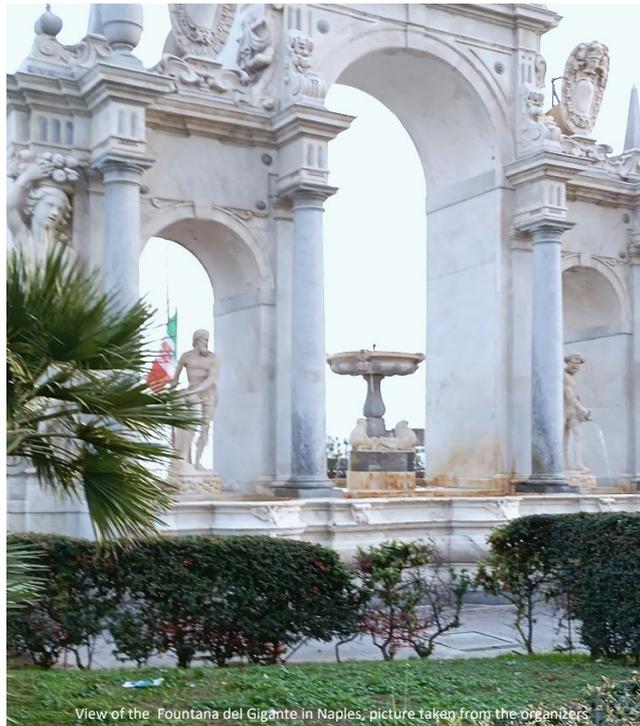


# BOOK OF ABSTRACTS

## 6th International Symposium on Water and Wastewater Technologies From Ancient Civilizations to Modern Times

23-24 February 2026



View of the Fontana del Gigante in Naples, picture taken from the organizers

**Centro Congressi dell' Università di Napoli  
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# FROM SEA TO LAND: THE LONG JOURNEY OF DESALINATION IN HUMAN HISTORY

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Only a hundred years ago, the only known form of desalination involved the distillation of seawater and it was mainly used by naval vessels. It should be noted, however, that distilling seawater to obtain drinking water was a technique known and even used since classical antiquity. Aristotle himself, in the 4th century BC, described this process with remarkable accuracy. However, it was only with the scientific advances following the Industrial Revolution (19th and 20th centuries) that humanity acquired the theoretical and practical knowledge necessary to develop suitable technologies, thus moving beyond a state of perpetual experimentation toward reliable and cost-effective processes.

Reverse osmosis, whose development dates back to the immediate post-World War II period, represents one of the most significant outcomes of these efforts. Today, the main constraints we face are economic and energy-related, although it is well understood that substantial opportunities for improvement remain and are actively being pursued.

This report traces the evolution of desalination from its origins to the present day, illustrating the pathways through which the necessary knowledge has been accumulated and how the practical challenges encountered along the way have gradually been overcome. Today, desalination, together with circular-economy approaches such as water reuse, is recognized as one of the key levers for addressing water scarcity—arguably one of the greatest challenges facing humanity.

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\*Speaker

# HOT WATER IN ROMAN BATHS

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The water heating system forms the core of a Roman bathhouse. Water was heated in the stoker's room, by a system of lead water basins, boilers, waterpipes and bronze valves. While those are all essential pieces of equipment in a bath, they are a rare find in archaeological contexts: once bathhouses ran out of use, these valuable metals were recycled fanatically.

Just one hot water installation is completely preserved, at the villa in Boscoreale, covered by volcanic debris from Mount Vesuvius. By using this complete find as a blue print, we can see where all the recovered fragments, found elsewhere (among others at Pompeii and Herculaneum), belong: from a distribution basin a pipe leads cold water to one or more boilers heated by a fire. From here heated water is mixed with cold water, and guided to the hot baths. The stoker was able to operate the installation using taps and controlling the fire. A first analysis of this system was made by Hubertus Manderscheid.

As Romans had no equipment to measure the amounts of water, nor its temperature, one starts wondering how this system was operated and supervised by the stoker. In this paper I want to go beyond Manderscheid's static presentation of the objects involved and see what happens when water starts flowing through the pipes and a fire starts heating the water. That is where the stoker would have been confronted with various problems: let's take a look at how he mastered them.

# FORTUNA ROMAN BATHS. SYSTEM MODELLING AND OPERATIONAL HYPOTHESES

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The Fortuna mineral-medicinal spring lies in south-eastern Spain, in the province of Murcia, approximately 30 km from the regional capital. The archaeological complex, first delineated in 1984, occupies a zone where the exploitation of thermal waters has been continuous from antiquity to the present day.

The excavations conducted thus far identify two main sectors: (i) an inn or service building associated with two large oval-shaped cisterns, and (ii) the the bathing area itself, which preserves structures from the Roman period alongside later Islamic facilities and installations dating to the fifteenth and the seventeenth–nineteenth centuries.

This study aims to formulate alternative operational scenarios for the Roman baths, drawing on the archaeological remains uncovered to date and on historical records of discharge and temperature. Water management within the thermal complex is characterised by analysing the variables that governed its operation, such as flow conveyed through the infrastructure, storage capacity, performance of drains and spillways, temperature gradients, and related factors.

To this end, the system will be characterized by means of three-dimensional hydraulic models that will allow the simulation of possible construction and operation hypotheses which, together with the study of possible parallels in other sites, will help to define the structure of the baths and their functionality.

# ROMAN THERMAE: THE ROLE OF RESERVOIRS IN THE IMPERIAL BATHS OF ROME

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Water storage systems played a crucial role in the functioning of Roman imperial bath complexes, acting as the key interface between aqueduct supply, hydraulic regulation, and internal water distribution. Far from being ancillary structures, reservoirs were integral components of the architectural and infrastructural design of large-scale thermae, directly influencing their layout, functionality, and long-term operation.

This paper presents an in-depth comparative analysis of the water reservoirs associated with major imperial bath complexes in Rome, including the Baths of Trajan, the Baths of Caracalla, the Baths of Diocletian, and the Baths of Helena. Drawing on archaeological evidence, architectural analysis, hydraulic features, and historical documentation, the study examines the location, morphology, capacity, and technical articulation of these reservoirs, together with their hydraulic levels and their relationship with aqueduct systems and the internal distribution networks of the bath complexes. The characteristics of carbonate deposits preserved on the internal surfaces of the reservoirs further provide valuable insights into patterns of water circulation and operational dynamics.

The comparative approach reveals strong technological continuities from the second to the fourth century CE, alongside significant adaptations related to changes in water management strategies. The results emphasize the central role of reservoirs within the imperial baths of Rome, contributing to a more integrated understanding of Roman hydraulic engineering and the water system of the city.

# A NEW INSIGHT INTO THE BATHING OF POMPEIANS

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Anthropogenic carbonates (limescale) from ancient water pipes, aqueducts and baths can provide abundant information on ancient water management practices, strategies and wider Roman history. These calcium carbonate deposits formed from hard water store the composition, temperature, biological content, quality and quantity of supplied water. The carbonate can also be used to learn about hygiene in Roman public baths. The presence of limescale incrustation versus its absence shows evidence for maintenance practices in the ancient Stabian, Forum and Republican Baths of Pompeii and the reasons for their renovations and abandonment. Decreasing stable carbon isotope values in the Republican Baths of Pompeii are evidence for poor water quality in the bath's pools because of the low capacity of the water-lifting machine in the well supplying the baths. This machine was then renovated and the well enlarged, most likely to increase replenishment of water, and a leakage problem of the first machine was eliminated. Stable carbon isotope patterns allow correlation of the well's building stages with renovation stages in the baths. Stable oxygen isotope values decreased in the Republican Baths after renovation due to higher water temperature in the pools. Pb concentration of the pool deposits of the same bath indicates installation of new lead pipes in the water network system. Different water composition in the groundwater of Pompeii and the aqueduct makes it possible to distinguish in carbonate deposits whether installations were provided by the wells, or by the aqueduct.

# WATER MANAGEMENT IN SOUTHERN HISPANIA: HYDRAULIC INFRASTRUCTURES AND HYDROGEOLOGY IN HILLTOP CITIES

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The HydroRemote project (PID2023-150976NA-I00) investigates the role of water management systems as key agents of cultural and territorial change in southern Hispania during Roman times. By combining archaeological, geophysical, hydrogeological, and spatial methods, the project explores how hydraulic infrastructures shaped the development and resilience of ancient hilltop cities and their surrounding territories in *Baetica* province.

The research focuses on several case studies in southern Iberia:

- Ocuri (Ubrique) and Zahara de la Sierra, in the Sierra de Cádiz, two prominent hilltop cities where complex water collection systems-cisterns, aqueducts, and terracing-reflect adaptation to steep terrain and limited water sources.
- The Laderas de Morana, located in the Sierras Subbéticas cordobesas, near present-day Lucena (Córdoba). This site corresponds to an *oppidum* that later became a Roman city. Although little is known about its urban layout, it features a system of cisterns distributed across the settlement, reflecting a planned approach to water management.
- In Tucci (Martos), a Roman colony situated in the Upper Guadalquivir, the project investigates three secondary elevated settlements that use bagnarola cisterns as their primary water supply system, illustrating the hydraulic strategies of rural-defensive support settlements in the territory of a major urban center.

Special attention is given to the identification and analysis of hydraulic constructions-such as reservoirs, channels, and aqueducts-through integrated techniques including remote sensing, geophysical prospection, excavation, and spatial modeling. These multidisciplinary studies aim to reveal how water management practices supported the sustainability and organization of hilltop urbanism and rural settlement in a Mediterranean context.

# MAPPING ROME'S ANCIENT AQUEDUCTS: AQUA VIRGO FROM ANTIQUITY TO GIS

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Ancient Roman aqueducts have long shaped the urban and suburban landscape of Rome. While the general routes of many aqueducts are broadly known, a precise cartography is still lacking. Given that many aqueducts run underground and leave little visible evidence, filling this gap would enable us to better understand how these aqueducts and the water they supplied shaped the landscape they crossed, including the people and activities they supported (distribution of production sites, baths, luxury living etc.).

This contextual approach is the aim of the ERC Advanced Grant project *IN-ROME*, within which my research aims to reconstruct the routes of Rome's aqueducts. Drawing on ancient sources, antiquarian accounts, data from 19th and 20th century field surveys, and the analysis of historical maps, these materials are examined alongside new archaeological discoveries recorded in the Geographic Archaeological Information System of Rome (SITAR) and are integrated into QGIS, together with other archaeological, topographical, and epigraphic evidence. To illustrate this methodology, this paper focuses on a case study centered on the *Aqua Virgo*, the oldest functioning aqueduct in Rome. Drawing on historical cartography and water management maps that remain in use today, I conducted speleological inspections inside the water channel beneath the Pincian Hill. This work led to the creation of a new detailed map that exposed the challenges of representing ancient aqueducts, particularly those running underground, and enabled a better understanding of *Aqua Virgo's* route and its technological features.

# THE SANGANO DRAINAGE GALLERIES: A UNIQUE 1859 INFRASTRUCTURE STILL SERVING THE DRINKING WATER SUPPLY OF THE CITY OF TURIN

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The first modern water supply system for the city of Turin (northwestern Italy) dates back to the mid-19th century. Following technical, qualitative, and financial evaluations, the *Società Acque Potabili* was established in 1852 with the mission to derive and distribute spring water from the Sangone Valley. After six years of construction, the aqueduct was inaugurated on March 6, 1859, with a maximum capacity of 650 L/s.

At the heart of the system lies the Sangano spring waterworks, a unique infrastructure consisting of four masonry drainage galleries built at different depths along both banks of the Sangone river. These galleries capture high-quality groundwater and converge into a gravity-fed open-channel masonry conduit. This channel partially supplies water to the municipalities of Rivalta and Grugliasco before reaching a storage reservoir, from which water is treated and distributed to the Turin network.

Remarkably, the entire system is still in operation and retains its original structure. All stages-collection, conveyance, and accumulation-are driven solely by gravitational energy, without the need for pumping.

Based on historical archives, technical surveys, and recent operational data, this contribution outlines the evolution of the Sangano system, emphasizing its engineering originality and hydraulic resilience. As a rare example of a 19th-century water infrastructure still fully integrated in a modern urban supply system, the Sangano galleries highlight the potential of historical solutions to inform future strategies, especially in the context of sustainability, energy efficiency, and long-term water security.

# THE BYBLOS AQUEDUCT: FORGOTTEN EVIDENCE OF ANCIENT WATER ENGINEERING ON THE LEBANESE COAST

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This study will present the results of the research conducted on the ancient aqueduct supplying the city of Byblos. Despite its imposing presence in its natural setting and its archaeological and historical importance, this aqueduct has never been the subject of any study that would allow us to better understand its relationship with the water sources that supply it (notably the source of the Adonis River), its archaeology, and its historical phasing.

Indeed, this aqueduct, of which only two aerial siphon bridges remain in the Nahr Ibrahim and Fidar valleys, but whose route is traced by the sections of a modern canal dating from the 1940s-1960s, formed the main source supplying water to the ancient city of Byblos. However, with the rapid urbanization of the city's immediate surroundings, where the castellum divisorium was likely located, the connection between the hydraulic monument and the city's intramural facilities appears to have been lost.

It is within this context that the study launched by the Holy Spirit University of Kaslik has made it possible to reconstruct, as far as possible, the original layout of the ancient hydraulic structure, reestablishing its overall chronology and the scenario of its original functioning. Moreover, this research has made it possible to demonstrate the continuity, over time, of ancient layouts in the organization of modern hydraulic developments on the Lebanese coast.

# EXTRA-URBAN AQUEDUCT SUPPLY AND CISTERN SIZE IN LATIUM: A LINK?

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Frontinus' treatise suggests that the aqueduct network of Ancient Rome supplied a significant amount of water to extra-urban private users. Despite this, very few of the thousands of villas that existed along the courses of Rome's conduits have been definitively accepted as being supplied by them. In the Tivoli-Gallicano area only one villa (that called 'Grotta Papale'), is accepted with any confidence as having been supplied by the city aqueducts, on the basis of the size and position of its cistern. This assertion, although probably correct in this instance, does beg the question of whether the existence of an aqueduct connection can indeed be justified by the size of the cistern at a villa site. One scholar suggests that many Roman villas in Central Italy must have been fed by aqueducts on the grounds that many of the cisterns were too large to have been supplied by anything other than aqueducts. (Marzano, 2007, 166) If one was to apply this logic to extra-urban villa sites, we might make the case that aqueduct-tapping sites could be identified on the basis of the size of their cisterns. I will investigate the question of whether cistern size can be linked to the likelihood of aqueduct supply. I will assess the evidence for cistern use across the Mediterranean world to ascertain whether a link between the size of a cistern and the method of its supply genuinely exists, or whether more caution is required when arguing in favour of an extra-urban aqueduct connection.

# AN UPDATE FROM AMPHIPOLIS: THE EAA/MYA FIELD SURVEY

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Between 2022 and 2026, the EAA/MYA project has been surveying the North Aqueduct of Amphipolis, a conduit suspected to be Classical in date but that certainly continues into the early Byzantine period. The aqueduct, which had been noted in the works of Pikoulas, but never properly studied, has now been surveyed extensively and we can propose a 15km course, with various construction techniques that hint at different phases of use. In this paper we will present the results of the field and cartographic surveys and highlight the questions that still remain; issues that will be addressed in the second phase of the project.

# AQUEDUCT WATER SUPPLY - THE SPRING OR THE RIVER

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Roman aqueducts contain carbonate deposits that registered both environmental and archaeological signals and this archive can be used to reconstruct past environmental setting and human interference with ancient water systems to manage water resources. Carbonate deposits from the upstream part of an aqueduct show mostly effects of the water source, while carbonate in the downstream parts records additional impact of seasonal air temperature fluctuations, and anthropogenic activities in the water channels such as repairs, cleaning or reconstruction. The slope and structure of an aqueduct channel, and any biological activity in the channel have strong influence on the type of carbonate fabric to form. Methods to analyse aqueduct carbonate include analysis of the microfabric and layering, and geochemical techniques of stable isotope and trace element analysis. We present examples of the formation of aqueduct carbonate and its interpretation for four ancient aqueducts in the Roman Empire, that were fed by water from a river (Syracuse), a karst spring (Aspendos, Fréjus) or both (Cahors). The most important effects of the water source are on stable isotopes of oxygen and carbon, and trace elements such as Sr, P, Mg, Y and Zn. For each aqueduct, we provide data from carbonate samples and results of multi-annual water monitoring. Only if the signal of the water source is properly understood can attempts be made to retrieve environmental data, and is it possible to correctly interpret signals of human interference in a water system.

# PFAS CONTAMINATION PROFILES AND FINGERPRINTING IN SURFACE WATER AND SEDIMENT FROM FIREFIGHTING FOAMS (FFF<sub>s</sub>) IMPACTED SITES

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PFAS are synthetic chemicals that are well known for their environmental persistence, toxicity, and potential for bioaccumulation. One of the primary applications of PFAS is in firefighting foams (FFFs). These FFFs are typically formulated using either electrochemical fluorination (ECF), which contains PFOS, PFHxS analogs, and their precursors, or telomerization (FT), which contains various PFAS precursors. In this study, surface water and sediment samples were collected from Seongnam Air Base (SN), Gyeonggi Fire Services Academy (FA), and Osan Air Base (OAF) in South Korea. Target analysis, suspect screening, and TOP assay were conducted to investigate the characteristics of PFAS contamination and to identify the types of FFFs used at each site. PFOS was detected at concentrations as high as 2,133 ng/L at OAF. 13 emerging PFAS classes characteristic of ECF-based FFFs were also identified, suggesting that ECF-based foams have been intensively used at this site. In contrast, the samples from SN and FA showed mixed PFAS profiles containing both ECF-based and FT-based compounds, indicating either the concurrent use of both formulations or a transitional phase from ECF-based to FT-based FFFs. Long-chain PFAS including PFOS were substantially accumulated in sediments, suggesting that sediments serve as major environmental sinks. TOP assay revealed the presence of PFCA precursors that were not detected by conventional target analysis. These precursors were observed at concentrations up to 914 pM, especially in samples from OAF. The results of this study suggest that PFAS fingerprinting is an effective approach for identifying contamination sources associated with firefighting foam applications.

# FROM WATERSHED TO STAGE: ACHELOOS RIVER, HYDRAULIC TECHNOLOGIES, AND THE EVOLUTION OF ANCIENT THEATERS IN WESTERN GREECE

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The Acheloos River has served as a critical natural and cultural landmark in Western Greece from antiquity to the present, shaping both the hydrological systems and the spatial development of ancient settlements. Several major cities-Stratos, Sauria, Mitropolis, Oiniades, Spolaita, Arsinoi, Konopi, Ithoria, and Paianion-emerged along its banks, underscoring its significance in fostering socio-economic and cultural growth.

Oiniades, strategically located on the fertile plain formed by the lower course of the Acheloos, exemplifies the interplay between environmental resources and urban planning. As the second most important city of Akarnania after Stratos, Oiniades featured extensive infrastructure, including a fortified acropolis, a sea port, a well-planned urban grid, cistern systems, and a theatre. Of particular interest is the theatre's integration with a sophisticated water management system: a euripus channeled stormwater into an array of cisterns, ensuring water availability during dry seasons or periods of conflict-a clear reflection of hydraulic foresight in urban design.

A similar hydrological strategy is observed in the theatre of Stratos. However, in this instance, the wastewater was directed into a downstream valley to enhance groundwater recharge an adaptive response to increasing soil salinity, supported by modern geological analyses.

These examples underscore how Acheloos influenced not only the geographical placement of ancient cities but also the development of sustainable hydrotechnical solutions. The integration of water infrastructure into civic architecture reveals a nuanced understanding of environmental constraints and urban resilience.

Today, the Acheloos delta is part of the Messolonghi Lagoon National Park, protected under Ramsar and Natura 2000.

# SUSTAINABLE WASTEWATER TREATMENT: LESSONS FROM ANCIENT BIOFILTER TECHNIQUES

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On-site wastewater treatment systems (OWTS) are crucial for rural communities that lack centralized sewer systems. Traditionally, septic tanks have served as the primary method for wastewater treatment. However, inadequate maintenance often leads to land contamination by effluent. Historically, sand-based trenches have been employed in various cultures as biofilter techniques for effective wastewater management, illustrating the long-standing relationship between natural filtration and sustainable practices. In modern applications, scientists and engineers have developed systems using sand trenches as biofilter media for wastewater treatment. Unfortunately, the high cost and limited availability of sand in regions like New Zealand present significant challenges. This study builds on previous research that compares various sustainable porous media, including crushed glass (CG), mussel shells (MS), and biochar, to sand, highlighting their potential as more economical and environmentally friendly alternatives. Findings from a 2019 project showed that CG performed similarly to 2A sand in laboratory-scale testing. All media were dosed at 50 mm/day, and the effluent was analyzed for biochemical oxygen demand (BOD<sub>5</sub>) and total nitrogen (TN). The results demonstrated impressive performance, with BOD<sub>5</sub> removal rates ranging from 92% to 98% and TN-nitrate removal rates between 60% and 89% across the tested media. This research confirms the viability of these alternatives while exploring their effectiveness, paving the way for sustainable and cost-effective wastewater treatment solutions in rural areas. Additionally, the study indicates that using these alternative materials can significantly reduce CO<sub>2</sub> emissions associated with wastewater treatment, enhancing their environmental benefits.

# ARCHIMEDEAN SCREW PUMPS IN HYDRAULIC PERPETUAL MOTION MACHINES

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The idea of perpetual motion travelled from India via the Arab world to Europe. Around 1230 the first drawing of a perpetual motion machine appeared in Europe. Subsequently, medieval engineers investigated many new methods and devices, with the recirculation mill attracting most attention. This paper discusses the further development of hydraulic perpetual motion machines in the Renaissance, when most books on this topic were printed. Drawings of hydraulic perpetual motion machines using Archimedean screw pumps appeared first in Italy during the early Renaissance at the end of the 14th century. Early pioneers were the engineers and artisans Mariano Jacopo (Taccola), Francesco di Giorgio Martini, and Leonardo da Vinci. Their aim was to invent a so-called recirculation mill which could be operated without the need for natural streams by using instead a closed cycle of water. In the 16th century the idea of perpetual motion was taken up by humanists, natural philosophers, mathematicians, and others who proposed various new schemes. The first treatise containing elaborate drawings of hydraulic perpetual motion machines using Archimedean screw pumps was published by Strada in 1629. The pinnacle of publications on new machines was reached between 1642 and 1683, starting and ending with Bettini and Lana-Terzi, respectively, when numerous Jesuits were attracted to the idea of natural motion for philosophical-theological reasons. In the 18th century, growing economic concerns led to increased competition and fraud. To curb speculation and deceitful practices, the Royal French Academy of Sciences declared in 1775 that perpetual motion was impossible.

# ENHANCING WATER SECURITY IN MALAYSIA: CHALLENGES, POLICIES, PROJECTS, AND TECHNOLOGICAL INNOVATIONS

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In Malaysia, water tells a complicated story in which abundant in rainfall yet tangled in shortages and silent losses. This paper explores the paradox that defines the nation's water security: an environment rich in resources shadowed by pollution, aging infrastructure, and non-revenue water. It threads through the nation's evolving response, where legacy supply-side strategies give way to integrated management and bold policy reform.

From monumental transfer tunnels slicing through mountains to subterranean treatment plants wrapped in green spaces, engineering becomes the stage for resilience. National frameworks like Water Sector Transformation 2040 and Integrated Water Resource Management reshape the governance structure of the water sector, while emerging technologies e.g. smart grids, digital twins, and pipe jacking, steer the sector toward precision and sustainability.

However, challenges persist. Fragmented institutions, financial constraints, and public disengagement create frictions. Climate change acts as both disruptor and driver, forcing adaptive design and forward-thinking conservation.

Ultimately, this paper reflects on Malaysia's long arc toward water resilience - not just through infrastructure and innovation, but through human participation, strategic foresight, and the quiet determination to turn abundance into true security.

# WASTEWATER-BASED EPIDEMIOLOGY: WATER AS A SENTINEL OF VIRAL DYNAMICS

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Since ancient times, water has been viewed as a reflection of community health. Today, this idea is revived through Wastewater-Based Epidemiology (WBE), which has become an essential tool for tracking viruses such as SARS-CoV-2 and others. In Brazil, between 2022 and 2024, nearly 15,000 analyses were conducted on wastewater collected from more than 40 cities. Peaks in viral loads, reaching up to  $3.3 \times 10^1$  copies per day, frequently aligned with periods of intense social activity, such as holidays and large gatherings. Genetic sequencing made it possible to detect SARS-CoV-2 variants, including unique mutations that appeared first in wastewater samples before being confirmed in clinical settings. Beyond SARS-CoV-2, the monitoring also revealed the presence of other viruses, including Influenza, Norovirus, and Adenovirus, underscoring WBE's value as an early warning system. These results demonstrate that water functions not only as a vital natural resource but also as a strategic component of public health surveillance and water security. This modern use of water for health insights connects with ancient practices of observing water to understand the wellbeing of populations. It shows how technological advances transform cultural knowledge into precise tools for disease prevention and community protection. Integrating wastewater monitoring into public health strategies is crucial for timely responses to emerging threats and highlights the role of water, both culturally and practically, as a pillar of social and environmental resilience.

# INTEGRATING WATER CULTURE, SMART METERING, AND CHLORINE DECAY MODELING FOR URBAN WATER MANAGEMENT

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Water has long shaped public health, infrastructure, and social practices in both ancient and modern civilizations. In Italy, Roman aqueducts and public fountains reflected advanced engineering and civic pride, where water access was closely linked to public space and social interaction. In Japan, water remains culturally embedded in daily routines through practices emphasizing cleanliness, environmental harmony, and personal hygiene. These traditions continue to influence modern urban water management.

This study explores how cultural context and smart technologies can be integrated to enhance water quality and system resilience. Traditionally, household water use was recorded manually every two months, offering limited insight into consumption behavior. In contrast, smart water meters provide hourly, high-resolution data for real-time analysis. In this study, hourly consumption data were collected from all households in a Japanese urban district, with a focus on single-person households. The analysis revealed distinct morning and evening demand peaks, increased weekend usage, and behavioral differences between going-out and staying-at-home lifestyles.

These patterns enabled more accurate simulation of chlorine decay using EPANET 2.2. Bulk decay coefficients were derived experimentally under varying temperatures, and wall decay was calibrated through simulation. The results identified several low-chlorine zones, particularly in terminal or low-use areas during night-time low-flow periods.

By combining culturally informed consumption analysis with smart metering and hydraulic modeling, this study proposes a demand-responsive framework for sustainable water management. It shows how integrating traditional water-use values with smart infrastructure can improve disinfection control and support adaptive urban planning.

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# WATER MILLS AND HEALTH

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There is a strong relationship between food quality and availability; as well as with the capacity of processing the raw materials to make food more digestive. This is the case of quite all grains/cereals, notably wheat, barley, rye, ..., usually milled to obtain flour. Additionally, transformations can help to keep good food conditions when storing the end-product.

Time ago, it was a period when parallel growth of cereals and its parasites (usually fungus) caused several inconveniences when milling both together. This was the case for several visions and similar episodes, individual or collective, which explains, for example, bizarre mind conditions / hallucinations in the Middle Age.

In any, case to cover the need to transform grain into flour, appeared the need to mill big quantities of the raw material. Initially, the necessary work force was ensured by hand milling (usually part of women daily tasks), but soon appeared the necessity to improve the efficiency of the process by external power: animals, wind, water, ...

The water power depends on its kinetic energy, and in this way appeared the water mills. Different solutions were engineered to transform the kinetic energy into power to mill the cereals. The different types of water mills and their components are analysed, along with their evolution along the centuries. Although many watermills disappeared in the last 100 years, it is still possible to find few of them still in use, many others are preserved as museums.

# WATER IN THE PHARMACEUTICAL MAGISTRAL FORMULATIONS IN THE LAST CENTURIES

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Water is part of almost all the magistral formulations that have appeared over the centuries, either as a main component or as an auxiliary component. However, it must be considered that numerous qualities of water are used in galenic, depending on the use and type of formula or medicine.

Water is the universal solvent for magistral formulations. Nowadays can have different qualities, depending on its final use, e.g.: potable, purified, highly purified and for injection. Many magistral formulations are named as water, followed by an explanatory word or a name.

Water-related formulations from XVIIth to XXth centuries are studied, considering that some abandoned the pharmacies and became common and highly consumed products

It is to note that depending on the type and activity of the medicament, there are plenty of variations (mint, chamomile, ...) and part of them have evolved to be commercial products sold in supermarkets, but its origins where the pharmacies. Examples of such evolutions have been the cola drinks, tonic water, Javel water (bleach), Cologne water, absinthe, soda, Seltz water, ... ; but also, disinfectants (e.g. chlorine dissolutions). As well, most of the bottled water, carbonated or not) in springs are also well known (San Pellegrino, Vichy, ...) and sometimes were commercialized in pharmacies.

The Pharmacopoeias along the XVII to XXth centuries quoted many different types of water, apart from the local ones, but at present nearly disappeared. A revision of the types of used water is performed in this communication.

# MICROPLASTICS AND WATER SECURITY: LINKING POLLUTION LEVELS TO FUTURE WATER QUALITY RISKS

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Microplastics are being increasingly recognised as pollutants of concern in freshwater as well as in marine resources. These tiny plastic particles, generally less than 5 mm in size, are resistant to degradation and have high surface area & bioaccumulation potential, making them a significant threat to water bodies. Currently, there are no established standards for microplastic removal in conventional wastewater treatment methods. Thus, regular monitoring programmes that look into the dynamics of interaction of microplastics with other microcontaminants, leading to established methodologies for improved functioning of wastewater treatment systems, are required. This research not only looks into the sources and pathways of microplastics in freshwater ecosystems, but also discusses their occurrence in water and wastewater treatment, while discussing the implications in terms of drinking water safety

It is also imperative to understand how microplastics can act as both physical contaminants and transporters of adsorbed pollutants, including microbial biofilm, heavy metals, and persistent organic pollutants, increasing their potential toxicity. Since microplastics analysis does not have a standardised protocol, methodological inconsistencies and geographic disparities are leading to enhanced confusion in its assessment. It also further hampers devising policy regarding standardised detection methodologies, life-cycle assessment techniques, and new-age treatment technologies. This research thus finally advocates for transdisciplinary governance that integrates pollution control, forms consistent standards, integrates circular economy strategies, and works towards sustainable water management.

# WATER MANAGEMENT AND WATER USE IN THE THEATRES OF ROMAN MACEDONIA

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The Romans effectively utilised water in their theatrical spaces. Ancient Roman theatres employed water for various purposes; water was used to supply drinking or cooling water to spectators; to serve decorative functions, with water features integrated into the theatre's architecture, such as fountains in designated areas, or to produce aesthetic and dynamic displays, such as aquatic spectacles like sea battles (*naumachiae*), where the arena could be flooded by diverting aqueduct water through concealed channels. Beyond entertainment, these hydraulic systems also facilitated drainage and sanitation purposes.

This paper focuses on evidence of water structures at theatres in Macedonia during the Roman period, compiled from existing published research. Its primary purpose is to identify – where possible - how Macedonian theatres addressed issues like drainage, decoration, or sanitation during the Roman era, and whether these solutions were introduced at that time or were already in use during the early phases of the theatre's construction. The connection of theatres to the city's aqueduct is also addressed, where and when possible. This brief overview does not intend to systematically describe or analyse any theatre excavated in Macedonia. Instead, examples will mainly include excavated theatres such as those of Philippi, Thasos, Dion, or Mieza, with secondary references to lesser-studied theatres, like those of Thessaloniki, Amphipolis, Maroneia or Abdera.

Such works employed in theatres reveal both Macedonia's technological achievements in the field of hydraulic engineering and its direct communication with the wider Roman world.

# PROPER OR IMPROPER FUNCTIONING? OPERATIONS AND MAINTENANCE OF WATER NETWORKS IN THE ROMAN EMPIRE

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It is well known that hydraulic engineering was highly developed during the Roman era. However, researchers have recently been questioning whether these magnificent hydraulic structures actually functioned properly. Of course, Roman engineers had a wide variety of risk prevention devices at their disposal. Nevertheless, despite these protective measures, hydraulic systems could malfunction or become damaged, either by natural factors or by human-induced causes. Our aim is to provide an overview of the archaeological evidence, primarily in Gaul and Hispania, concerning the maintenance and restoration of water systems, both for supply and sanitation. Examples to be discussed will include levelling errors, stability failures, calcareous crust formation, sedimentation and illegal water abstractions. This global approach demonstrates that, despite the technical advancements in Roman hydraulic infrastructure, we are often far from knowing whether they functioned optimally.

# WATER MANAGEMENT IN THE LARGE THEATRE AT POMPEII: INTERDISCIPLINARITY AND CHALLENGES

Katerina Gottardo \* <sup>1</sup>

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The Large theatre at Pompeii can be considered 'representative' for the study of hydraulic installation in relation to aquatic displays in theatres. Indeed, the novelty in the Italian peninsula occurred in the theatre during the Late Republic, when the Roman influence on the cities of Campania expanded. The type of solution adopted for hosting aquatic displays were basins built into the orchestra supplied by a cistern in the earlier phases of this water management system, and later by a tank built along the rear of the cavea. Although previous scholarship (Spano 1913) tried to analyse and give an interpretation of the succession of basins in Pompeii, its studies remained incomplete. What is lacking, above all, is an understanding of what should be the focal point of studies investigating hydraulic structures, namely the operation of the water system for which they were built. Accordingly, this research has been developed using the most appropriate methodology, which includes an interdisciplinary approach, to achieve satisfactory results. This research uses up-to-date archaeological methodologies for the study of buildings and considers engineering aspects to understand these installations related to the aquatic performances, as well as the sewerage system of the building. Due to the quantity and quality of the available data for the theatre at Pompeii, being the hydraulic installationless known, buried, inaccessible and uninvestigated, it was decided to conduct a geophysical survey in collaboration with the BSR. A hypothesis on the operation of the water system is presented.

# WATER MANAGEMENT IN THE HOUSES OF PHILIPPI: THE CASE OF THE FOURTH INSULA EAST OF THE FORUM

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Archaeological excavations in the city of Philippi have brought to light several domestic buildings dating from the 3rd to the 6th century AD. All of these houses were equipped with systems for water supply, drainage, and sanitation, reflecting a high level of urban infrastructure. Among them, the *domus* located in the fourth insula east of the Forum stands out as the most thoroughly investigated example. This residence underwent three main phases of construction and modification between the 4th and 6th centuries AD, followed by two later phases of use. The purpose of this paper is to trace the evolution of the water distribution and sewage systems in this *domus* and to explore how these changes might relate to broader historical events or shifts in the city's economy. We will also consider whether similar developments can be observed in other domestic buildings across Philippi, offering insights into how urban life and household management adapted over time.

# CHANGING NEEDS: HOW PETRA'S WATER SUPPLY SYSTEM EVOLVED FROM FIRST CENTURY BCE TO SECOND CENTURY CE

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In the semi-arid environment of ancient Petra (Jordan), the inhabitants created sophisticated water systems not only for ensuring their survival but also to enable luxury. Years of research have unveiled many of these systems from the first century BCE to the second century CE, consisting of run-off collection and spring-water conduits, expertly crafted into the surrounding ranges and the city itself.

A series of surveys, specifically focusing on the 'Ain Braq Aqueduct, have now led to new insights into how Petra's water management functioned. As part of the ongoing *Urban Development of Ancient Petra* project (UrDAP), a joint venture by BTU Cottbus-Senftenberg and HU Berlin (Germany), several sections of the aqueduct on Jabal al-Madhbah and structures related to the intra-urban water-distribution were investigated, revealing a complex and interconnected system. Contrary to prior belief, the aqueduct featured not one, but two conduits leading water into the city in two successive phases: the first, a long, pressurized lead-pipeline, supplied the large reservoir on az-Zantur hill, while the second, a series of open channels and terracotta pipes, transported water over a stone-built substructure to a small *castellum divisorum* with two outlets.

In these two phases, different structures were supplied by the aqueduct, which corresponds to the changing needs of Petra's inhabitants. As a matter of fact, the two aqueduct-phases reflect a general shift of how water was used and displayed. The discoveries significantly enhance our understanding of Petra's advanced hydraulic engineering and water management systems, which will be investigated in the author's dissertation.

# THE CAMPANIAN AUGUSTAN AQUEDUCT AT BAIAE (NAPLES - ITALY)

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The thermal complex of Baia was a wealthy residential district of nearby Cuma which, thanks to the geomorphological characteristics of the Phlegraean Fields area, was and still is rich in hydrothermal springs, whose exploitation dates back to at least the end of the 3rd century BC - beginning of the 2nd century BC. However, this abundance of hydrothermal springs contrasts with the absence of freshwater sources suitable for human consumption. In fact, between the 2nd and 1st centuries BC, the thermal baths were organised with a complex system of rainwater collection capable of guaranteeing the necessary supply for the proper functioning of the first villas built there. In the last decades of the 1st century BC, however, the Augustan aqueduct of Campania was built to provide a stable supply of drinking water to the Phlegraean region. Scholars believed that the Augustan aqueduct ran underground within the volcanic ridge behind the structures of the Baths of Baia, but in reality little was known about it. Fifteen years of speleological and archaeological research conducted by the Cocceius Association have made it possible to explore and document a 200-metre-long section of the aqueduct, with two branching chambers. The article describes the section of the aqueduct and the branches with the aid of 3D models in confined underground spaces. Some preliminary clues are provided on the management of fresh water in the area of the Baths.

# THE SUPPLY OF IMPERIAL ROME THROUGH WATER INFRASTRUCTURE ON THE BAY OF NAPLES

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The pressing political and social need to supply the high population densities of Imperial Rome shaped not only the capital's immediate hinterland (which was turned over to high-value, perishable goods) but also the Mediterranean more broadly. A vital link in the supply system connecting Rome to the Mediterranean were the ports on the Tyrrhenian coast within a few hundred km of Rome. One of the most important of these, especially early in this period, was Puteoli on the Bay of Naples, around which grew a network of commercial and military ports. Imperial Rome attempted to shape the Bay of Naples in manifold ways to supply (and protect) itself, including the creation or improvement of deep-water ports and the transfer of water hundreds of kms between river basins: a very modern example of environmental imperialism. These attempts took place in the context of seismic and climatic dynamism, however. During the early and high empire, resources were sufficient to meet these challenges. Changing capabilities and priorities in late antiquity led to the collapse of this system. *This presentation will investigate this 500-year history of human-environment interaction. It will consider how useful it is to view the supply networks of Rome, and the water supply of the ports of the Bay of Naples as a form of niche construction.*

# ANCIENT RESTORATION OF THE AUGUSTAN AQUEDUCT

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The great Augustan Aqueduct that served the Naples Bay area with fresh water in the ancient Roman times has a remarkable history. The aqueduct's true testament to Roman ingenuity lies in its longevity and sustainability-made possible through careful repair and restoration efforts that sustained its function during centuries of use. This paper explores the remarkable story of how Roman engineers not only built, but preserved, one of the great hydraulic achievements of antiquity. Engineered during the reign of Augustus, this vast water system once delivered the pure, abundant flow of the Acquaro-Pelosi springs to the heart of Roman civilization around Naples Bay. The Augustan Aqueduct has a long history of use as documented in ancient and historical accounts.

The aqueduct traversed very different geological and topographical conditions from the Acquaro-Pelosi springs in the limestone and dolomite of the Picentini Mountains to the Sarno Mountains (covered by volcanic soils) to the volcanic material in the Sarno/Campania Plain. Over the years of operation, there were different conditions that led to restrictions to the flow capacity of the channel at various locations.

Along the alignment of the aqueduct, at least nine locations are known where ancient Roman engineers undertook significant restoration work to address the declining flow capacity of the original channel caused by erosion and deterioration. These sites will be cataloged and analyzed to understand the specific problems encountered. The study will also examine the engineering responses, detailing the design strategies, construction methods, and materials used in each restoration effort.

# DIACHRONIC CHANGE IN IMPERIAL- ERA WATERPROOF LINING TECHNOLOGY: EVIDENCE FROM POMPEII, OPLONTIS, THE BAY OF NAPLES AND ROME

Rory Mclennan \* <sup>1</sup>, Duncan Keenan-Jones <sup>2</sup>

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The monumental water features of ancient Rome and the Bay of Naples represent the largest Imperial-era investment in public hydraulic infrastructure known from the ancient Mediterranean. Underlying and enabling all these works were highly specialised waterproof linings, the composition of which reflect the know-how and intentions of ancient builders. To investigate how ancient waterproof lining technology changed through time in Rome and the Bay of Naples- and understand what broader factors may have motivated their development - 15 mortar specimens dating between the 1st century BCE – 4th century CE were collected from water features located in Pompeii, Oplontis, the Bay of Naples and Rome. Each specimen was analysed using standard instrumental techniques, including ultra-high resolution mosaic scans of thin sections and polarised light microscopy (PLM). These established techniques were paired with a novel use of Micro-X-Ray Fluorescence Microscopy ( $\mu$ XFM), which allowed the elemental composition of whole thin sections to be rapidly and accurately visualised and compared. Together, these instrumental analyses produced data sets that showed clear trends in the composition of Imperial-era Italian waterproof linings through time. These included the use of specialised aggregates like volcanic ash, crushed terracotta and even crushed marble to change the function of specific mortar layers, as well as a general decrease in the aggregate/binder ratio of mortars through time. These trends could be contextualised with contemporaneous socio-economic and political changes to demonstrate how extraneous factors deeply influenced the development of Imperial-era waterproofing materials in Rome and the Bay of Naples.

# THE FORO CIVILE DRAINAGE SYSTEM IN POMPEII - PRELIMINARY ANALYSIS OF ANCIENT AND PRESENT WATER FLOW

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In Pompeii, beneath the Civil Forum, there is a complex rainwater drainage system. It is the result of various ancient urbanisation projects and it was partially explored and recovered at the beginning of the 20th century in order to restore its original function and to convey rainwater outside the archaeological area. In recent years, the system has shown some shortcomings in its ability to collect rainwater during heavy storms. In order to better understand the system and its shortcomings, the Archaeological Park of Pompeii and the Cocceius Association signed an agreement that included a speleological-archaeological research project aimed at verifying and reviewing the known data. The objectives of the research were to identify the structural characteristics of the passages and the potential causes of failure, together with the definition of optimal ways to restore full, sustainable and lasting functionality.

The investigations made it possible to explore some passages that had never been studied before and to identify several points of water inflow and outflow from the overlooking structures. Furthermore, the observation of this system made it possible to collect a series of data useful for the archaeological reconstruction of the urban area between the Forum and the so-called Imperial Villa. As a preliminary step intended to support future flow modeling actions, the paper reports an analysis of the ancient and present water flow directions and properties, together with present water management issues and suggestions about possible conservation and refurbishing actions.

# INDUSTRIAL WATER USES IN ANCIENT POMPEII

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Industrial water use in Pompeii constituted one of the primary categories of urban water consumption. Prominent industries included textile production, leather tanning, and food and beverage processing. Within the textile sector, two main types of workshops have been identified: dyeing facilities and fulling establishments (*fullonicae*).

The Wright Paleohydrological Institute (WPI) has conducted investigations into water use at two industrial sites in Pompeii. The first is a dye workshop, the *Officina Tinctoria* of Terentius. WPI research indicates that the workshop initially relied on rainwater collected in cisterns. In a subsequent phase, however, the site received water through lead piping connected to the municipal system, likely sourced from the Augustan Aqueduct.

The second site examined is a tannery (*Officina Coriariorum* – Mt. Versonius Primus), with emphasis on its water supply. The presence of numerous large in-ground vats suggests substantial water requirements for leather processing. Despite the proximity of aqueduct infrastructure, there is no evidence that the tannery used water from the Augustan Aqueduct. Instead, the water supply appears to have come from a pre-existing groundwater well, which likely met the operational needs of the facility.

# WATER AS A DISPLAY OF BEAUTY, LIFE ABUNDANCE AND WEALTH. FEATURES AND TYPICAL WATER CONSUMPTION OF ATRIA (ENTRANCES) FOUNTAINS IN THE ANCIENT ROMAN RESIDENCES OF POMPEII

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The water consumption in ancient Roman towns, supplied by a public water network, was traditionally estimated from the size of the external aqueduct channels and top reservoirs, but without accounting for the quantity of water delivered to single premises. How much water did various types of fountains' displays use, how did they operate and did they run continuously or for limited times only? Pompeii represents an ideal case study to verify principles for water distribution to single houses, blocks of houses and entire regions; in fact, various parts of the lead piping system are sometimes preserved. The project developed in the years 2023-2025 thanks to the funding received by British Academy, estimated the water demand of various types of private buildings. This paper presents the results on the water consumption of fountains present in atria, the house entrances. The fountains stood within the shallow basin collecting the rainwater from the house roofs, typically comprising a side pillar with a fountain statue on top, discharging a water jet into a basin in front; in the centre of the impluvium basin, a nozzle produced a tall vertical jet. The water demand was estimated for impluvia of side length between 2 and 7 m, by means of hydraulic modelling of the supply piping system, connected to the reservoir at the top of a nearby public water tower.

# THE KNOWN AND UNKNOWN OF POMPEII PUBLIC WATER SUPPLY AND DRAINAGE SYSTEMS

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The archaeological site of Pompeii preserves exceptionally well the remains of structures associated with its public water supply and drainage systems, including the castellum divisorium, street water towers and fountains, cisterns, and underground drainage channels. These elements offer invaluable evidence for understanding how water was managed in the ancient city. However, important questions remain unanswered: how were these components functionally related to one another? What is their precise chronology, and how do they reflect changes in urban planning and social organization over time? To what extent can we trace the development of water infrastructure across the various phases of Pompeii's history, and what gaps in knowledge persist?

This contribution seeks to review and synthesize the current state of research on Pompeii's water systems, integrating archaeological, engineering, and historical perspectives. By assessing both what is known and what remains uncertain, it aims to identify key directions for future interdisciplinary investigations.

Starting from a review of recent research on the aqueduct channels, water deposits, public street fountains, and the piping system into houses, as well as the drainage channels and structures of the Foro Triangolare, the authors provide details on the known and accessible structures. They summarise current understanding and propose hypotheses regarding the town's water management and the system's development up to the time of the town's destruction.

# A COMPREHENSIVE REVIEW OF THE DESIGN AND PERFORMANCE OF MICROBIAL FUEL CELLS IN CONJUNCTION WITH MODIFICATION AS AN ECO-FRIENDLY MEANS FOR SUSTAINABLE ENERGY GENERATION FROM WASTEWATER

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The globally expanding population and its surging environmental costs of thriving have already raised concerns for water pollution and energy crisis, and have compelled us to place growth-focused progress trajectories at odds with sustainable development. An exemplification of sustainability is the Microbial Fuel Cell (MFC), which originated in the early 20th century with M. C. Potter's biochemical experiment using *Saccharomyces* and *E. coli* microbes to generate electricity in a cell-type system. In later years, this technology was used by the National Aeronautics and Space Administration (NASA) to produce electricity from human waste. This 100-year-old technology gained considerable attention since the late 90s as an eco-friendly carbon-neutral technique for wastewater treatment that utilizes electrogenic bacterial actions to biochemically convert organic substrates in wastewater into electrical energy while considerably removing chemical oxygen demand (COD), nitrogen, and total suspended solids (TSS). Most conventional wastewater treatment plants (WWTPs) rely on cost- and energy-intensive deployments that are subject to either secondary pollution or inefficient recovery of resources. MFCs accessorized with modifications can be regarded as an alternative platform technique, showing promising potential for green energy while minimizing sludges, discharges, and operational emissions, transforming the existing WWTPs into an energy-efficient system. This work reviews the practical applicability of MFC combined with modified and/or hybrid systems as a value-addition to the WWTPs in terms of their design, efficiency, operational parameters, and limitations from a waste-to-energy perspective, and inherently provides a future direction for the feasibility of integrating MFCs as a climate-smart choice of techniques in traditional WWTPs.

# SHOWCASING UNDERGROUND WATER CANALS (QANĀT/KĀRĪZ) IN YAZD (IRAN) AND TURFAN (CHINA): ISSUES OF PUBLIC HISTORY

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Showcasing traditional techniques of water management in museums or other type of exhibitions creates spaces where societies negotiate patterns of self-definition and issues they want their past to be identified with. The paper focuses on strategies of showcasing a technique of extracting and transporting water in arid regions that is generally known as *qanāt* or *kārīz*. The paper focuses on the exhibition practice (i.e. spaces of presentation, choice of exhibited objects, interpreting narratives) in the cases of Yazd (Iran) and Turfan (China), and traces the evolution of the strategies through which the *qanāt/kārīz* issue is introduced into the dominant national heritage discourse and tourism policy in Iran and China.

In the case of the recently rehabilitated old town of Yazd (Iran), three *kārīz* networks were included in the 11 "Persian Qanāts" inscribed in the UNESCO World Heritage List (2016). In the national narrative, the "Persian Qanāts" are regarded as the origin of this water-management technique in a world-wide scale.

In the case of Turfan (Xinjiang, West China) two branches of the *kārīz* network have been differently arranged as exhibition museums with a variety of narratives regarding the relations between the *kārīz*, the local ethnic group (Uyghurs), and the water management know-how of the whole country. The "Karez Wells of Turfan" are inscribed since 2008 in the tentative list of the UNESCO World Heritage.

By showcasing aspects such as intentionality, performativity, and engagement of local actors in the above strategies, the paper situates the subject into the field of Public History.

# MINOAN HYDRAULIC INFRASTRUCTURE: CONDUITS AND CATCHMENT SYSTEMS IN NEOPALATIAL CONTEXTS

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This study examines specialized liquid management systems within Minoan Neopalatial villas (conventionally 1730–1450 BCE), highlighting their crucial role as productive and administrative centers within the regional territorial structure.

Specialized liquid management-essential for intensive agricultural and industrial production-is archaeologically identified by specific indicators, which often consist of fixed installations designed for evacuation. A key technological indicator for specialized production is the "basin + collector" system ( $\lambda\eta$ ), typically comprising an upper conical vessel (often fitted with a spout) and a lower pithos used for collection

These integrated systems were crucial for specialized activities, including textile production, which required organized liquid discharge (e.g., washing or dyeing fibers).

At Kommòs (Oblique House, House X), for example, sloping stone slabs served as "washing installations," directing spent liquids via conduits toward outdoor areas or light wells.

In large-scale productive units, the complexity of these infrastructures increased significantly.

At Vathypetro, a low monolithic stone basin was found connected to an outflow conduit that fed into the underground sewer system. Similarly, the multiple processing facilities at Epano Zakros utilized lithic conduits and specialized drainage channels for disposal. Furthermore, evidence from Petràs House II demonstrates localized water control, where bedrock floors were cut with channels and a small well to manage liquids associated with textile production.

The architectural integration of permanent conduits and specialized drainage points reflects a technical sophistication designed to support a high intensity and scale of production, exceeding typical domestic needs in these key Minoan centers.

# THE RISKS AND ADAPTATION MEASURES FOR WATER HERITAGE: THE CASE OF BENT STREAM CORRIDOR IN ANKARA

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Water heritage structures have been affected by several risks, including natural hazards, climate change, and human interventions. These risks necessitate a thorough investigation to safeguard water heritage from such threats, especially along waterfronts. The surroundings of Bent Stream in Ankara, Türkiye, have been selected as a case study area to explore such dynamics. The study focuses on the Great Roman Bath, one of the most important structures of the ancient period in this area, as a representative of broader water heritage assets. The area provides a valuable example for examining the effects of these risks, especially after interventions, including stream covering, flood control works, due to intensive urbanization and floods, occurred in Ankara after the 1950s. Such interventions affected the heritage water structures and destroyed the spatial and symbolic relationship between water and heritage. This paper comprises a comprehensive literature review, archival analysis (aerial photographs), a field survey, and spatial mapping (via QGIS) to understand the transformation of streams and their effects on heritage. Also, a SWOT analysis was conducted for risk characterization to develop adaptation measures. Finally, the study develops risk management and mitigation actions to safeguard water heritage structures for improving cultural continuity and resilience from environmental pressures at the site level, the urban level, and the policy level. With interdisciplinary perspectives from the conservation of cultural heritage and environmental engineering, this paper aims to investigate the effects of the risks and sustainable adaptation measures for water-exposed cultural assets by promoting ancient water knowledge, reuse, and historical infrastructure.

# SUCSESSES AND FAILURES IN THE CONSTRUCTION OF THE EMISSARY OF LAKE FUCINO

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In ancient times, Lake Fucino was the third largest lake in Italy, but lacked sufficient natural emissaries. Since the times of ancient Rome, the creation of an artificial emissary to drain the lake and obtain agricultural land was the subject of ambitious projects.

The emissary, 5650 m long, was built by the emperor Claudius. It was also the subject of subsequent considerable restoration work under Trajan and Hadrian, but proved to be rather subject to ruinous and repeated subsidence, then becoming inactive with the end of the Roman Empire.

In modern times, in the period 1854-1877, with funding from Prince Alessandro Torlonia and project and direction of the works entrusted to illustrious French engineers, a modern emissary was built, while at the same time carrying out accurate surveys of the ancient emissary. The reasons for the vulnerability of the Roman emissary were erroneously attributed to imperfect or malicious construction. However, even the modern emissary proved to be subject to serious collapses.

Only with the first constructions of tunnels under the Alps, also afflicted by ruinous collapses, was the real reason for the vulnerability of underground channels understood and suitable countermeasures were adopted.

In fact, when an underground channel passes through materials with parts that are not well bonded to each other, especially when the materials get wet and tend to behave like fluids, the structure is subjected to very high pressures on all sides and failure becomes inevitable if the walls are not designed and built to resist them.

# BRIDGING TRADITIONAL AND MODERN WATER QUALITY APPROACHES: A MICROPLASTIC ASSESSMENT OF SURFACE WATERS

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Microplastic contamination has become an emerging problem in urban river systems and poses a critical challenge to water quality and aquatic ecosystem integrity. India produces over 9 million tons of plastic waste annually, most of which end up in water bodies due to inefficient recycling and management turning Indian surface water systems into a major microplastic hotspots. Microplastics detected in freshwater species show bioaccumulation across food chains, and human exposure through polluted water, salt, seafood, etc. can cause serious health impacts. Though several national initiatives aim to restrict single-use plastics and control plastic pollution in water bodies, at the local level this issue has not yet gained enough public attention and awareness. Not many studies have examined traditional water management practices that use physical filtration and coagulation or flocculation based settling for microplastic removal, while most research focuses on advanced techniques such as membrane filtration, advanced oxidation processes, and adsorption, which often face scalability, economic, and ecological constraints in developing regions. This study highlights how microplastic removal and retention are influenced by existing water-treatment infrastructure and traditional methods of water clarification using plant-based coagulants, which can bind with microplastics and promote their settling for easy extraction. Traditional filtration systems, including layered gravel-sand beds, wood or coconut shell biochar, and slow sand filters, can also capture microplastics during water flow. This review provides valuable insights on sustainable pathways for restoring contaminated rivers and lakes by combining cost-effective, eco-friendly ancient water treatment methods with contemporary water-treatment technology.

# ASSESSING PARAMETERS FOR MICROORGANISM INACTIVATION IN PLASMA ACTIVATED WATER

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Natural groundwater reserves in Georgia comprise 43% of surface runoff. Most of the organic matter in wastewater that pollutes rivers and aquatic environments is bacteria. Georgia has always treated wastewater with natural clays. During the Paleogene epoch, bentonite clay (askangel) was created in two areas of Georgia: Tsikhisubani and Vaniskedi. Askangel filters polluted water as a natural colloid. Safe drinking water and microbial inactivation from surfaces and devices are WHO priorities. The global SARS-CoV-2 pandemic necessitated liquid disinfection methods. Thermal arc plasma technology generates plasma activated water (PAW), exhibiting antiviral properties against SARS-CoV-2. PAW may serve as a novel disinfectant in addition to established agents such as chlorine and alcohol. The Andronikashvili Institute of Physics (TSU) has created a device that produces PAW. PAW's antibacterial effectiveness was assessed on gram-negative *E. coli* and gram-positive *B. pumilus* using the PrestoBlue™ Cell Viability test, which accurately measures cellular metabolic activity. *E. coli*, a common inhabitant of animal intestines and environmental surfaces, is mostly harmless, though certain strains pose health risks. The interest in *B. pumilus* arises from its remarkable resistance and adaptability to various toxic effects. In bacterial inactivation experiments, the bacterial pellet was incubated with PAW. PWA decreases *E. coli* cell numbers by an order of magnitude following 10 minutes of exposure, whereas the *B. pumilus* population is reduced by only 50%. Thermal arc plasma efficiently generates PAW with measurable bactericidal activity, though optimization of conditions is necessary for practical application. This work was supported by the grant #FR-22-3307 from SRNSFG.

# ASSESSMENT MODEL FOR THE IMPACT OF SMALL HYDROPOWER PLANT ON AQUATIC HABITAT- CASE STUDY OF WANCHANGCHUN CHANNEL

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With the growing demand for power generation, the Wanchangchun Channel in Taiwan, completed in 1811, will be endowed with a new function of hydropower generation in addition to its original irrigation function. However, enhancing hydropower efficiency through flow generation requires careful consideration of the irrigation function and flood safety, with potential impacts on aquatic habitats. This study constructed an assessment model encompassing four modules: database module, model base module, knowledge base module, and graphical user interface (GUI) module. The database module includes digital elevation, flow, and fish survey data. The model base module incorporates the HEC-RAS hydraulic simulation model. The knowledge base module contains habitat classification, Habitat Suitability Index (HSI), and Weighted Usable Area (WUA) calculations. The graphical user interface (GUI) module employs Quantum GIS (QGIS) as the visualization platform. Through this assessment model construction, the impacts of flow conditions on aquatic habitat can be visualized and quantitatively assessed under different scenarios to support decision-making. According to the results, as flow increases, the water area expands, and the WUA for the indicator species (*Acrossocheilus paradoxus*, *Opsariichthys pachycephalus*, and *Rhinogobius candidianus*) varies with flow. When flow increases from current conditions (5–10 cms) to 15–20 cms, WUA decreases initially, followed by a subsequent increase as flow continues to rise, reaching parity with current conditions at 40 cms. This assessment model supports optimal solution selection considering irrigation function, flood safety, power generation efficiency, and aquatic habitat impact, providing a comprehensive framework for small hydropower development for the irrigation and drainage system.

# FROM ANCIENT NATURAL ATTENUATION TO MODERN CARBON SINKS: A BIBLIOMETRIC ANALYSIS OF BIOCHAR-ENHANCED CONSTRUCTED WETLANDS

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The use of wetlands for wastewater management dates back to ancient civilizations in Mesopotamia and China, where natural attenuation processes were empirically utilized for water reuse in agriculture. While modern engineering formalized these principles in the 1950s through the pioneering work of Käthe Seidel in Germany, who scientifically demonstrated the capacity of macrophytes to degrade specific pollutants, current global environmental pressures demand a new technological leap. This study analyzes the most recent evolution of this ancestral method: the integration of biochar into Constructed Wetlands (CWs). Through a bibliometric review of 207 articles published between 2001 and 2023, we mapped the global trends transforming these traditional systems. The analysis reveals that biochar acts as a superior upgrade to conventional gravel substrates. Its highly porous structure enhances the adsorption of refractory organic compounds and heavy metals while providing an ideal surface for microbial biofilms responsible for nitrification and denitrification. Furthermore, biochar converts the wetland into a long-term carbon sink, mitigating greenhouse gas emissions. Geographically, China leads this modernization, contributing 66% of the publications, with a primary focus on municipal sewage. However, a disconnect remains between the technology's potential and its global application: the review identified a critical lack of studies in tropical regions and limited large-scale implementations. By bridging historical wetland principles with advanced functionalized materials, biochar-CWs emerge not only as efficient treatment units but as climate-resilient solutions essential for the modern circular economy.

# REVITALIZING ANCIENT CARBON FILTRATION: PERFORMANCE OF VERTICAL FLOW WETLANDS AMENDED WITH RESIDUAL WOOD BIOCHARS

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The application of carbonaceous materials for water purification is a practice as old as civilization itself, with Sanskrit texts (c. 2000 BC) and ancient Egyptian records documenting the use of charcoal to filter impurities. While modern sanitation has shifted towards energy-intensive technologies, there is a resurgence in adapting these ancestral low-cost principles for contemporary needs. This study evaluates the efficiency of upgrading modern Constructed Wetlands (CWs) with biochar, a scientifically refined analogue of ancient charcoal. Three pilot-scale vertical flow prototypes treating sanitary sewage were operated for 56 days: PI (control with gravel), PII (amended with *Eucalyptus* sp. biochar, produced at 250–350 °C), and PIII (amended with *Citrus sinensis* biochar, produced at 500 °C). The results revealed that the high-temperature *Citrus* biochar (PIII) significantly outperformed other substrates, achieving 91% removal of Consumed Oxygen (OC) and 90.4% of Nitrate-Nitrogen. This performance is directly attributed to its superior specific surface area (138.88 m<sup>2</sup>/g) compared to *Eucalyptus* biochar (35.42 m<sup>2</sup>/g), as confirmed by BET and SEM analyses. Furthermore, EDS analysis indicated that the biochar surface facilitated chemical precipitation and microbial biofilm colonization. Conversely, the gravel control (PI) proved most effective for Total Phosphorus retention (87.8%), driven by mineral interactions. Microbiologically, the biochar amended systems reduced *E. coli* by up to 88%, adhering to agricultural reuse standards. By validating that residual biomass can be converted into high-performance filter media, this research successfully bridges the gap between ancient charcoal filtration wisdom and modern circular economy goals, offering a resilient solution for decentralized sanitation.

# MEMBRANE-BASED APPROACHES FOR MITIGATING MICRO/NANOPLASTIC POLLUTION IN WATER EFFLUENTS

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Microplastic (MP) pollution is a growing global environmental concern due to their persistence, widespread distribution, and potential impacts on ecosystems and human health. MPs are increasingly detected in marine environments and wastewater effluents, where conventional treatment technologies often show limited removal efficiency. Addressing this issue requires innovative solutions capable of both monitoring MPs in aquatic systems and reducing their release into the environment.

Within the Tech4You project, two complementary pilot-scale technologies have been developed. The first is a compact aquatic drone equipped with membrane-based systems for non-invasive monitoring and ex situ characterization of MPs in coastal waters. The second is a pilot-scale treatment plant integrating membrane separation and advanced processes, designed as a tertiary treatment for municipal wastewater effluents to enhance MP removal under real operating conditions.

By bridging laboratory research and pilot-scale validation, these technologies provide integrated monitoring and remediation strategies. The proposed approaches support sustainable water management and contribute to the mitigation of microplastic pollution in aquatic environments.

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# LONG-LIVED REACTIVE SPECIES IN THERMAL ARC PLASMA TREATED WATER AND MICROORGANISM DISINFECTION

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Georgia possesses an abundance of water resources, including 26,000 rivers, 860 lakes, and more than 730 types of mineral water, which provide exceptionally clean drinking water. The water system of Tbilisi, the capital of Georgia, was established in 1887. Historically, water carriers provided this service. Twelve Mtkvari River locations in Tbilisi supplied drinking water. The Mtkvari River is currently contaminated with pollutants, including harmful microorganisms. Multiple studies indicate that thermal arc plasma treatment effectively eliminates microorganisms, while also degrading toxins in water. The Andronikashvili Institute of Physics at TSU developed a plasma arc device for water treatment with an extended arc length. This study analyzes the impact of different plasma treatment setups on the microbiological content of heavily contaminated Mtkvari River water in Tbilisi, showing that the thermal plasma arc method significantly decreases microbial contamination through both contemporary and conventional microbiological approaches. The elimination of microorganisms is facilitated by the generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) in plasma-treated water. This study employs spectrophotometric methods to analyze the production of long-lived ROS, specifically hydrogen peroxide, and RNS, namely nitrate and nitrite ions, generated via thermal arc plasma techniques. The results indicate that the concentration of strong bactericides (ROS and RNS) is affected by the plasma source type, exposure duration, and water composition. Optimizing plasma conditions regulates the production of long-lived reactive species and enhances the efficacy of water plasma treatment for environmental applications. This work was supported by the grant #FR-22-3307 from SRNSFG.

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