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Innovative Eco-sink Technology for Efficient Water Management in Household Settings

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Abstract. This paper presents an innovative author's technology that aims to address the issue of inefficient water usage in modern cities and towns. The study focuses on developing an eco-sink, which incorporates a mechanical lever to control the water flow and direct it to a reservoir for future use. The project's primary objectives include prioritizing long-term solutions, promoting climate resilience and adaptation, engaging the private sector and other stakeholders, and enhancing environmental education. The project utilizes various research methods, including surveys, data comparison, engineering-constructive analysis, biochemical water testing, and experimental implementation. Through these methods, the research team identifies the problem of water wastage, analyzes statistical data, determines optimal design solutions, assesses water composition and quality, and evaluates the effectiveness of the eco-sink in real-life applications. The envisaged outcomes of the project include improved water and land productivity, efficient water usage, increased adoption of water-saving systems by users, development of novel water management models and tools, and the potential for generating profits. The successful implementation and adoption of the eco-sink technology can contribute to sustainable water resource management in households, thereby mitigating the environmental impact and promoting a more resilient and eco-conscious society.

Keywords: Eco-sink, water management, efficiency, innovation, household, sustainability.

INTRODUCTION

Water is a natural resource necessary for the life and activity of the population, the economy, and especially for agricultural producers, as well as for maintaining ecological balance [1]. Providing a sustainable water supply is one of the most prominent challenges of the 21st century, as global water demand is escalating faster than the existing water supply can accommodate due to population growth, climate change, and urbanization [2]; [3]. The residents of modern cities have grown accustomed to having a constant water supply; however, wastage amidst this seeming abundance is a growing concern [4]. While uses such as irrigation and power generation form the mainstay of water utilization in developed nations, conserving water at the household level continues to be crucial for the sustainability of the planet's freshwater reserves. For instance, nearly 10% of fresh water usage in the US is attributed to households [5]. Every person in the UK consumes around 142 liters of water daily, with an average household's daily consumption standing at 349 liters [6].

The main institutional problem of water management in Turkmenistan, as in the rest of Central Asia, is the need for effective use of water by water consumers (primarily by agricultural producers and the population), individuals, and organizations responsible for water infrastructure [1]. Water wastage in day-to-day household activities is a critical yet often overlooked issue. Modern environmental problems are associated with accumulating a large amount of water waste (washing vegetables, fruits, various grains, etc.). Statistical findings suggest that an individual consumes approximately 243 liters [7] of water daily, with more than 8 liters being used inefficiently [8]. For instance, it's stated that each person effectively consumes 3496 liters of water daily through food production, and an additional 10% of household water usage goes towards food preparation, notably half of which gets wasted [9]. Over a year, a family of five might consume up to 451,05 m^3 of water, highlighting the scale of the water waste problem [7]. Against this backdrop, innovative solutions become increasingly vital. This article introduces the "Eco-Sink" project, an innovative eco-business seeking to provide a sustainable intervention in the water consumption

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landscape. This project seeks to transform inefficient day-to-day water usage through innovative design, utilizing a mechanical lever control to optimize water flow and conserve water within a household setting.

The primary objectives of this project encompass increasing the productivity of water and land, encouraging rational water use, stimulating the adoption of water-saving systems by urban residents, developing and testing novel models for water control, and the possibility of profit generation.

In subsequent sections of this article, we will detail the implementation strategies, projected outcomes, and potential implications of the Eco-Sink initiative. In addressing the issue of water wastage in daily life, the Eco-Sink project provides a promising case study of how innovation can support more sustainable urban water management.

METHODS AND MATERIALS

Identifying the problem. Study protocol

The study aims to identify the problem of inefficient water usage among various populations, such as residents of cities, villages, hotels, and public institutions. This involves understanding the factors contributing to inefficient water usage and its impact on water resources. This systematic review study was carried out to determine the efficacy of wastewater treatment systems by searching all articles published in English-language, Russian-language, and Turkmen-language Journals of Environmental Health [2-5, 8]. The data were collected by referring to the specialized site of each journal from the beginning of 2016 to the latest issue of 2021.

Gathering opinions and suggestions

Through interviews and surveys, the study seeks to gather the opinions and suggestions of participants, specifically students from the S. A. Niyazov Turkmen Agricultural University. Surveys were conducted among selected students to assess the level of water wastage, the awareness of water conservation, and the potential acceptance of the eco-sink. A systematic approach was taken to gather and analyze this data. This helps in understanding the perspectives of individuals directly affected by the issue and can provide valuable insights and innovative proposals.

Data analysis and comparison. Search strategy. Inclusion criteria

The study compares the statistical data obtained from international sources with the data collected from the student survey. Historical data from national water companies and municipalities were also compiled and analyzed to understand the issue of water wastage further. This analysis helps understand the broader context of inefficient water usage and provides a basis for making informed decisions and recommendations. Inquired information was collected from the Scientific Journals by searching for keywords on the sites. Keywords included: 'waste water' OR 'wastewater' OR 'wastewater treatment' OR 'effluent' OR 'sewage' OR 'sewage treatment' OR 'sewage disposal' OR 'wastewater disposal' AND 'treat'. A manual search was performed by checking all published articles. Inclusion criteria for this study included the year of publication, type of wastewater samples (municipal wastewater, domestic wastewater, hospital wastewater), and number of samples (more than 5 wastewater samples) [10].

Consultation with stakeholders

The study involves consultation with a local entrepreneur involved in ceramic production to gain insights into the industry and explore potential solutions. This collaboration helps consider practical aspects and realistic approaches to addressing the problem.

Engineering and design. Engineering-Constructive Analysis

Engineering students conduct studies and utilize software programs like AutoCAD, SolidWorks, and ThinkDesign to develop various design options for the "Eco-Sink." A technical drawing tool was used to develop a blueprint for the eco-sink. The design was then analyzed for potential efficiencies and improvements. The objective is to identify the most optimal design that meets project requirements and can effectively contribute to water conservation efforts.

Biochemical analysis

The study involves analyzing water's biological and chemical composition in the sewage system and reservoirs after usage. Water samples were collected from the eco-sink reservoir and regular sinks for comparison. These samples were then subjected to biochemical analysis to ensure the safety and quality of the conserved water. This analysis helps understand the water's quality and characteristics and suitability for secondary use [Table 2].

Experimental implementation

The study implements a pilot "Eco-Sink" prototype in student dormitories for experimentation and evaluation. The eco-sink was installed and used in a real-life setting. Usage data like the volume of water saved, frequency of use, and mechanical durability were collected and analyzed. This allows for assessing the technology's implementation, functionality, and potential challenges. The findings from this experimentation phase will inform improvements and refinements to the technology.

Overall, the purposes and tasks of the study revolve around understanding the problem of inefficient water usage, gathering opinions and data, conducting analysis and design, and implementing experiments to develop and test the "Eco-Sink" technology as a potential solution. The entire procedure ensured a scientific experimental design, which combined technical and societal parameters to thoroughly validate the eco-sink technology.

RESULTS AND DISCUSSION

Based on the analysis of water consumption patterns throughout the day (table 1 [8]), it has been observed that a specific proportion of water (approximately 3%) is allocated for various washing activities. These activities include hand hygiene practices, such as using running water to cleanse hands and eliminate potential dirt and harmful microorganisms. Additionally, the act of refreshing oneself or removing perspiration from the face is accomplished by applying water. Furthermore, the process of rinsing fruits and vegetables to eliminate impurities, debris, and contaminants utilizes running tap water. Dishwashing procedures involve employing water to eradicate food particles from dishware, cutlery, and utensils before their placement in a dishwasher. Wetting sponges or cloths is facilitated by using tap water to create an appropriately dampened state for these cleaning implements. Likewise, the swift rinsing of utensils, including knives, forks, and spoons, transpires under running water to eliminate residual residue. Delicate glassware, such as drinking glasses, cups, and other vessels, is subjected to rinsing with running water to ensure the removal of any remaining residues or impurities. These activities exemplify the multifaceted uses of tap water in household washing practices.

TABLE 1. Indoor household use by fixture based on large study involving more than 23,000 homes in North America.

Usage	Volume%
Toilet flush	24%
Shower	20%
Dishwasher	2%
Washing machine	16%
Faucet (general usage)	20%
Bath	3%
Leak	12%
Other	3%

* Table 1 presents data on indoor household water consumption by fixture, derived from a comprehensive study conducted in North America that involved over 23,000 homes [11]. It's important to note that the statistics and figures in the report are influenced by regional factors, making them not entirely representative of all Western countries or the entirety of Central Asia. However, the relative distribution of indoor water usage in terms of percentages is unlikely to vary significantly.

Based on the findings derived from this study, the potential for water reuse becomes evident, as individuals commonly wash vegetables and fruits, hands, faces, etc., under regular running water, avoiding the use of chemical agents. The primary objective of this research initiative is to promote water conservation and recycling practices, thereby facilitating sustainable lifestyles for consumers while mitigating the depletion of water resources.

Consequently, a project that aligns with these objectives has been developed, namely the "Eco-Sink" project. An "Eco-sink" refers to a sink or a household fixture that is designed with sustainability and environmental considerations in mind. It typically incorporates various features and technologies to reduce water consumption, minimize waste, and promote efficient resource usage. The main objective of an eco-sink is to provide an eco-friendly alternative to traditional sinks, to conserve water and energy and reduce the overall environmental impact associated with daily activities such as washing dishes, washing hands, or performing other household tasks.

This innovative endeavor aims to segregate water contaminated with pesticides (if one washes vegetables, fruits, or greens) from water contaminated with chemical substances (soap, detergents, cleaning products, etc.). The core concept of this project involves incorporating modifications to the design of household sinks, both internally and externally (Figure 2, Figure 3). One notable feature is the integration of a mechanical lever that governs a special flap of the water control mechanism. After a thorough evaluation of multiple design options, it has been determined that the following model serves as the most suitable choice:

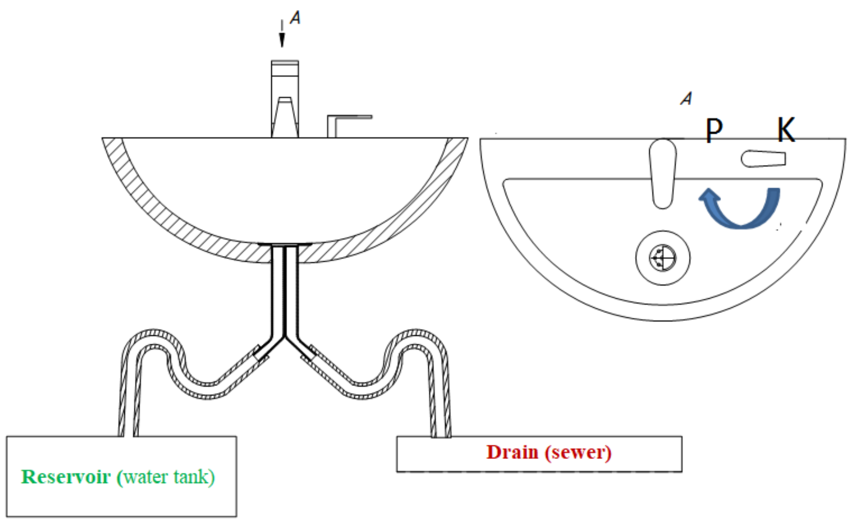

FIGURE 1. Eco-sink scheme.

Figure 1 elucidates the process whereby "uncontaminated" water is directed towards water collection devices (reservoirs) through a leftward rotation of the mechanical lever. Correspondingly, the clockwise movement of the mechanical lever facilitates the disposal of water adulterated with chemical substances into the drain (sewer).

FIGURE 2. 3D model of exterior of eco-sink.

The functionality of this sink design has been substantiated by empirical investigations, positioning it as an economically sound, user-convenient, and facile product. Notably, the absence of supplementary costs and dependence on additional electrical equipment heightens its practicality [12]. Moreover, this sink design caters to diverse functionalities. Thus, we assert that the implementation of this project is poised to be unchallenging and yield considerable advantages from a financial and environmental perspective. Additionally, significant savings in water costs are anticipated upon implementing this technology.

The conceptualized sink exhibits profitability, practicality, and operational ease, deriving from its inherent design that eradicates superfluous expenses and the need for supplementary electrical apparatus. Furthermore, the sink boasts a multifunctional nature, enhancing its versatility and utility in diverse contexts.

FIGURE 3. Eco-Sink Interior Design System.

Implementing this sink in daily life is anticipated to be seamless, accompanied by significant financial gains and positive environmental implications. The integration of this technology empowers consumers to not only optimize their water consumption but also economize their water-related expenditures, resulting in considerable cost savings.

The magnitude of the reservoir may fluctuate, contingent upon the preferences and requirements of prospective buyers. For instances where the incorporation of the "eco-sink" is intended within household premises encompassing a designated area, opting for a reservoir with a volumetric capacity of 1500 liters is recommended. This selection rationale is predicated on the expansive nature of the terrain, thereby enabling flexible placement possibilities within the property. Additionally, the augmented demand for water, such as irrigation purposes for garden cultivation, supersedes typical apartment settings [13].

Conversely, in scenarios where the implementation of the "eco-sink" is envisioned within multi-story residential structures, a reservoir with a capacity ranging from 100 to 200 liters is deemed appropriate. This calculated volume suffices to cater to the everyday water requirements within apartment units.

Assessing the suitability of water from a reservoir post-eco-sink treatment for everyday use raises a significant concern. To address this matter comprehensively, a biochemical analysis was conducted on a water sample withdrawn from the reservoir after a storage duration of two days. This analysis was performed in collaboration with the Central Production Laboratory "Turkmengeologiya" State Concern, renowned for its expertise in water quality assessment. A comprehensive account of the analysis outcomes is presented in Table 2.

Delving into the findings depicted in Table 2, it becomes evident that all key water indicators fall within acceptable ranges. Consequently, the water from the reservoir exhibits a profile akin to that of regular tap water, with insignificant variations in certain indicators that remain well within the permissible limits for domestic usage. By adhering to these established standards, it becomes conceivable to employ this water resource for many economic purposes, particularly those about horticulture and gardening [14].

For instance, the stored water may be utilized effectively for vegetable garden irrigation and the watering of domestic plants. This technology garners significant advantages and cost-effectiveness, particularly for individuals residing in suburban areas actively engaged in gardening activities. In addition to promoting judicious water consumption and eco-protection, this practice facilitates substantial savings in terms of expenditure on water for irrigation purposes [14].

Moreover, the potential applications of stored water after filtration are broad and diverse. They encompass activities encompassing washing floors and windows, vehicles, and personal care tasks such as showering, hand and face rinsing. Furthermore, this resource may be used for toilet flushing, clothes laundering, and even drip irrigation for gardening purposes. Consequently, implementing this eco-sink technology underpins prudent water consumption and eco-protection endeavors and fosters substantial savings for users engaging in horticultural practices.

The biochemical analysis conducted on the water sample retrieved from the reservoir substantiates its viability for everyday purposes. Consequently, the outcomes highlight the potential benefits of employing this treated water, especially concerning conservation efforts and cost-effectiveness. Further research could focus on evaluating the long-term effects of using stored water from an eco-sink for everyday tasks and explore how this practice contributes to overall sustainability.

TABLE 2. Abbreviated analysis of water sample from the reservoir.

№	Name of indicator	Method of analysis	Analysis results
1.	The hydrogen index, pH	TDS-2874-82	6.86
2.	Total mineralization (sum of minerals), mg/dm^3	Calculated	707
3.	Dry residue, mg/dm^3	TDS-18164-72	650
4.	Total stiffness, mol/m^3	TDS-4151-72	6.50
5.	Carbonate ion (CO_3^{2-}), mg/dm^3	TDS-23268.3-78	absent
6.	Bicarbonate ion (HCO_3^-),mg/dm^3	TDS-23268.3-78	122.0
7.	Chloride ion (Cl^-), mg/dm^3	TDS-23268.17-78	141.8
8.	Sulfate ion (SO_4^{2-}),mg/dm^3	TDS-23268.4-78	230.5
9.	Calcium ion (Ca^{2+}), mg/dm^3	TDS-26449.1-85	88.2
10.	Magnesium ion (Mg^{2+}), mg/dm^3	TDS-23268.5-78	25.5
11.	Sodium ion (Na^+) + Potassium ion (K+), mg/dm^3	Calculated	98.8

Source: «Compiled by the authors».

During studying the implementation of an eco-sink, a noteworthy challenge emerged in the form of human error. It was observed that individuals frequently neglected to operate the control lever of the eco-sink correctly, resulting in adverse consequences. Specifically, instances arose where the lever was not properly adjusted, leading to either water loss, wherein clean water was inadvertently directed into the sewer, or water contamination, as wastewater entered the storage reservoir, compromising the overall water quality within the reservoir.

Human error can significantly impact the efficacy of utilizing eco-sinks in practice. The improper manipulation of the control lever poses a considerable risk, as it directly determines the water flow direction, either diverting it to the intended storage reservoir or draining it into the sewer. This error stems from forgetfulness or misinterpretation of the required lever position, undermining the eco-sink system's intended functionality.

The consequences of such human error have tangible implications for water conservation and overall water quality management. In cases where the control lever is not adjusted correctly, the result is a loss of clean water, diminishing the desired efficiency of water consumption and perpetuating unnecessary water waste. Conversely, when wastewater is mistakenly directed into the storage reservoir, it leads to inadvertent contamination of the entire water supply within the reservoir, raising concerns regarding its suitability for further use.

Regarding safeguarding against human error, we can confidently assert that through meticulous analysis and consultations with experienced engineers, viable solutions have been devised to address this concern. One such solution involves the incorporation of an intermediate reservoir between the "eco-sink" and the primary reservoir (Figure 4), providing consumers with an additional layer of protection. This mitigation strategy proves particularly beneficial in instances of human oversight, wherein an individual mistakenly or inadvertently fails to switch the mechanical lever while employing the "eco-sink," resulting in the ingestion of chemically contaminated water into the primary reservoir. Currently, several options exist regarding the volumetric capacity of the intermediate reservoir, contingent upon the size of the primary reservoir. These options span 5L, 10L, and 30L, offering users choice and flexibility. The operational control of the intermediate reservoir is relatively straightforward. Following the utilization of the "eco-sink" and the subsequent activation of the lever switch, the water is initially directed towards the intermediate container. Consequently, if the consumer can ascertain with certainty that no chemical agents were employed during the process of washing vegetables, fruits, or herbs, among other items, the user can confidently rotate the control lever of the intermediate reservoir, allowing "clean water" to proceed further and accumulate within the primary reservoir. Conversely, in the event of a user error or uncertainty regarding the "purity" of the water, the user can reverse the rotation of the intermediate reservoir lever, consequently opening the passage towards the sewer, wherein the chemically contaminated water shall be discarded.

In addition to introducing an intermediate reservoir, several other solutions have been devised to enhance the functionality and user experience of eco-sink. Some notable solutions include: 1. Automatic chemical detection [15]: Utilizing advanced sensors and detection systems, eco-sinks can be equipped with the ability to detect the presence of chemicals in the water automatically. If any contaminants are detected, the system can divert the water directly to the drain, preventing it from being collected in the reservoir. 2. Education and user guidelines [16]: To address human error, comprehensive user guidelines and educational materials can be developed to promote proper usage and maintenance of the eco-sink. Clear instructions and visual cues can minimize the likelihood of mistakes and enhance user understanding of the system's functionalities. 3. Improved filtration systems [17]: Upgraded filtration systems can be implemented to ensure efficient removal of impurities and chemicals from the water. Advanced filtration technologies, such as activated

carbon filters or reverse osmosis membranes can purify the water effectively, providing users with clean and safe water for various purposes.

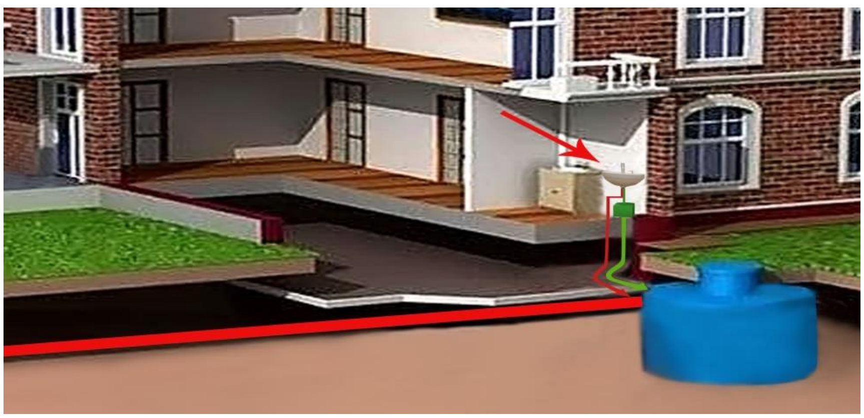

FIGURE 4. Layout of the eco-sink, intermediate reservoir, reservoir, and sewer system indoors.

Addressing the challenge of human error within the context of eco-sink utilization necessitates the development of effective strategies. Firstly, comprehensive user education and training programs should be implemented to ensure individuals are properly acquainted with the correct operation of the control lever. This may involve clear and concise instructions, informative visual aids, and demonstrations to enhance user understanding and minimize the occurrence of errors. Additionally, the eco-sink control lever's design can be enhanced to include prominent indicators or intuitive mechanisms that help users easily identify the appropriate position for water flow direction.
These additional solutions address various aspects of eco-sink functionality, including error prevention, water quality assurance, user education, and system optimization. By combining these strategies, eco-sinks can deliver enhanced performance, increased sustainability, and improved user satisfaction.

CONCLUSIONS

Summarizing the above, the study produced a series of notable findings that advance our understanding of efficient water usage and provide insight into developing eco-sinks.

1. Survey Analysis: The surveys conducted among students from the S. A. Niyazov Turkmen Agricultural University revealed a heightened awareness of water conservation but a lack of practical tools or methods to enact this mindfulness in their daily lives. Most participants were willing to switch to water-saving systems, indicating potential success in adopting the eco-sink technology.

2. Existing innovative solutions: Several researchers have proposed solutions to address inefficient household water usage. For example, a study by Smith et al. (2014) suggests the implementation of smart water meters and

real-time feedback systems to create awareness among users about their water consumption patterns. They found that introducing such technologies significantly reduced water wastage and increased user engagement in conservation practices (Smith et al., 2014) [18]. Another study by Roccaro et al. (2011) investigates the effectiveness of water-saving devices, such as low-flow faucets and showerheads, in conserving water. The results demonstrate a considerable reduction in water consumption when these devices are utilized (Roccaro et al., 2011) [19].

3. Eco-Sink technology implementation: The implementation of the Eco-Sink technology in student dormitories provided valuable insights into its functionality and potential for water conservation. Usage data, including the volume of water saved, frequency of use, and mechanical durability, were collected and analyzed. The results demonstrated that the Eco-Sink technology effectively regulated water flow and directed it to a reservoir for future use, reducing water wastage and promoting efficient water usage.

4. Biochemical water analysis: to ensure the safety and quality of the conserved water, biochemical analysis was conducted on water samples collected from the Eco-Sink reservoir and regular sinks. The analysis aimed to determine the suitability of the conserved water for secondary use. The results indicated that the conserved water met all relevant quality standards and was suitable for various non-potable applications, such as irrigation or toilet flushing. This finding supports the viability and effectiveness of the Eco-Sink technology in promoting sustainable water resource management.

5. Implications and potential for future research: The successful implementation of the Eco-Sink technology in student dormitories highlights its potential for broader adoption in household settings. Further research on the scalability and cost-effectiveness of the technology could provide valuable insights into its long-term viability and impact. Additionally, conducting awareness campaigns and educational programs to promote the adoption of water-saving technologies [20], such as the Eco-Sink, among the general population could significantly contribute to efficient water management efforts.

Overall, the results obtained from the study demonstrate that the Eco-Sink technology effectively addresses the issue of inefficient water usage in households. By significantly reducing water wastage and promoting efficient water management practices, the Eco-Sink technology can contribute to sustainable water resource management and mitigate the environmental impacts of inefficient water usage. Future research and initiatives should focus on scaling up the implementation of the Eco-Sink technology and raising awareness about its benefits to achieve widespread adoption.

The growing problem of water wastage in households necessitates innovative, sustainable solutions. This study's results underline eco-sink technology's capacity to target this issue, paving the way towards a more water-efficient future. By combining mechanical water flow control with a reservoir for future use, the eco-sink system allows significant water conservation while offering a practical tool for daily use.

In light of these results, further research could focus on refining the overall design of the eco-sink and enhancing its aesthetic appeal without compromising functionality. Besides, the eco-sink's scale-up process and mass production also warrant further research and planning.

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