ORIGINAL RESEARCH
published: 18 May 2022
doi: 10.3389/fcomm.2022.810266

Who Speaks for Water in Times of Crisis? A Case for Co-production of Engineering and Governance

Ehsan Nabavi [1,2]*

[1] *Australian National Centre for the Public Awareness of Science (CPAS), The Australian National University, Canberra, ACT, Australia,* [2] *Responsible Innovation Lab, Australian National University, Canberra, ACT, Australia*

Studying the relationship between water expertise and the state's governance is important as it helps to explain the mechanism by which a certain group of experts rise to power, speaking for water—its challenges, and opportunities. This is particularly of concern in the times of crisis when the society does not know where to turn, and who to trust. Some aspects of this relationship have been addressed in the literature through now-familiar notions such as hydraulic bureaucracy and the hydraulic mission, in which the prevailing role of water engineers in problem framing and communicating solutions has been brought into the spotlight. However, the reciprocal nature of this relationship, particularly in difficult times when the society is fraught with fear of an uncertain future, has remained heavily under-researched. To fill this gap, this paper suggests we can productively draw on the concepts of "co-production" and "epistemic community". Using Iran's looming water crisis, the paper provides an example of how governance and water engineering co-produce one another through an ongoing process of mutual constitution. On one hand, engineering artifacts are integral part of state-making process; while on the other hand, water engineers become the gatekeepers of knowledge-making processes. This creates a hegemonic power for water engineers, their epistemic practices, and institutions of power. This research also illustrates how this co-production reinforces the epistemic injustice in water governance by marginalizing non-engineering communities most particularly indigenous knowledge-holders. This is, of course, a great concern as it can lead to depoliticization of the water crisis, monopolization of water science, and demonization of participation in water governance.

Keywords: water crisis, co-production, epistemic community, hydrocracy, water engineering, epistemicide, hegemony

OPEN ACCESS

Edited by:
Nova Ahmed,
North South University, Bangladesh

Reviewed by:
Voltaire Alvarado Peterson,
University of Concepcion, Chile
Peter Haas,
University of Massachusetts Amherst, United States

Correspondence:
Ehsan Nabavi
ehsan.nabavi@anu.edu.au

Specialty section:
This article was submitted to Science and Environmental Communication, a section of the journal Frontiers in Communication

Received: *06 November 2021*
Accepted: *18 March 2022*
Published: *18 May 2022*

Citation:
Nabavi E (2022) Who Speaks for Water in Times of Crisis? A Case for Co-production of Engineering and Governance. Front. Commun. 7:810266. doi: 10.3389/fcomm.2022.810266

INTRODUCTION

Water resource issues and problems around the world, including insufficient water supply and inadequate quality of water resources, are one of the critical situations in our time that science has a key role to play. Decision-makers and people across different territorial boundaries are increasingly turning their attention to published research to know what should be done and how. Coupled with this social and political need, the mix of high stakes, fear, urgency, and uncertainty—that are all quite prevalent in times of crisis— make the experts the hub for everything, ranging from understanding the status quo, to speculating the future pathways. In other words, the crisis provides an environment in which expertise and technical knowledge are the main sources of power and legitimacy in both framing the challenge and finding the "right" solution.

It is through this circumstance that water experts, in a water crisis, become the obligatory passage point (Latour, 2005) in defining "what counts" as valid, credible, legitimate, and salient knowledge capable of addressing the nature of water crisis but also potential solutions. The crisis, in fact, sets the stage for the water experts to impose their own way of knowing onto decision-makers and the public.

Often in this process, a particular type of science is privileged in producing water knowledge; certain epistemic approaches are used in characterizing the crisis; and a specific application of the produced knowledge is taken on for decision-making. All this means that a certain community of experts—or a certain "epistemic community" (Haas, 1992)—, emerges more strongly to speak on behalf of water and how it should be treated.

However, this is also context-specific. The most vocal experts on the same subject might vary in different societies. That is mainly because, the ways in which the public expect the expertise, knowledge, and reasoning to be produced, analyzed, and applied in decision-making are often culturally specific [see Jasanoff's notion of "civic epistemologies" (Jasanoff, 2005)]. In addition to this context-specific idiosyncrasy, the literature suggests that this domination of a certain group of experts over others is subject to change over time, even in a single context. For example, Crase et al., 2009 (2009, p. 440) describe the shift in political power and scientific authority among different communities of Australian water experts. Tracing water engineers throughout the Australian history, they argue that the status of community of engineers in the water governance transformed from "king to servant" over the past few decades.

Given this background, this paper aims to unpack the relationship between engineering, power, and social order through using the example of Iranian water crisis. The water crisis presents a unique opportunity to disentangle the interaction between different actors, showing how engineering expertise turns into a dominant knowledge-frame for addressing the issues and making decisions while other forms of knowledge are systematically overlooked. A combination of content analysis with semi-structured interviews is used to shed light on how water science communicated with public as water crisis peaks in the country in 2015.

Drawing on the idea of "co-production" of science and governance (Jasanoff, 2004), the paper shows how Iranian governance and engineering have co-produced one another through an on-going process of mutual constitution. The social implication of this co-production has been the emergence of a society in which ways of knowing, norms of expertise, importance of evidence, level of argumentation, ways of communication, style of reasoning, method of presentation, and psychology of judgment are all heavily shaped by an engineering paradigm and technocratic views and ideas.

Accordingly, the paper begins with a stage-setting review of relationship between engineering and state formation in modern world, and then focuses on how this interaction has manifested itself in water governance. Using the example of Iran's looming water crisis, the next section illustrates the hegemony of engineer and its motifs in establishing and sustaining governance activities. Looking into Iran's education system and water research, the paper shows the domination of engineering graduates among professionals and certain form of water knowledge while others epistemic communities are largely marginalized. The final section then draws conclusions, and reflects on the findings.

ENGINEERING IN MODERN SOCIETY

The literature in history of science and technology offer insights into the deep and long-lasting relationship between engineering and state formation (e.g., Winner, 1980; MacKenzie and Wajcman, 1999; Carroll, 2006; Pritchard, 2011; Barry, 2013; Rowland and Passoth, 2015). Since the beginning of the Industrial Revolution, "engineering" in particular have helped the modern government to manage the land, water, people, and the built environment in an unprecedented way; or as Guildi puts it, they help governments to "design the flows of bodies, information, and goods" (Guldi, 2012, p. 3). A quick observation in this modern world makes one realize that the seventeenth-century's engineering mindset and language stills prevails all aspects of our everyday life. Think about all techniques and methods in different disciplines that are profoundly shaped and enacted by the idea of metering, scoping, mapping, and graphing (Carroll, 2006). Drawing on this historical perspective, this research uses hydraulic bureaucracies to unpack the interwoven, heterogeneous, and multifaceted relationship between state's governance and water engineering—as a subset of engineering discipline.

The paper is built on the central idea that "engineering has politics". The more politics (or politicians) gains from the water engineering, the more it (they) will foster inequalities in knowledge production and communication in favor of water engineering. In this process, the "development" becomes an engineering project which non-engineering communities, including indigenous people, have minimum influence on shaping it. A process in which engineers are perceived as "*development soldiers*", realizing political ambitions. And in return, the politics reciprocates by making the engineers the gatekeeper of knowledge, and the engineering the gold-standard to define what is valid and what is not.

Co-production of Water Engineering and Governance

As defined by Jasanoff (2004), the concept of "co-production" advocates the idea that not only science is deeply shaped by politics, but it influences the way reality and policy are constructed and employed. In other words, it suggests knowledge-making and state-making are mutually constitutive. The outcome of this reciprocal relationship includes skills, technologies, machines, tools, concepts, ideas, and many other forms of socio-technical apparatus that are developed and deployed in both processes of knowledge-making and state-making (see Pickering, 2010).

Drawing on this concept, we can also study how water engineering and governance co-produce one another. The great example of that is the ongoing relationship between water science production and the formation of modern societies across the world.

Over the last century, the theoretical and practical advancements in understanding of hydrology, hydraulics, aquatic ecology has enabled societies to go beyond their traditional water management. As a result, a new community of water engineers (made of a diverse range of academics and practitioners) is emerging who has expertise in irrigation and drainage engineering, hydro-electric structures and machinery. With their help, new development projects are defined and implemented in order to improve the performance of the irrigation and support the economy of the society. Gradually, large-scale hydropower dams and modern irrigation schemes change the face of local communities and become the symbols of progress and prosperity. Their underpinning knowledge and engineering skills provided the necessary passage point for states across the world to recast themselves as modern societies, liberated from old fashioned customs and traditions.

In Iran, for example, this group of experts develop authoritative bureaucratic institutions during 1960s. They become strong actors at the national level viewing the existing agricultural practices as obsolete, and "barriers" to the country's modernization—including Qanat (water systems that Iranians historically depended on) and its traditional mechanisms for water regulation. They believe the technology that is developed in western countries (e.g., deep wells, large-scale dams) could transform the landscape of local communities for the betterment of society (Nabavi, 2017b). In a speech at the International Conference on "Water and Peace" on May 29, 1967, Iran's then Minister for Agriculture and Water and Power lay out the country's development strategy:

> *"Although Qanats were the main source of water for the country's agriculture in the past, now that we are supposed to use the maximum potential of the country's water resources they are just barriers in further groundwater abstraction. Given this explanation, Qanats have no role in Iran's future economy, and their drying-up is sure thing. As a consequence, 35 thousand villages relying on Qanat are doomed to change in terms of reshaping and merging into massive agricultural development projects. This enormous transformation means disappearance of small and uneconomical village unites and their replacement with bigger villages similar to ones in the developing countries".*

This new engineering community enabled the Iranian government to exercise its control over water flows and supplies in an unprecedented way. And that helped the state to expand its authority over land, environments, and people by introducing new forms of policy and regulatory arrangements (see Swyngedouw, 2004). The new arrangements together with the large investment required for structural projects have permitted the state to monopolize water governance, and exploit water resources.

This story, of course, is not unique to Iran. There is a growing body of evidence that shows countries from across the world, have been on political mission to utilize every single drop of the water resources by building hydraulic infrastructures (hydraulic mission) (Molle et al., 2009). In the literature they are often referred as "hydraulic society" (Wittfogel, 1957) or "hydraulic bureaucracy" (hydrocracy) (Reisner, 1993; Swyngedouw, 1999; Wester, 2008; Wester et al., 2009), where the infrastructure projects primarily serve "the interests of a narrow, entrenched elite, while projecting a rhetoric around modernization, securitization and nation-building themes" (Blake, 2021).

In the evolution of this new form of centralized bureaucracies, water engineers—mostly trained in civil engineering—have been the most vital components. They represent the liberating power of engineering in constructing large-scale dams, modern irrigation schemes, and water treatment plants. Since the French Revolution, engineering expertise has been employed to reimagine a new world inspired by the very idea of human control over nature and its destiny (see Alder, 2010). Even as military engineers, engineers have been actively involved in realizing modern states across the world (for the history of Army Corps of Engineers see Shallat, 2010).

Hence, hydraulic infrastructures, such as large-scale dams, reservoirs, and irrigation schemes increasingly found a firm foothold internationally as symbols of modernity and development. The literature is replete with examples from across the world how these water engineering technologies have been used for the state reconstruction, and nation building projects: such as in California (Worster, 1985), Germany (Blackbourn, 2011), Spain (Swyngedouw, 2015), Mexico (Wester et al., 2009), Thailand (Benedikter, 2014), and Tajikistan (Menga, 2015).

In the co-production of water engineering and governance, we could also see how engineering concepts are used by government to shape their agenda and political narratives. "Efficiency" is a great example of that. In hydrocracies, the notion of efficiency plays a key role in what policies are adopted. It is often said that rivers should not reach the sea without being used "optimally" (Waterbury, 1979); or the solution lies in increasing the efficient use of available resources by converting traditional irrigation systems into modern irrigation schemes. In this system of thought and action, every drop of water has a role to play in enhancing the state's economic viability. The more successful engineers are in harnessing water, the greater power the state might retain in shaping the society and economy. Thus, the importance of efficiency is widely communicated to the public as the enabler of a more prosperous future. In contrast to the traditions and indigenous ways of life that is presented as primitive, backward, and generally something which lacks progressive thinking.

The engineering mindset is gradually internalized as the standard way of knowing things, including water issues. Technical aspects are perceived as the most crucial part of a "rational", and "reasonable" decision-making process, whereas other forms of knowledge—those related to socio-political and economic factors of stakeholders, or indigenous knowledge—are taken as inconsequential or irrelevant. As a result, non-engineering management options find less room to maneuver and create consensus, as they are assumed to be failed strategies in advance. Instead, it is those options stemming from command-and-control approaches (Holling and Meffe, 1996) that are viewed as reasonable policy actions. One of the main reasons is that command-and-control approaches usually prescribe a hierarchical structure for policymaking where both water engineers and bureaucrats sit on the top—largely free from public scrutiny and participation.

The Water Engineering Epistemic Community

To better understand the reciprocity between water engineering and governance, it is useful to look into how the interests between water engineers and the state are aligned and sustained in the hydrocracy. For that, let's begin with a short discussion on how people usually make sense of the world around them.

Social theorists such as Ulric Beck arguing that our modern society heavily relies on the rationality and technology for solving its problems. Not limited to times of crisis, the members of society often make sense of social and environmental problems with help of scientific methods and technology. However, given the diversity of scientific approaches, the outcome of this sense-making project is often contested, and subject to interpretation and continuing debate. Different communities of experts inform the public and decision-makers differently about how the world is, and how it ought to be. Communities distinguish themselves from one another by having different ways of framing the controversy, interpreting state interests, setting standards and developing policy and regulations (Stephens et al., 2011).

From our personal experience we all know, it is not always the case that all involved communities have equal footing for characterizing the problem and developing solutions. Rather, we tend to listen to a certain group of experts for a specific subject matter. In the case of COVID, for example, policies are largely developed and mobilized by virologists and epidemiologists, and their institutions of power. The implication is being that these communities gain more control over policy debates, resulting in the silencing of alternative voices—from anthropologists and philosophers to general practitioners.

In a hydrocracy, it is the water engineers that control the policy options, by actively participating in everyday forms of state formation and governance (see Molle et al., 2009). A cadre of water engineers, who this paper calls "technocrat engineers", become the dominant epistemic community in shaping how society makes sense of the world and imagine the future. Believing in the power of engineering as a means for modernization, economic growth and social prosperity, they want to "build" their country and "manage" it at the same time.

Here we refer to water engineering not merely as a profession but as an epistemic practice[1] which insists on technical solution to almost all forms of societal and environmental problems. It serves as an anchor around which a coalition of engineers from various disciplines could involve in building and managing the country. Their professional competence perceived as an indispensable part of the governance, without which the country's journey toward modernization (a better future) is impossible.

In that respect, water engineers could play a pivotal role not only in designing and propelling the state's development policies, but also in forming the national identity—through creating artifacts like dams which can be deployed in the process of nation-state building (e.g., Menga, 2015). The result of this complex interaction has been rational societies and bureaucracies which tend to embrace a more engineering and mechanistic perspective in the governance, social regulation, and the design and operation of enterprises. In this context, the process of knowledge-making largely falls into the hands of a "guilt of engineers" (Benedikter, 2014, p. 551), in which the legitimacy of knowledge and credibility of outputs are only measured against the engineering criteria (e.g., design, standard, attitude, judgment). As a result, the "truth", or any proposition that is accepted within the society as the truth, needs a solid engineering or technical foundation.

This hegemonic position of water engineers in knowledge production and communication have had two main drivers: first, a successful alliance with decision-makers, and second, the social and political appeal of their expertise in the society. And both are intertwined and influence each other through an ongoing process of mutual constitution.

Given this specification of knowledge production in hydrocracies, the water engineering epistemic community can be defined as a community of water engineers whose expertise, competence, and outputs (e.g., models, discourse, reports) put them in the position in claiming truth about water problems and policy solutions. It is important to stress that while water engineers as a whole constitute a profession, here we are referring to a community of water engineers who systematically contribute to water engineering projects informed by technocratic views and ideas.

As research indicate, the centrality of this epistemic community within hydrocracies in addressing how the world is, and how it ought to be, has encouraged water engineers to think too highly of themselves as the upper level of hierarchical understanding of knowledge about water, closed to any public scrutiny and participation (McCulloch, 2009; Watson et al., 2009; Nabavi, 2017b). However, this situation was challenged in the last quarter of the 20th century by environmental movements, decentralization of power, and neoliberal critique of state governance (Molle et al., 2009). Particularly, a series of water policy reforms in many states resulted in a significant shift of power from water engineers.

[1]"Epistemology" essentially concerns about "how do we know things?". Accordingly, "epistemic practices" entail important aspects of doing a profession (e.g. engineering) and learning about how to be an expert in that area of knowledge (e.g., see Cunningham and Kelly, 2017 for 16 epistemic practices of engineering).

Nevertheless, this transformation should not be taken for granted as a universal phenomenon. This is because, the political appeal of engineering, i.e., the second driver, varies in different parts of the world. Moreover, there is not such a universal category of themes shared among engineers. As Tim Mitchell succinctly demonstrates in his seminal book "Rule of Experts", even categories of themes that we think are universal such as capitalism, technology, politics, and ecology are, in fact, contextual: products of locally contingent networks of actors, social practices, and institutions of power.

The lesson here is that, even the water engineering epistemic community, itself, is culturally specific and varies in different contexts. It invents its own thematic categories in different contexts based on local understandings of issues of concerns for engineers such as sustainability, risk, vulnerability, rationality, practicality, safety, and effectiveness.

In the following section, an example of Iranian water crisis is used to demonstrates the analytic potential of notions of (1) water engineering epistemic community and (2) the co-production of engineering and governance.

SCIENCE COMMUNICATION IN IRAN'S WATER CRISIS

The Context of Crisis

Iran is experiencing a severe water crisis. Over the last decade, successive droughts, rising water demand, lack of effective water regulation and public participation have left many rivers and lakes dry, groundwater resources depleted, and many villages abandoned. Hundreds of dams that are built by civil engineers to address the growing demand for electricity and country's self-sufficiency policy has exacerbated pressure on water resources and created nation-wide water shortage (Nabavi, 2016).

As a country which has historically relied on groundwater resources for development purposes, Iran is experiencing a progressive decline in water levels of aquifers. Groundwater policies and measures to control overabstraction have largely failed to restore the groundwater balance (Nabavi, 2018).

On top of that, there are problems of massive soil erosion, desertification, biodiversity loss, and frequent dust storms, which are just some of the many grave socio-environmental concerns (Stone, 2015). Claiming the largest share of soil erosion by any one country (around 7.7% of all soil erosion), and having four out of the ten most polluted cities in the world in 2013 (Rayman, 2013), are just two of the indicators showing why some of Iranian policymakers are deeply worried about Iran's future (Al-Monitor, 2015).

Water-related conflicts have also increased, resulting grievances and unrest spread throughout the country. Protests over water management has increasingly become a regular feature of the Iran's news.

These environmental challenges call into question the "legitimacy" of engineers and their technocratic perspectives who have been the dominant actors in Iran's policy landscape, over the last four decades. As a result, the growing number of academics, and NGOs in the country criticize the government's command-and-control approaches in addressing the challenge, using supply-oriented initiatives, such as investments in mega transbasin water transfer projects and desalination plants (Nabavi, 2011, 2017a; Zafarnejad, 2016). Instead they advocate policies that support demand management, such as revisiting the new population growth policy, improving the efficiency of the agricultural sector, increasing water and energy prices, implementing an efficient water market (Madani et al., 2016). Also, there is an argument that since Iran is heavily rely on groundwater resources, the country needs to revisit "water law" as a structural cause of water crisis (Nabavi, 2018). The response of the government however has been ad hoc, confusing and lacking in direction—but also a crackdown on critical voices and on dissent more generally (Schwartzstein, 2020).

The Deep Hegemony of Engineering

In this and the following section, the paper provides details about the co-production of engineering and governance in Iran's political landscape; and then show how it manifested itself in water science. The notion of co-production used here is very close to what geographers such as Eric Swyngedouw and Sarah Whatmore suggest when they use the concept of cyborg for the historical-material analysis of water. In their studies they emphasize it as the "process of hybridization" (Swyngedouw, 1996, 2015), and "coupling" (Whatmore, 1997).

To trace the co-production of engineering and state-making in Iran's history we can go back to 1850s when chief minister Amir Kabir established Iran's first polytechnic institute (Dar al-Fonoun), or even earlier to 1810s when Prince Abbas Mirza attempted to modernize army[2] (Nezam-e Jadid, lit. "new order/system") (Abrahamian, 1982; Amanat, 2017). Yet, this paper focuses great attention on the emergence of engineering particularly after Islamic revolution 1979.

In late 1970s, the socio-political problems caused by development projects led Iran to revolt against Shah, the biggest sponsor of technology and modernization in the region (Nabavi, 2017b). The revolution not only changed the Iran's political and social orders, but also transformed the political language of Iranian governance. Islamic words, concepts, and phrases were not the only change in the political rhetoric of the new government. Also, as time passed and the system of governance became more established, the metaphors and themes inspired by engineering and construction was more heard and used[3]. Engineering motifs and tropes become the linguistic foundation for new way of thinking about post-revolutionary governance. This new language after 1979 revolution has to be juxtaposed with dominant language during and after Iran's previous revolution which took place in 1900s, i.e., Enghelab-e Mashruteh, mostly been informed by tropes stemming from the medical sciences (see Tavakoli-Targhi, 2012).

[2] Particularly after May 1807 Franco-Persian Treaty of Finckenstein when France offered training and modernisation of Iranian army by French officers and military engineers (for more see Amanat, 2017).

[3] Along with many socio-political reasons, this shift to engineering-laden language can be explained through the outstanding role of engineering students in the success and sustaining the revolution.

After 1979 revolution, engineering motifs and tropes quickly merged into social, religious, and political concepts and give birth to new ideas about governance. The following terms that are often used in Iran's current political sphere clearly shows how engineering and related terms and concepts like "geometry,"[4] which has a very close etymological connection to engineering in Persian, are actively engaged in making Iran's new political sphere. Terms such as "cultural engineering," "social engineering," "religious engineering," "geometry of theology," "geometry of politics," "social geometry," "divine geometry." It is beyond the scope of this paper to elaborate on how this process took shape and has affected Iran's political rhetoric; yet, it is important to consider this as an outcome of the co-production of engineering and governance in Iran.

As discussed, this political appeal toward engineering forged a new relationship between religion, engineering, and governance. Not limited to the language, it affected Iran's post-revolutionary development agenda. According to Nabavi (2017b, p. 58), the influence of engineering on the Iran's post-revolutionary development agenda has been very significant. It was such that in less than a decade the revolutionary ideal of "social justice" was eclipsed by technocratic development policies advocated by neo-liberal technocrats, and engineers.

During Rafsanjani administration (1989–1997), for example, fast-paced development in water resources became the major symbol of country's development. According to Rafsanjani himself (Rafsanjani, 2012), nothing in that period was as important to him as harnessing water for agricultural purposes. Opening on average one dam every 45 days, he earned himself the nickname "commander of construction". Agricultural production increased by ∼60% through the development of irrigation schemes, and the introduction of fertilizer, agricultural education, and electric pumps (Hooglund, 2009). Water engineers, then,—as the "development soldiers" of the country—have been granted more power for pursuing the country's development agenda through aggressive development plans, turning the mainly arid country, perhaps ironically, into the third biggest dam builder in the world.

Epistemic Injustice in Water Governance

The flip side of hegemony of water engineering is the marginalization of other epistemic communities in Iran's political landscape, including social sciences and the indigenous communities whose knowledge has been underestimated by modern science. This happens against the backdrop that Iran is home to many ingenious and sustainable solutions for water management, most famously qanat technology (Manuel et al., 2018).

Much of the existing epistemology of water in Iran, which is propagated through universities and research institutions, does not employ indigenous knowledge as part of their approach in addressing the problem. Instead, the pedagogy remains within engineering disciplines, most particularly civil and agricultural engineering. Government also barely invests in protecting and promoting the indigenous knowledge systems. And that is mostly because traditional knowledge, skills, and customary laws are generally perceived insufficient and ineffective to address the country's growing water crisis.

This creates a "flat epistemic landscape" in which there is nothings, but only the mountain of water engineering. Non-engineering communities and their epistemic authorities are silenced and excluded, particularly leading to large-scale destruction of indigenous water knowledge and customs. Inspire by the work of Santos (2015), this paper calls this situation a "non-engineering epistemicide"—a mass extinction of non-engineering knowledges and approaches in the context of water management.

As a result, the water engineering epistemology becomes the main and only actor responsible for shaping development projects by managing and controlling water[5]. While these projects were initially designed to boost the economy and improve local people's livelihood, now there is a growing number of scholars who argue that the projects, which are based on reductionist mindset of engineers, has caused the water crisis.

To explore the underlying reasons behind the epistemic injustice and co-production, we need to first discuss some background information about Iran's education system; and then its implication for water engineering, and lastly the ways in which public participation and science communication is perceived by water engineers. The following three sections are presented to provide a contextual background about how and why non-engineering knowledge systems and approaches have been largely marginalized in Iran's governance system.

Marginalization of Non-engineering Disciplines

Entry to Iran's tuition-free public universities is based on the Konkur—the very competitive entrance exam known. Top students usually go into engineering disciplines, as they can guarantee better career prospects (WES, 2017). This is also strongly encouraged by their families as they value "engineering" over other fields of study[6]. As a result, Iran's universities are producing over 233,000 engineers annually, making the country a high-ranking member of the club of engineer-producing states: one of the top 5, alongside Russia, the United States, China and India[7]. This number becomes even more relevant when we consider it percentage-wise: it equates to 41% of all Iranian graduates. If one was to compare these figures with the international averages either at the start of the 21st century (i.e., 15%) or its most recently recorded rate in 2013 (i.e., 13%), the percentages for Iran seem even more extreme. From yet another standpoint, this share of engineers in Iran is 56% higher than that

[4]In Persian, the etymology of term "mohandes" meaning engineer derived from term "hendese" meaning geometry.

[5]Of course, we need to keep the debate open to as many points of view as possible about the ways in which the knowledge associated with collective water use regimes is built in the society.

[6]Medical field also preferred by Iranian students. The issue is that there are far too few seats to address the demand. The Medical universities are supervised by the Ministry of Health, Treatment and Medical Education, whereas other fields of science are supervised by the Ministry of Science, Research and Technology.

[7]China or India are not in this ranking due to lack of data. However, Wadhwa et al. (2007) showed that they rank high on the list.

of the country with the second highest number of engineering graduates per capita, namely Qatar (see **Figure 1**).

It is equally important to not ignore the trend. From 1999 to 2013, Iran has seen an increase of 150% in the development of the engineering programs at its universities, which is the exact opposite of trends seen in other countries, such as Turkey or South Korea (**Figure 2**).

This paper argues that the high number of engineering graduates in Iran and its long-lasting trend should be read as one of the outcomes of co-production of engineering and governance. For the Iranian students, being a graduate from an engineering discipline will make them more employable, particularly in the areas that government usually heavily invest in such as civic and industrial infrastructure. And that creates a mutual interest for both government and society to invest and pursue engineering in tertiary education. Apparently, the other side of this great interest in engineering, is lack of attention to (and often devaluation of) graduates from social sciences.

Bias in Water Research

There is no official data on the number of water engineering graduates. But as we might expect, a large group of this overwhelming number of engineering graduates belongs to students trained in disciplines related to water engineering such as civil engineering, agriculture engineering, irrigation and drainage engineering, etc. The massive number of publications produced from their Master and PhD research, is a good indicator of this rapid growth. Iran is now joining the club of countries with the most publications in water research, such as UK, Canada and Germany (from 0.45 paper/year to 231 papers in 2016) (see **Figures 3**, **4**)[8]. Immersed in the realm of mathematical modeling, this new generation of water experts are now inclined to use sophisticated computing algorithms for solving water problems, such as Artificial Neural Networks (ANNs), Genetic Algorithm, Fuzzy Systems, Adaptive Network-based Fuzzy Inference System (ANFIS), and Wavelet Networks. Looking at the Journal of Water Resources Management, as the first home to many published papers by Iranian water scientists, the list of mathematical methods include: Game Theory; Multi-Objective Optimization; Markov Chain; Monte Carlo Simulation; as well as many works on meteorological drought indices of Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) (**Figure 5**).

Reviewing Iran's water research publication in international journals, also shows that there is a lack of research on other aspects of water knowledge produced by humanities, social, and environmental scientists. The indigenous approaches to water management, as discussed, are also systematically overlooked and devalued because the majority of researchers are engineers engaged in the technical work of water engineering.

[8]It is equally important to read this giant scientific leap in light of the fact that, according to the International Monetary Fund, Iran tops the list of countries losing their academic elite, with an annual loss of 150,000–180,000 specialists, often migrating to the US and European countries (Financial Tribune, 2016). This implies that the Iranian water expert diaspora also contributes to their host countries through looking at water resources through predominantly mathematical and engineering contexts.

Given all this background information about water research in Iran, it comes as no surprise that when the country attempts to address water problems, it is the technicalities and mathematics that receive greater scholarly attention and government's funding. Looking at the most important keywords in Iranian water research, quantitative modeling and optimization techniques used for "more efficient" water allocation has secured a firm place among the water experts for finding solutions to the country's pressing water challenges—e.g., optimization, genetic algorithm, artificial neural network, system dynamics (**Figure 6**).

This shows that although water engineering has initially been shaped by the state through traditional engineering notions of "construction" and "building", over the last two decades it has moved to another realm in which mathematical modeling and optimization reside at the heart of characterizing water crisis and proposing policy options. In this "neo-engineering" paradigm, the credible, legitimate and salient evidence is that of knowledge that is produced through a whole variety of mathematical models. And still there is no role for social science, law and humanities to play.

Unequal Opportunities for Participation and Communication

In the last two sections, some background information was provided to indicate the fact that the production of water knowledge in Iran is mostly dominated by water engineers as Iran's education system produce more engineers than social scientists. And that means the socio-technical apparatus of water engineering emerged stronger in any decision and debates. This creates a "flat epistemic landscape" in which there is nothings, but only the mountain of water engineering.

Apparently, the education system is not the only driver of marginalization of other knowledge systems in Iran. There is also an element of lack of participation that needs to be discussed for understanding this epistemic inequality.

The relation between Iranian water engineers and bureaucrats on the one hand and public (lay stakeholders) on the other hand has traditionally been problematic. Reviewing the country's development policies over the last 100 years, Nabavi (2017b) found that participation and indigenous knowledge have never been of central importance in Iran's law- and policy-making for water resources, and even where it was incorporated into law, many stakeholders found the participation process inauthentic and disingenuous.

The same mindset also prevails in the corridors of universities and consultant companies. Public participation and communicating risk are not central to the definition of problems and the formulation of solutions. This is particularly more pronounced in difficult times when water becomes a security issue, not only for optimal use but also a variety of socio-political issues entangled.

Water engineers understand this very well and know that both government and the public have no scientific authority to challenge their judgment. For example, in the interviews with some of the prominent water scientists, I documented the

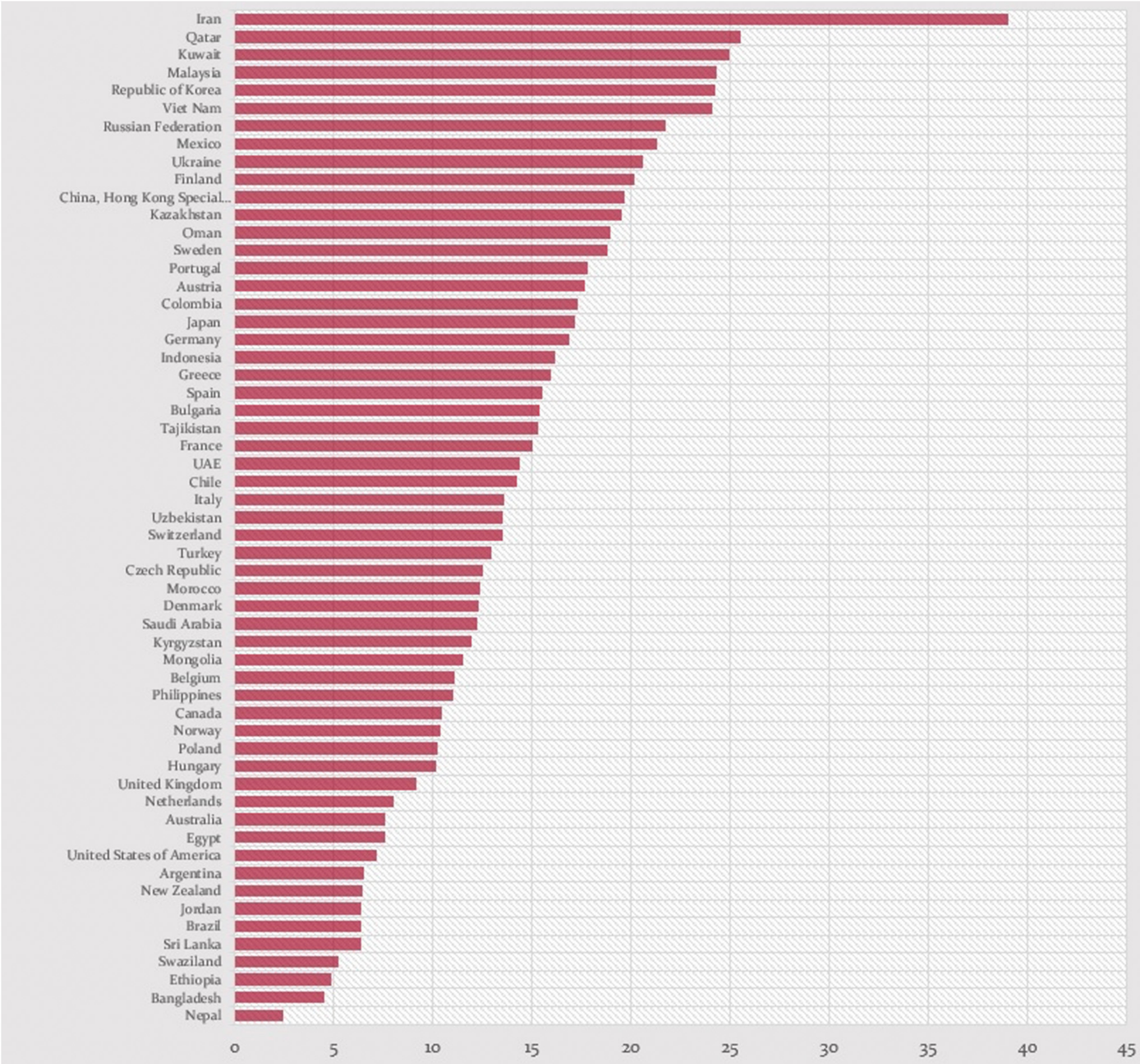

FIGURE 1 | The average percentage of graduates of Engineering, Manufacturing and Construction programs, both sexes (%) 2011–2013 (Data Source: World Economic Forum and UNESCO Institute for Statistics).

repeated analogy of "*giving meat to the cat*" when they took a dim view of letting people be involved in making decision. In Persian proverbs, cat often symbolizes greed[9]. It represents a situation when someone attempts to steal something off a table for its very own interests. And meat always is the most wanted thing that cat has a burning desire to steal. By replacing cat and meat with people and water, respectively, those experts tried to tell me that people cannot make good decisions for managing water resources themselves, very similar to the cats that are inherently untrustworthy for managing a butchery.

[9]See Fakhri et al. (2013) for a detailed description of cat in the Persian literature.

This lack of participation is not limited to the public sphere. Even other peer experts from non-engineering disciplines, particularly social scientists, are not actively engaged in the discussions; or as some of them believe, are "*systematically*" kept out as they take critical stance against development projects. This provides an environment in which a diverse range of stakeholders and experts find themselves excluded from debate, deliberation, and policy-making.

In 2015 when the water crisis in Iran peaks, the domination of water engineers in shaping the narratives around the nature of the crisis and the potentials exit pathways become more apparent than ever. Even it was water engineers who were interviewed to

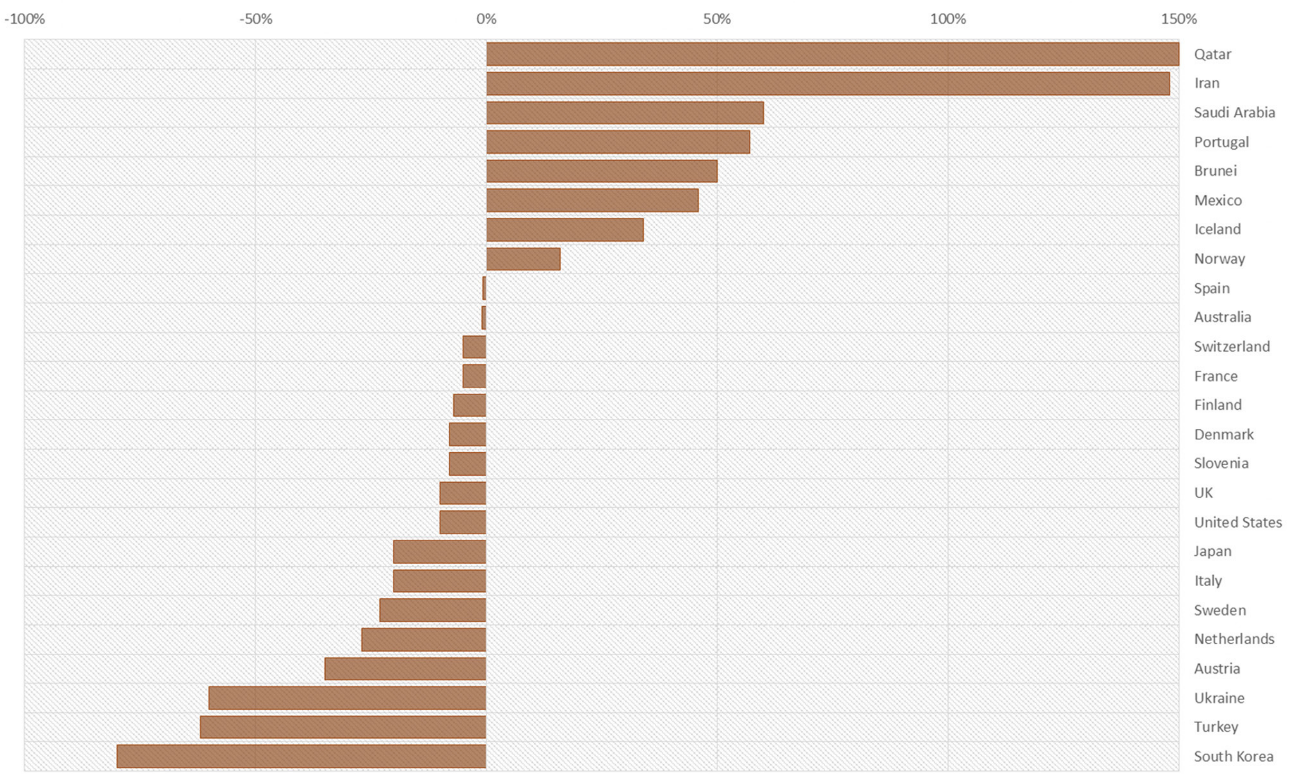

FIGURE 2 | The average percentage of graduates of Engineering, Manufacturing and Construction programs, both sexes (%) 1999–2013 (Data Source: World Economic Forum and UNESCO Institute for Statistics).

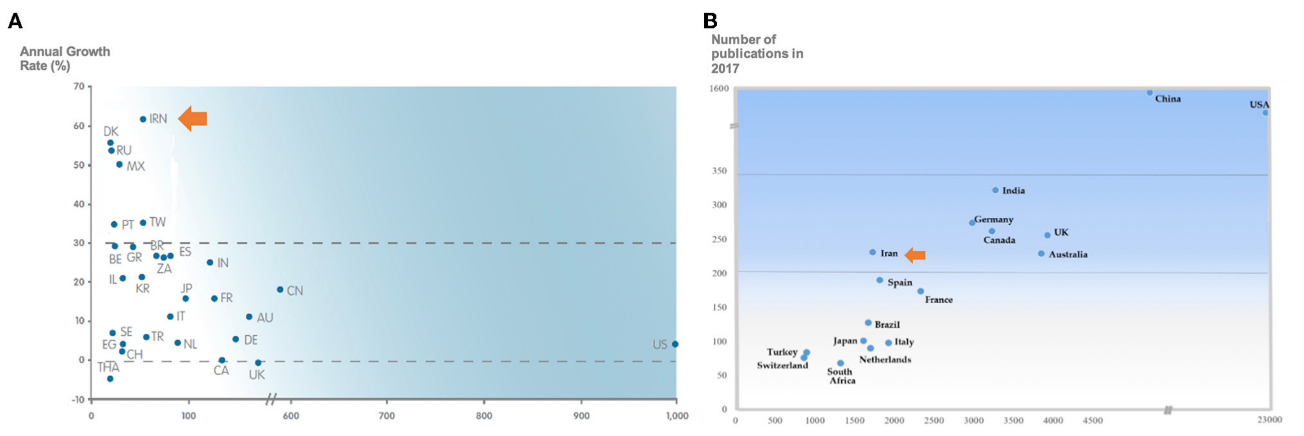

FIGURE 3 | (A) Annual percentage growth per average annual article output [Source: Scopus, adapted from SciVal (2011)]; **(B)** Top 16 countries in accordance to their publications in water research in 2017, and total publication output (1910–2017) "water resource", 2005–2008 (Source: Scopus).

inform society about social, political, and economic aspects of the water crisis. Water engineers become the water spokesperson.

To illustrate the situation more clearly, this research conducts a content analysis measured 86 stories appearing in nine leading newspapers, newsmagazines, and television networks in 2015. Additional documents available online relevant to this research was also considered, including blog entries published by Iran's mainstream media websites, and press releases and documents circulated in the social media ($n = 16$).

The analysis of the main media coverage of water issues during 2015 clearly illustrates the domination of water engineers and marginalization of other groups. As **Figure 7** shows, it was mostly water engineers (trained in civil and agricultural engineering) who were the main science communicators in

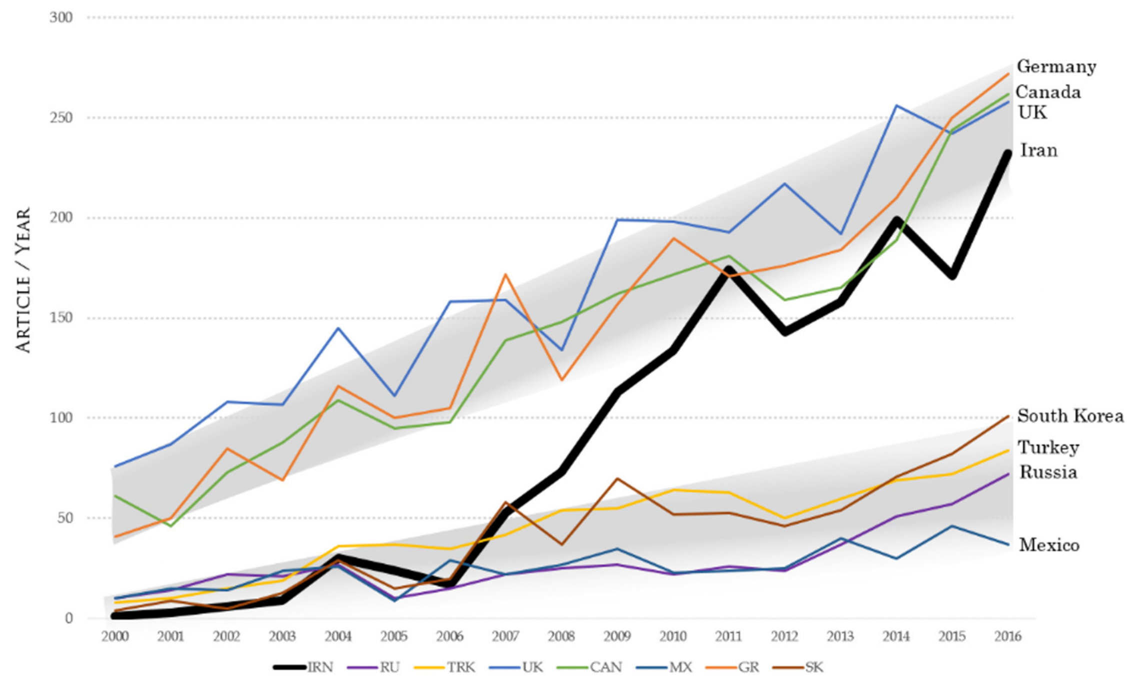

FIGURE 4 | Growth of publication on "water resources", 2000–2016 (Source: Scopus).

times of crisis. Also, non-engineering communities, including indigenous knowledge-holders, have no voice to speak of what they think and how their knowledge can guide society to respond to the water crisis.

DISCUSSION AND CONCLUDING REMARKS

Water-related hazards such as drought and floods are becoming the frequent feature of global environmental landscape because of climate change. The rising number of water conflicts because of water shortage is ringing the alarm bell for many countries. The looming water crisis however provides water experts—as the gatekeeper of science—with a unique opportunity to use their knowledge and experience to provide exit pathways. Yet, we do not know much how a certain group of water experts rise to power, speaking for water, and shaping the political discourse around the potential solutions. Focusing on the practices of the "hydraulic bureaucracy", this paper attempted to add new dimension to the growing research investigating the complex interactions between science, hydraulic infrastructure in various countries, such as Peru (Stensrud, 2019), Thailand (Blake, 2021), Mozambique (Rusca et al., 2019), Ecuador (Warner et al., 2017), and Vitenam (Evers and Benedikter, 2009). The Iranian case showed, it is water engineers and their technical expertise that play the key role in communicating water science during the crisis. However, we need more research to generalize such results to other hydraulic bureaucracies.

Using the concept of "co-production" (Jasanoff, 2004) in the context of hydrocracy, this paper shows the way in which water engineering and social order are intertwined—that is how water engineers contributes to (re)defining what water "is" and how "ought" to be managed.

This is a mutually reinforcing relationship that has been explored and documented by various researchers such as Swyngedouw (1999), Linton (2010), Bouleau (2014), and Aubriot et al. (2018), to name a few among many. In this relationship, the states seek to invest in building critical infrastructures such as dams and canals, which requires quantification from the modern hydrology and hydraulic engineering. Once the "waterscape" is realized (Swyngedouw, 1999), the states then pay back by offering them more research and funding opportunities. And the cycle goes on. The water engineers, will then have the opportunity to shape the "puzzle" they want to solve around water management (Bouleau, 2014). This will be based on their training and disciplinary paradigm. For example, in the case of water crisis, a water engineer is likely to frame it as the problem of "supply" in the need for more technical innovation (i.e., increasing efficiency or building a larger infrastructure); an economist is likely to understand it in terms of supply-demand problem requiring a "market" solution; a law expert is likely to focus on regulations and "water laws" as the source of problem; and a sociologist who may read it as the problem of "participation" and "trust" between policymakers and the public.

In the case of hydrocracy, this paper shows that it is the "water engineers" that gain more legitimacy in policy debates over determining which types of science is more crucial than

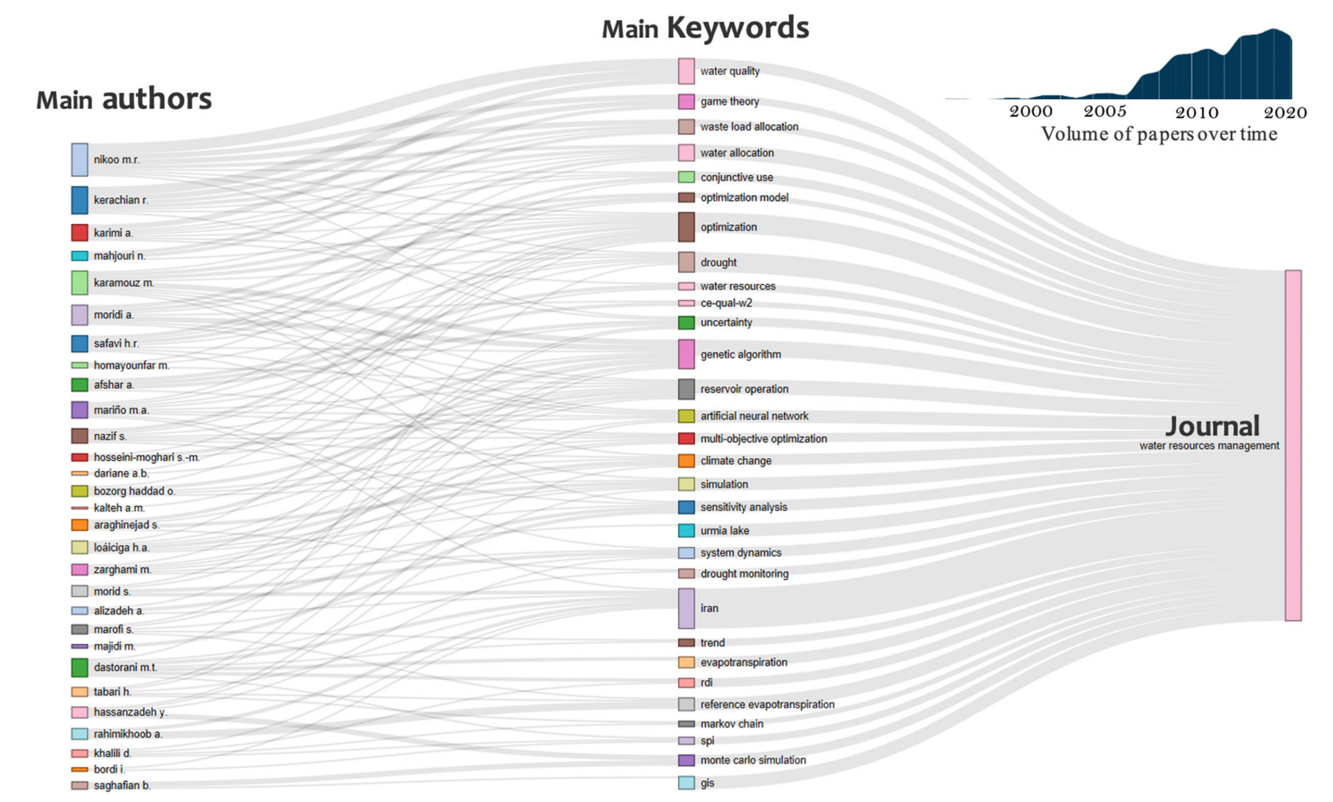

FIGURE 5 | Visualizing the volume of papers, and how top authors and keywords associate (S-K-J Snaky diagram) in the Journal of Water Resource Management based on ["Water resource management" or "water management"] AND [Iran], (1995–2020); Source: Scopus.

others (in producing knowledge); which epistemic approaches are more required (in characterizing the problems), and which applications of that knowledge are more practical.

It is important to stress the point that these categories are dynamics and rank differently in various places and contexts. They are the outcome of the co-production process where the relevant categories of science and expertise are negotiated.

The case of Iranian hydrocracy showed that the result of this co-production has been the monopolization of water epistemology by water engineers and their technocratic views and ideas. The broader consequence of that has been something this paper calls "non-engineering epistemicide"—that is a forced exclusion (and extinction) of non-engineering knowledge systems. It describes a situation in which the society and other communities of practice (i.e., those not aligned with the engineering paradigm), find themselves in the midst of a "great silence", one that is fostered from epistemic injustice.

There is a caveat of course about this great hegemony of water engineers. This paper argues that there are certain cultural and historical elements associated with knowledge construction in water engineering that makes it susceptible to contributing to this situation. One of them, for example, is the strong connection between masculinities and engineering profession in hydrocracies (Zwarteveen, 2017). In the Iranian case, the tendency of water engineers to "control water knowledge", put their professional expertise in congruence with bureaucrats' interests in "controlling the society" through a centralized governance. Thus, making them both reluctant to be engaged in public deliberation, and participation.

The disinterest in deliberation and participation and devaluation of non-engineering disciplines in education system, widens the gap not only between government and society, but also between experts and people; thus, reinforcing the co-production engineering and governance.

While the analysis emphasizes Iran's unique context, the case also reflects broader patterns in hydrocracies in other parts of world, and how they might communicate science in times of crisis. Thus, the article provides several conclusions for research in this domain.

- A water-related hazard in the modern world creates a new socio-technical reality in which science has a key role to play. Effective communication is more needed than ever. The conventional water engineering practice is failing Earth's ecosystem, including rivers, lakes, springs and groundwater. Water engineers need to be open for more transdisciplinary research and more interdisciplinary debate on how to respond to complex water problems that are inherently social and political problems. Water engineers need to recognize the importance of collaboration and dialogue-oriented science communication beyond their own epistemic community to include a wide range of knowledge-holders and the publics.

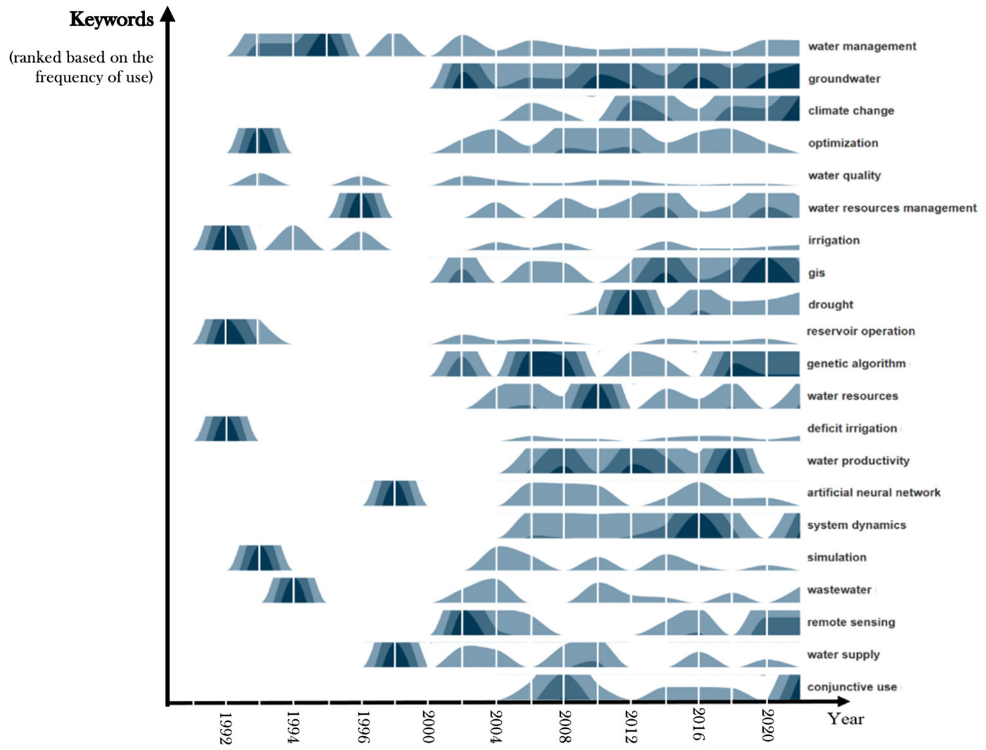

FIGURE 6 | Visualizing the most important keywords in the research published by Iranian scholars (1990–2021); Source: Scopus (The normalization divides by total number of papers each year) ["Water resource management" or "water management"] AND [Iran].

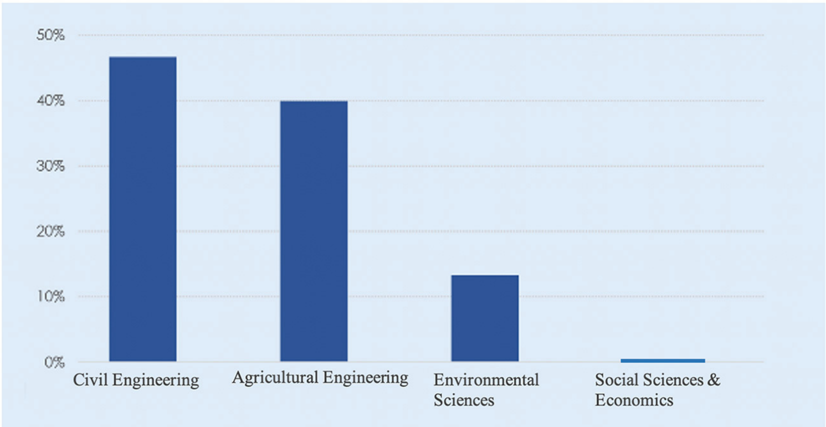

FIGURE 7 | Disciplinary background of experts speaking for water during Iran's water crisis—2015.

- The concept of co-production of water engineering and governance can open a novel conversation between water engineers and social scientists and augments the existing efforts by environmentalists to address the root causes of water crisis. For social theorists it helps them to ask critical questions about the water science, beginning with: what does count as water science? Where is the source of legitimacy and credibility? How epistemic legitimacy is constructed and asserted in making decisions about water use and allocation? Where does engineering derive its authority to give voice to water? Who has the privilege to speak on behalf of water? Whose ideas and talks mater and whose speech is just unimportant or mere opinion?

- Water science scholarship should better address political aspects of education in water resources, as the graduates are the next generation of water experts shaping decision about land and water. It is through disciplinary training that an expert makes sense of a situation and understand risks and benefits of potential solutions. Institutions and people in positions of power has responsibility to break the spiral of epistemic injustice and address the solution by revisiting the water engineering syllabus. In this regard, drawing on theories and insights from political ecology, environmental sociology and science and technology studies is productive. In the case of Iran, it is on water engineers and their community of practice to facilitate the agency of all science communicators, and engage them in water projects especially if they have been marginalized for long time.
- The exclusion and silencing non-technical approaches in water research and practice represent a case of epistemic injustice which needs to be addressed. We need a new commitment toward a more just production and communication of water knowledge. In the world that disciplinary boundaries fall and fragmentation is replacing by holistic views, it is the responsibility of all to develop anti-hegemonic discourse within their own epistemic community. That will liberate water knowledge from the domination of a certain epistemology.
- Research is needed that inform our limited knowledge on the emergence of "engineering paradigm" resulting from the co-production of engineering science and governance. This is particularly important for societies where the way of knowing, norm of expertise, ways of communication, and psychology of judgment are all heavily shaped by the engineering apparatus, including engineering skills, technologies, machines, tools, and concepts.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Australian National University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EN: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

FUNDING

This work was funded from ANU Research Scholarship and an EU Jean Monnet grant for the Water Policy Innovation Hub. Funding to pay the Open Access publication charges for this paper was provided by the ANU Centre for Public Awareness of Science.

ACKNOWLEDGMENTS

I would like to thank Peter Haas and Voltaire Peterson, whose comments helped to improve and add clarity to this manuscript.

REFERENCES

Abrahamian, E. (1982). *Iran Between Two Revolutions*. Princeton, NJ: Princeton University Press.

Alder, K. (2010). *Engineering the Revolution: Arms and Enlightenment in France, 1763-1815*. Princeton, NJ: University of Chicago Press.

Al-Monitor (2015). *Iran Official Warns Water Crisis Could Lead to Mass Migration*. Available online at: http://www.al-monitor.com/pulse/originals/2015/04/iran-water-crisis-mass-migration.html# (accessed April 7, 2022).

Amanat, A. (2017). *Iran: A Modern History*. Yale, CT: Yale University Press.

Aubriot, O., Fernandez, S., Trottier, J., and Fustec, K. (2018). Water technology, knowledge and power. Addressing them simultaneously. *Wiley Interdiscip. Rev. Water* 5, e1261. doi: 10.1002/wat2.1261

Barry, A. (2013). *Material Politics: Disputes Along the Pipeline*. Oxford: John Wiley and Sons.

Benedikter, S. (2014). Extending the hydraulic paradigm: reunification, state consolidation, and water control in the Vietnamese Mekong delta after 1975. *Southeast Asian Stud.* 3, 547–587.

Blackbourn, D. (2011). The Conquest of Nature: Water, Landscape, and the Making of Modern Germany. London: Random House.

Blake, D. J. (2021). Unsettling bureaucratic designs: inter-bureaucratic competition and patrimonialism in the pursuit of Thailand's hydraulic mission. *Int. J. Water Resources Dev.* 1–21. doi: 10.1080/07900627.2021.1949966. [Epub ahead of print].

Bouleau, G. (2014). The co-production of science and waterscapes: the case of the Seine and the Rhône Rivers, France. *Geoforum* 57, 248–257. doi: 10.1016/j.geoforum.2013.01.009

Carroll, P. (2006). *Science, Culture, and Modern State Formation*. Berkeley, CA: University of California Press.

Crase, L. R., O' Keefe, S. M., and Dollery, B. E. (2009). The fluctuating political appeal of water engineering in Australia. *Water Alternatives* 2, 440.

Cunningham, C. M., and Kelly, G. J. (2017). Epistemic practices of engineering for education. *Sci. Educ.* 101, 486–505. doi: 10.1002/sce.21271

Evers, H.-D., and Benedikter, S. (2009). Hydraulic bureaucracy in a modern hydraulic society-strategic group formation in the Mekong Delta, Vietnam. *Water Alternatives* 2, 416.

Fakhri, K. P., Bakhtiari, R. M., and Adelzadeh, P. (2013). Sanctity and malevolence of cat in world mythology and persian prose and verse. *Nigerian Chapter Arabian J. Bus. Manage. Rev.* 62, 1–11. doi: 10.12816/0003658

Guldi, J. (2012). *Roads to Power*. Cambridge: Harvard University Press.

Haas, P. M. (1992). Introduction: epistemic communities and international policy coordination. *Int. Org.* 46, 1–35. doi: 10.1017/S0020818300001442

Holling, C. S., and Meffe, G. K. (1996). Command and control and the pathology of natural resource management. *Conserv. Biol.* 10, 328–337. doi: 10.1046/j.1523-1739.1996.10020328.x

Hooglund, E. (2009). Thirty years of Islamic revolution in rural Iran. *Middle East Rep.* 250, 34–36.

Jasanoff, S. (2004). *States of Knowledge: The Co-production of Science and the Social Order*. London; New York, NY: Routledge.

Jasanoff, S. (2005). *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ: Princeton University Press.

Latour, B. (2005). *Reassembling the Social-An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Linton, J. (2010). *What Is Water?: The History of a Modern Abstraction*. Vancouver, BC: UBC Press.

MacKenzie, D., and Wajcman, J. (1999). *The Social Shaping of Technology*. Buckingham: Open University Press.

Madani, K., AghaKouchak, A., and Mirchi, A. (2016). Iran's socio-economic drought: challenges of a water-bankrupt nation. *Iran. Stud.* 49, 997–1016. doi: 10.1080/00210862.2016.1259286

Manuel, M., Lightfoot, D., and Fattahi, M. (2018). The sustainability of ancient water control techniques in Iran: an overview. *Water Hist.* 10, 13–30. doi: 10.1007/s12685-017-0200-7

McCulloch, C. (2009). The Water Resources Board: England and Wales' venture into national water resource planning 1964-73. *Water Alternatives* 2, 461.

Menga, F. (2015). Building a nation through a dam: the case of Rogun in Tajikistan. *Natl. Papers* 43, 479–494. doi: 10.1080/00905992.2014.924489

Molle, F., Mollinga, P. P., and Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: flows of water, flows of power. *Water Alternatives* 2, 328–349.

Nabavi, E. (2011). *Determining criteria and monitoring sustainability of Zayandeh-rud River Basin from water resources management point of view* (MSc thesis). Civil Engineering, Isfahan University of Technology, Isfahan, Iran.

Nabavi, E. (2016). *Iran's Environmental Crisis: Why We Should Be Mindful of Depicting a Dystopian Future*. Available online at: http://steps-centre.org/2016/blog/irans-environmental-crisis-why-we-should-be-mindful-of-depicting-a-dystopian-future/ (accessed April 7, 2022).

Nabavi, E. (2017a). *More-Than-Water, More-Than-Human: A Transdisciplinary Sociology of Water Conflict in Central Iran* (Doctoral dissertation). The Australian National University, Canberra, ACT, Australia.

Nabavi, E. (2017b). (Ground)water governance and legal development in Iran, 1906–2016. *Middle East Law Governance* 9, 43–70. doi: 10.1163/18763375-00901005

Nabavi, E. (2018). Failed policies, falling aquifers: unpacking groundwater overabstraction in Iran. *Water Alternatives* 11, 699.

Pickering, A. (2010). *The Mangle of Practice: Time, Agency, and Science*. Chicago, IL: University of Chicago Press.

Pritchard, S. B. (2011). *Confluence The Nature of Technology and the Remaking of the Rhône*. Cambridge: Harvard University Press.

Rafsanjani, A. (2012). *Today We Should Be a Wheat Exporter (in Persian)*. Available online at: http://goo.gl/C0sa4I (accessed April 7, 2022).

Rayman, N. (2013). *The 10 Most Polluted Cities in the World*. Available online at: http://science.time.com/2013/10/18/the-10-most-polluted-cities-in-the-world/ (accessed April 7, 2022).

Reisner, M. (1993). *Cadillac Desert: The American West and Its Disappearing Water*. New York, NY: Penguin.

Rowland, N. J., and Passoth, J. H. (2015). Infrastructure and the state in science and technology studies. *Soc. Stud. Sci.* 45, 137–145. doi: 10.1177/0306312714537566

Rusca, M., dos Santos, T., Menga, F., Mirumachi, N., Schwartz, K., and Hordijk, M. (2019). Space, state-building and the hydraulic mission: crafting the Mozambican state. *Environ. Plan. C Polit. Space* 37, 868–888. doi: 10.1177/0263774X18812171

Santos, B. D. S. (2015). *Epistemologies of the South: Justice Against Epistemicide*. London; New York, NY: Routledge.

Schwartzstein, P. (2020). How Iran is destroying its once thriving environmental movement. *National Geographic Magazine*. p. 12.

SciVal (2011). *Confronting the Global Water Crisis Through Research*. Available online at: https://www.elsevier.com/__data/assets/pdf_file/0018/53082/Water-Resources_WP_lr.pdf (accessed April 7, 2022).

Shallat, T. (2010). *Structures in the Stream: Water, Science, and the Rise of the US Army Corps of Engineers*. Austin, TX: University of Texas Press.

Stensrud, A. B. (2019). The social embeddedness of hydraulic engineers in the regulation of water and infrastructure in Peru. *Environ. Plan. C Polit. Space* 37, 1235–1251. doi: 10.1177/2399654419866835

Stephens, J. C., Hansson, A., Liu, Y., De Coninck, H., and Vajjhala, S. (2011). Characterizing the international carbon capture and storage community. *Glob. Environ. Change* 21, 379–390. doi: 10.1016/j.gloenvcha.2011.01.008

Stone, R. (2015). Fragile ecosystems under pressure. *Science* 349, 1046–1047. doi: 10.1126/science.349.6252.1046

Swyngedouw, E. (1996). The city as a hybrid: on nature, society and cyborg urbanization. *Capital. Nat. Social.* 7, 65–80. doi: 10.1080/10455759609358679

Swyngedouw, E. (1999). Modernity and hybridity: nature, regeneracionismo, and the production of the Spanish waterscape, 1890–1930. *Ann. Assoc. Am. Geogr.* 89, 443–465. doi: 10.1111/0004-5608.00157

Swyngedouw, E. (2004). *Social Power and the Urbanization of Water: Flows of Power*. Oxford: Oxford University Press.

Swyngedouw, E. (2015). *Liquid Power: Contested Hydro-Modernities in Twentieth-Century Spain*. Cambridge, MA: MIT Press.

Tavakoli-Targhi, M. (2012). The emergence of Clerico-engineering as a form of governance in Iran. *Iran Nameh* 27, 4–37.

Wadhwa, V., Gereffi, G., Rissing, B. A., and Ong, R. (2007). *Where the Engineers Are. Issues in Science and Technology*. Austin: University of Texas.

Warner, J. F., Hoogesteger, J., and Pablo Hidalgo, J. (2017). Old Wine in new bottles: the adaptive capacity of the hydraulic mission in ecuador. *Water Alternatives* 10, 322–340.

Waterbury, J. (1979). *Hydropolitics of the Nile valley*. Syracuse, NY: Syracuse University Press.

Watson, N., Deeming, H., and Treffny, R. (2009). Beyond bureaucracy? Assessing institutional change in the governance of water in England. *Water Alternatives* 2, 448.

WES (2017). *Education in Iran*. World Education Services. Available online at: https://wenr.wes.org/2017/02/education-in-iran (accessed April 7, 2022).

Wester, P. (2008). *Shedding the Waters: Institutional Change and Water Control in the Lerma-Chapala Basin, Mexico*. Wageningen University.

Wester, P., Rap, E., and Vargas-Velázquez, S. (2009). The hydraulic mission and the Mexican hydrocracy: regulating and reforming the flows of water and power. *Water Alternatives* 2, 395–415.

Whatmore, S. (1997). Dissecting the autonomous self: hybrid cartographies for a relational ethics. *Environ. Plan. D Soc. Space* 15, 37–53. doi: 10.1068/d150037

Winner, L. (1980). Do artifacts have politics? *Daedalus* 109, 121–136.

Wittfogel, K. A. (1957). *Oriental Despotism: A Comparative Study of Total Power*. New Haven, CT: YaleUniversity Press.

Worster, D. (1985). Rivers of Empire: Water, Aridity, and the Growth of the American West. Oxford: Oxford University Press.

Zafarnejad, F. (2016). A critique of the water transfer plan from the Persian Gulf and the sea of Oman to the central plateau of Iran. *J. Water Sustain. Dev.* 3, 124–129.

Zwarteveen, M. Z. (2017). Hydrocracies, engineers and power: questioning masculinities in water. *Eng. Stud.* 9, 78–94. doi: 10.1080/19378629.2017.1358730

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.