Аңдатпа
Мақалада цеолиттер мен әртүрлі сүзгі материалдарын пайдалана отырып, табиғи және тұрмыстық ағынды суларды ауыр металдардан тазарту әдістері қарастырылған. Ауыр металдар су ортасының басты ластаушылары болып табылады, сондықтан оларды судан шығару қажеттілігі негізделген. Авторлар цеолиттердің физика-химиялық қасиеттерін, олардың ион алмасу және адсорбциялық сыйымдылықтарын, сондай-ақ белсендірілген көмір сияқты басқа толтыру тиімділігін қарастырады. Ауыр металл иондарын кетіруге арналған негізгі су тазарту технологиялары, соның ішінде сүзу, сіңіру және аралас әдістер талданады. Бұл технологиялардың су өңдеу және сарқынды суларды тазарту жүйелеріндегі қолдану салалары қарастырылады. Әртүрлі сүзгі материалдарының тиімділігінің салыстырмалы талдауы ұсынылған. Су тазарту сапасын жақсарту және су ресурстарының экологиялық қауіпсіздігін қамтамасыз ету мақсатында цеолиттер мен сүзгі орталарын қолдану перспективалары туралы қорытындылар жасалған.
Түйін сөздер: цеолиттер, ауыр металдар, су тазарту, сарқынды сулар, сүзгі материалдары, сорбция, су тазарту.

Использование цеолитов и инновационных природных фильтрующих материалов в технологиях очистки природной и сточной воды

*[1]Д.Ибрагимкызы, [1]Л.М.Утепбергенова, [1]Нуриева Г.А.
[1]Евразийский национальный университет имени Л.Н.Гумилева (Астана, Казахстан)
[2]Азербайджанский университет архитектуры и строительства (Баку, Азербайджан)

Аннотация
В статье рассматриваются методы очистки природных и сточных вод от тяжелых металлов с использованием цеолитов и различных фильтрующих материалов. Дается характеристика тяжелых металлов как приоритетных загрязнителей водной среды и обосновывается необходимость их удаления из воды. Авторы рассматривают физико-химические свойства цеолитов, их ионообменные и сорбционные способности, а также эффективность применения других загрузочных материалов, таких как активированный уголь. Проанализированы основные технологии очистки воды, применяемые для удаления ионов тяжелых металлов, включая фильтрационные, сорбционные и комбинированные методы. Рассмотрены области применения данных технологий в системах водоподготовки и очистки сточных вод. Приводится сравнительный анализ эффективности различных фильтрующих материалов. Сделаны выводы о перспективности использования цеолитов и фильтрующих загрузок для повышения качества очистки воды и обеспечения экологической безопасности водных ресурсов.
Ключевые слова: цеолиты, тяжелые металлы, очистка воды, сточные воды, фильтрующие материалы, сорбция, водоподготовка.

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WATER SCARCITY AND WAYS TO OVERCOME IT IN AFRICA

*[1]E.A.TASHEVA, [1]S.T.TOXANBAYEVA
[1]L.N.Gumilyov Eurasian National University
(Astana, Kazakhstan)
*kallenelis67@gmail.com, toxanbayeva_st_1@enu.kz

Abstract
Water is the main source of life. Consequently, water scarcity leads to critical indicators in socio-economic aspects, the ecological situation and deterioration in public health. Water scarcity in developing countries in Africa is the result of natural factors, management issues, socioeconomic causes. The main area of water deficit is located in the arid and semi-arid (ASALs) zones of developing countries in Africa. For the sustainable

development goals in developing countries, water resources are key to achieving the causal pathways of water stress in Africa. The solution to the problem of water scarcity lies in effective water resources management based on a program to increase literacy in the field of water use, the introduction of water–saving technologies and investment decisions. Achievements in combating water deficit contribute to poverty reduction (SDG 1), the elimination of hunger (SDG 2), the protection of health (SDG 3), and the preservation of aquatic and terrestrial ecosystems (SDG 14 and 15). The article reviews the factors contributing to water scarcity and possible ways to resolve this problem. Economic growth in developing African countries is currently unstable, and water policy is weak. In this condition, water stress in Africa is influenced by both physical structures and management strategies.
Keywords: water scarcity, Africa, ASAL, water management program, investment decision.

Introduction

The article is the relevant for all of Africa. Arid and Semi-arid areas are located all over Africa. They constitute about 40% of the earth's surface and 66% of the total territory of Africa. The population living in these areas is approximately 200 million people [Okello C. et al., 2024]. These regions are characterized by low precipitation, high evaporation, and aridity. Population growth, inefficient water use, and water pollution have a significant impact on water scarcity. As a result, the health of population and the socio-economic sphere are deteriorating. The subject of this scientific article is relevant since water scarcity is not only an environmental problem but also a socio-economic one.

The scientific significance of the work includes an analysis of the problem, considering water scarcity comprehensively. The literature review used Web of Science, Scopus, and Elsiver, KKSON as they include contemporary research and represent scientific value. The results of the research are relevant to effective water management, scientific interests, the development of water literacy, and the creation of scientific publications.

The aim of the study is to reveal the problem of water scarcity in developing African countries, explore possible ways to solve it, and present an individual approach to resolving this problem.

Main body

This topic was chosen because of the relevance of water scarcity issues in Africa. In addition, there are practically no studies related to this topic in Kazakhstan. Existing studies are mainly focused on Central Asia. There are few studies that address the economic aspects of this topic. For example, there is an article by Kamaldzhanova T.A. entitled "The Contribution of the Analysis of Sustainable Sources of Funds to the Understanding of Poverty in the Developing World," which is published in the KKSON RK. Thus, this study fills a gap in the understanding of the global water problem and the analysis of water shortages in Africa. The data presented was dominated by institutional and governance issues. Many sources point to weak institutions, ineffective governance, and weak political will as factors hindering effective water management. The absence or inadequacy of legal and institutional frameworks, as well as a lack of coordination between sectors and regions, have hindered the adoption of comprehensive measures. In South Africa, in particular, the gap between the intentions enshrined in the National Water Resources Act and their actual implementation has caused a serious management failure. Market inefficiencies, high transaction costs, and weak competitive structures further complicated the allocation of water resources. Overall, the most appropriate solution is to improve water literacy. This strategic step should be reflected in both institutional and political matters.

It is necessary to expand effective practices for the implementation and updating of water collection technologies. In terms of policy, attention should be paid to attracting investment to the market. At present, technological solutions are at the stage of development, planning, and expansion. Climate sustainability projects are underway. Overall, the water literacy program should include: rational use and conservation of water; treatment and reuse of wastewater; raising awareness of water resource management among the population and politicians; integration into educational programs.

Literature review

Water scarcity in Africa and the impact of the problem

Water scarcity remains a critical challenge in Africa. As of 2022, approximately 400 million people in sub-Saharan Africa still lacked access to basic water supply services, and safely managed sanitation services only covered a small part of the population. The region faces serious constraints in water resources due to inadequate infrastructure, poor governance, and insufficient financial resources and incentives [Jin S. et al., 2025].

Basically, water scarcity is a complicated issue. There are lots of different reasons for it, and it's made even more difficult by competition and the way different sectors have to make trade-offs. The complexity of the risks specific to each sector affected by water scarcity, as seen most clearly in the water-energy-food nexus, can create 'wicked' problems that make trade-offs ineffective for planning responses. Increased competition for water from agriculture, fishing, tourism, energy, and industry, for example, is being experienced and livelihoods systems across Africa are being threatened. These challenges are likely to increase as demands for domestic, industrial and agricultural water are expected to rise sharply by up to 40% within the next decade [Leal Filho W. et al., 2022].

Obviously, competition for limited water resources in ASALs often leads to social and economic tensions. Communities and sectors such as agriculture, industry and domestic users compete for access to this scarce resource, sometimes resulting in conflict exacerbated by the abstraction and diversion of waterways.

Furthermore, the overuse and contamination of dwindling water sources can lead to a deterioration in water quality in these regions, posing significant health risks as populations rely on these compromised water sources for drinking, cooking, and sanitation.

This makes effective water management strategies critical, involving both local adaptations and broader policy implementations. Such strategies must include enhancing water use efficiency in agriculture, investing in water reclamation technology, and implementing strict water pollution regulations to ensure the available water meets the needs of people and ecosystems.

The sustainable management of water resources, as advocated by SDG 6, is therefore crucial and must encompass modern practices and traditional water conservation techniques. Consequently, water scarcity in ASALs is a prevalent and pivotal challenge that extends its repercussions beyond mere ecological disruptions to profound societal ramifications.

This is due to the fact that the freshwater available is often inadequate to meet human and environmental needs. The impact of water scarcity is pervasive, encompassing all facets of life, including agriculture and food production, as well as fundamental human needs. The ongoing presence of arid conditions has been demonstrated to intensify the aforementioned challenges, as water resources become increasingly strained or diminished. For instance, the predominant reliance on rain-fed agriculture in ASALs renders these systems particularly vulnerable to fluctuations in water availability, frequently giving rise to crop failures, livestock loss and a marked decline in food security. It is evident that such agricultural vulnerabilities have the potential to exacerbate malnutrition and deepen poverty. This emphasises the critical importance of sustainable water resource management.

Crop failures are becoming increasingly prevalent due to insufficient irrigation, resulting in diminished food security and elevated prices, particularly impacting the most vulnerable demographics. Competition for limited water resources in ASALs often leads to social and economic tensions. Communities and sectors such as agriculture, industry and domestic users compete for access to this scarce resource, sometimes resulting in conflict exacerbated by the abstraction and diversion of waterways. Furthermore, the overuse and contamination of dwindling water sources can lead to a deterioration in water quality in these regions, posing significant health risks as populations rely on these compromised water sources for drinking, cooking, and sanitation.

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Climate

The biggest impacts of climate change in southern Africa are on water resources. This is causing water supplies to be limited, and people to have to share less water and food. Water insecurity poses the greatest threat to the region's ability to meet its developmental targets and achieve the 2030 Global Agenda for Sustainable Development. Anticipated decreases of around 20% in annual precipitation in southern Africa by 2080 will reduce water resources and cause problems with hydropower generation and crop production.

Across the African continent, meteorological drought typologies manifest marked spatial variability, shaped by regional climatic patterns. In the northern part of the continent, particularly in the desert and semi-arid regions of the Sahara, prolonged droughts are commonplace, characterised by low levels of precipitation throughout the year. Droughts in the Sahel are both seasonal and interannual. The Sahel is in western Africa. Climate variability strongly influences these droughts. In contrast, occasional droughts, which are generally associated with anomalies in precipitation patterns, affect Central Africa, with its predominantly equatorial climate. The Horn of Africa is considered to be one of the most vulnerable regions on the continent, where recurrent and long-lasting droughts are experienced, reflecting the high irregularity of seasonal rainfall. In southern Africa, droughts tend to be seasonal or interannual, influenced by climate teleconnections. Conversely, in Eastern Africa, particularly in the highlands, droughts are seasonal and intermittent, closely tied to monsoon variability and regional atmospheric circulation [Pena-Angulo D. et al., 2025].

Water management

The world is facing increasing water scarcity. This has created a need for an appropriate WWT. This should be based on a circular economy (CE). This would be an improvement on the current linear treatment system. The latter is based on disposal for sustainability. This is the way to achieve sustainability. Adequate management of water resources and sustainable development (SD) are crucial to transforming the traditional system into sustainable, closed-loop wastewater management (WWM). The growing global demand for clean, safe and affordable drinking water has made adequate wastewater management (WWM) and recycling essential in order to mitigate environmental pollution and prevent the projected water crisis.

When WW is properly treated, it can be used for consumption and a variety of other purposes. Therefore, appropriate regulations must be put in place for water recovery. In countries such as North America and Australia, laws and regulations for WW assessment and remediation have already been developed [Onua M.A. et al., 2023]. At the same time, fifteen of the region's major river basins are considered to be transboundary, and a water resources dependency ratio of over 50% is observed in five countries, meaning that more than half of their total water requirements are met by water originating from outside their political boundaries. As well as water resources being spread out unevenly across southern Africa, the amount of water that falls as rain each year (MAP) is the lowest in the world compared to the amount of water that flows into rivers and streams each year (MAR) [Matchaya G. et al., 2019].

In such cases hydrological modelling can provide a system to address this knowledge gap. Through simulating water resource dynamics, hydrological modelling can inform our understanding of current water resources. It can also help us to forecast future hydrological scenarios [Hinton R., et al., 2025]. At the same time, geographic and climatic contexts explain substantial variation in solution appropriateness. Desalination emerges as a proposed solution for specific African countries projected

to face severe water scarcity by 2050, including Uganda, Burundi, Nigeria, Somalia, Malawi, Eritrea, Ethiopia, Tanzania, Niger, Zimbabwe, and Sudan, which currently lack desalination infrastructure. Analysis of sources has shown the relevance of the water problem in Africa, while institutional solutions, management approaches, and climate adaptation measures remain insufficiently studied [Dhakal N. et al., 2022].

Social factor and water market

Recent estimates suggest that 10% of the world's population lives on less than $1.90 per day. Many countries in Africa, India and Mexico are below the poverty line. There is now a greater recognition that attention must be paid to the various factors and processes that either limit or enhance the ability of poor people to earn a living in an economically, environmentally and socially sustainable manner. The concept of sustainable living provides a consistent and comprehensive approach to tackling poverty. It should be noted that water scarcity in developing African countries is not only an environmental problem, but also a factor that exacerbates poverty and reduces the quality of life of the population. Sustainable means of subsistence include natural, human, physical, and social capital. Water is a natural resource that is essential for humanity [Kamaljanova T.A., 2019].

The map shows (see Figures 1-3) how much money African countries spend on water in three different ways. It shows the total amount spent in US dollars. It also shows how much this spending is compared to the total amount of money spent by the government. And it shows how much this spending is compared to the total amount of money the country makes. This helps us to see how money for water is used in developing countries on the continent and to check if the budget is right for the amount of water shortages and climate problems there are.

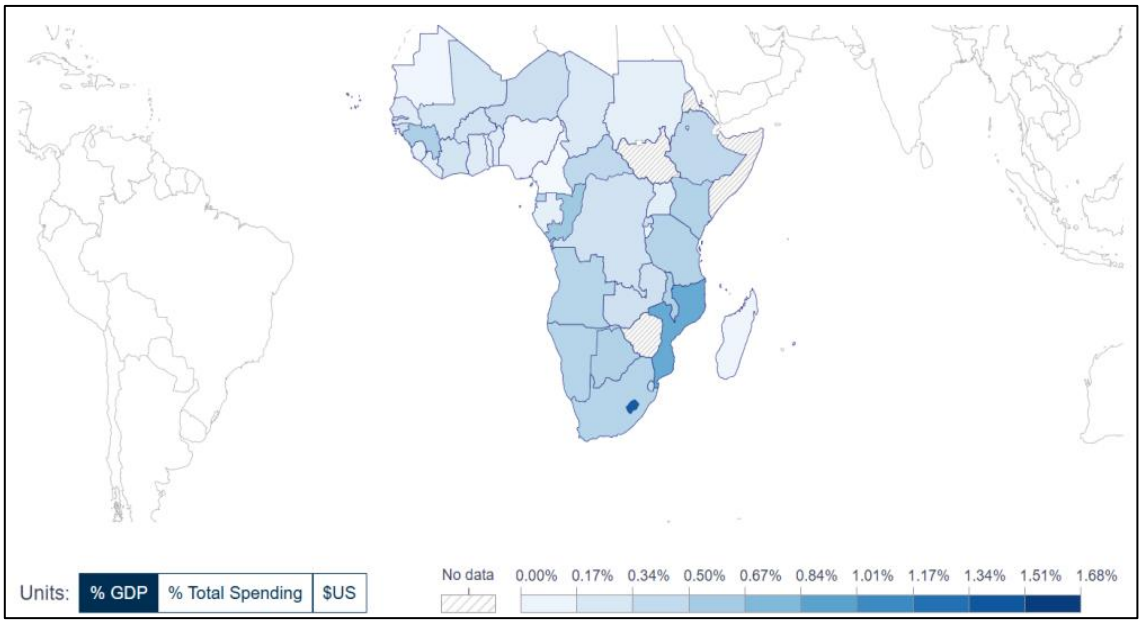

Figure 1. Estimated Annual Spending in the Water Sector (2017 USD) in Sub-Saharan Africa, shows in GDP (%)

The distribution of spending in absolute terms shows an extremely unequal picture, with significant differences between the haves and the have-nots. In most countries, low levels of investment in the water sector are seen, with only a limited number of countries with relatively larger economies generating significant volumes of investment. This shows that even when there is an objective need to develop water supply, irrigation and sanitation infrastructure, state financial capabilities are significantly limited. Another sign of problems in institutions is the presence of countries with missing or incomplete data.

This may show that budget accounting systems are weak, management is not open enough, and planning is done in a way that doesn't work well. A thorough examination of the percentage of

government expenditure represented by the water sector reveals that in the majority of African countries, this metric shows considerable stability and rarely achieves levels that would suggest that the sector is a priority. Even in countries with a higher percentage of spending on water resources, it should be noted that this percentage is within the context of an overall limited budget. Therefore, an increased share of the water sector does not necessarily mean the sector receives the necessary funding; it often shows the need to divide limited resources between competing socio-economic areas.

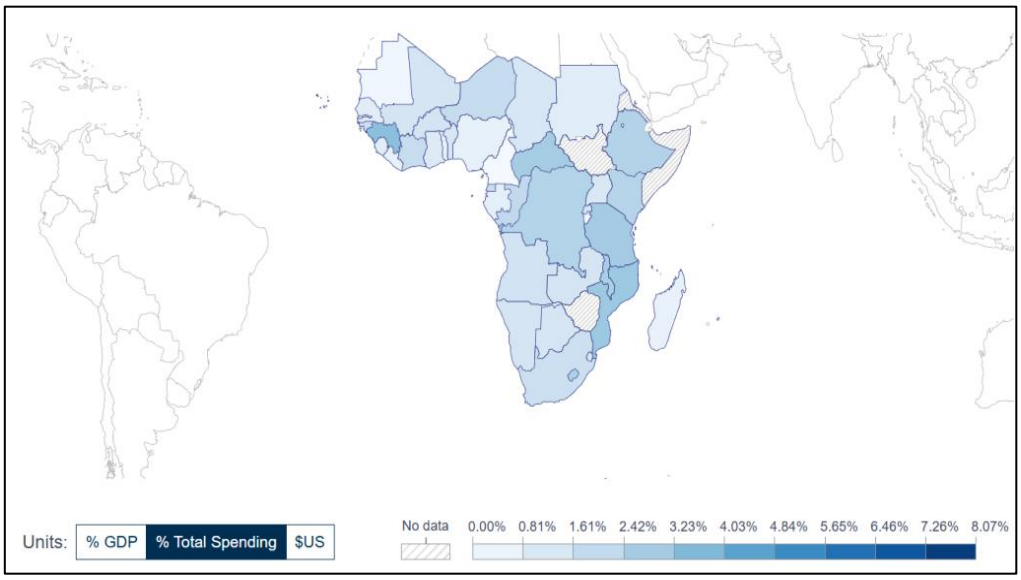

Figure 2. Estimated Annual Spending in the Water Sector (2017 USD) in Sub-Saharan Africa, shows in Total spending (%)

It is very important to look at how much money is spent on water compared to the size of the economy. This helps us understand how important it is to invest in water and how much it costs. In most countries under review, expenditure on the water sector continues to represent less than 1% of GDP, indicating systemic shortages of investment in the sector. Even in countries that have more, this number is still small compared to how much infrastructure is needed, how many people are growing, and how much climate change is affecting things. Low levels of spending are made worse by moderate or low shares in state budgets and GDP, creating a situation where there is often a lack of investment. This limits the chances to update water infrastructure, get more people access to clean water and toilets, and deal with climate change.

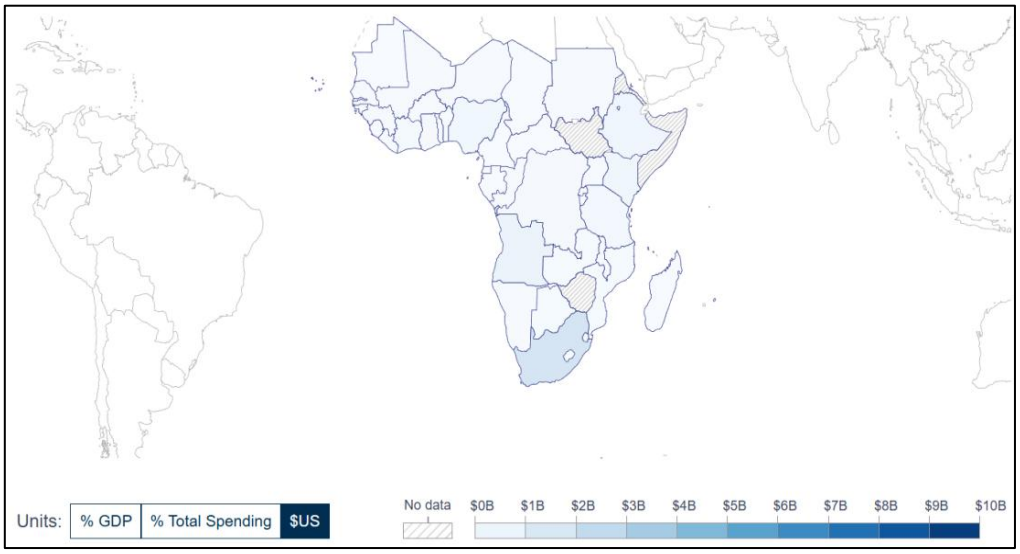

Figure 3. Estimated Annual Spending in the Water Sector (2017 USD) in Sub-Saharan Africa, shows in $US

The current situation is mostly because of limited money available in the country, a lot of reliance on help from other countries, problems with how things are run, and competition from other important areas for development, like healthcare, education, and making sure everyone has enough food. So, looking at map data shows that in most African countries that are still developing, there is not enough money for water, in general and compared to other things. This creates long-term risks to sustainable social and economic development, increases danger of droughts and water shortages, and makes it harder to achieve international sustainable development goals, particularly Sustainable Development Goal 6, which is all about making sure everyone has access to water and sanitation [Joseph G. et al., 2024].

Methodology and methods

The study uses a methodology for analyzing scientific literature on the topic. The main method is a literature review and a search for scientific sources in international databases such as Scopus, Web of Science, and Elsevier. The analysis mainly includes data from the last five years. A review of the climate and landscape, water scarcity, and all aspects of the impact of water resources was conducted. Issues related to the application of SDG solutions to water were studied. Based on the literature database, the socio-economic component and causal relationships were examined. To illustrate the distribution of water scarcity across Africa, a map of water scarcity indicators was created using ArcGIS software based on data from the World Bank.

Results and discussion

The results obtained contribute to the achievement of SDGs, namely SDGs 1, 2, 3, 14, and 15. As a result, the study presents individual possible solutions for combating water scarcity.

The study revealed the following:
1. Causes of water scarcity and its consequences
2. The climatic nature of the territory and drought
3. Accessibility and financial factors, social factors affecting the water market
4. Strategic steps for water resource management
5. Possible solutions to the problem of water scarcity.

The results obtained largely confirm that there is a water shortage in Africa. Most studies agree that the causes of water shortages are inefficient water resource management, climate patterns, and pollution. With the growing demand for safe, clean drinking water, there is a need for wastewater treatment. Competition for water does not improve this situation. Based on all of the above, the authors propose solutions involving the implementation of broad policies, effective management, and investment in technology. However, social issues have been little studied. Opportunities for improving institutional infrastructure remain open.

Conclusion

The research allows us to make the following conclusions. Firstly, water scarcity in Africa is a widespread problem that has socio-economic and environmental consequences. Secondly, there is an urgent need to satisfy human needs and address hunger and poverty. The research also indicated that more attention should be paid to water resource management and improving the institutional framework. Investment needs to be increased and attracted. To ensure literacy, a water literacy program should be implemented, which can be presented in both the educational and political spheres. This program aims to improve the efficiency of water resource management and educate the population about water literacy, distribution, and reducing internal competition for water. Climatic characteristics also play a significant role in this issue. This leads to the need to make decisions regarding climate change and technology upgrades. In all contexts, strengthening institutional capacity is becoming a prerequisite for sustainable solutions.
This requires solutions to access issues, a balance between water supply and social objectives, and international financial support. The establishment of sound governance structures, legal frameworks, and capacity-building mechanisms allows for both the introduction of technologies and community-

level management. Coordination between sectors and regions, synchronization of national strategies with regional efforts, and cooperation with multiple stakeholders create an opportunity for a variety of solutions. Without resolving fundamental institutional and governance challenges, including weak law enforcement, gaps in policy implementation, and limited political will, even well-designed technical solutions face challenges in implementation that prevent the realization of potential impacts.

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Дефицит водных ресурсов и пути его преодоления в Африке

*[1]*Е.А.Ташева,* [1]*С.Т.Токсанбаева*
[1]*Евразийский национальный университет имени Л.Н.Гумилева (Астана, Казахстан)*

Аннотация
Вода является основным источником жизни. Следовательно, дефицит водных ресурсов приводит к критическим последствиям в социально-экономической сфере, ухудшению экологической обстановки и состояния общественного здоровья. Нехватка воды в развивающихся странах Африки обусловлена совокупностью природных факторов, проблем управления и социально-экономических причин. Основные зоны водного дефицита сосредоточены в аридных и семиаридных районах (ASALs) развивающихся стран Африки. Для достижения целей устойчивого развития в развивающихся странах водные ресурсы являются ключевым фактором в формировании причинно-следственных механизмов водного стресса в Африке. Решение проблемы дефицита воды заключается в эффективном управлении водными ресурсами, основанном на реализации программ повышения грамотности в сфере водопользования, внедрении водосберегающих технологий и принятии инвестиционных решений. Достижения в борьбе с водным дефицитом способствуют сокращению бедности (ЦУР 1), ликвидации голода (ЦУР 2), защите здоровья населения (ЦУР 3), а также сохранению водных и наземных экосистем (ЦУР 14 и 15). В статье рассматриваются факторы, способствующие дефициту водных ресурсов, и возможные пути решения данной проблемы. Экономический рост в развивающихся странах Африки в настоящее время носит нестабильный характер, а водная политика остается недостаточно эффективной. В этих условиях водный стресс в Африке определяется как физическими факторами, так и стратегиями управления водными ресурсами.
Ключевые слова: дефицит водных ресурсов, Африка, аридные и семиаридные районы (ASAL), программа управления водными ресурсами, инвестиционные решения.

Африкадағы су тапшылығы және оны жеңу жолдары

*[1]*Е.А.Ташева,* [1]*С.Т.Токсанбаева*
[1]*Л.Н.Гумилев атындағы Еуразия ұлттық университеті (Астана, Қазақстан)*

Аңдатпа
Су өмірдің негізгі көзі болып табылады. Демек, су ресурстарының тапшылығы әлеуметтік-экономикалық салада ауыр зардаптарға,экологиялық жағдайдың нашарлауына және қоғамдық денсаулық жағдайына әкеледі. Африканың дамушы елдеріндегі судың жетіспеушілігі табиғи факторлардың, басқару проблемаларының және әлеуметтік-экономикалық себептердің жиынтығына байланысты. Су тапшылығының негізгі аймақтары Африканың дамушы елдерінің құрғақ және семиаридті аймақтарында (ASALs) шоғырланған. Су тапшылығының себеп-салдарлық механизмдері Африка елдерінде тұрақты даму мақсаттарына қол жеткізудің негізгі факторы болып табылады. Су тапшылығы мәселесін шешу үшін, су пайдалану саласындағы сауаттылықты арттыру бағдарламаларын іске асыру, су үнемдеу технологияларын енгізуге және инвестициялық шешімдер қабылдауға негізделген су ресурстарын тиімді басқарудан тұрады. Су тапшылығымен күрестегі жетістіктер кедейлікті азайтуға (ТДМ 1), аштықты жоюға (ТДМ 2), халықтың денсаулығын қорғауға (ТДМ 3), сондай-ақ су және құрлық экожүйелерін сақтауға (ТДМ 14 және 15) ықпал етеді. Мақалада су тапшылығына ықпал ететін факторлар және осы мәселені шешудің мүмкін жолдары қарастырылады. Қазіргі уақытта Африканың дамушы елдеріндегі экономикалық өсу тұрақсыз, ал су саясаты жеткіліксіз болып қала береді. Мұндай жағдайларда Африкадағы су стрессі физикалық факторлармен де, суды басқару стратегияларымен де анықталады.
Түйін сөздер: су тапшылығы, Африка, аридті және семиаридті аудандар (ASAL), суды басқару бағдарламасы, инвестициялық шешімдер.

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