INNOVATION FOR WATER

YOUTH PERSPECTIVES ON TECHNOLOGICAL ADVANCES IN THE WATER SECTOR

WORLD YOUTH PARLIAMENT FOR WATER

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About the World Youth Parliament for Water

The World Youth Parliament for Water (WYPW) is a network of passionate young people from over 80 countries. We are your 'Leaders of Tomorrow,' making waves of change in the water sector. Our members take action on water issues at all levels; from concrete actions in local communities, to advocacy for youth leadership in the water sector at the United Nations General Assembly.

Learn more about WYPW at youthforwater.org

About the WYPW Research Group

The WYPW Research Group is one of several working groups within WYPW. It aims to empower young and early career researchers and to conduct and promote youth-led research related to the water sector. Its core objectives are:

- Foster collaboration between young water researchers across both geographic and disciplinary boundaries.
- Conduct original research on youth-related issues in the water sector and produce knowledge that can influence decision-making processes on multiple levels.
- Raise awareness about the scientific contributions of young and early-career researchers as well as the added value of transdisciplinary and citizen-based research approaches in the water sector.

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Water Scarcity and Water Security

Amrita Gautam

Water is the resource essential to the existence of human civilization and natural ecosystem. It covers about 71% of the planet, but the freshwater that can be used to drink, bath in, irrigate farmlands is in very limited supply. Only about 2.5% of the Earth's water is freshwater, and most of it is unavailable – either locked up in glaciers, polar ice caps, atmosphere, and soil; highly polluted; or lies too far under the earth's surface to be extracted at an affordable cost, leaving only 0.5% of the Earth's freshwater in our reach [1].

Clean freshwater and sanitation facilities are vital for a healthy living. Access to these facilities plays a crucial role in the overall social and economic development of a community and a nation. Around 1.1 billion people worldwide lack access to water, 2.4 billion people face problems with inadequate sanitation, and a total of 2.7 billion find water scarce for at least one month of the year. About 2 million people, mostly children, die each year from diarrheal diseases alone [2].

Water is also the key medium of many sufferings and solutions to deal with the real meaning of climate action. The unavoidable consequences of climate change, natural disasters and extreme events have questioned our existence and we cannot deny the truth. There is an urgent need for action to save Mother Earth, so that we all can survive and thrive. Water security in terms of quantity and quality is a must to achieve global goals of development and sustainability.

Most of the developing countries are suffering from a lack of regular and effective monitoring of water quantity and quality to support necessary decisions and actions when it is needed. Participatory practice, proper use of modern technologies and the creation of healthy spaces for innovation in the water and climate sector can lift us to the world we want to live in – inclusive, secure, and sustainable.

If we are able to connect this loop right from the early start of emerging water leaders in making, i.e. teaching youth (from high school to university level) an actual understanding and work of water management and monitoring using ICTs, we can support the sustainable development of the sector, water security and open up future doors of 'Water Innovations and Technologies'.

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drinkPani – A Youth-led Participatory Sensing Model to Enhance Drinking Water Security: The Case of Pokhara Metropolitan City, Nepal

Amrita Gautam

Approximately 80% of the communicable diseases in Nepal are due to poor sanitation and lack of access to quality water. The initial phase of this research initiative 'drinkPani' has developed a Youth-led Participatory Sensing (YPS) design to improve water quality monitoring and water supply management.

Drinking Water Security

Availability of safe drinking water and basic sanitation facilities are the indispensable need for human civilization. Water supply for drinking purposes with adequate quality is a global challenge. Majority of the developing countries face serious problems in proper technology and management strategy to regulate drinking water quality, though there are numerous cases of adverse health impacts. Drinking water security means not only the access and sufficient availability of water but also the qualitative supply of water. Water is directly concerned with the health of living beings and the balance of the ecosystem.

According to the report by Joint Monitoring Programme (JMP) in 2017 [1], 5.2 billion people used safely managed drinking water services in 2015 as shown in Figure 1, which also illustrates that developing countries like Nepal are between 26 to 50% in proportion of population using safe drinking water services in the same year.

Nepal is ranked among the top 40 water stressed countries worldwide by the recent report of the World Resources Institute, having an average of 40% to 80% of the available water extracted every year to meet the annual demand. According to the institute's Aqueduct Water Risk Atlas, the country is among those countries facing

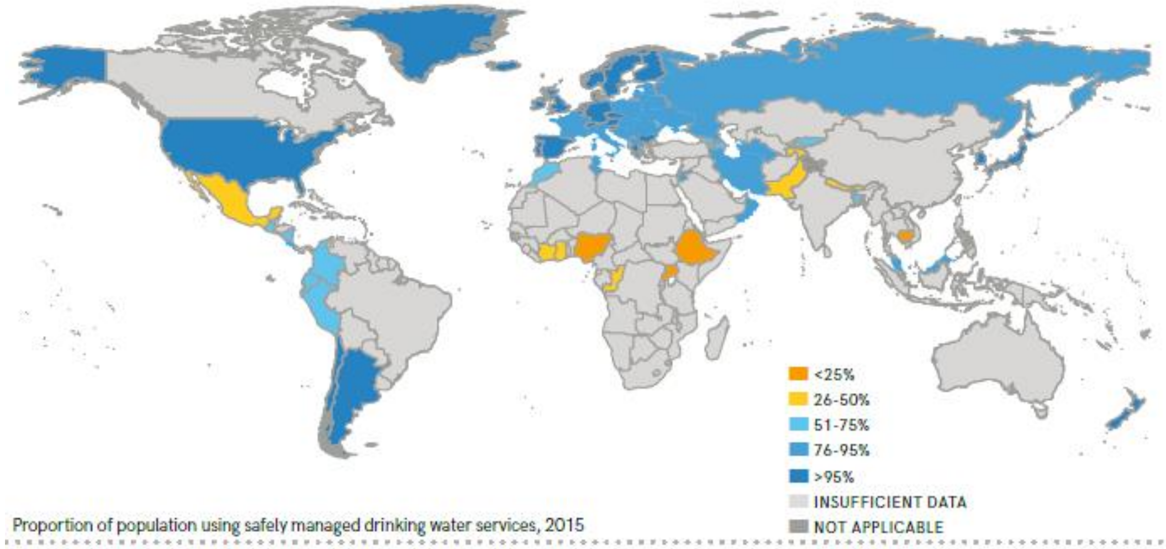

Figure 1. Global data on proportion of population using safely managed drinking water services, 2015. Source: JMP [1].

2 to 4 cm of groundwater depletion per year [2]. Thus, evidence shows the demand for water is increasing significantly in Nepal and access to safe and adequate drinking water is crucial. About 27% of the population has access to basic sanitation, those without access rely on local surface water sources like rivers for bathing, washing dishes and clothes. Children under the age of five are the most affected from waterborne diseases with an estimated 44,000 children dying every year. The public lacks awareness and education on safe drinking water rights, proper sanitation requirements, and domestic-industrial wastewater treatment plants need to be widespread [3]. About 91% of the population in Nepal drink from an improved water source, however, E. coli is still detected in most of it, as illustrated in Figure 2. This also implies that more investment should focus on low-cost techniques to test the drinking water quality in taking required corrective actions in the water supply system, also for those who are not connected to regulated piped networks [4].

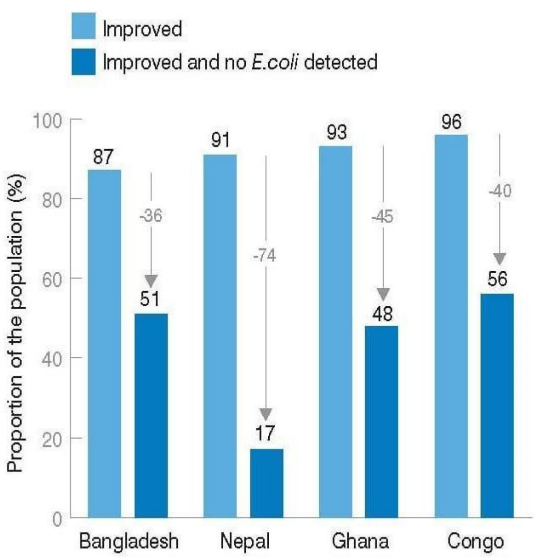

Figure 2. Overview on proportion of the population in Bangladesh, Nepal, Ghana, and Congo -using improved source and case of E. coli detection. Source: Slaymaker and Bain [4].

Participatory Approach and Emerging Technologies

Information and communication technology (ICT) systems are a convenient means of providing meaningful services and other functions, such as wireless sensor networking, mobile phone applications, etc., to agricultural management schemes. In recent years, such systems have considerably improved and have been used in many sectors including environmental monitoring and management [2]. These widespread ICTs in the developing world have transformed the opportunity costs of communication by minimizing greatly the time and cost of data collection, storage, procession, dissemination, and display of information via electronic means [5]. In addition, ICTs have the potential to connect people who are isolated by location and socio-economic situation which can help improve security by assisting in risk management. Thus, several water and sanitation practitioners have started to uplift respective services by leveraging the ubiquity of mobile phones, web interfaces and applications [6].

Without the clear linkage between emerging technologies for monitoring perspective of water quality issues, policy, and cooperation with local stakeholders from the outset [7], any desired water monitoring networks in water supply schemes that are based on results will be ineffective. Water quality is a vital dimension of water security, and “drinking water and human well-being” is an essential section of water security definition by UN-Water, which states: “Populations have access to safe, sufficient and affordable water to meet basic needs for drinking, sanitation and hygiene to safeguard health, well-being and to fulfil basic human rights.” [8, 9]. Community participation in monitoring activities from the beginning is vital to gain public trust in resulting data providing credible information and justification to the public and authorities for better execution of any development works [10-12].

Youth-led Initiatives, Participatory Sensing and Innovation

"Youth participate in authentic science. With youth-focused citizen and community science, youth contribute to authentic science. They can do it through data collection, but also interpreting or sharing findings" [13]. Young Water Stewards is a free, outdoor-focused program for high school students, which includes anywhere from three to five class periods, depending on each teacher's objectives and class schedule: three in-class lessons, one or two field trips to tour your local watershed and perform water quality sampling, and a stewardship project [14]. A study explains the use of ICT for greening tools regarding lake monitoring, where 'Design science' was used as a research methodology. This mobile participatory sensing application called 'Jarvi' was developed to enable citizens to monitor their environment. It represents an example of ICT for greening, which addresses an environmental issue by actively boosting citizen stewardship via embedded gamification mechanics such as challenges, achievement, and storytelling [15]. The concept of 'seven flags approach of total sanitation' (7FATS) in Nepal has been suggested by Panthi, WHO [16], where seven implementation steps can be used as systematic approach to meet seven major indicators of total sanitation, each with five sub-indicators. If a school meets the standard of each indicator, it will be declared a 7FATS school. Water quality monitoring programs for schools are introduced to teach children the concept of reporting on the 'state of the environment' by raising the awareness of water quality issues and providing skills to monitor water quality [17].

drinkPani: Youth-led Participatory Sensing Model - A Pilot Case Study from Nepal

In Nepal, about 80% of prevalent communicable diseases are due to poor sanitation and lack of access to quality

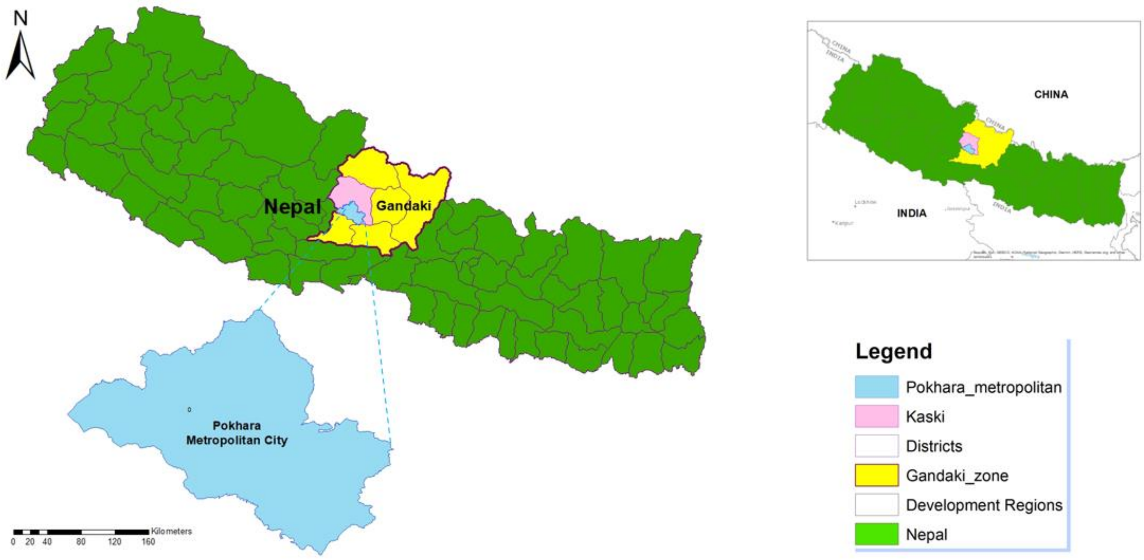

Figure 3. Case Study - Location Map: Pokhara Metropolitan City, Nepal.

Figure 4. a) School students receiving training (outdoor) to use field kits to test water in different points of water supply system.
b) Trained students as Young Water Volunteers (YWVs) taking water sample at a household level.
c) YWVs receiving training (indoor) to use different water test kits in a local lab.
d) A YWV using mobile app to send water supply and quality data as a reporting tool.

water [18]. The coverage and functionality of the water supply system is still crucial owing to the degraded quality of water. In fact, there is no data available on water quality. “Current situation of drinking water quality is extremely poor. There are very few monitoring systems available. Here, water has high turbidity, microbial contamination (which changes hourly). The people who know how to test the water quality, they test the quality of water once in a lifetime and declare that the quality of water is good. There is an absence of a regular monitoring system of quality of water” [16].

Studies have mentioned water, sanitation and yygiene (WASH) practices in schools and possibilities of involving schools in ‘Water Safety Plan’ programs as well [19], but the systematic method and model to integrate students or youth and ICTs in drinking water quality monitoring is yet unexplored. A small effort of response to valuing water in enhancing drinking water security using youth-led participatory approach and ICTs by drinkPani in a pilot study area Pokhara Metropolitan City (PMC; Figure 3), Nepal is illustrated in the photos in Figure 4.

This is a part of on-going doctoral research where ‘water supply and quality monitoring using emerging technologies’ is the main focus area. Here, youth are the key actors as Young Water Volunteers (YWVs), assigned officially in ‘water clubs’ – called drinkPani Clubs – with intensive training and tools for water sampling, test, data collection, reporting and sharing under a ‘Youth-led Participatory Sensing’ (YPS) Model in progress, including regular verification and preparation initiatives for climate action as well, to enhance drinking water security using ICTs as the major component, including field kits, water quality sensors, mobile apps, data dissemination digital platforms like

“Water acts as the first line of defense for any bacterial or viral contamination. Drinking water security is one of the biggest challenges we are facing in 21st century and I am interested in investigating the use of hydroinformatics for required solutions in this sector, to envision and shape a digital water future.”

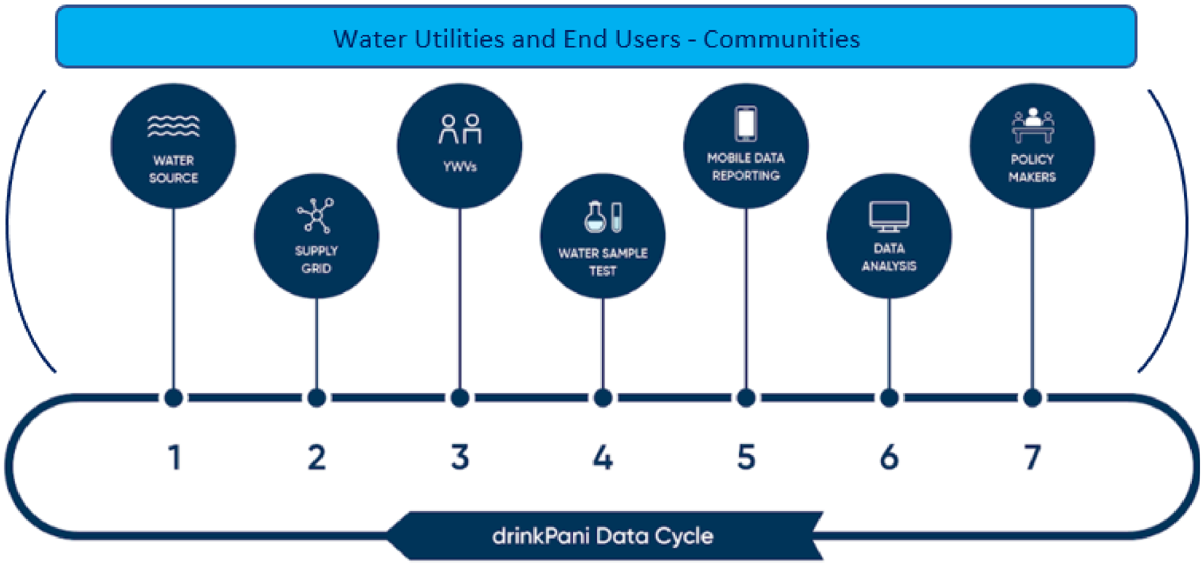

Figure 5. Overview of different steps, activities, and information flow in drinkPani research initiative.

websites, which can also support for research based learning environment. Now, with the regular workshops, seminars and training sessions, including direct consultations with water utilities, other stakeholders and advisors, YWVs tend to support the Climate Resilient Water Safety Plan (CR-WSP) for the respective water supply schemes.

"drinkPani is a research based initiative which intends to bridge the gap between water utilities and communities in information flow on water supply and quality with youth as key actors and ICTs as the main tool to navigate the path to reach policy makers for evidence-informed decision-making, illustrated in Figure 5. We have launched our own app and website – 'drinkPani'. It reflects the continuous iteration process since a year, with users and advisors to come to this point. And, we follow the Iterative Design Cycle, TMPI: Think, Make, Play, and Improvise, for our model, activities, and products. We look forward to upscale the YPS Model and activities in advancing the required tools and targets to serve and support in solving the issue regarding 'water supply and quality monitoring using emerging technologies" [20].

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Per Capita Water Consumption Detector for the MENA Region

Nabil Khorchani

The MENA region is considered the most water-scarce region in the world, with population growth and injudicious household use making water conservation strategies very important. A design for a household-level smart water consumption detector is proposed, which will allow users to be aware of their daily water use and prevent over-consumption above the daily rate designed by authorities.

The Middle East and North Africa (MENA) is the most water-scarce region in the world, with more than 60% of the population under severe water stress. Additionally, national economies are threatened as about 70% of the region's GDP is exposed to high or very high-water stress [1]. According to the World Bank, the MENA region's population continues to grow, leading to the per capita water availability projected to fall by 50% by 2050. In addition, as per the World Bank [2], the MENA region is expected to suffer from the greatest economic losses due to climate-related water scarcity, estimated at 6 to 14% of regional GDP by 2050. This scarcity poses a significant threat to the region's long-term socio-economic development.

Unsustainable water consumption is therefore an important issue in the MENA region. Based on regional water consumption patterns, one of the key reasons for this unsustainable consumption is the injudicious household use.

Water resources in the MENA region

As stated above, the MENA countries are considered as the most water-scarce region of the world (Figure 1), due to the

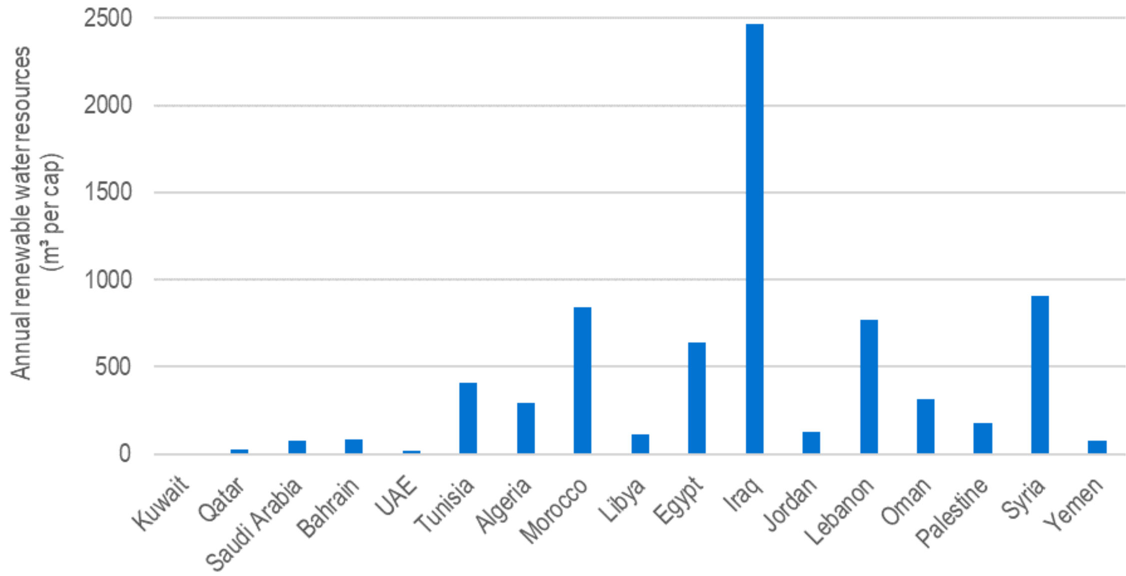

Figure 1. Annual renewable water resources per capita in different MENA countries in 2014. Reproduced from OECD and FAO [3].

combination of its limited renewable water resources and its fast population growth. Unsustainable water consumption patterns further aggrevate the situation, with a significant imbalance between the annual renewable water resources per capita and the average domestic water consumption per capita.

My homecountry Tunisia, for example, faces high risks of water scarcity. With only 470 m³of renewable water resources availableper capita and year, the country is now classified as under water stress (less than 500 m³ per capita and year).

Monitoring water consumption

Following the problems outlined above, it is thus important to better monitor domestic water consumption as a first step towards more sustainable use and management. The Water Consumption Detector is intended to fulfill three purposes:

- Ensure that the domestic daily water consumed per capita does not exceed the amount designed by the National Water and Sewerage Corporation (NWSC);
- Raise the awareness among the consumers regarding their daily water consumption, whereby they receive warning messages delivered by the detector upon consumption of water beyond the NWSC limit;
- Support the achievement of SDG 11 and 12: Sustainable cities and communities, and Responsible consumption and production.

In its essence, the Per Capita Water Consumption Detector is a device that converts pulses, generated from spins in the water pipe, into a water flow (m³/s). The real time flow information is then transferred to a mobile app based on IoT technology, where it can be accessed by the user. As not all households have reliable access to internet, a Bluetooth module and a GSM module will be used as an alternative in case of a lack of internet connection.

The device consists of:

- A Water Flow Sensor (a tool containing a spin installed within the main pipeline directly after the main flow meter)
- A dashboard where the customer can enter the maximum daily per capita water consumption as designed by the water authorities in the country.
- A sever or micro-controller (e.g. Arduino)
- Transmitter and receiver modules (Wi-Fi, Bluetooth and Bluetooth)

In order to monitor the water consumption in each household, the device will be installed directly after the water meter for each house. The maximum per capita amount of water consumption per day can be manually or automatically regulated, depending on the consumption limit designed by NWSC of every country. It

“In my home country Tunisia, water quality in households has depleted due to overexploitation. I want to address this issue and support governments in their policies toward valuing water and enhancing water conservation strategies.”

creates the possibility of calculating specific per capita consumption for each household, reflecting the individual household size. If the per capita consumption nears the threshold, the device will then send a warning to the user's phone, informing them about their current consumption rate. If preferred, it is also possible to automatically cut the water supply when the threshold amount of water is reached.

In conclusion, this device can assist households in monitoring their domestic consumption and conserve water; an important step towards relieving water stress in the MENA region. In addition, the data will assist governments and utilities in developing strategies towards sustainable water management and evidence-based policies.

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Strengthening Systems-Based Leak Prevention in Ciudad de México through Blockchain

Neil Patel, Huong "Katie" Truong

Ciudad de México loses an estimated forty percent of its piped water to leaks each year, contributing to the acute water scarcity that impacts the city's 21 million residents. Our research identifies potential applications of blockchain toward harmonizing the efforts of various stakeholders in the city's water sector and improving the efficiency of leak prevention systems.

When it rains in Ciudad de México (CDMX), it pours. In the summer months, the capital of Mexico receives up to 1,484 millimeters of rainfall, routinely flooding parts of the city [1, 2]. Despite this seeming overabundance, water is a scarce resource for the city's 21 million inhabitants, one-fifth of whom routinely experience shortages [3]. This fundamental paradox of water insecurity in CDMX underlies the city's "wicked problem"––how does a city that regularly floods run out of water?

The Wicked Problem: A History

When Spanish conquistador Hernan Cortés first laid eyes on the Aztec capital of Tenochtitlán over five hundred years ago, the grand city was built upon an island in the middle of what was formerly Lake Texcoco. Serviced by a complex system of canals, dikes, and floating agricultural plots called chinampas, the city harnessed the region's ample hydrological resources to support a bustling population of up to 400,000 residents [4]. Upon conquering the city, however, the Spaniards proceeded to drain the lake as a flood-mitigation measure and build what would become CDMX on the lake bed below—the consequences of which still contribute to the city's water challenges in the present.

Today, water is extracted from the groundwater aquifers that serve the metropolitan area at nearly the double the natural recharge rate [5]. This alarming trend will only be exacerbated by shifting climate patterns and rapid population growth––the availability of local water resources is projected to decrease by up to 17 percent by 2050, while the population is expected to hit over 24 million by 2030 [6, 7].

To meet rising demand, two-thirds of CDMX's water supply is extracted from the aquifers beneath the valley; the remainder comes from the Cutzamala and Lerma systems, where water is transported upward over a kilometer to the surface and across a distance of 127 kilometers before being distributed throughout a network of nearly 12,000 kilometers of piped infrastructure [8]. The aged pipe network, half of which was constructed over six decades ago, loses forty percent of its water to leaks [9]. In 2019 alone, the city spent nearly $15 million repairing over 12,000 individual leaks [3]. In order to alleviate the pressure on CDMX's water resources, addressing the substantial losses in its piped infrastructure is a top priority.

In 2020, CDMX launched a five-year, $550 million program to rehabilitate city-wide infrastructure and reduce total water

Photo 1. Aerial view of Ciudad de México. Photo credit: Hera Alexandros, December 2015, via Flickr.

extraction by two cubic meters per second, a six percent reduction from current levels [10]. However, part of the challenge in implementing such an ambitious program is coordinating efforts between the numerous local and national stakeholders involved in the city's water sector, including the National Water Commission (CONAGUA) and CDMX's water operator (SACMEX) [11, 12]. This underscores the importance of a systems-based approach to leak prevention, harmonizing the unique capabilities of each stakeholder to efficiently address the city's multi-faceted infrastructure challenges [13].

Our research explores the value of a blockchain-based model for leak prevention in CDMX, built upon the validated flow rate data collected through a network of remote sensors. By establishing a baseline of trust between stakeholders in the sector, blockchain can eliminate inefficiencies in coordinating efforts between actors, setting the foundation for an integrated approach to infrastructure management.

Building Trust through Blockchain

The use of internet-enabled devices to monitor water infrastructure is hardly a new idea—cities like CDMX are deploying these technologies to improve leak detection. These remote sensors are placed through a network of pipes, where they monitor water for specific environmental conditions such as flow rate, water pressure, or acoustic emissions from pipe bursts [14]. The physical infrastructure becomes 'smart' by sharing recorded data onto a centralized platform, where analytics can reveal accurate predictions as to the location of leaks [15].

Despite the advantages of smart devices, the insights generated are only as good as the underlying data. Information stored on a single, centralized record creates a security concern, as manipulating the data would only require altering the information in one location. In complex multi-stakeholder situations, such as in managing CDMX's water infrastructure, trust among users is critical for building resilient leak detection systems. Citizens, government agencies, service providers, and financing sources all depend on reliable data to balance competing interests and coordinate efforts in addressing the significant water threats facing the city [11].

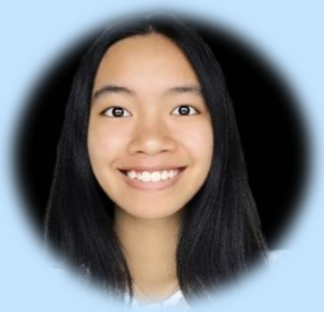
Blockchain offers a unique solution to this problem by creating a distributed ledger in which transactions are recorded across all devices in a network, rather than in a single centralized location. This decentralized structure makes it nearly impossible to manipulate data by any single user, as altering one ledger would require also altering the majority of other ledgers to avoid rejection by the network [16]. A blockchain architecture enables smart water devices distributed through CDMX's piped infrastructure to create a public record of validated water data, available for access through a digital interface that allows stakeholders to interpret relevant information for various purposes [17].

The uneditable record created by a blockchain is not just a means of fending off the occasional hacker—accurate data, validated in real-time, can dramatically transform the process of detecting and responding to leaks by setting a basic foundation of trust between the various entities involved in the management of water infrastructure.

Take, for example, fixing a routine pipe burst. SACMEX deploys in-house repair teams upon detecting leaks, with response times averaging between four hours to three days depending on the type of damage [10]. These teams often struggle with capacity shortages, especially given the estimated 150 new leaks appearing each day across the city [18, 19]. Despite these capacity constraints, contracting external service providers to reduce the burden on in-house staff isn't always acceptable due to perceived misaligned incentives between private service providers and the utility, which would require SACMEX to independently validate the adequacy of maintenance work. But what if there was a way to build an inherent form of trust into the system?

Picture instead a system in which the real-time detection of leaks triggers an automated notification of a maintenance provider in the area. Using blockchain-

"As an enthusiast interested in the application of emerging technologies to pressing real-world problems, I am fascinated by the potential of blockchain to aid in water conservation. Water scarcity affects the lives of millions of people all over the world yet receives little discussion in the mainstream. By conserving water, we can improve lives and protect fragile ecosystems dependent on these water resources."



"My family comes from a part of India routinely affected by both flash floods and extensive droughts, which has always made me conscious of the role water plays in our lives. Over the next few decades, communities around the world will be challenged with preventing water shortages in the face of rapid urbanization and shifting climate patterns. As a youth water researcher, my goal is to find innovative ways of using technology to preserve our planet's most vital resource for future generations."

validated flow rate data, SACMEX can issue smart performance-based contracts which automatically release payment upon detecting a return to a normal flow rate at the site of the leak, removing the need for human supervision [20]. Establishing a mutually-trusted data set for validating performance helps streamline the coordination of stakeholders in responding to leaks, preventing additional water loss.

Blockchain can also play a key role in closing financing gaps for infrastructure investments. While CDMX has significantly increased its budget spending allocated to the water sector, meeting the significant capital requirements for the city's proposed five-year investment program can be more efficiently achieved by merging public funds with external financing [21, 22]. Over the past four years, Mexico has successfully raised over a billion dollars in funding for sustainable infrastructure projects through the release of green bonds; however, the lack of transparency into the actual use of funds is a concern for impact-focused investors [23]. Blockchain can build a foundation for mutual trust through validated performance data that quantifies the impact of investments, reducing the diligence and compliance burdens for potential financiers [24]. By streamlining the process of accessing external financing for infrastructure investments, CDMX can free up public funds to focus on short-term priorities such as operations and maintenance.

Most importantly, blockchain can build trust between the utility and the consumers. Water insecurity parallels economic inequality in CDMX—households in the highest income quintile consume 42 percent of available water resources, six times more than those in the poorest quintile [25]. Protests are often driven by a lack of trust in public water officials due to perceived politicization of repairs, with leaks in wealthier neighborhoods sometimes prioritized over those in low-income areas [19, 26]. This distrust creates a vicious cycle, as 45 percent of utility customers consequently do not pay tariffs for water, depriving the utility of working capital to invest in necessary service improvements [27, 28]. A public ledger of validated water distribution data is a powerful tool for consumers to use in holding the utility accountable for equitable service provision, while also helping the utility assure customers that they are paying for quality services provided.

The wicked problem of water insecurity in CDMX is not just an issue of repairing broken pipes—it is the result of over five hundred years of inefficient management, inequitable distribution, and persistent under-investment. Navigating these interconnected issues requires integrating stakeholders at all levels—citizens, governments, service providers, and financing sources—through a systems-based approach built on a foundation of mutual trust. Developing 'smarter' infrastructure with technology like blockchain can help CDMX adopt intelligent water solutions that protect its water resources for all.

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Water Purification Using Natural Coagulants

Malaz M. Suliman

Drinking water purification using plants-based materials from the environment surrounding the source is gaining in importance. Several studies investigated the efficiency of natural coagulants in reducing turbidity in water, with many promising results.

Water Treatment Process

The source and the quality of water determine the type of treatment and the process required. In general, drinking water treatment involves two major steps: coagulation/flocculation and disinfection. The main purpose of these two steps is to remove turbidity and microbial load [1]. Turbidity is a measure of suspended solids in water; the World Health Organization recommends that, for water to be considered disinfected, the turbidity should be less than 5 NTU[1] [2]. While some types of suspended solids in water can settle on their own, fine particles of sand, clay or algae need an external catalyst to support the settling process. The negative surface charges of these fine particles prevent them from agglomerating and forming larger particles that eventually settle [3].

Aluminum sulfate is a so-called coagulant. It is added to water because it has positive charge which can neutralize the surface charge of suspended solids and allow them to agglomerate with each other and form larger particles which can settle under gravity by sedimentation [3]. Although aluminum sulfate is efficient, it is relatively expensive and has to be imported in many developing countries [4]. It can also synthesize byproducts which may pollute the environment [1]. Moreover, residuals of aluminum sulfate left after treatment process may cause several health effects. It was reported that aluminum-based coagulants are linked to intestinal constipation, loss of memory, convulsions, abdominal colic's, loss of energy and learning difficulties [5]. There is thus a need to develop natural coagulants as a potential substitute to coagulants currently in use. Such natural coagulants would be biodegradable, cheap, safe and environmentally friendly [6].

These natural coagulants can be extracted from animals, microorganisms and plants [5]. Using plants-based materials in water treatment has a long history and has been used in developing countries for many centuries for the purification of turbid water. For water treatment at home, plants-based materials can be used in the form of powder or paste [6]. Several studies investigated the efficiency of natural coagulants extracted from plants in reducing turbidity in water, with many promising results.

Examples of Natural Coagulants

The application of *Rajma* seeds or kidney beans on surface water treatment was examined by Merlin *et al.* [1], showing a removal efficiency of 48.80% for an optimum dosage of 0.5 g/l. Another study analyzed the potential of *Acacia catechu,* a thorny tree of up to 50 ft height which is common in the central and northern parts of India. *Acacia catechu* extract derived from the heartwood of the tree was air

[1] Nephelometric Turbidity Units

"I am interested in developing sustainable materials for water treatment. Natural coagulants are a biodegradable, safe and environmentally friendly alternative which is particularly important for remote communities where expensive chemicals and technologies are not available."

dried, grinded into powder and sieved. The powder has reduced 91% turbidity of a pond water sample [6].

Another potential natural coagulant is *Dicerocaryum Eriocarpum* (DE), a plant species found in grasslands and known by its common name 'devil's thorns'. DE plant has a wide range of applications; it has an antibacterial characteristic and parts of the plant have been used to treat diseases in the rural areas of the Vhembe District, South Africa, where it is locally available. Moreover, if the plant is crushed and left overnight in water, the resultant mucilage from the leaves becomes a useful substitute for soap and shampoo. In a study, fresh DE leaves were suspended in hot deionized water and salts solutions to extract mucilage from the leaves. The final transparent mucilage solution was recovered by filtration and it has shown to have the potential to reduce turbidity with an efficiency of up to 99% [7].

Plantago Ovata, which is an abundantly available, low-cost and fast growing plant that is found from the Mediterranean region to East Asia and India, has been examined as well. A bio-coagulant was extracted from *Plantago Ovata* and its potential as natural coagulant was tested for treating turbid water of a river. Results achieved removal efficiency of more than 95.6% of all initial turbidity concentrations [4].

Roselle, or *Hibiscus Sabdariffa,* grown in tropical central and western Africa is found to be rich in proteins which are soluble in water and carry an overall positive charge. These positive charge proteins would bind to the negatively charged particles of suspended solids. A study showed that the natural coagulant extracted from Roselle seeds gave comparable performance with aluminium sulphate. The turbidity removal efficiency of aluminium sulphate was within 82.9 to 99.0%, while the removal efficiency of Roselle seeds was within 81.2 to 93.13% [5].

Moringa Oleifera is a tropical tree native to India, but it is widely cultivated across the world, as it can withstand both severe drought and mild forest conditions [8]. It has many interesting uses in human and animal nutrition, pharmacology and cosmetics. Water treatment is one of the most important applications of *Moringa Oleifera*. The seeds of this tropical tree have a high amount of proteins that act like cationic polyelectrolytes once they are added to raw water. Water clarified under optimum parameters using *Moringa Oleifera* was found to be competitive with other well-known coagulants and its quality is within standard ranges for clarified water [9].

Omer et al. [10] tested the effectiveness of guar gum as a coagulant aid with aluminium sulphate. Guar gum is extracted from guar beans found in Eastern Asia and India. It is used as stabilizer and thickener in various food products. Results showed that the use of guar gum alongside aluminium sulphate decreased the turbidity from 12050.0 NTU to 3.8 NTU in comparison with 192.0 NTU when using aluminium sulphate alone [10]. Another study analyzed the Okra plant, *Cassia Auriculata*, which is found in the range of East Asia, India, Sri Lanka and Myanmar, and *C. Procera*, which is found in the range of tropical Africa through Arabia to the Indian subcontinent and Malaysia, for their potential to remove turbidity. The maximum turbidity removal efficiencies using Okra, *Cassia Auriculata* and *C. Procera* were 58%, 52% and 62% for low turbid water and 83%, 68% and 73% for high turbid water, respectively [11].

Finally, some common fruit peels such as banana, mango and orange were also studied by researchers. Results showed that banana peels achieve the better turbidity removal efficiency than mango and orange peels. This was attributed to the lowest moisture content of banana peels; it has about 63% moisture content compared to 78% for orange peels [12].

Table 1 provides a summary of the discussed natural coagulants along with their turbidity removal efficiency. It can be observed that half of these plants have achieved more than 90% turbidity removal efficiency. This result indicates that plants-based coagulants are promising and have the potential to be used as substitute for conventional chemicals.

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Table 1. Summary of natural coagulants and their turbidity removal efficiency.

Natural Coagulant	Turbidity Removal Efficiency
Rajma seeds [1]	48.8%
Acacia Catechu [6]	91%
Dicerocaryum Eriocarpum [7]	99%
Plantago Ovate [4]	95.6%
Roselle seed [5]	99.1%
Moringa Oleifera [9]	95%
Guar gum [10]	99%
Okra [11]	83%
Cassia Auriculata [11]	68%
C. Procera [11]	73%
Banana peels [12]	85.4%
Mango peels [12]	84.4%
Orange peels [12]	78.9%

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The Way Forward: Innovation and Sustainability

Amrita Gautam

The world has enough issues to deal with, but every challenge can also be an opportunity for innovation and growth. The planet's freshwater resources, if managed sustainably and effectively, can meet the water demands of the world's growing population with good quality water [1]. It is evident from studies that the water supply and sanitation sector continues to face increasing pressures, especially due to the impacts of climate change, and that governments in the developing world will need to be proactive and improve the sector's resilience and sustainability. Thus, innovation and technology have a vital role to play in water scarcity, security and safety, water efficiency, utility operations, monitoring and treatment and data and analytics [2]. Researchers, practitioners and policy-makers worldwide need to collaborate and work with local communities to identify relevant issues, raise awareness and create spaces for innovations that can provide sustainable solutions.

If we want to bring any real change, there are no shortcuts. We need to work at the grassroots level and have enough patience in transforming communities in the context of resource development, inclusion, equal distribution, and sustainable practice. As young water professionals, this is what we advocate for.

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