Publications: https://extensionpubs.unl.edu/publication/g1493/html/view
16. Solar, E. (n.d.). Solar Water Heaters. Retrieved from Enerquip.com:https://enerquip.com.pk/solar-water-heaters-2/
17. Tamkinat Rauf, M. W. (2009). Price-setting for Residential Water: Estimation of Water Demand in Lahore. The Pakistan Development Review, 14.
18. Tubewell Timings. (2022, May 25). Retrieved from WASA Punjab:https://wasa.punjab.gov.pk/tubewell_timing
19. Yida. (2020). TDS in Water – What is TDS and How to measure TDS in water with Arduino? Retrieved from Seeedstudio: https://www.seeedstudio.com/blog/2020/01/19/tds-in-water- what-is-tds-and-how-do-you-measure-tds-in-water/
20. Panchal, Hitesh & Sadasivuni, Kishor kumar & Muthusamy, Suresh & Israr, Mohammad & Sengottain, Shanmugan. (2021). A concise review on Solar still with Parabolic trough collector..International Journal of Ambient Energy. 43. 1-27. 10.1080/01430750.2021.1922938.
21. Babalola, T. (2015). Effect of Water Depth and Temperature on the Productivity of a Double SlopeSolar Still. Journal of Energy and Natural Resources, 4(1), 1. https://doi.org/10.11648/j.jenr.20150401.11
22. Abbas, Z., Su, C., Tahira, F., Mapoma, H. W. T., & Aziz, S. Z. (2015). Quality and hydrochemistry ofgroundwater used for drinking in Lahore, Pakistan: analysis of source and distributed groundwater. Environmental Earth Sciences, 74(5), 4281–4294. https://doi.org/10.1007/s12665-015-4432-5
23. Ahmad, A., Kashif, S. A. R., Saqib, M. A., Ashraf, A., & Shami, U. T. (2019). Tariff for reactiveenergy consumption in household appliances. Energy, 186, 115818. https://doi.org/10.1016/J.ENERGY.2019.07.148
24. Cong, J. (n.d.). Advantages and disadvantages of energy from fossil fuels.https://doi.org/10.15651/GJPRAF.22.1.007
25. Dozens of water plants in disrepair. (n.d.). Retrieved April 6, 2024, from https://tribune.com.pk/story/2407062/dozens-of-water-plants-in-disrepair
26. Environmental-Issues-and-Concerns. (n.d.).
27. Faysal, M., Matin Juliana, F., Johirul Islam, M., Islam, R., Md Faysal, S., Ruhul Amin, M., Jahangir Alam, M., Nazir Hossain, M., Asaduzzaman, M., & Author, C. (n.d.). Assessment of pH and Total Dissolved Substances (TDS) in the Commercially Available Bottled Drinking Water. 6, 35–40. https://doi.org/10.9790/1959-0605093540
28. GROUNDWATER FILTRATION BASICS. (2016).
29. HELAIMIA, R. (2023). CONDENSATION, DESALINATION, AND WATER RECYCLING TO ENCOUNTER WATER STRESS. International Conference on Pioneer and Innovative Studies, 1, 515–523. https://doi.org/10.59287/icpis.883
30. Hussain, S., Habib-Ur-Rehman, M., Khanam, T., Sheer, A., Kebin, Z., & Jianjun, Y. (2019). Healthrisk assessment of different heavy metals dissolved in drinking water. International Journal of Environmental Research and Public Health, 16(10). https://doi.org/10.3390/ijerph16101737
31. Kapadia, Y., Mehta, A., Shah, V., Kotadia, D., Shah, S., & Shah, M. (2021). A comprehensive studyon amalgamation of sustainable solar powered distillation for arsenic and fluoride removal from groundwater. In Environmental Science and Pollution Research (Vol. 28, Issue 48). https://doi.org/10.1007/s11356-021-15789-z
32. Majeed, A., Shahid, S., Ali, S., & Firdous, N. (2023). Safety assessment of water purification plantsof Lahore. Journal of the Pakistan Institute of Chemical Engineers, 50(2). https://doi.org/10.54693/piche.05023
33. M., C., & Yadav, A. (2017). Water desalination system using solar heat: A review. In Renewableand Sustainable Energy Reviews (Vol. 67, pp. 1308–1330). Elsevier Ltd. https://doi.org/10.1016/j.rser.2016.08.058
34. Mirza, A. I., Mirza, A. I., Jamal, T., Hassan, S. S., Butt, M. A., Ali, A., Batool, H., Mahmood, R., Naz, A., Sohail, A., Kaukab, I. S., Alvi, S., Ahmad, J., Ali, S., Aamir, M., Akhtar, A., & Javed, A. (2018a). Environmental Assessment and Analysis of Chemical Properties of Drinking Water Using Geo-Spatial Technologies: Examples from Lahore Metropolitan. Advances in Remote Sensing, 07(03),259–275. https://doi.org/10.4236/ars.2018.73018
35. Mirza, A. I., Mirza, A. I., Jamal, T., Hassan, S. S., Butt, M. A., Ali, A., Batool, H., Mahmood, R., Naz, A., Sohail, A., Kaukab, I. S., Alvi, S., Ahmad, J., Ali, S., Aamir, M., Akhtar, A., & Javed, A. (2018b). Environmental Assessment and Analysis of Chemical Properties of Drinking Water Using Geo- Spatial Technologies: Examples from Lahore

Metropolitan. Advances in Remote Sensing, 07(03), 259–275. https://doi.org/10.4236/ars.2018.73018

36. Mohammed, A. H., Shmroukh, A. N., Ghazaly, N. M., & Kabeel, A. E. (2023). Active solar still with solar concentrating systems, Review. In Journal of Thermal Analysis and Calorimetry (Vol. 148, Issue 17, pp. 8777–8792). Springer Science and Business Media B.V. https://doi.org/10.1007/s10973-023-12285-z
37. Muhammad, A. M., & Zhonghua, T. (2014). Municipal solid waste and its relation withgroundwater contamination in lahore, Pakistan. Research Journal of Applied Sciences, Engineering and Technology, 7(8), 1551–1560. https://doi.org/10.19026/rjaset.7.431
38. Pusch, D., Ihle, S., Lebuhn, M., Graeber, I., & López-Pila, J. M. (2005). Quantitative detection of enteroviruses in activated sludge by cell culture and real-time RT-PCR using paramagnetic capturing. Journal of Water and Health, 3(3), 313–324. https://doi.org/10.2166/wh.2005.039
39. Rasheed, H., Altaf, F., Anwaar, K., Ashraf, M., & Pakistan Council of Research in Water Resources. (n.d.). Drinking water quality in Pakistan : current status and challenges.
40. Sabir Hussain, M., & Abbas, S. (2019). RELATIONSHIP BETWEEN RAINFALL VARIATIONS AND HARVESTING OF RAINFALL WATER IN CHOLISTAN DESERT, PAKISTAN. In Pakistan Geographical Review (Vol. 74).
41. Sadasivuni, K. kumar, Panchal, H., Awasthi, A., Israr, M., Essa, F. A., Shanmugan, S., Suresh, M., Priya, V., & Khechekhouche, A. (2022). Ground water treatment using solar radiation- vaporization & condensation-techniques by solar desalination system. International Journal of Ambient Energy, 43(1), 2868–2874. https://doi.org/10.1080/01430750.2020.1772872
42. Saidur, R., Elcevvadi, E. T., Mekhilef, S., Safari, A., & Mohammed, H. A. (2011). An overview of different distillation methods for small scale applications. In Renewable and Sustainable Energy Reviews (Vol. 15, Issue 9, pp. 4756–4764). https://doi.org/10.1016/j.rser.2011.07.077
43. S. Ali. (2023). CLEAN DRINKING WATER AND FUTURE PROSPECTIVE. Pakistan Journal of Science, 74(1). https://doi.org/10.57041/pjs.v74i1.140
44. Samuel, A., Brizuela, J., Chang, K. C., & Lin, C. T. (2022). Design and Investigation of an Effective Solar Still Applicable to Remote Islands. Water (Switzerland), 14(5). https://doi.org/10.3390/w14050703
45. Shahid, S. U., & Iqbal, J. (2016). Groundwater Quality Assessment Using Averaged Water Quality Index: A Case Study of Lahore City, Punjab, Pakistan. IOP Conference Series: Earth and Environmental Science, 44(4). https://doi.org/10.1088/1755-1315/44/4/042031
46. Shah, S. I. H., Ahmed, A., & Nawaz, R. (2021). ANALYSIS OF LAND USE CHANGE AND POPULATION GROWTH USING GOE-SPATIAL TECHNIQUES IN LAHORE-PAKISTAN. In Pakistan Journal of Science (Vol. 73, Issue 2).
47. STATE OF INDUSTRY REPORT 2022 CONTENTS. (n.d.).
48. Statistics | UN World Water Development Report. (n.d.). Retrieved October 15, 2024, from https://www.unesco.org/reports/wwdr/en/2024/s
49. Tzen, E., Zaragoza, G., & Padilla, D. C. A. (2022). Solar Desalination. Comprehensive Renewable Energy, Second Edition: Volume 1-9, 1–3, 590–637. https://doi.org/10.1016/B978-0-12-819727-1.00034-0
50. WATER QUALITY AND HEALTH-REVIEW OF TURBIDITY: Information for regulators and water suppliers. (n.d.).
51. What is TDS? (n.d.). Retrieved October 15, 2024, from https://www.waterdropfilter.com/blogs/water-contaminants/what-is-tds-in-water-and-how-to- measure-it