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TECHNOLOGY OF NON-PUMP EVAPORATION COOLING BASED ON SALINE WATER, OPERATING ON SOLAR ENERGY IN A DRY AND HOT CLIMATE

B.A.Uzakov, Sh.M. Esemuratova

Karakalpak State University named after Berdakh, Nukus, Uzbekistan
e-mail: bakhadir_0909@mail.ru, e_shiyrin@karsu.uz

Abstract: This article examines the technology of a solar-powered pumpless evaporative cooling system designed for operation in the hot and dry climate of the Aral Sea region. The main objective of the study is to analyze the operating principle and structural features of an energy-efficient cooling device that uses saline water as the working medium and can operate autonomously with minimal electricity consumption.

The proposed device consists of a saline water reservoir, capillary fabric, a ventilation fan, and small solar panels that supply power to the fan. In the system, water rises along the capillary fabric due to capillary forces and spreads across the surface of the material. As evaporation occurs, heat from the surrounding air is absorbed, producing a cooling effect. The fan enhances air circulation through the moist surface of the fabric, accelerating the evaporation process and improving cooling efficiency.

The research results demonstrate that this technology consumes significantly less electricity than conventional air-conditioning systems, does not use harmful refrigerants such as freon, and is environmentally friendly. In addition, the device can operate autonomously and can be effectively applied in areas with limited or unstable electrical infrastructure, including settlements, social infrastructure facilities, and temporary structures. The study also considers certain limitations of the system, such as dependence on climatic conditions and possible salt crystallization during operation. Overall, solar-powered evaporative cooling based on saline water is considered a promising, energy-efficient, and sustainable cooling solution for the Aral Sea region.

Keywords: Aral Sea region, evaporative cooling, solar energy, pumpless cooling unit, salt water, capillary fabric, energy-saving technology, hot and dry climate, environmentally friendly cooling, autonomous cooling system.

The global energy crisis is intensifying day by day, affecting households, businesses, and the entire economy. The high cost of fuel - more than half of which is natural gas - accounts for 90% of the growth in the average world cost of electricity production. Rising prices and economic pressures have become the main obstacles preventing people from using modern electricity[1].

Today, the rapid depletion of energy resources in the world and the release of large amounts of greenhouse gases, which cause climate change, are causing deep concern. In many regions, extreme heat waves and droughts are becoming increasingly widespread[2]. With the rise in global temperature, the load on building cooling also increased sharply. Consequently, air conditioning systems became necessary to ensure the thermal comfort of rooms. However, most heating, ventilation, and air conditioning (HVAC) systems consume large amounts of electricity.

Thermal comfort of a person is defined as the state of a person's feeling of comfort in relation to the temperature, humidity, and movement of air in the environment. Conditions accompanied by high temperatures and especially low relative humidity can cause discomfort, heat stress, and in some cases, health risks. Heat stress has a high probability of negatively affecting worker productivity and leading to serious health problems, especially among the elderly [3].

For the human body to feel comfortable, a certain balance of air temperature, relative humidity, and airflow is necessary. Usually, a temperature between 22-27°C and relative humidity around 40-60% is considered the most optimal environment for humans. When humidity is sharply

below or above the norm, the environment becomes unfavorable. Therefore, it is especially important to use cooling mechanisms in hot and dry regions.

The Aral Sea region is extremely dry, with summer temperatures reaching 40-45°C and low relative humidity. This makes the evaporation process very efficient. Therefore, solar-powered pumpless, natural convection-driven cooling technologies are very useful in this region. The Aral Sea region belongs mainly to the arid climate zone and is characterized by typical features of hot desert and cold desert types. The region receives very little precipitation, with extremely hot and dry summers and cold and windy winters. Sharp fluctuations in air temperature throughout the year, low humidity, and high evaporation are the main characteristics of the region's climate.

The sharp shrinking and practically disappearing Aral Sea has had a great impact on the natural and climatic conditions of the region. As a result of the loss of the regulatory role of seawater, the degree of continentality here has increased, namely:

In summer, the temperature warms up even more (+45°C and higher),

In winter, the temperature drops sharply (up to -25...-30°C),

increased annual and daily temperature fluctuations,

Strong winds and dust storms (especially "Aral salt storms") have increased,

air humidity decreased, and the degree of dryness increased.

Moreover, the vast virgin lands (known as the Aralkum Desert) emerging from the seabed are becoming increasingly desertified. This process further influences the climate of the region, further strengthening its characteristics of the ultra-arid desert type.

As a result, the Aral Sea region today has become one of the most severe and unfavorable climatic conditions in Central Asia, which has a serious impact on the ecological situation and human health (Fig. 1).

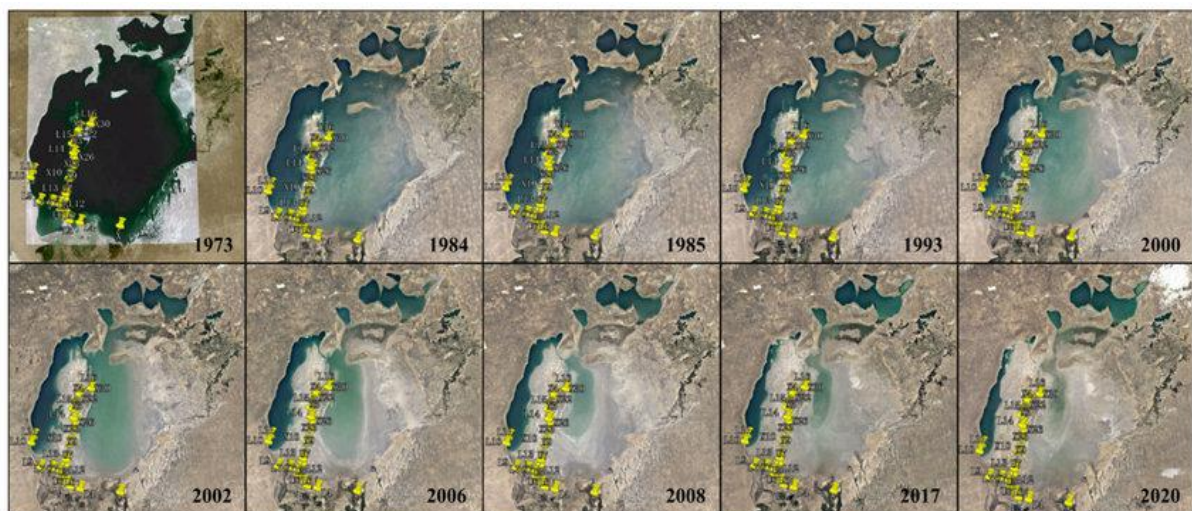


Figure 1. Changes in the water level of the Aral Sea in 1973-2020 (satellite images)

The Aral Sea was one of the largest bodies of water in Central Asia, but it has almost dried up in the last 60-70 years. Until the mid-20th century, it was the fourth largest lake in the world. It is located on the territory of Uzbekistan and Kazakhstan[4].



Figure 2. Desertification process and shipwrecks due to the drying up of the Aral Sea

In such conditions, traditional air conditioners require heavy electricity and are not practical in areas with weak infrastructure. Therefore, the application of passive evaporative cooling technology based on solar energy, operating without a pump, in the Aral Sea region is considered an optimal and economically correct solution.

This device, developed based on the analysis of the above problems, can be effectively used in settlements and social infrastructure facilities located in the dried-up areas of the Aral Sea [5]. The device consists of the following main parts:

- tank (reservoir) for storing salt water;
- fabric with capillary properties (cotton or synthetic fiber material);
- sticks or frames that hold the fabric vertically;
- upward-flow fan;
- small solar panels that power the fan;
- an umbrella and dust-protective coating on the outside.

Saltwater Reservoir: Located at the lowest point of the equipment. Salted or pickled water is poured into this vessel, the bottom of the fabric is immersed in the water, and the water rises up through the fabric fibers. This process occurs naturally due to capillary forces and does not require a pump or electricity. **Capillary fabric (Capillary cloth):** Its function is to draw water from bottom to top, maintain the fabric surface in a uniform moisture state, and accelerate the evaporation process. Cotton or synthetic fiber fabrics perform such capillary movement very well. **Vertical supporting metal rods, frame (Vertical supports):** The fabric is secured with vertical rods on both sides. This keeps the fabric upright, facilitates the free passage of airflow through the fabric surface, and ensures the stability of the device. **Fan:** The fan is mounted on the top of the fabric. Its function is to draw air from bottom to top, accelerate evaporation from the surface of the wet fabric, and release cool air. Here, very little electricity is required to turn the fan, as it operates at a small power. **Solar panels:** Power the fan. Their advantages: there is no need for an electrical network, they operate completely autonomously, and operate the fan continuously for most of the day (Fig. 3). **Umbrella, Shade cover:** An arrow-shaped metal umbrella is shown under the solar panels. Its function is to protect the device from direct sunlight, protect the fabric from rapid drying, and protect it from dust and rain [6].

The general operating principle of the device is that the salt water poured into the reservoir rises upward along the fabric under the action of capillary forces. Water rising to the fabric surface begins to evaporate, and this process draws heat from the surrounding air, creating a cooling effect. The fan directs air to the moistened fabric, increasing the evaporation rate, and the resulting cool air is transferred outside or to the indoor area. The device is based on natural capillarity, evaporation, and simple air circulation.



Figure 3. Solar-powered evaporative cooling unit without a pump

Capillary rise is a natural process and practically does not require electrical energy. Small solar panels will be sufficient for the fan. The removal of water molecules from the surface during evaporation leads to heat absorption; in a dry climate, especially in the Aral Sea region, this is very effective. Since the evaporation temperature of salt water is lower, the cooling rate increases again. Crystallization of salt changes the properties of the water surface and further activates the evaporation process. The structure of the fabric, the density of the fibers, and the material strongly influence the rise of water [7]. Although a solar-powered, salt water-based, pumpless evaporative cooling unit is an innovative and power-saving technology, it has a number of advantages and disadvantages (Table 1).

Table 1

Advantages	Disadvantages
The need for electricity is very low.	strong dependence on climate
Freon and other harmful refrigerants are not used.	limited cooling temperature
environmentally friendly	salt accumulation
easy and inexpensive to make	the device's performance changes throughout the day.
does not require service	requires a large area
can be used in field, desert, temporary camps, or observation posts.	health and hygiene requirements
can be made from local and ordinary materials.	dependence on air circulation
	high water consumption
	low level of administration and automation

To achieve the intended scientific and practical results of the project implementation, the following should be taken into account.

The use of saline water as a working medium in evaporative cooling systems significantly expands the possibilities of implementing this technology in areas with scarce freshwater resources. That is, it will be possible to effectively use cooling systems by using existing sources of saline water, while reducing the consumption of fresh water intended for drinking or agriculture. This ensures the rational use of water resources and creates new conditions for applying the technology in arid and water-scarce regions [8].

Within the framework of the project, it is planned to develop the device without the use of pumps. This approach allows reducing electricity consumption, simplifying the design of the system, and reducing maintenance costs. At the same time, high energy efficiency is one of the key factors of decisive importance for the successful implementation of this technology in practice.

The use of materials with capillary properties for efficient moisture distribution ensures uniform wetting of the evaporating parts across the entire surface. This prevents the formation of dry areas, stabilizes the evaporation process, and increases the overall cooling efficiency [9].

The economic analysis conducted on the project will serve to determine the possibilities of reducing operating costs as a result of the implementation of the device. It also allows reducing the need for similar devices imported from abroad by establishing local production and assessing the economic benefits arising from import substitution.

In the context of the intensification of the global energy crisis, rising fuel prices, and climate change, the need for energy-efficient and environmentally friendly cooling technologies is sharply increasing. Especially in the Aral Sea region, where a hot and dry climate prevails, the use of traditional air conditioners is economically inefficient due to high electricity consumption and weak infrastructure.

The analysis shows that a solar-powered refrigeration unit, operating on the principle of pumpless and capillary evaporation, is one of the most optimal solutions for the Aral Sea region. In the region, high air temperature and low relative humidity make the evaporative cooling process very effective. The fact that the device practically does not require electricity, the possibility of using salt water, and the ability to operate autonomously make it economically and environmentally attractive. The proposed device, while ensuring thermal comfort for humans, reduces electricity consumption, limits the negative impact on the environment, and can be used in accordance with local conditions. Its implementation is of great practical importance, especially in settlements, social infrastructure facilities, and temporary structures.

At the same time, the main limiting factors are the dependence of the device's cooling efficiency on climatic conditions and the need for maintenance as a result of salt crystallization. However, in general, solar evaporative water cooling technology is considered a promising and sustainable solution that serves to mitigate the environmental, economic, and social problems of the Aral Sea region. The conducted research and analysis show that in arid and hot climates, especially in the Aral Sea region, the technology of evaporative cooling based on solar energy, without pumps and with salt water, is an effective and priority solution. This device:

- works with minimal need for electricity,
- provides access to saline water, which contributes to the conservation of freshwater resources,
- increases the efficiency of the moisture distribution and evaporation process through capillary materials,
- reduces operating costs and makes it possible to substitute imports through local production.

The device is also environmentally safe and can be used in settlements, social infrastructure, and temporary facilities. However, the dependence of the device's effectiveness on climatic conditions and salt crystallization are its main limiting factors. In general, solar evaporative salt water cooling technology provides an energy-efficient, environmentally friendly, and sustainable cooling solution in the Aral Sea region.

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ТҮЗДЫ СУ НЕГІЗІНДЕГІ, КҮН ЭНЕРГИЯСЫМЕН ЖҰМЫС ІСТЕЙТІН, ЫСТЫҚ ЖӘНЕ ҚҰРҒАҚ КЛИМАТ ЖАҒДАЙЫНДА ҚОЛДАНЫЛАТЫН НАССОСІЗ БУЛАНДЫРУ АРҚЫЛЫ САЛҚЫНДАТУ ТЕХНОЛОГИЯСЫ

Б.А. Узаков, Ш.М. Есемуратова

Бердақ атындағы Қарақалпақ мемлекеттік университеті, Нүкіс, Өзбекстан
e-mail: bakhadir_0909@mail.ru, e_shiyryn@karsu.uz

Аннотация: Бұл мақалада Арал теңізі аймағының ыстық және құрғақ климат жағдайында қолдануға арналған күн энергиясымен жұмыс істейтін насоссіз буландыру арқылы салқындату технологиясы қарастырылған. Зерттеудің негізгі мақсаты – тұзды су негізінде жұмыс істейтін, энергияны аз тұтынатын және автономды түрде жұмыс істейтін салқындату құрылғысының жұмыс принципін және конструкциялық ерекшеліктерін талдау болып табылады. Ұсынылған құрылғы тұзды су резервуарынан, капиллярлық қасиеті бар матадан, ауа қозғалысын қамтамасыз ететін желдеткіштен және желдеткішті қоректендіретін шағын күн панельдерінен тұрады. Жүйеде су капиллярлық күштің әсерінен матаның бойымен жоғары көтеріліп, оның бетінде булану процесі жүреді. Булану кезінде қоршаған ортадан жылу сіңіріліп, нәтижесінде салқындату әсері пайда болады.

Зерттеу нәтижелері көрсеткендей, ұсынылған технология дәстүрлі кондиционерлік жүйелермен салыстырғанда электр энергиясын әлдеқайда аз тұтынады, фреон сияқты зиянды салқындатқыштарды пайдаланбайды және экологиялық тұрғыдан қауіпсіз болып табылады. Сонымен қатар құрылғыны электр инфрақұрылымы әлсіз немесе жоқ аймақтарда, әсіресе елді мекендерде, әлеуметтік инфрақұрылым нысандарында және уақытша құрылымдарда қолдануға мүмкіндік бар. Зерттеу барысында жүйенің артықшылықтарымен қатар оның климаттық жағдайларға тәуелділігі мен тұздың кристалдануы сияқты шектеулері де қарастырылған. Жалпы алғанда, күн энергиясына негізделген буландыру арқылы салқындату технологиясы Арал теңізі өңірі үшін энергия тиімді, экологиялық таза және тұрақты салқындату шешімі ретінде бағаланады.

Түйін сөздер: Арал теңізі аймағы, буландыру арқылы салқындату, күн энергиясы, сорапсыз салқындату құрылғысы, тұзды су, капиллярлы мата, энергия үнемдейтін технология, ыстық және құрғақ климат, экологиялық таза салқындату, автономды салқындату жүйесі.

ТЕХНОЛОГИЯ БЕЗНАСОСНОГО ИСПАРИТЕЛЬНОГО ОХЛАЖДЕНИЯ НА ОСНОВЕ СОЛЁНОЙ ВОДЫ, РАБОТАЮЩЕГО НА СОЛНЕЧНОЙ ЭНЕРГИИ В УСЛОВИЯХ ЖАРКОГО И СУХОГО КЛИМАТА

Б.А. Узаков, Ш.М. Есемуратова

Каракалпакский государственный университет имени Бердаха, Нукус, Узбекистан
e-mail: bakhadir_0909@mail.ru, e_shiyrin@karsu.uz

Аннотация: В данной статье рассматривается технология безнасосного испарительного охлаждения, работающего на солнечной энергии и предназначенного для эксплуатации в условиях жаркого и сухого климата Приаралья. Основной целью исследования является анализ принципа работы и конструктивных особенностей энергоэффективного охлаждающего устройства, использующего солёную воду в качестве рабочего вещества и способного функционировать автономно при минимальном потреблении электроэнергии.

Предлагаемое устройство состоит из резервуара с солёной водой, капиллярной ткани, вентилятора и небольших солнечных панелей, обеспечивающих питание вентилятора. В системе вода поднимается по ткани за счёт капиллярных сил и равномерно распределяется по её поверхности. В процессе испарения происходит поглощение тепла из окружающего воздуха, что создаёт охлаждающий эффект. Вентилятор усиливает движение воздуха через влажную поверхность ткани, ускоряя процесс испарения и повышая эффективность охлаждения.

Результаты исследования показывают, что данная технология потребляет значительно меньше электроэнергии по сравнению с традиционными системами кондиционирования, не использует вредные хладагенты, такие как фреон, и является экологически безопасной. Кроме того, устройство может эффективно применяться в районах со слабой или отсутствующей электрической инфраструктурой, включая населённые пункты, объекты социальной инфраструктуры и временные сооружения. Также в работе рассмотрены некоторые ограничения системы, такие как зависимость эффективности от климатических условий и возможная кристаллизация соли. В целом технология солнечного испарительного охлаждения на основе солёной воды рассматривается как перспективное, энергоэффективное и устойчивое решение для региона Приаралья.

Ключевые слова: Приаралье, паровое охлаждение, солнечная энергия, холодильная установка без насоса, солёная вода, капиллярная ткань, энергосберегающие технологии, жаркий и сухой климат, экологически чистое охлаждение, автономная система охлаждения.