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Ecological Disaster of the Aral Sea: Water Management, Drought, and Legal Implications for Uzbekistan's Coastal Cities

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Abstract

This study examines the ecological disaster of the Aral Sea by focusing on the management of the Amu Darya River and its implications for coastal cities in Uzbekistan from an environmental law perspective. The shrinkage of the Aral Sea is not merely the result of natural processes but primarily stems from water resource policies oriented toward exploitation and detached from ecological balance. The research applies a normative juridical method using statute and conceptual approaches, complemented by a socio-legal perspective through secondary data such as environmental reports, scientific studies, and policy documents. The findings indicate that Uzbekistan's water governance framework has not fully incorporated the principles of sustainable development, precaution, and ecosystem-based management. The absence of legally binding ecological flow requirements, inefficient irrigation practices, and weak law enforcement have accelerated environmental degradation and intensified regional drought. These ecological impacts have translated into social, economic, and public health challenges, directly affecting the rights to health, livelihood, and a healthy environment of coastal communities. At the transboundary level, limited regional cooperation further complicates restoration efforts. The study underscores the need for preventive and justice-oriented environmental law reforms grounded in ecological limits.

Keywords Aral Sea; Environmental Law; Water Management; Drought; Uzbekistan

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INTRODUCTION

The Aral Sea was once one of the largest inland lakes in the world and a major life-support system in Central Asia. On the Uzbek side, the existence of the lake formed a stable ecological network, sustaining the fisheries sector, supporting small-scale local agriculture, and maintaining a microclimate for coastal cities. For surrounding communities, the Aral Sea was

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not merely a natural landscape but a living space that integrated economic activity, public health, and collective memory[1].

The history of the Aral Sea's shrinkage is often portrayed as an environmental tragedy; however, its root causes lie in highly specific policy choices. During the Soviet era, development strategies prioritized cotton production as a flagship commodity. To achieve these production targets, water was massively diverted from the rivers feeding the lake particularly the Amu Darya into continuously expanding irrigation networks[2].

This diversion of river flows drastically altered the regional water balance. The volume of water that should have reached the lake declined year by year, while irrigation demand increased without ecological restraint[3]. When inflows were no longer sufficient to offset evaporation, the lake's surface area and volume began to shrink, eventually fragmenting into several separate bodies of water and leaving shorelines that receded far from coastal settlements.

This crisis demonstrates that drought in Uzbekistan's coastal regions is not solely the result of climatic dynamics. It also arises from water distribution designs that prioritize certain sectors while neglecting the ecological functions of water bodies. Water has been treated as a production input rather than as a prerequisite for the sustainability of social life and ecosystems. From an environmental law perspective, the Aral Sea represents a serious failure in the application of the principle of sustainable development[4].

This principle requires the integration of economic interests, environmental protection, and social needs. Water management policies that focused exclusively on increasing cotton production have caused intergenerational losses, including environmental degradation, the loss of ecosystem services, and the weakening of nature's recovery capacity. The damage also reveals the fragility of the precautionary principle in practice. Technocratic decisions regarding irrigation projects should have been accompanied by rigorous environmental impact assessments, including long-term risk evaluations. When such assessments are not conducted, law loses its preventive function and is reduced to a mere administrative instrument that legitimizes exploitation.

The ecological impacts of the Aral Sea's shrinkage are evident in the extreme increase in salinity. As the water volume decreased, salts and pollutants became concentrated, destroying

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aquatic biota and collapsing food chains. Surrounding land was also degraded due to salt intrusion and hydrological changes, leading to declining soil productivity and exacerbating poverty in coastal areas. Coastal cities in Uzbekistan have experienced profound socio-economic changes. Traditional fisheries collapsed, seafood processing industries ceased operations, and employment opportunities disappeared. As the economic base eroded, migration increased, families were separated from their homelands, and the social structures of coastal communities weakened.

Public health problems constitute another layer of the crisis. Dust storms carrying salt particles and chemical residues from the dried lakebed have increased the risk of respiratory diseases and placed a heavier burden on public health systems. The right to health cannot be separated from environmental quality, as polluted air, water, and soil directly affect the human body[5]. Changes in the local microclimate have further worsened the situation. The lake, which once stabilized local temperatures, no longer performs this function, resulting in hotter summers and harsher winters.

These changes put pressure on subsistence agriculture and increase water demand, creating a vicious cycle in which water becomes scarcer, demand rises, and distribution conflicts intensify. Viewed through a human rights framework, the shrinkage of the Aral Sea is closely linked to the right to water, the right to work, and the right to a healthy environment. As ecosystems collapse, access to clean water declines and living costs rise. Coastal residents experience multiple layers of vulnerability that are not always captured by development policies focused solely on production indicators[6]. At the national level, this case challenges the effectiveness of Uzbekistan's water resource regulation and environmental protection frameworks.

The existence of regulations does not automatically guarantee effective protection, as problems often lie in institutional design, monitoring mechanisms, and development priorities. The gap between legal norms and policy practice becomes a critical issue requiring systematic analysis. Water management that results in ecological disaster also signals governance problems: who is entitled to extract water, what limits apply, and what sanctions exist for violations[7]. Without extraction limits based on ecological carrying capacity, law loses its binding force over large-scale water users. As a result, ecological interests and domestic needs are frequently marginalized.

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The fact that the rivers supplying the Aral Sea cross more than one national boundary places this issue firmly within the realm of transboundary environmental law. The Amu Darya River and its related river basin systems involve regional interests, meaning that decisions by one party can cause harm to others. This situation creates a need for cooperation, data-sharing mechanisms, and enforceable agreements. The no-harm principle in international environmental law becomes particularly relevant when upstream activities or national policies cause significant impacts in other territories. In addition, the principle of equitable utilization requires fair and reasonable use, rather than use determined by political or economic power.

The Aral Sea demonstrates that inequitable water distribution can evolve into a humanitarian crisis. Conflicts of interest between agricultural irrigation, domestic needs, and ecological protection must be understood as both legal and policy conflicts. Without clear and transparent allocation rules, vulnerable groups bear the heaviest burdens. Coastal cities in Uzbekistan experience a double impact: the loss of economic resources and the deterioration of environmental quality. Decades of recovery and adaptation efforts show that environmental restoration requires a combination of legal instruments, governance reforms, and technical interventions. Land rehabilitation, dust control, improvements in health services, and economic diversification must proceed simultaneously.

Environmental law plays a crucial role as a framework that defines direction, accountability, and the allocation of responsibilities. However, recovery efforts are insufficient if they focus solely on physical projects. Water management reform must address licensing, monitoring, enforcement, and public participation. The experience of the Aral Sea shows that decisions that ignore local community voices tend to compound problems, as local knowledge often provides early warnings of environmental change.

This article draws attention to the causal relationship between water management, drought, and the fate of Uzbekistan's coastal cities. The analysis positions the Aral Sea as empirical evidence that water policies can create long-lasting "artificial droughts." The primary focus is not only on ecological damage but also on its impacts on fundamental rights and the socio-economic resilience of coastal communities.

The discussion evaluates how the principles of sustainable development and precaution should operate in the planning and control of water extraction. In addition, it explores the relevance of the no-harm principle and equitable utilization in strengthening regional cooperation. By presenting the Aral Sea as a case study of ecological disaster resulting from governance failure, this article seeks to offer a more robust, just, and effective environmental law framework capable of protecting the lives of Uzbekistan's coastal cities from similar crises in the future.

METHODS

This study is designed to examine the ecological disaster of the Aral Sea through an environmental law framework by positioning law as the central object of analysis. A normative juridical method is employed because it allows an in-depth examination of legal norms governing water resource management, both at the national level in Uzbekistan and within

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relevant international environmental law regimes[8]. The statutory approach is used as the primary foundation for identifying and analyzing the regulatory structures that govern river water utilization and environmental protection.

The analysis focuses on laws, government regulations, and sectoral policies related to water management and ecosystem conservation. Through this approach, the study evaluates the consistency of legal norms, the scope of institutional authority, and the monitoring mechanisms available within Uzbekistan's legal system. The examination of these regulations is not merely descriptive but also analytical and critical. Each norm is interpreted in relation to the objectives of environmental protection and public welfare.

The study assesses the extent to which water regulations establish clear limits on water abstraction and whether the ecological protection of the Aral Sea and its coastal areas is adequately reflected in the design of legal policies. A conceptual approach complements the statutory analysis by examining fundamental ideas and principles of environmental law[9]. The principles of sustainable development, precaution, prevention, and intergenerational and intragenerational equity serve as the primary references.

This approach helps clarify the normative meaning underlying written rules and assess their suitability in addressing the ecological challenges faced by the Aral Sea region. The theoretical framework of international environmental law is also employed to broaden the analytical perspective. Global and regional instruments governing transboundary water resources, including the principle of equitable and reasonable utilization and the obligation not to cause significant harm, are examined.

This analysis is essential given the transboundary nature of the rivers supplying the Aral Sea, which cross national borders and involve the interests of more than one jurisdiction. The conceptual approach enables the researcher to connect legal norms with broader social objectives. Environmental protection principles are not understood merely as prohibitions or administrative obligations, but as instruments to safeguard the rights to water, health, and livelihoods of coastal communities. In this way, law is positioned as a tool for understanding the relationships between power, resources, and social vulnerability. In addition to normative analysis, this study adopts a socio-legal approach to bridge the gap between written law and practical implementation.

This approach is chosen because the Aral Sea crisis cannot be fully understood through legal texts alone, but must also be examined through its impacts on social life and ecological conditions. Law is thus tested against the realities faced by coastal cities in Uzbekistan. The socio-legal approach is carried out by examining how water management policies are implemented and experienced by affected communities. This analysis draws on secondary data in the form of environmental reports, academic studies, and policy documents that record

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changes in ecosystems, public health conditions, and economic transformations in coastal regions.

These data are used to assess the effectiveness of law in achieving environmental protection objectives. Secondary data sources are selected selectively based on relevance, credibility, and the currency of information. Reports from international organizations, recent scientific publications, and official policy documents are used to ensure that the analysis reflects the current conditions of the Aral Sea and its surrounding areas. This data selection also supports the empirical dimension of the study, despite its foundation in a normative methodology.

The collection of legal materials is conducted through systematic library research[10]. Primary legal materials include legislation and international instruments, while secondary legal materials consist of books, academic journals, and previous research findings. Tertiary legal materials are used sparingly to clarify terms and concepts relevant to environmental law and water management. The analysis of legal materials is carried out qualitatively using methods of legal interpretation. Grammatical, systematic, and teleological interpretations are employed to understand the intent of norm-makers and the environmental protection objectives underlying the rules. This approach helps reveal gaps between normative objectives and the actual impacts of water policies on the Aral Sea.

The results of the normative analysis are then linked with socio-legal findings to build a comprehensive understanding[11]. The interaction between legal rules, policy implementation, and ecological impacts becomes the central focus. In this way, the study does not stop at formal legal evaluation but also assesses the function of law as a regulatory and corrective instrument. The methodological approach adopted enables the identification of structural factors that contribute to the failure of water management.

These factors include regulatory design, development priorities, and weak accountability mechanisms. This analysis provides a basis for a critical evaluation of the role of law in preventing or conversely exacerbating environmental crises. Overall, the research methodology is structured to address the research questions in a systematic and focused manner. The emphasis on the Aral Sea and coastal cities in Uzbekistan allows for an in-depth examination of a specific case with broad theoretical implications. This methodology supports a logical and relevant analysis of issues related to water management and drought.

Through the combination of normative juridical and socio-legal approaches, this study seeks to present an environmental law analysis that remains closely connected to social and ecological realities. This methodological framework is expected to produce findings that contribute to the development of environmental law theory while also providing practical

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references for improving water resource governance in regions vulnerable to environmental crises.

RESULTS AND DISCUSSION

The management of water from the Amu Darya River in Uzbekistan developed from a natural resources law paradigm that places water as a factor of production. Within this framework, water is understood primarily as a support for economic targets, especially irrigated agriculture, rather than as part of an ecological system with finite carrying capacity[12]. This orientation shaped policy directions, regulatory design, and irrigation technology choices that from the outset neglected the minimum ecological needs of the Aral Sea ecosystem.

Subsequent findings show that the regulatory framework governing water abstraction fails to establish clear ecological limits. At the normative level, regulations focus predominantly on quota allocation, distribution, and conveyance for agricultural interests. Meanwhile, environmental requirements such as minimum environmental flows do not receive a strong position as legally enforceable obligations. When minimum flows are not recognized, water extraction becomes "normal" even when it is ecologically destructive[13].

The absence of effective withdrawal limits directly contributed to the accelerated shrinkage of the Aral Sea. The reduction in inflow did not occur as an isolated incident but rather repeatedly and cumulatively. What could initially have been controlled gradually turned into systemic degradation, as water withdrawals continued at levels exceeding the lake's capacity for recovery[14]. In such conditions, the law loses its limiting function and instead becomes a facilitator of exploitation.

The research also finds that irrigation regulations fail to provide sufficient incentives for efficiency. Many provisions emphasize network expansion and fulfillment of production needs, while canal leakage, evaporation losses, and wasteful irrigation techniques are not treated as violations subject to sanctions. Weak oversight allows water wastage to become common practice, increasing water demand without proportional gains in benefit[15].

This efficiency problem is closely linked to law enforcement. Enforcement mechanisms are not strong enough to prevent water abstraction beyond administrative limits, let alone to ensure compliance with environmental protection standards. When violations carry no

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meaningful consequences, compliance becomes voluntary. This creates a significant gap between written norms and actual water management practices.

From the perspective of modern environmental law theory, such a model contradicts the principle of sustainable development. Sustainable development requires a simultaneous balance of economic, social, and environmental interests[16]. The research findings demonstrate that this balance is absent in water management policy design, as the environment is positioned as a cost that can be deferred rather than as a prerequisite for sustainability.

The precautionary principle is also absent as a binding operational consideration. Decisions on water diversion and irrigation expansion were made without strict long-term ecological risk assessment standards. The lack of risk-based prevention turns water policy into a large-scale experiment, with ecosystems and public health at stake. The shrinkage of the Aral Sea, as interpreted in this research, meets the criteria of serious environmental harm. Its impacts extend beyond local damage, affecting microclimatic stability, soil quality, public health, and the economic resilience of coastal cities[17]. Such damage should trigger state obligations to prevent, halt, and restore harm, as well as to ensure protection for affected communities.

However, state responsibility faces serious obstacles due to the legacy of Soviet-era policies. The water policies at the root of the problem were shaped by power structures and inter-republic decisions of the past. After political transformation, accountability became complex: determining who made the decisions, who inherits restoration obligations, and how to distribute restoration burdens across newly independent states. This complexity often serves as a justification for stagnation, even as damage continues.

At the national level, the research finds that Uzbekistan's environmental law has not fully adopted an ecosystem-based approach. River and lake management remains largely sectoral: water for agriculture, domestic use, and industry are regulated separately. An ecosystem approach requires viewing the watershed as an integrated whole, encompassing rivers, lakes, soil, and human health. When sectoral regulation dominates, damage at one point easily spreads throughout the system[18].

The ecological impact of increasing salinity is the clearest indicator of failed aquatic ecosystem protection. High salinity kills many species, collapses fisheries, and transforms the lake into an environment no longer capable of sustaining life as it once did. Biodiversity loss demonstrates that nature protection has not functioned as a priority mandate but rather as a belated discourse. Land degradation in coastal areas is also a significant finding. As the lakebed dries, salt and sediments are lifted and dispersed by wind[19]. Agricultural soils become less

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productive, natural vegetation weakens, and formerly fertile regions become vulnerable to desertification. This impact highlights the direct relationship between water governance and the degradation of other resources, particularly land and air.

Toxic dust storms represent the most tangible consequence for local residents. The research assesses that health threats posed by dust carrying salt and chemical residues place the Aral Sea case within the domain of human rights. The right to a clean and healthy environment cannot be confined to normative texts; it requires concrete pollution prevention policies and real protection for affected populations[20]. The emerging health crisis also reveals inequalities in protection. Coastal cities far from policy centers often receive weaker health services and environmental protection. As a result, disease burdens increase among groups with limited access to medical facilities and economic resources. This strengthens the argument that environmental damage has a clear social dimension.

The collapse of the fishing economy provides concrete evidence that the environment and economy cannot be separated. When fisheries fail, livelihoods disappear and the social identity of coastal communities erodes. Many families lose stable income sources, while supporting sectors processing, distribution, and trade also collapse[21]. This cascading effect shows that environmental damage creates structural crises, not merely resource loss. The dimension of environmental justice is strongly reflected in the research findings. Local communities bear the heaviest impacts: illness, job loss, declining quality of life, and migration. Meanwhile, the economic benefits of irrigation policies are enjoyed on broader national and regional scales. This inequality reflects an unjust distribution of risk that should be a central concern of environmental law.

Prolonged drought in former coastal areas also reveals unresolved conflicts over water allocation. Competition among irrigation, domestic, and ecological needs is often addressed without transparent and participatory guidelines. When priorities are set top-down, the most affected groups rarely have sufficient bargaining power to defend their basic needs. Findings on the transboundary dimension show weak legal coordination in Central Asia. Rivers crossing multiple states require harmonized rules, data exchange, and effective dispute resolution mechanisms. Although principles of international cooperation are often formally recognized, their implementation is hindered by national interests and inter-state distrust. As a result, water use tends to follow political power rather than principles of justice.

The principles of no-harm and equitable utilization, which underpin international environmental law on transboundary water resources, have not been effectively realized in practice. When states in the region lack control mechanisms to restrain excessive water withdrawal, ecological impacts easily spread. The Aral Sea demonstrates that failure in cooperation prolongs community suffering and delays recovery.

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The research also finds that restoration policies are often fragmented. Technical efforts such as vegetation planting on the dried lakebed to reduce dust, selective land rehabilitation, and integrated water management programs indicate a shift toward more environmentally friendly thinking. However, results remain limited because the root problems of water allocation and irrigation efficiency have not been comprehensively reformed. Rehabilitation measures are important as they signal a change in policy direction. The state has begun to acknowledge that damage cannot be left without response. Nevertheless, the research finds that restoration programs often rely on short-term projects and specific funding sources, making long-term sustainability a challenge. Without institutional guarantees, restoration efforts can easily stall when political priorities shift.

The preventive role of environmental law is shown to be underperforming. Law should operate before damage occurs through protective standards, strict permitting, and oversight. In the Aral Sea case, law more often appears after the crisis has escalated, tasked with managing consequences. This reactive model significantly increases social, economic, and health costs. From a corrective perspective, the law also faces challenges in recovery and compensation mechanisms. Coastal communities require concrete protection: health services, access to clean water, economic recovery, and dust pollution mitigation. Without clear liability frameworks, recovery often depends on social programs that are insufficient to cover long-term losses.

Regulatory reform of water law emerges as the most prominent necessity in the research findings. Withdrawal limits based on ecological carrying capacity, recognition of minimum ecosystem flows, and mandatory irrigation efficiency must be positioned as legal obligations rather than technical recommendations. When these duties are integrated into permitting and enforcement systems, water abstraction can be more effectively controlled.

Improving irrigation efficiency must also be understood as a legal and governance issue, not merely a technological one. Efficiency standards, water-use audits, and sanctions for waste must be designed to be both effective and fair. Otherwise, reform risks becoming a slogan that fails to change on-the-ground practices. The research emphasizes the importance of consistent law enforcement. Weak enforcement reinforces a culture of tolerance and strips regulations of authority. Independent oversight, transparency in water withdrawal data, and public participation can strengthen accountability. Without these measures, the risk of similar degradation will persist, both in the Aral Sea and in other regions dependent on major rivers.

Overall, the Aral Sea demonstrates that environmental law must not be purely reactive. Law must guide development policy to respect ecological limits, prioritize public health protection, and ensure justice for the most affected communities. This case serves as a lesson that when water is treated solely as a commodity, damage does not stop at the environment it spreads into social structures, economic systems, and human dignity.

CONCLUSION

The shrinkage of the Aral Sea is a direct consequence of the exploitative management of the Amu Darya River, which disregards ecological limits. The water resources legal framework in Uzbekistan has not yet fully integrated the principles of sustainable development, the

precautionary principle, and an ecosystem-based approach. The absence of minimum flow regulations, combined with weak efficiency standards and law enforcement, has accelerated environmental degradation and intensified regional drought. These ecological impacts have transformed into social, economic, and public health crises for coastal cities, while simultaneously reflecting environmental injustice. At the transboundary level, weak cooperation and the inadequate application of the principle of equitable utilization further complicate recovery efforts. The Aral Sea case underscores that environmental law must function both preventively and correctively, and must be capable of guiding development policies to align with environmental carrying capacity and the protection of the rights of affected communities.

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