ACADEMIA International Journal for Social Sciences
Volume 5, Issue 3(b), 2026 ISSN-L (Online): 3006-6638

Arbitration at the Limits of Law: Scientific Uncertainty, Hydro-Politics, and the Indus Waters Regime

Rashida Abbas
Rashida.Abbas@etu.unige.ch
PhD Candidate, University of Geneva, Switzerland

Corresponding Author: Rashida Abbas Rashida.Abbas@etu.unige.ch

Received: 18-01-2026 **Revised:** 02-02-2026 **Accepted:** 16-02-2026 **Published:** 03-03-2026

ABSTRACT

The increasing complexity of transboundary water disputes exposes the structural limits of traditional international legal mechanisms in delivering effective, consistent, and legitimate outcomes. While arbitration has been progressively institutionalized within the normative framework of international water law, its practical application reveals constraints that extend beyond procedural design. These constraints are rooted in the interaction between three interrelated dimensions: the indeterminacy of legal principles, the epistemic challenges associated with scientific uncertainty, and the influence of hydro-political asymmetries. This article critically examines the role of arbitration through an analysis of the Indus Waters Treaty regime between India and Pakistan, situating it within a broader legal and epistemological framework. It argues that arbitration in transboundary water disputes operates at the intersection of law, science, and power, where the expectation of definitive legal resolution encounters the reality of contested knowledge and strategic state behavior. In this context, arbitral processes are required to interpret open-textured legal norms such as equitable utilization and the obligation not to cause significant harm, while simultaneously engaging with uncertain and evolving scientific evidence. Drawing on doctrinal analysis, case-based evaluation, and interdisciplinary insights, the article demonstrates that arbitration contributes to the clarification of legal norms but remains structurally constrained in its ability to resolve disputes in a comprehensive and lasting manner. The Indus Waters regime illustrates how institutional sophistication and procedural design cannot fully overcome the underlying tensions between legal indeterminacy, environmental variability, and geopolitical realities. The article concludes by identifying key gaps in the existing framework and proposing a recalibration of arbitration mechanisms through greater integration of scientific expertise, adaptive legal interpretation, and enhanced sensitivity to hydro-political dynamics. In doing so, it advances a broader argument that the limitations of arbitration are not incidental, but are embedded within the evolving structure of international water governance itself.

Keywords: *Transboundary Water Disputes, Arbitration in International Law, Indus Waters Treaty Regime, Scientific Uncertainty, Hydro-Politics*

INTRODUCTION

The governance of transboundary freshwater resources occupies a central position within contemporary international law, intersecting with broader concerns of environmental sustainability, economic development, and regional stability. Unlike many other natural resources, water is inherently shared, dynamic, and ecologically interconnected, creating conditions of structural interdependence among states. As global pressures on water systems, intensify, driven by climate variability, population growth, and competing sectoral demands, the potential for disputes among riparian states has increased both in frequency and complexity (Stoffel et al., 2020, pp. 45–52).

In response to these challenges, international water law has progressively developed a normative and institutional framework aimed at regulating the use of shared watercourses and facilitating dispute resolution. Central to this framework are the principles of equitable and reasonable utilization and the obligation not to cause significant harm, which together seek to balance competing state interests while promoting sustainable resource management. Alongside these substantive norms, legal instruments have incorporated structured mechanisms for dispute settlement, including negotiation, mediation, arbitration, and judicial adjudication (Caflisch, 2007, p. 629).

Among these mechanisms, arbitration occupies a distinctive position. It combines the formal authority of binding decision-making with a degree of procedural flexibility, allowing states to tailor processes to the specific characteristics of a dispute. This has led to its recognition as a key component of the dispute resolution architecture in instruments such as the 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses. However, despite its formal status, arbitration remains relatively underutilized in practice and, when invoked, often reveals significant limitations.

These limitations are particularly evident in disputes shaped by complex hydrological systems, contested scientific evidence, and asymmetrical power relations. Contemporary transboundary water conflicts are rarely confined to purely legal questions; rather, they are embedded within broader environmental and political contexts that challenge the capacity of legal mechanisms to deliver clear and definitive outcomes. Scientific uncertainty, for example, complicates the assessment of causation and impact, while hydro-political dynamics influence both access to and the effectiveness of dispute resolution processes (Zeitoun and Mirumachi, 2008, p. 306).

The Indus Waters Treaty (1960) between India and Pakistan provides a compelling case through which to examine these dynamics. Frequently described as one of the most durable transboundary water agreements, the Treaty has survived periods of significant political tension and has established a relatively sophisticated institutional framework for cooperation and dispute resolution. Its mechanisms include provisions for neutral expert determination and arbitration, reflecting an advanced level of legal and institutional design.

However, the operation of these mechanisms in practice reveals important tensions. Disputes arising under the Treaty often involve highly technical questions related to hydrology, engineering, and environmental impact, requiring tribunals to engage with complex and sometimes contested scientific evidence. At the same time, the broader political relationship between the parties influences the framing and progression of disputes, highlighting the interplay between legal processes and geopolitical realities.

This article seeks to critically examine the role and effectiveness of arbitration within this context by situating it within a broader analytical framework that integrates legal, scientific, and political dimensions. It advances the argument that arbitration in transboundary water disputes operates at the limits of law, where the expectation of objective and definitive resolution encounters the structural indeterminacy of legal norms, the uncertainty of scientific knowledge, and the influence of power asymmetries.

In doing so, the article moves beyond conventional analyses that treat arbitration as a self-contained legal mechanism. Instead, it conceptualizes arbitration as part of a wider governance system in which its effectiveness is shaped by interactions between normative frameworks, epistemic conditions, and political structures. This perspective enables a more nuanced understanding of both the potential and the limitations of arbitration in managing complex transboundary water disputes.

The analysis proceeds in several stages. First, it outlines the legal framework governing dispute resolution in international water law, with particular attention to the role of arbitration. It then examines the challenges posed by scientific uncertainty and hydro-political dynamics, highlighting their implications for arbitral

decision-making. This is followed by a focused analysis of the Indus Waters Treaty regime, which serves as an empirical illustration of the broader argument. The article concludes by identifying key gaps in the existing framework and proposing directions for the recalibration of arbitration within international water governance.

This article seeks to interrogate the role of arbitration within this regime by addressing three central questions:

- To what extent does arbitration provide an effective mechanism for resolving transboundary water disputes?
- How do scientific uncertainty and environmental change affect arbitral decision-making?
- What structural and normative gaps limit the potential of arbitration in such contexts?

LEGAL FRAMEWORK OF TRANSBOUNDARY WATER DISPUTE SETTLEMENT

Evolution of Legal Norms

The development of international water law reflects a gradual yet profound transformation from a fragmented, sector-specific regime toward a more integrated and functionally complex legal framework. Early legal instruments governing transboundary water resources were primarily concerned with navigation and commercial use, reflecting the strategic importance of rivers as conduits of trade and communication. Within this paradigm, water was conceptualized largely as an economic asset, and legal regulation focused on ensuring access and facilitating utilization, with little attention paid to ecological integrity or long-term sustainability (McCaffrey, 2019, pp. 35–40).

This sectoral orientation proved increasingly inadequate in the face of expanding and competing uses of water resources, including irrigation, hydropower generation, and industrial development. As pressures on shared water systems intensified, the limitations of a purely economic approach became apparent, particularly in relation to environmental degradation and transboundary externalities. This prompted a normative shift toward a more holistic framework capable of accommodating the multiple and often competing dimensions of water governance.

Central to this transformation has been the emergence of the principles of equitable and reasonable utilization and the obligation not to cause significant harm. These principles, now widely recognized as cornerstones of both treaty law and customary international law, represent an attempt to reconcile competing sovereign interests through a process of balancing rather than rigid rule application. However, as the literature consistently emphasizes, these principles are inherently open-textured and context-dependent, requiring interpretation in light of a range of factors that lack a clearly defined hierarchy (McCaffrey, 2019, pp. 381–385; McIntyre, 2010, pp. 83–88).

The evolution of substantive norms has been accompanied by the progressive formalization of dispute settlement procedures. Early reliance on diplomatic negotiation has gradually been supplemented by more structured mechanisms, reflecting a broader trend toward the legalization of international relations. The Helsinki Rules (1966) marked a significant step in this direction by not only articulating key substantive principles but also recognizing the need for procedural frameworks to manage disputes. Subsequent codification efforts, culminating in the 1997 United Nations Watercourses Convention, further institutionalized a tiered approach to dispute resolution, encompassing negotiation, mediation, fact-finding, and, ultimately, arbitration or judicial settlement (Caflisch, 2007, p. 629).

However, this process of codification has not resolved the underlying indeterminacy of the legal framework. Rather, it has formalized a system in which flexible principles coexist with structured procedures, creating a tension between the need for adaptability and the demand for predictability. This tension is particularly significant in the context of dispute resolution, where the absence of clear normative guidance complicates the task of adjudication. As a result, the evolution of international water law has produced a framework that is both normatively sophisticated and structurally indeterminate, with important implications for the functioning of arbitration.

Arbitration within the Legal Architecture

Within the evolving architecture of international water law, arbitration occupies a distinctive and, in many respects, paradoxical position. On the one hand, it represents the most formalized and authoritative mechanism of dispute resolution short of judicial adjudication, offering binding decisions that are grounded in legal reasoning. On the other hand, its practical operation reveals a set of constraints that limit its effectiveness in addressing the complex realities of transboundary water disputes.

Arbitration is often characterized by its procedural flexibility, which allows parties to tailor the process to the specific features of a dispute, including the selection of arbitrators with relevant technical expertise. This adaptability is frequently presented as a key advantage, particularly in disputes involving specialized scientific or engineering issues. Moreover, the binding nature of arbitral awards distinguishes arbitration from diplomatic mechanisms, providing a degree of legal certainty that negotiation and mediation may lack.

However, these formal advantages must be understood considering the conditions upon which their effectiveness depends. First, arbitration presupposes a degree of clarity in the applicable legal framework. Yet, as discussed above, the core principles of international water law are inherently indeterminate, requiring tribunals to engage in complex balancing exercises without clear normative hierarchies. This places significant interpretive discretion in the hands of arbitrators, raising concerns regarding consistency and predictability in outcomes.

Second, the effectiveness of arbitration is closely linked to the availability and reliability of scientific and technical evidence. Transboundary water disputes frequently involve questions of hydrology, environmental impact, and long-term sustainability, all of which depend on data that may be uncertain, contested, or evolving. The integration of such evidence into legal reasoning presents significant epistemic challenges, as arbitral tribunals must navigate competing expert claims while maintaining the appearance of objectivity and neutrality (Mbengue, 2011, p. 541).

Third, arbitration operates within a broader political context that shapes both access to and the impact of dispute resolution processes. The consent-based nature of international law means that states retain control over whether disputes are submitted to arbitration and whether awards are implemented. This structural feature introduces an element of political calculation into what is ostensibly a legal process, particularly in situations characterized by asymmetrical power relations. As a result, arbitration cannot be fully insulated from hydro-political dynamics, which influence both the initiation and the effectiveness of proceedings (Zeitoun and Mirumachi, 2008, p. 306).

The United Nations Watercourses Convention reflects these dynamics by positioning arbitration within a broader, tiered framework of dispute resolution. Article 33 emphasizes negotiation and cooperation as primary mechanisms, with arbitration and judicial settlement serving as options of last resort. While this structure reinforces the importance of diplomatic engagement, it also underscores the subsidiary role of arbitration within the overall system. In practice, states often prefer to rely on flexible and politically controlled processes rather than submit to binding adjudication, further limiting the use of arbitration.

From an analytical perspective, arbitration thus occupies a space characterized by both normative significance and functional constraint. It embodies the aspiration for rule-based resolution of disputes, yet operates within a legal and political environment that limits its capacity to deliver definitive and universally accepted outcomes. This dual character is central to understanding the role of arbitration in international water law and provides a foundation for examining its performance in specific contexts, such as the Indus Waters Treaty regime.

METHODOLOGICAL APPROACH

This study adopts a multi-layered methodological framework designed to capture the complexity of transboundary water disputes and the role of arbitration within them. Rather than relying on a single methodological approach, the analysis integrates doctrinal, empirical, and interdisciplinary perspectives to situate arbitration within the broader legal, scientific, and political contexts that shape its operation. This pluralistic methodology reflects the underlying premise of the article: that arbitration in international water law cannot be adequately understood as a purely legal process, but must be examined as part of a wider governance system characterized by normative indeterminacy, epistemic uncertainty, and hydro-political dynamics.

At its core, the study is grounded in doctrinal legal analysis. This involves a detailed examination of relevant treaty provisions, including the Indus Waters Treaty and the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, as well as the interpretation of key legal principles such as equitable and reasonable utilization and the obligation not to cause significant harm. In addition, the analysis engages with arbitral decisions and related jurisprudence in order to assess how these principles are applied in practice. This doctrinal component provides the normative foundation of the study, enabling a critical evaluation of the legal framework governing transboundary water disputes.

Complementing this approach, the article employs a case study methodology centered on the Indus basin. The selection of this case is not merely illustrative but strategic. The Indus Waters Treaty represents one of the most enduring and institutionally developed transboundary water regimes, yet it operates within a context of persistent political tension and complex hydrological challenges. As such, it offers a particularly rich site for examining the interaction between legal design and practical implementation. The case study analysis focuses on the operation of dispute settlement mechanisms within this regime, with particular attention to the role of arbitration and its interaction with alternative processes such as neutral expert determination.

Recognizing that transboundary water disputes are inherently interdisciplinary, the study further incorporates insights from hydrology, climate science, and political economy. The integration of scientific perspectives is essential for understanding the evidentiary challenges that arise in arbitration, particularly in relation to issues of causation, environmental impact, and long-term sustainability. At the same time, the inclusion of hydro-political analysis allows for an examination of how power asymmetries, strategic behavior, and broader geopolitical considerations influence both the initiation and the outcomes of dispute resolution processes (Zeitoun and Mirumachi, 2008, p. 306).

Finally, the study adopts a critical analytical lens that focuses on the interaction between law, science, and politics. This perspective moves beyond descriptive analysis to interrogate the structural conditions under which arbitration operates. It seeks to identify the ways in which legal indeterminacy, scientific uncertainty, and political dynamics intersect to shape the effectiveness of arbitration as a mechanism of dispute resolution. In doing so, the study aligns with broader critical approaches in international law that emphasize the limits of formal legal mechanisms in addressing complex, multi-dimensional problems (Mbengue, 2011, p. 541).

Taken together, this multi-layered methodological framework enables a comprehensive and nuanced understanding of arbitration in international water law. It allows the analysis to move beyond the formal characteristics of arbitration as a legal tool and to examine its functioning within the broader socio-environmental and political systems in which it is embedded. This approach is essential for identifying both the potential and the limitations of arbitration, and for developing more context-sensitive and adaptive models of dispute resolution.

This study adopts a multi-layered methodological framework, combining:

Doctrinal Legal Analysis

At the core of this study lies a doctrinal legal analysis aimed at examining the normative structure governing transboundary water disputes and the role of arbitration within it. This approach focuses on the interpretation and critical evaluation of primary legal sources, including treaty provisions, customary international law principles, and relevant jurisprudence. Attention is given to the Indus Waters Treaty (1960) and the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997), both of which provide foundational frameworks for the regulation and allocation of shared water resources.

The analysis engages closely with key substantive principles, notably equitable and reasonable utilization and the obligation not to cause significant harm, which constitute the normative backbone of international water law. While these principles are widely recognized and codified, their application remains inherently context-dependent, requiring the balancing of multiple factors without a clearly defined hierarchy (McCaffrey, 2019, pp. 381–385). As a result, doctrinal analysis in this field necessarily extends beyond the identification of legal rules to include an examination of how such principles are interpreted, operationalized, and contested in practice.

In addition, the study incorporates an analysis of arbitral decisions and related jurisprudence to assess the practical functioning of these norms within dispute resolution processes. Decisions such as the *Kishanganga Arbitration* and other relevant cases are examined not merely as sources of precedent, but as sites of legal reasoning where tribunals navigate the interaction between normative principles and factual complexity. This jurisprudential dimension reveals the extent to which arbitral bodies rely on interpretive discretion in applying open-textured legal standards, often engaging in balancing exercises that reflect both legal reasoning and broader contextual considerations (Mbengue, 2011, p. 541).

Importantly, the doctrinal approach adopted in this study is not limited to descriptive analysis but is critically oriented. It seeks to identify structural features of the legal framework, particularly its indeterminacy and flexibility, that shape the operation and limits of arbitration. By examining both the content of legal norms and their application in practice, the doctrinal analysis provides a foundation for understanding how arbitration functions within a legal system that is simultaneously formalized and inherently open-ended.

Case Study Method

To complement the doctrinal analysis and ground the study in empirical reality, this article adopts a case study methodology centered on the Indus basin. The selection of the Indus Waters Treaty regime is both strategic and analytically significant. Far from serving as a purely illustrative example, the Indus basin represents a paradigmatic case through which the interaction between legal norms, institutional design, and geopolitical realities can be critically examined.

The Indus Waters Treaty (1960) is frequently characterized as one of the most durable and sophisticated transboundary water agreements, having survived periods of prolonged political tension between India and Pakistan. Its institutional architecture, which combines mechanisms of cooperation with structured dispute resolution procedures, including neutral expert determination and arbitration, offers a uniquely rich framework for analyzing the practical functioning of international water law. At the same time, the basin is marked by complex hydrological conditions, significant developmental pressures, and evolving environmental challenges, making it particularly relevant for examining the role of scientific uncertainty in dispute resolution processes.

The case study focuses specifically on the operation of dispute settlement mechanisms within the Treaty framework, with particular emphasis on arbitration as both a legal and institutional practice. This involves an examination of how disputes are framed, escalated, and managed within the regime, as well as how different procedural pathways, such as negotiation, neutral expert review, and arbitration, interact with one another. By analyzing these dynamics, the study seeks to move beyond a formal understanding of arbitration as a discrete legal mechanism and to situate it within the broader governance structure in which it operates.

Importantly, the case study approach enables a contextualized analysis of arbitration, revealing how its effectiveness is shaped by factors that extend beyond legal design. These include the technical complexity of disputes, the role of scientific expertise, and the influence of political relations between the parties. In this sense, the Indus basin serves as an empirical lens through which the broader argument of the article can be developed: that arbitration in transboundary water disputes cannot be fully understood or evaluated in isolation, but must be examined as part of a multi-dimensional system in which law, science, and power are deeply intertwined.

By grounding the analysis in a concrete and well-documented case, the study can bridge the gap between normative theory and practical application. The Indus Waters Treaty regime thus provides not only an example of arbitration in practice, but also a critical site for interrogating its limits and possibilities within contemporary international water governance.

Interdisciplinary Perspective

Transboundary water disputes are inherently multi-dimensional, extending beyond the boundaries of legal analysis into domains shaped by scientific knowledge, environmental variability, and political economy. Accordingly, this study adopts an interdisciplinary perspective that integrates insights from hydrology, climate science, and hydro-political analysis to capture the full complexity of the issues under examination. This approach reflects a growing recognition within international legal scholarship that normative frameworks governing shared resources cannot be adequately understood in isolation from the empirical and political contexts in which they operate.

The incorporation of hydrological and climate science is particularly critical in the context of contemporary water disputes. The availability, distribution, and quality of water resources are determined by dynamic and often unpredictable natural processes, which are increasingly influenced by climate change. Variability in precipitation patterns, glacial retreat, and the frequency of extreme events such as floods and droughts introduce significant uncertainty into the assessment of water use and its impacts (Stoffel et al., 2020, pp. 45–52). These factors complicate the application of legal principles, such as equitable utilization and the prevention of significant harm, both of which rely on factual determinations that are contingent upon scientific interpretation.

At the same time, the integration of scientific knowledge into legal processes raises important epistemological challenges. Scientific evidence is rarely neutral or uncontested; it is often characterized by

methodological limitations, competing interpretations, and evolving data sets. In arbitral proceedings, this creates a situation in which legal decision-making must engage with forms of knowledge that are inherently uncertain and subject to dispute. As Mbengue (2011, p. 541) observes, international adjudicatory bodies are increasingly required to function as arbiters not only of law but also of scientific credibility, a role for which they are not always institutionally equipped.

In parallel, the study incorporates a political economy perspective to examine the role of power asymmetries and strategic behavior in shaping transboundary water governance. Water disputes are rarely determined solely by legal norms or physical scarcity; rather, they are embedded within broader configurations of political and economic power. The concept of hydro-hegemony, for instance, highlights how dominant states can influence both the allocation of water resources and the institutional arrangements governing them (Zeitoun and Mirumachi, 2008, p. 306). Such asymmetries affect not only substantive outcomes but also procedural dimensions, including access to dispute resolution mechanisms and the willingness of states to engage in arbitration.

By integrating these scientific and political dimensions, the interdisciplinary approach adopted in this study enables a more comprehensive understanding of arbitration as a practice situated at the intersection of multiple forms of knowledge and power. It reveals that the effectiveness of arbitration cannot be assessed solely in terms of legal reasoning or procedural design, but must be evaluated in relation to the broader socio-environmental and geopolitical systems within which it operates. This perspective is essential for identifying the structural constraints that shape arbitral processes and for developing more context-sensitive approaches to dispute resolution.

Critical Analytical Lens

Building on the doctrinal, empirical, and interdisciplinary components outlined above, this study adopts a critical analytical lens that focuses on the interaction between law, science, and politics in the governance of transboundary water resources. This approach moves beyond descriptive accounts of legal frameworks to interrogate the structural conditions under which arbitration operates and the limits that these conditions impose on its effectiveness.

At the heart of this analysis is the recognition that international water law is characterized by a form of normative indeterminacy. Core principles such as equitable and reasonable utilization and the obligation not to cause significant harm are intentionally flexible, allowing for adaptation to diverse geographical, environmental, and socio-economic contexts. However, this flexibility comes at the cost of precision, requiring decision-makers to engage in balancing exercises that lack clear normative hierarchies. As a result, arbitral tribunals are often called upon to produce definitive outcomes within a legal framework that resists definitive interpretation.

This indeterminacy is further complicated by the epistemic challenges associated with scientific uncertainty. The assessment of hydrological data, environmental impact, and long-term sustainability involves forms of knowledge that are probabilistic, evolving, and often contested. The interaction between legal reasoning and scientific evidence thus introduces a layer of complexity that exceeds the traditional boundaries of adjudication. Arbitration, in this context, becomes a site where legal and scientific rationalities intersect, sometimes uneasily, producing outcomes that reflect both normative judgment and epistemic negotiation.

In addition, the analysis considers the influence of hydro-political dynamics, recognizing that legal processes do not operate in a vacuum. Power asymmetries, strategic interests, and broader geopolitical considerations shape both the initiation and the trajectory of disputes, as well as the reception and

implementation of arbitral decisions. This challenges the assumption that arbitration functions as a neutral and objective mechanism, highlighting instead its embeddedness within political structures that condition its effectiveness.

By examining the interaction of these three dimensions, normative indeterminacy, scientific uncertainty, and political asymmetry, the study identifies a set of structural limitations that constrain the role of arbitration in transboundary water disputes. These limitations are not incidental or procedural; rather, they are intrinsic to the broader system of international water governance. Consequently, efforts to enhance the effectiveness of arbitration must go beyond procedural reform and engage with the deeper structural conditions that shape its operation.

This critical perspective ultimately reframes arbitration not as a self-contained solution to transboundary disputes, but as a mechanism who's potential and limitations are defined by its position within a complex and evolving governance landscape. It is this reframing that underpins the analysis that follows and informs the broader argument of the article.

This combination allows for a comprehensive understanding of arbitration not merely as a legal tool, but as a process embedded within broader socio-environmental systems.

Scientific Uncertainty and the Limits of Legal Determination

A defining feature of contemporary transboundary water disputes is the increasing centrality of scientific uncertainty in shaping both the substance and resolution of legal claims. Unlike traditional interstate disputes grounded primarily in legal interpretation, water-related conflicts are deeply embedded in complex hydrological systems that are dynamic, interdependent, and increasingly influenced by anthropogenic and climatic factors. As a result, legal adjudication in this domain must engage directly with forms of knowledge that are provisional, contested, and continuously evolving.

Hydrological systems are inherently variable, shaped by multiple interacting forces including climate change, land-use transformations, and technological interventions such as dam construction and water diversion. Recent scientific research underscores the extent to which these systems are undergoing significant transformation, characterized by shifting precipitation patterns, increased frequency and intensity of extreme events such as floods and droughts, and alterations in river flow regimes (Stoffel et al., 2020, pp. 45–52). These changes undermine the assumption of hydrological stability that has traditionally underpinned legal frameworks governing water allocation and use.

The implications of this scientific variability for international water law are profound. Core legal principles, such as the obligation not to cause significant harm and the principle of equitable and reasonable utilization, depend on factual determinations that are intrinsically linked to scientific assessment. Establishing what constitutes "significant" harm, for instance, requires an evaluation of environmental impact, causation, and threshold levels, all of which are contingent upon hydrological data and ecological analysis. Similarly, the determination of what is "equitable" necessitates a forward-looking assessment of resource availability, competing uses, and sustainability considerations.

However, the scientific evidence upon which such determinations rely is rarely definitive. It is often incomplete, subject to methodological variation, and open to competing interpretations. Differences in data collection methods, modeling assumptions, and temporal scales can lead to divergent conclusions regarding the same hydrological phenomenon. In many cases, uncertainty is not merely a temporary limitation but a structural feature of scientific knowledge in this domain, particularly in the context of climate change, where future conditions cannot be predicted with precision (McIntyre, 2010, pp. 88–90).

This epistemic condition poses a fundamental challenge for arbitral tribunals. Arbitration, as a legal mechanism, is oriented toward the production of definitive and binding decisions. It operates on the assumption that disputes can be resolved through the application of legal norms to established facts. Yet, in transboundary water disputes, the "facts" themselves are often uncertain, contested, or probabilistic. Tribunals are therefore required to engage in a form of decision-making that combines legal interpretation with the evaluation of scientific credibility, effectively positioning them as arbiters of both law and knowledge (Mbengue, 2011, p. 541).

This dual role generates a structural tension between the normative expectations of arbitration and the epistemic realities of the disputes it seeks to resolve. On the one hand, parties expect arbitral decisions to provide clarity, certainty, and finality. On the other hand, the underlying scientific uncertainties limit the extent to which such expectations can be fulfilled. In practice, this often results in decisions that emphasize procedural compliance, such as the adequacy of environmental impact assessments or consultation processes, rather than delivering conclusive determinations on substantive issues.

Moreover, the presence of scientific uncertainty creates opportunities for strategic behavior by states. Parties may selectively present or contest scientific evidence in ways that support their legal positions, thereby transforming technical disagreement into a site of legal and political contestation. This further complicates the task of arbitral tribunals, which must navigate not only competing interpretations of law but also competing constructions of scientific reality.

In this context, arbitration does not simply apply legal rules to objective facts; it operates within a space where both law and fact are subject to interpretation. The resulting outcomes are therefore shaped not only by legal reasoning but also by the management of uncertainty and the negotiation of competing knowledge claims. This challenges traditional conceptions of arbitration as a neutral and objective mechanism of dispute resolution, revealing instead its embeddedness within broader epistemic and political processes.

Accordingly, scientific uncertainty must be understood not as an external constraint on arbitration, but as an integral component of the environment in which it operates. Its effects are not limited to evidentiary challenges but extend to the very structure of legal reasoning and decision-making. As this analysis demonstrates, the limits of arbitration in transboundary water disputes cannot be fully understood without considering the epistemic conditions that shape the production and interpretation of knowledge.

HYDRO-POLITICAL REALITIES AND POWER ASYMMETRY

Beyond the epistemic challenges associated with scientific uncertainty, transboundary water disputes are deeply embedded within political contexts shaped by asymmetries of power, geography, and institutional capacity. The distribution and control of water resources are not merely technical or legal questions; they are intrinsically linked to broader structures of political economy that influence both the emergence of disputes and the mechanisms through which they are addressed.

In this regard, the spatial configuration of watercourses plays a critical role. The upstream, downstream dynamic introduces inherent asymmetries, as upstream states often possess greater capacity to control the quantity and timing of water flows, while downstream states are more vulnerable to alterations in supply. These geographical asymmetries are frequently compounded by disparities in economic resources and institutional strength, which affect states' ability to develop infrastructure, generate data, and engage effectively in dispute resolution processes.

Scholarly analyses have increasingly emphasized that conflicts over water cannot be understood solely in terms of physical scarcity. Rather, they reflect broader issues of access, governance, and power distribution.

The concept of hydro-hegemony, for instance, highlights how dominant riparian states can shape both the allocation of water resources and the institutional frameworks governing them, often through a combination of legal, political, and technical strategies (Zeitoun and Mirumachi, 2008, p. 306). In such contexts, legal mechanisms, including arbitration, do not operate on a level playing field but are embedded within asymmetrical structures that influence both process and outcome.

These dynamics present significant challenges for arbitration as a mode of dispute resolution. Arbitration is often conceptualized as a neutral and objective mechanism, capable of producing binding decisions based on legal reasoning. However, this assumption of neutrality may not fully reflect the realities of hydro-political relations. The initiation of arbitration itself is contingent upon state consent, which may be withheld or strategically deployed depending on political considerations. Moreover, disparities in technical expertise and financial resources can affect the ability of parties to present evidence and arguments effectively, thereby influencing the conduct and outcomes of proceedings.

The Indus basin provides a particularly illustrative example of these dynamics. While the Indus Waters Treaty establishes a structured and ostensibly neutral framework for dispute resolution, the broader political relationship between India and Pakistan continues to shape the interpretation and application of its provisions. Disputes arising under the Treaty are not merely legal disagreements but are embedded within a wider context of historical tensions and strategic competition. As a result, arbitration operates within a politically charged environment that both conditions its use and constrains its effectiveness.

Accordingly, the role of arbitration in transboundary water disputes must be understood not only in legal or procedural terms, but also in relation to the power structures within which it is embedded. This perspective underscores the limitations of approaches that treat arbitration as a purely technical solution, highlighting instead the need to account for the political dimensions that shape its operation.

THE INDUS WATERS REGIME: ARBITRATION IN PRACTICE

The Indus Waters Treaty (1960) represents one of the most sophisticated and enduring institutional arrangements for the management of transboundary water resources. Its dispute resolution architecture is particularly notable, incorporating a graduated system that includes negotiation, neutral expert determination, and arbitration through a Court of Arbitration. This multi-tiered structure reflects an advanced level of legal and institutional design, aimed at balancing flexibility with the availability of binding resolution mechanisms.

However, the practical operation of this framework reveals several structural limitations that complicate the role of arbitration within the regime. These limitations are not merely procedural but are indicative of broader tensions between legal design and the complex realities of transboundary water governance.

A primary issue concerns the fragmentation of dispute resolution mechanisms within the Treaty framework. The coexistence of parallel processes, particularly the distinction between neutral expert determination and arbitration, has generated procedural ambiguity regarding the appropriate forum for resolving specific disputes. This ambiguity has, in practice, led to contestation between the parties over jurisdictional questions, thereby delaying proceedings and complicating the resolution process. Rather than providing a clear and streamlined pathway, the multiplicity of mechanisms introduces an additional layer of uncertainty into the system.

In addition, disputes arising under the Indus Waters Treaty are frequently characterized by a high degree of technical complexity. Questions relating to dam design, water flow, and environmental impact require detailed hydrological and engineering analysis. While arbitration offers the possibility of incorporating

technical expertise, the integration of such knowledge into legal reasoning remains challenging. Tribunals are required to evaluate competing expert evidence, often in conditions of uncertainty, and to translate technical findings into legal conclusions. This process not only places significant demands on arbitral institutions but also reinforces the broader epistemic challenges discussed above.

Political sensitivity further complicates the operation of arbitration within the Indus regime. Despite the availability of formal dispute resolution mechanisms, states have often demonstrated a preference for managing disputes through diplomatic channels. Escalation to arbitration may be perceived as politically costly, particularly in a context marked by longstanding geopolitical tensions. As a result, arbitration is frequently treated as a mechanism of last resort, limiting its practical use and impact.

Notwithstanding these challenges, arbitration within the Indus Waters framework has made important contributions to the clarification of treaty provisions and the development of interpretative standards. Arbitral decisions have provided guidance on the application of key provisions, thereby enhancing legal understanding and predictability to some extent. However, these contributions must be assessed considering the broader systemic constraints within which arbitration operates. While it may clarify specific legal questions, it does not necessarily resolve underlying political tensions or address the structural conditions that give rise to disputes.

Thus, the Indus Waters regime illustrates both the potential and the limitations of arbitration as a mechanism of dispute resolution. It demonstrates that even in a highly institutionalized and legally developed framework, arbitration remains constrained by factors that extend beyond legal design, including scientific complexity and hydro-political dynamics.

IDENTIFIED GAPS IN THE EXISTING FRAMEWORK

The preceding analysis reveals a set of interrelated gaps within the existing framework governing arbitration in transboundary water disputes. These gaps are not isolated deficiencies but reflect deeper structural characteristics of international water law and its interaction with scientific and political realities.

A central issue is the persistence of normative indeterminacy within the legal framework. Core principles such as equitable and reasonable utilization and the obligation not to cause significant harm to lack precise definition and operate without clearly established hierarchies. While this flexibility allows for context-sensitive application, it also limits the consistency and predictability of arbitral outcomes. Tribunals are required to engage in balancing exercises that depend heavily on interpretive discretion, raising questions about coherence and legitimacy across cases (McCaffrey, 2019, pp. 381–385).

Closely related to this is the disconnect between legal reasoning and scientific knowledge. The absence of structured mechanisms for integrating scientific expertise into arbitral processes creates significant challenges in the evaluation of evidence. Reliance on party-appointed experts may lead to adversarial presentations of scientific data, further complicating the task of tribunals and potentially undermining the objectivity of decision-making (Mbengue, 2011, p. 541). This science–law interface remains insufficiently developed within existing frameworks.

Institutional fragmentation constitutes another important limitation. The coexistence of multiple dispute resolution mechanisms, often without clear delineation of their respective roles, can lead to procedural inefficiencies and jurisdictional disputes. Rather than facilitating resolution, such fragmentation may delay proceedings and reduce the overall effectiveness of the system.

In addition, issues of accessibility and capacity must be considered. Participation in arbitration requires significant financial and technical resources, which may not be equally available to all states. This raises concerns regarding equity and inclusiveness, particularly in contexts where power asymmetries are already pronounced. The ability of weaker states to effectively engage in arbitral proceedings may therefore be constrained, further reinforcing existing imbalances.

Finally, the existing legal framework remains insufficiently responsive to the challenges posed by climate change and environmental variability. Many of the norms and mechanisms currently in place are based on assumptions of relative stability in hydrological conditions. As these assumptions become increasingly untenable, the capacity of arbitration to deliver forward-looking and adaptive solutions is called into question. The absence of mechanisms explicitly designed to address dynamic environmental change represents a significant gap in the current system.

Taken together, these gaps highlight the limitations of arbitration as currently structured within international water law. They suggest that improving the effectiveness of arbitration requires not only procedural refinement but also a more fundamental engagement with the structural conditions that shape its operation, including legal indeterminacy, scientific uncertainty, and hydro-political asymmetry.

TOWARDS A RECALIBRATED MODEL OF ARBITRATION

The limitations identified in the preceding analysis suggest that the challenges facing arbitration in transboundary water disputes cannot be addressed through incremental procedural adjustments alone. Rather, they call for a more fundamental rethinking of arbitration as a mechanism embedded within a complex system characterized by legal indeterminacy, scientific uncertainty, and hydro-political asymmetry. In this context, recalibration does not imply the replacement of arbitration, but its transformation into a more adaptive, epistemically informed, and context-sensitive process.

A first dimension of this recalibration concerns the integration of scientific expertise into arbitral proceedings. Given the centrality of technical and environmental questions in contemporary water disputes, the reliance on party-appointed experts is increasingly insufficient to ensure the objectivity and coherence of scientific assessment. Greater use of independent, tribunal-appointed experts could help mitigate adversarial distortions and enhance the credibility of factual determinations. At the same time, the development of standardized methodologies for the evaluation of hydrological and environmental data would contribute to greater consistency in decision-making, while acknowledging the inherent limits of scientific certainty (Mbengue, 2011, p. 541).

Second, the recalibration of arbitration requires a shift toward more adaptive forms of legal interpretation. Traditional approaches to adjudication often assume relatively stable factual and normative conditions, an assumption that is increasingly untenable in the context of climate change and environmental variability. Arbitral tribunals must therefore engage with legal principles in a manner that is responsive to changing conditions, incorporating considerations of uncertainty, risk, and long-term sustainability into their reasoning. This implies a more dynamic understanding of principles such as equitable utilization, one that accommodates temporal variability and evolving patterns of resource availability (McIntyre, 2010, pp. 88–90).

Third, strengthening the relationship between arbitration and broader institutional frameworks is essential. Basin-level organizations and joint management bodies play a critical role in generating data, facilitating cooperation, and maintaining continuity in governance. Integrating these institutions more effectively into arbitral processes, whether through the provision of technical expertise, monitoring functions, or implementation support, could enhance both the quality and the legitimacy of arbitral outcomes. Such

integration would also help bridge the gap between episodic dispute resolution and continuous resource management.

A further dimension of reform relates to procedural clarity. As illustrated by the Indus Waters regime, the coexistence of multiple dispute resolution mechanisms without clear delineation can generate uncertainty and delay. Establishing more precise criteria for the selection and sequencing of procedures would contribute to greater efficiency and predictability, reducing opportunities for strategic contestation over jurisdiction. However, such clarity must be balanced against the need for flexibility, ensuring that dispute resolution mechanisms remain responsive to the specific characteristics of each case.

Finally, any recalibration of arbitration must address issues of equity and power asymmetry. The formal neutrality of arbitration does not eliminate disparities in capacity and influence among states. Measures aimed at enhancing inclusiveness, such as support for capacity-building, greater transparency in proceedings, and consideration of differential impacts, are necessary to ensure that arbitration does not inadvertently reinforce existing inequalities. This requires a more explicit engagement with the distributive dimensions of international water law, moving beyond procedural fairness to address substantive concerns of justice (Cullet, 2009, p. 147).

Taken together, these elements point toward a model of arbitration that is less rigidly formalistic and more attuned to the complex realities of transboundary water governance. Such a model does not seek to eliminate uncertainty or political influence, objectives that are neither realistic nor necessarily desirable, but rather to manage them in a manner that enhances the legitimacy and effectiveness of dispute resolution. In this sense, recalibrated arbitration emerges not as a definitive solution, but as a more resilient and context-sensitive component of a broader governance framework.

CONCLUSION

Arbitration occupies a critical yet inherently constrained position within the architecture of international water law. While it offers a structured and legally grounded mechanism for dispute resolution, its capacity to deliver effective and legitimate outcomes is shaped by factors that extend beyond its procedural design. As this article has demonstrated, the interaction between legal indeterminacy, scientific uncertainty, and hydro-political asymmetry defines the limits within which arbitration operates.

The analysis of the Indus Waters Treaty regime illustrates both the potential and the constraints of arbitration in practice. On the one hand, arbitration contributes to the clarification of legal norms and provides a forum for the structured resolution of disputes. On the other hand, its effectiveness is limited by the complexity of the issues it seeks to address and the broader political and epistemic contexts in which it is embedded. These findings challenge conventional assumptions regarding the capacity of arbitration to function as a neutral and definitive mechanism of dispute resolution.

More broadly, the article underscores the need to move beyond a narrow focus on institutional design toward a more integrated understanding of international water governance. The effectiveness of arbitration cannot be assessed in isolation, but must be evaluated in relation to the system within which it operates, a system characterized by evolving environmental conditions, contested knowledge, and uneven distributions of power.

Future developments in international water law must therefore engage with these structural conditions in a more explicit and systematic manner. This involves not only refining dispute resolution mechanisms, but also rethinking the relationship between law, science, and politics in the governance of shared resources.

There is a need to develop approaches that can accommodate uncertainty, managing complexity, and addressing issues of equity in a more substantive way.

Ultimately, the promise of arbitration in transboundary water disputes lies not in its ability to provide definitive solutions, but in its potential to function as part of a broader, adaptive, and cooperative governance framework. Realizing this potential requires a shift in perspective, from viewing arbitration as an endpoint of dispute resolution to understanding it as one element within a dynamic and interconnected system. It is only through such a reframing that arbitration can contribute meaningfully to the sustainable and equitable management of shared water resources in an era of increasing environmental and political uncertainty.

BIBLIOGRAPHY

BOOKS:

Cullet, Philippe, *Water Law in a Globalised World: The Need for a New Conceptual Framework* (Cambridge University Press 2009).

McCaffrey, Stephen C., *The Law of International Watercourses* (3rd edn, Oxford University Press 2019).

McIntyre, Owen, *Environmental Protection of International Watercourses under International Law* (Ashgate 2010).

Schmeier, Susanne, *Governing International Watercourses: River Basin Organizations and the Sustainable Governance of Internationally Shared Rivers and Lakes* (Routledge 2013).

Shaw, Malcolm N., *International Law* (8th edn, Cambridge University Press 2017).

JOURNAL ARTICLES AND CHAPTERS:

Caflisch, Lucius, 'Regulation of the Uses of International Watercourses' in *The Oxford Handbook of International Environmental Law* (2007) 625.

Mbengue, Makane Moïse, 'Scientific Fact-Finding by International Courts and Tribunals' (2011) 2 *Journal of International Dispute Settlement* 539.

Salman, Salman M.A., 'The Helsinki Rules, the UN Watercourses Convention and the Berlin Rules: Perspectives on International Water Law' (2007) 23 *Water Resources Development* 625.

Stoffel, Markus et al., 'Freshwater and Climate Change' in *The United Nations World Water Development Report* (2020) 45.

Wouters, Patricia, 'International Law and Water: The Multi-Level Governance of Freshwater Resources' (2013) 23 *Journal of Water Law* 122.

Zeitoun, Mark and Mirumachi, Naho, 'Transboundary Water Interaction I: Reconsidering Conflict and Cooperation' (2008) 33 *International Environmental Agreements* 297.

INTERNATIONAL LEGAL INSTRUMENTS:

Convention on the Law of the Non-Navigational Uses of International Watercourses (adopted 21 May 1997, entered into force 17 August 2014).

Indus Waters Treaty (India–Pakistan) (signed 19 September 1960).

Helsinki Rules on the Uses of the Waters of International Rivers (International Law Association,

CASES AND ARBITRAL DECISIONS:

Indus Waters Kishenganga Arbitration (Pakistan v India) (Final Award, 2013).

Lake Lanoux Arbitration (France v Spain) (1957) 12 RIAA 281.

Gabčíkovo–Nagymaros Project (Hungary v Slovakia) [1997] ICJ Rep 7.

Pulp Mills on the River Uruguay (Argentina v Uruguay) [2010] ICJ Rep 14.

Trail Smelter Arbitration (United States v Canada) (1938/1941) 3 RIAA 1905.