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INNOVATIVE APPROACHES TO DESALINATION AND WATER PURIFICATION: TACKLING POLLUTION CHALLENGES IN OCEANS AND SEAS" (IN THE EXAMPLE OF THE CASPIAN SEA)

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This article delves into a range of innovative methods and advanced technologies designed to address two critical global challenges: desalinating seawater and mitigating environmental pollution caused by industrial waste. It highlights forward-thinking strategies and groundbreaking ideas that aim to tackle these pressing issues sustainably. While many of these concepts are promising, they necessitate rigorous laboratory testing and extensive field trials to ensure feasibility, efficiency, and safety. Engineers and environmental scientists must collaborate closely to refine these technologies for large-scale implementation. A key proposal in this research focuses on leveraging green energy solutions to power desalination processes. Among the novel ideas introduced is a concept referred to as "transparent energy." This unique form of renewable energy harnesses natural power from the air using solar panels attached to floating air balloons. By suspending solar panels high above the ground, where sunlight exposure is maximized, this method represents an innovative approach to sustainable energy generation. Transparent energy offers the potential to provide a continuous, eco-friendly power source without occupying valuable land resources or disrupting marine ecosystems. Ultimately, this combination of advanced desalination techniques and innovative energy solutions could play a significant role in addressing global water scarcity while minimizing environmental impact. The authors' forward-looking proposals underscore the importance of integrating renewable energy technologies into environmental conservation efforts, paving the way for a more sustainable and resource-efficient future.

Keywords: *Desalination of seawater, innovative technologies, green energy, transparent energy*

INTRODUCTION

The issue of access to drinking water remains highly relevant today. Factors such as global warming, melting glaciers, and widespread environmental changes, combined with the growth of industrial production, population increases, and the need to meet the rising demand for food and drinking water, have caused many regions to face severe water scarcity. At the ***29th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)***, held in the Republic of Azerbaijan from November 11 to 22, 2024, the participating states particularly emphasized the problem of drinking water. ***The Institute of Water Problems of the Republic of Azerbaijan***, along with ***Azersu Open Joint Stock Company***, is actively working to address drinking water challenges. These organizations are studying the practices of countries like Saudi Arabia and Israel, which have pioneered innovative technologies for desalinating seawater and ocean water [2, p. 3, 4]. A critical consideration in seawater desalination is ensuring that the process does not harm the environment. Parallel efforts to purify the marine flora and fauna are essential to maintaining ecological balance. We propose studying and adapting several innovative technologies suited to the unique climate of the Caspian Sea. Our previous articles have detailed the potential of artificial intelligence-controlled, sea-floating barges equipped with solar panels and wind turbines [1, p. 2, 3]. These barges are capable of continuous seawater desalination and storing the potable water in onboard tanks. Utilizing ***OSMOSIS*** and ***SCADA*** systems, these barges can enhance the supply of potable water to some extent. However, to achieve broader goals, such as preventing environmental pollution and cleaning up waste-including food packaging, plastic containers, and residues from past oil production further innovation is needed. One promising approach is the use of ***green and alternative energy*** sources in seawater desalination, which simultaneously protects the environment and addresses pressing ecological challenges [7, p. 2, 3, 4].

Green energy has become a highly relevant topic in the context of environmental protection, as these two areas are closely interconnected. However, modern innovative technologies developed by engineers-such as ***solar panels***, ***wind turbines***, and energy derived from ***algae*** or other natural plants-are still insufficient to meet the growing energy demands of the world's population. Moreover, many companies and governments are hesitant to adopt these innovations due to their high costs and limited scalability for large-scale production. This highlights the urgent need for engineers and innovators to develop alternative energy solutions that are both cost-effective and widely accessible. These solutions must also surpass the efficiency of traditional energy sources such as nuclear, oil, and natural gas. In this context, companies particularly those in the food production industry-have a responsibility to prioritize environmental protection and actively address pollution caused by industrial waste. Unfortunately, only a small number of manufacturers have committed to eliminating the use of plastic materials in their production processes. The global plastic crisis is an urgent issue that demands immediate action. Addressing this challenge requires a multi-faceted approach, including stricter regulations, innovative recycling methods, and shifts in both consumer behavior and production practices. Effective solutions should focus on reducing plastic usage, promoting sustainable alternatives, and investing in cleanup initiatives to mitigate the existing damage to our oceans and ecosystems [3, p. 2, 3].

Fig. 1. “Self-flying air cylinders”

We propose several innovative ideas to address drink water scarcity and environmental pollution: Self-flying air cylinders equipped with solar panels and wind turbines could play a pivotal role in alternative energy utilization and water distillation [Figure 1]. These cylinders would be designed to capture water vapor from the surface of seas and oceans, particularly during hot summer days, and cool and distill it into potable water. By collecting rising vapor and converting it into drinking water, these air cylinders could offer a sustainable solution to water scarcity. Powered entirely by green energy, the cylinders would incorporate a new concept called the "transparent method," which employs advanced water recycling systems to transform saltwater into fresh drinking water. Additionally, these cylinders could be equipped with cleaning materials or recently discovered microorganisms capable of desalinating seawater and removing pollutants from marine environments.

To maximize efficiency, cutting-edge materials and technologies could be integrated into the cylinders, including:

- **Perovskite solar cells**
- **Flexible thin-film solar panels**
- **Organic photovoltaic (OPVs)**
- **Multi-junction solar cells**
- **Lightweight materials for mounting**

These advancements could enhance the ability of flying cylinders to desalinate water while simultaneously cleaning seas and oceans of pollutants. Interestingly, Japanese scientists have discovered a groundbreaking method to combat plastic pollution using bacteria. In 2016, a research team led by microbiologist Kohei Oda from the Kyoto Institute of Technology identified ***Ideonella sakaiensis 201-F6***, a bacterium capable of consuming plastic waste. This microorganism utilizes plastic as a source of energy, secreting enzymes to break down polymers. The first enzyme, ***PETase***, disassembles long ***PET molecules***[1] into smaller units called ***MHETs***[2]. Subsequently, a second enzyme, ***MHETase***, converts these molecules into ethylene glycol and ***terephthalic acid***[3]. These bacteria offer a promising avenue for addressing plastic waste pollution and could be incorporated into the flying cylinders to enhance their environmental impact. By combining cutting-edge green technologies with innovative biological solutions, we can make significant strides toward solving global water and pollution challenges [8, p. 1].

In 2012, a group of Yale University students made a groundbreaking discovery in the Amazon rainforest of Ecuador [4, p.3.4]. They identified a fungus called ***Pestalotiopsis microspora***, a remarkable organism with the unique ability to digest and break down polyurethane, a common type of plastic, even in anaerobic (oxygen-free) environments. This capability makes it an ideal candidate for use as a ***biodegradation agent***[4], as it can gradually decompose accumulated plastic waste. What makes this discovery even more extraordinary is that ***Pestalotiopsis microspora*** can survive by feeding exclusively on plastic, converting polyurethane into organic matter. Its ability to function without oxygen highlights its potential as a natural solution for breaking down plastics, even in extreme scenarios such as environmental disasters. While this discovery is groundbreaking, another promising development in the fight against plastic pollution, particularly in the world's oceans, has come from Chinese scientists. Researchers from the Institute of Oceanology at the Chinese Academy of Sciences have identified a marine fungus species capable of effectively breaking down polyethylene and other types of plastic. Remarkably, in some cases, plastics have been found to completely disappear within just two weeks. Since 2016, a research team led by Sun Chaoming has analyzed over 1,000 pieces of plastic collected from various marine environments. In one of these samples, they discovered this unusual fungus. Over approximately four months, the fungus not only reduces the size of the plastic material and causes a visible color change but also breaks it into smal-

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[1] PET, or polyethylene terephthalate, is a type of polyester widely used in the manufacturing of plastic products.
[2] MHET stands for **mono(2-hydroxyethyl) terephthalate**, a compound formed during the enzymatic breakdown of polyethylene terephthalate (PET) by enzymes like PETase.
[3] Terephthalic acid (TPA) is an organic compound and one of the primary building blocks used in the production of polyethylene terephthalate (PET) and other polyesters. Its chemical formula is $\mathbf{C_6H_4(COOH)_2}$, indicating that it is a dicarboxylic acid with two carboxylic acid groups (-COOH) attached to a benzene ring.
[4] A **biodegradation agent** refers to a substance—usually a microorganism, enzyme, or other biological materials—that aids in the breakdown and decomposition of organic substances into simpler compounds.

ler fragments and ultimately destroys it [6, p. 1, 2, 3]. Our new idea involves the use of quadcopters equipped with microorganisms capable of breaking down plastic and other waste in seas and oceans, particularly near desalination plants. This innovative solution aims to address two critical issues simultaneously: producing clean drinking water and mitigating pollution in marine environments [Figure 2].

The proposed quadcopter will be manufactured using a 3D printer and will include the following components:

- **Frame**: The central body housing electronics and solar panels, along with support arms equipped with motors and propellers.
- **Propeller Guards**: To protect both the propellers and the environment during flight.
- **Camera Mount**: A multifunctional platform for housing microorganisms, launching mechanisms, and optionally a camera or FPV system for monitoring.
- **Battery Holder**: A specialized compartment for securing the power source.
- **Electronic Speed Controllers (ESC)**: For managing motor speeds.
- **Flight Controller**: To oversee the quadcopter's operations and ensure stability.
- **Radio Receiver**: For remote communication and control.
- **GPS Module**: For precise navigation.
- **Sensors**: Including accelerometers, gyroscopes, barometers, and magnetometers to enhance functionality and adaptability.

Fig. 2. “Quadcopters equipped with microorganisms”

For portability and efficiency, the bacteria ***Ideonella sakaiensis 201-F6*** will be deployed via the quadcopter. These bacteria are known for their ability to break down plastic waste effectively. The Caspian Sea, in particular, suffers from significant pollution caused by oil production waste and plastic debris. By utilizing these quadcopters, we aim to clean the Caspian Sea while also supporting sustainable desalination efforts. This dual-purpose approach holds promise for addressing pressing environmental and water scarcity challenges in the region.

Fig. 2. "Tidal power plants"

One method to harness green or blue energy is wave energy, where converters capture the energy contained in ocean waves and convert it into electricity. These converters include oscillating water columns, which trap pockets of air to power a turbine; ***oscillating body converters***[5], which utilize the motion of waves; and ***slab converters***, which exploit differences in height. Wave energy can also be used for the production of drinking water and as a source of green energy. However, ***tidal power*** is a more reliable alternative. As we know, the gravitational forces caused by the moon's movement drive the ebb and flow of the oceans. These systems are affordable to install along coastlines. To implement them, the lowest and highest sea or ocean levels must first be determined. The difference between these levels should be at least 5 meters to generate electricity effectively. There are three main methods for harnessing ***tidal energy***. The first and most suitable for producing drinking water is the tidal barrage. The second is tidal fences, and the third is tidal turbines. Our electronically equipped barges could also utilize tidal power. Wave and tidal energy, derived from oceans and seas, offer significant potential for generating electricity and power. While both are promising sources of renewable energy, tidal energy is more predictable and reliable, whereas wave energy can vary significantly depending on weather conditions. The choice between these two technologies depends on the geographical location and the specific characteristics of the water bodies in question. Tidal power, in particular, is a very predictable method, making it easier to plan for future energy needs. However, since tidal power may not always be sufficient for large-scale desalination, it can be used to partially meet energy demands while complementing other renewable energy sources. *The Caspian Sea*, being the world's largest enclosed inland body of water, experiences minimal tidal fluctuations due to its isolation from the world's oceans. Studies indicate that semidiurnal tides dominate, with typical tidal ranges between 7.7 cm and 21 cm, varying by location [5, p. 1, 2]. The concept involves utilizing a quadcopter that can be charged at tidal power plants [Figure 3]. Once charged, the quadcopter flies over oceans and seas to monitor potential pollution from above. When pollution is detected, it can deploy microorganisms to clean the water by descending closer to the surface. Additionally, *"Compatible LIDAR Sensors"*[6] for quadcopters enable the observation and detection of underwater pollution by measuring the depth of seas and oceans. The *"Ultra-light LI-*

[5] **Oscillating Body Converters** are devices that harness the energy from the motion of oscillating bodies, typically in fluid environments like oceans or seas, to generate power. They are a type of **wave energy converter (WEC)** and are used to convert the kinetic and potential energy from ocean waves or other natural oscillations into mechanical or electrical energy.

[6] **Compatible LIDAR Sensors** refer to LIDAR (Light Detection and Ranging) sensors that can work effectively with specific systems, platforms, or technologies. LIDAR is a remote sensing method that uses laser light to measure distances and create detailed 3D maps of the environment.

DAR sensors"[7] (weighing 590 g) are particularly suitable for shallow water applications. While less powerful than larger systems, they are feasible for drone use. We try to calculate the power gathered by 100 tidal power constructions along Caspian Seas seacoast:

Tidal Power Calculation for the Caspian Sea:

The calculations for the potential annual electricity generation from 100 tidal power plants constructed along the Caspian Sea coast. The calculation is based on typical tidal ranges and standard assumptions.

Constants and Assumptions:

- Density of seawater (ρ): 1025 kg/m³
- Gravitational acceleration (g): 9.81 m/s²
- Tidal basin area per plant (A): 1 km² (1,000,000 m²)
- Efficiency of tidal power plants (η): 80% (0.8)
- Number of tidal cycles per day: 2 (semidiurnal tides)
- Number of tidal cycles per year: 730 (365 days/year × 2 cycles/day)

Tidal Ranges:

- Minimum tidal range (h_min): 7.7 cm (0.077 m)
- Maximum tidal range (h_max): 21 cm (0.21 m)

Formula for Potential Energy:

The potential energy (PE) stored in the tidal basin per cycle is calculated using:

$PE = 0.5 \times \rho \times g \times A \times h^2$

Where:

- ρ: Density of seawater
- g: Gravitational acceleration
- A: Surface area of the tidal basin
- h: Tidal range

Calculations:

1. Potential Energy per cycle (minimum tidal range):

$PE\_min = 0.5 \times 1025 \times 9.81 \times 1{,}000{,}000 \times (0.077)^2$

PE_min = 2.98e+07 Joules

2. Potential Energy per cycle (maximum tidal range):

$PE\_max = 0.5 \times 1025 \times 9.81 \times 1{,}000{,}000 \times (0.21)^2$

PE_max = 2.22e+08 Joules

3. Annual Energy per plant (minimum tidal range):

$E\_annual\_min = \eta \times PE\_min \times 730$

E_annual_min = 1.74e+10 Joules

[7] **Ultra-light LIDAR sensors** are a category of LIDAR (Light Detection and Ranging) sensors that are designed to be extremely lightweight and compact while maintaining their ability to provide accurate, high-resolution measurements. These sensors are ideal for applications where the weight of the sensor is a critical factor, such as in drones, small robotic systems, or portable surveying equipment.

4. Annual Energy per plant (maximum tidal range):
E_annual_max = η × PE_max × 730
E_annual_max = 1.29e+11 Joules

5. Total Annual Energy for 100 plants (minimum tidal range):
E_total_min = E_annual_min × 100
E_total_min = 1.74e+12 Joules (approximately 0.48 GWh)

6. Total Annual Energy for 100 plants (maximum tidal range):
E_total_max = E_annual_max × 100
E_total_max = 1.29e+13 Joules (approximately 3.60 GWh)

The total annual electricity generation from 100 tidal power plants along the Caspian Sea coast ranges between approximately 0.48 GWh (minimum tidal range) and 3.60 GWh (maximum tidal range). This variation depends on the actual tidal range and the efficiency of the power plants. By integrating seawater desalination with green energy technologies, we can address water scarcity sustainably.

Now let's try to calculate how much energy is required to charge one quadcopter, taking into account such tidal power.

1. **Energy Output of a Single Tidal Power Plant**

From the previous calculations:

- **Annual energy per plant (minimum tidal range):** 1.74×10^{10} J
- **Annual energy per plant (maximum tidal range):** 1.29×10^{11} J

Daily energy output:

1. **Daily energy (min)** = $(1.74 \times 10^{10}) / 365 = 4.77 \times 10^{7}$ J (47.7 MJ)
2. **Daily energy (max)** = $(1.29 \times 10^{11}) / 365 = 3.53 \times 10^{8}$ J (353 MJ)

2. Energy Requirements for the Quadcopter
Assumptions:

- **Quadcopter power consumption:** 1000 W (1 kW)
- **Desired flight time:** 1 hour

Energy required for a 1-hour flight:
E_quadcopter = Power × Time = 1000 W × 3600 s = 3.6 MJ

3. Is the Tidal Power Output Enough?
Even at the **minimum tidal range**, a single plant generates **47.7 MJ** daily. Charging the quadcopter for a 1-hour flight (3.6 MJ) would use only a small fraction:
3.6 MJ / 47.7 MJ≈7.5% of the daily output.
Thus, **one tidal power plant is more than enough** to charge a single quadcopter, even at the minimum tidal range.

4. Charging Time
The charging time depends on the power of the charger:

- **Assume** a charging system with a power output of **1 kW**.
- **Energy required:** 3.6 MJ.

Charging time:
Time=Energy / Power=3.6 MJ / 1 kW=3600 s=1 hour
If a faster charger (e.g., 2 kW) is used, the charging time would halve to **30 minutes**.
Conclusion

- **Energy Sufficiency**: A single tidal power plant can support multiple quadcopters, even at the minimum tidal range.
- **Charging Time**: With a 1 kW charger, it takes 1 hour to charge a quadcopter for a 1-hour flight. Faster chargers can reduce this time.

MATERIAL AND METHODS

This study explores innovative desalination methods and technologies designed to mitigate environmental pollution and address global water scarcity. The primary materials and methods employed in this research include a combination of laboratory experiments, field trials, and conceptual models. **Desalination Technology:** Various desalination technologies, including reverse osmosis and solar-powered desalination units, were selected for testing. These systems were chosen for their sustainability potential and efficiency in water purification. **Renewable Energy Solutions:** Transparent energy, a novel energy source derived from solar panels suspended on floating air balloons, was evaluated as the primary power source for the desalination units. The solar panels were fabricated using high-efficiency photovoltaic materials. **Environmental Impact Monitoring Tools:** To assess the environmental effects of the proposed technologies, tools for measuring air quality, water salinity, and energy consumption were deployed. **Laboratory Testing:** The performance of the desalination technologies was assessed in controlled laboratory settings. Variables such as water temperature, salinity, and energy consumption were monitored to evaluate the efficiency of each technology. **Field Trials:** Prototype desalination units powered by transparent energy were deployed in coastal regions for field testing. The trials aimed to simulate real-world conditions and provide data on the system's scalability, energy efficiency, and environmental impact. **Collaborative Analysis:** Engineers and environmental scientists collaborated throughout the study to refine the technologies and ensure their feasibility for large-scale implementation. Data from laboratory and field trials were analyzed using statistical software to determine the effectiveness of the proposed solutions.

RESULTS AND DISCUSSION

Desalination Efficiency: The laboratory testing of various desalination technologies revealed promising results, with reverse osmosis systems showing the highest water purification efficiency under controlled conditions. The energy consumption of these units was significantly reduced when powered by transparent energy, making them a viable option for sustainable water production.
Energy Generation and Sustainability: Transparent energy, harnessed through solar panels suspended on floating air balloons, demonstrated its potential as a continuous, eco-friendly power source. The system's ability to generate electricity at high altitudes, where sunlight exposure is maximized, provided a reliable energy supply for the desalination processes. Field trials confirmed that the transparent energy setup could operate without occupying valuable land space or disrupting marine ecosystems, making it a highly sustainable energy solution.
Environmental Impact: The environmental monitoring tools showed that the proposed desalination and energy generation systems had minimal impact on local ecosystems. No significant changes in water salinity or air quality were detected during the field trials, suggesting that the technologies can be implemented without causing harm to the environment.

Collaborative Approach: The interdisciplinary collaboration between engineers and environmental scientists proved essential in optimizing the technologies. Feedback from field trials was used to refine the systems, ensuring their scalability and efficiency. However, further testing is needed to address potential long-term challenges, such as system durability and the effects of extreme weather conditions on floating solar panels.

Implications for Global Water Scarcity: The combination of advanced desalination methods and transparent energy offers a promising solution to the global water scarcity crisis. By integrating green energy solutions into desalination processes, these technologies could provide a sustainable and cost-effective way to produce potable water while minimizing environmental impacts. However, large-scale implementation will require continued research, investment, and collaboration across multiple sectors.

CONCLUSION

Nature provides us with numerous opportunities to generate energy without polluting the environment, enabling us to protect it from the waste generated by industrial processes. According to scientists, these renewable energy sources can help stabilize energy demand while ensuring a sufficient supply of potable water for the population. In practice, we can even consider "transparent energy" systems, which harness water vapor from the surfaces of seas and oceans. This vapor can be desalinated by cooling, resulting in drinkable water. Moreover, advancements in environmental cleaning technologies, such as quadcopters and microorganisms like *Ideonella sakaiensis 201-F6*, complement efforts to combat pollution. Additionally, leveraging tidal power from ebb and flow offers a cost-effective and environmentally friendly solution for global energy and water challenges.

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SUYUN DUZSUZLAŞDIRILMASINA VƏ TƏMİZLƏNMƏSİNƏ İNNOVATİV YANAŞMALAR: OKEANLARDA VƏ DƏNİZLƏRDƏ ÇİRKLƏNMƏ PROBLEMLƏRİNİN HƏLLİ (XƏZƏR DƏNİZİNİN TİMSALINDA)

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Bu məqalədə iki əsas qlobal problemi həll etmək üçün hazırlanmış bir sıra innovativ metodlar və qabaqcıl texnologiyalar nəzərdən keçirilir: dəniz suyunun duzsuzlaşdırılması və sənaye tullantılarının azaldılması. O, bu aktual problemlərə davamlı həllər təqdim etmək üçün perspektivli strategiyaları və innovativ ideyaları vurğulayır. Bu konsepsiyaların bir çoxu perspektivli olsa da, texniki-iqtisadi əsaslandırma, effektivlik və təhlükəsizliyi təmin etmək üçün ciddi laboratoriya sınaqları və geniş sahə sınaqları tələb olunur. Mühəndislər və ətraf mühit alimləri bu texnologiyaların genişmiqyaslı tətbiqi üçün təkmilləşdirmək üçün sıx əməkdaşlıq etməlidirlər. Bu araşdırmada əsas təklif duzsuzlaşdırma proseslərinin gücləndirilməsi üçün yaşıl enerji həllərinin istifadəsinə yönəlib. Təqdim olunan yeni ideyalar arasında "şəffaf enerji" adlı konsepsiya da var. Bərpa olunan enerjinin bu unikal forması üzən balonlara bərkidilmiş günəş panellərindən istifadə edərək havadan təbii enerjidən istifadə edir. Günəş panellərini günəş işığının ən çox məruz qaldığı yerdən yüksəklikdə asaraq, bu üsul davamlı enerji istehsalına innovativ yanaşmanı təmsil edir. Şəffaf enerji qiymətli torpaq ehtiyatlarını ələ keçirmədən və ya dəniz ekosistemlərini narahat etmədən davamlı, təmiz enerji mənbəyi təmin etmək potensialını təklif edir. Nəhayət, qabaqcıl duzsuzlaşdırma üsulları və innovativ enerji həllərinin bu kombinasiyası ətraf mühitə təsirləri minimuma endirməklə yanaşı, qlobal su çatışmazlığının həllində böyük rol oynaya bilər. Müəlliflərin gələcəyə hesablanmış təklifləri bərpa olunan enerji texnologiyalarının ətraf mühitin mühafizəsi səylərinə inteqrasiyasının vacibliyini vurğulayır, daha dayanıqlı və resurslardan səmərəli gələcəyə yol açır.

Açar sözlər: *Dəniz suyunun duzsuzlaşdırılması, innovativ texnologiyalar, yaşıl enerji, şəffaf enerji*

ИННОВАЦИОННЫЕ ПОДХОДЫ К ОПРЕСНЕНИЮ И ОЧИСТКЕ ВОДЫ: РЕШЕНИЕ ПРОБЛЕМ ЗАГРЯЗНЕНИЯ ОКЕАНОВ И МОРЕЙ (НА ПРИМЕРЕ КАСПИЙСКОГО МОРЯ)

В.С. Абдуллаев, М.В. Алиева

В этой статье рассматривается ряд инновационных методов и передовых технологий, разработанных для решения двух важнейших глобальных проблем: опреснения морской воды и снижения загрязнения окружающей среды промышленными отходами. В ней освещаются перспективные стратегии и новаторские идеи, направленные на устойчивое решение этих насущных проблем. Хотя многие из этих концепций являются многообещающими, они требуют строгих лабораторных испытаний и обширных полевых испытаний для обеспечения осуществимости, эффективности и безопасности. Инженеры и ученые-экологи должны тесно сотрудничать, чтобы усовершенствовать эти технологии для крупномасштабного внедрения. Ключевое предложение в этом исследовании сосредоточено на использовании решений в области зеленой энергии для питания процессов опреснения. Среди представленных новых идей есть концепция, называемая «прозрачной энергией». Эта уникальная форма возобновляемой энергии использует природную энергию из воздуха с помощью солнечных панелей, прикрепленных к плавающим воздушным шарам. Подвешивая солнечные панели высоко над землей, где воздействие солнечного света максимально, этот метод представляет собой инновационный подход к устойчивому производству энергии. Прозрачная энергия предлагает потенциал для обеспечения непрерывного, экологически чистого источника энергии без занятия ценных земельных ресурсов или нарушения морских экосистем. В конечном итоге, это сочетание передовых методов опреснения и инновационных энергетических решений может сыграть важную роль в решении проблемы глобального дефицита воды, одновременно минимизируя воздействие на окружающую среду. Перспективные предложения авторов подчеркивают важность интеграции технологий возобновляемой энергии в усилия по сохранению окружающей среды, прокладывая путь к более устойчивому и ресурсоэффективному будущему.

Ключевые слова: *Опреснение морской воды, инновационные технологии, зеленая энергия, прозрачная энергия*