H.R. 873 WATER QUALITY AND INNOVATION ACT

Source: pexels.com

Source: City of Cleveland, 2019

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ACKNOWLEDGEMENTS

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Pine Knoll Shores Living Shorelines.

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EXECUTIVE SUMMARY

The waters of the United States currently face many challenges that threaten the usability of this vital resource. HR 873 allocates funding for organizations to study how emerging technologies can address threats to water quality. This report will examine the science behind each of these potential threats and the solutions the bill calls for. Each approach has potential controversies and limitations that must be examined before they are applied in any particular situation, and clear metrics must be established to measure the successes of each application. HR 873 ultimately seeks to use 21st-century technology to address water quality issues.

Source: Ansloos, 2023

INTRODUCTION TO H.R 873

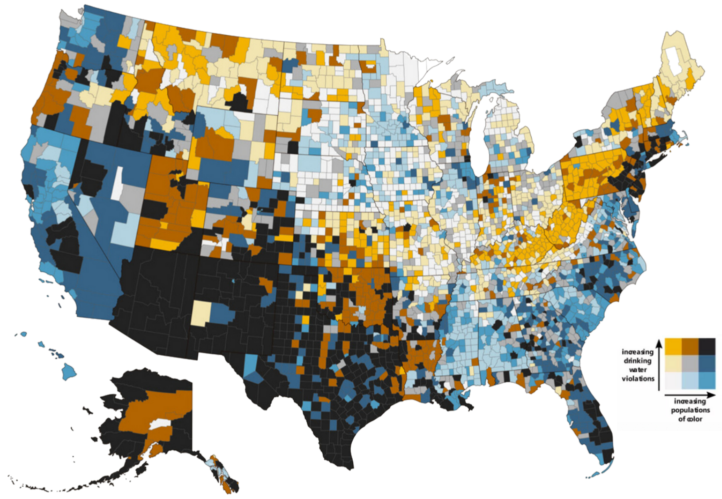


Image: Intersection of all drinking water violations of the Safe Drinking Water Act and racial, ethnic and language vulnerability by county across the US from June 1, 2016 to May 31, 2019.

Source: Fedinick, Taylor, & Roberts, 2019

The Water Quality and Environmental Innovation Act (or HR 873) aims to address threats to water quality in the U.S. by providing funding for projects that use emerging technologies to improve water quality - from nutrient pollution and algal booms to plastics and sea-level rise. The bill also supports innovative solutions in water quality testing and remediation.

HR 873 was introduced in the House of Representatives in January of 2023 by Rep. Byron Donalds (R-FL) and on behalf of Representative Josh Gottheimer (D-NJ) before being referred to the Committee on Transportation and Infrastructure and the Committees on Energy and Commerce, and Science, Space, and Technology. The bill recognizes that “Science, technology, and innovation are major cornerstones of the economy of the United States” ("Congress.gov," 2023) and seeks to use these innovations to improve and protect US water quality through “market-based solutions” (Congress.gov, 2023).

HR 873 will draw funding from fees collected from the Motor Vehicle and Engine Compliance program and transfer them to the Water Quality and Innovation fund established by the bill. The EPA will oversee this fund and will award grants or contracts for projects studying or using emerging technologies to solve the problems facing water quality, or the research and development of these technologies. These projects may be led by a non profit, higher education institution, for profit company or any other entity the EPA administrator deems fit within the U.S. The program will run from 2024 to 2028, and the EPA administrator will report annually to congress on the results of the program.

The bill lists nine specific threats to water quality that awards must address and eleven possible technologies that should be prioritized. Whether or not any of these technologies will have an effect upon these issues remains to be seen, and this funding allows for further study to determine their feasibility and effectiveness of this approach - if the EPA needs to update the tools currently being used to tackle water quality issues. Should this program prove successful, it could potentially have significant impacts on both how water is managed and how the EPA is run.

BREAKING DOWN THE ENVIRONMENTAL PROBLEM

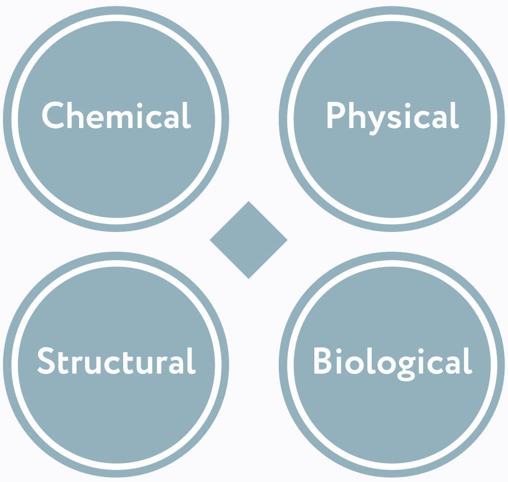
For the purposes of this analysis, we placed water quality threats into four categories. We defined them as being any physical or chemical changes to the composition of water from a certain source that has the potential to cause harm to ecosystems and human health. This definition also includes structural changes to existing land or water masses with such adverse effects. Threats to water quality can have significant negative impacts on water systems and the ecosystem services they provide.

H. R. 873 mentions the following threats:

- acidification
- accumulation of plastics, trash, and microplastics
- hydrologic alterations, such as restricting tidal flow
- nutrient release and eutrophication, including harmful algal blooms
- sea-level rise
- waste carbon dioxide accumulations
- adverse soil health conditions
- erosion and sedimentation
- karst, sinkholes, and land subsidence ("Water Quality and Environmental Innovation Act," 2023)

Image: Algal Bloom in Lake Okeechobee, FL
Source: Florida Atlantic University

FOUR CATEGORIES OF THREATS



CHEMICAL THREATS

Chemical threats affect water quality by altering the chemical composition of the water. Among those addressed by the Act are acidification, nutrient release, eutrophication, and waste carbon dioxide accumulation). For instance, the process of acidification due to the increased uptake of carbon dioxide by oceans leads to a change in the pH level of ocean water to a more acidic level. This dissolved carbon dioxide reacts with water to form mildly acidic (weak) carbonic acid, which subsequently dissociates into hydrogen and carbonate ions through a series of chemical reactions, disrupting the pH balance of ocean water. It is estimated that the ocean's pH has reduced by nearly 0.1 since the beginning of the industrial revolution (National Oceanic and Atmospheric Administration, 2020). The reduction of available dissolved calcium carbonate affects marine organisms that rely on its presence to build shells (National Oceanic and Atmospheric Administration, 2020). This can also lead to endangerment of coral reefs, which is a significant negative outcome on the ecosystem.

PHYSICAL THREATS

Physical threats affect water quality through their physical presence. Among the threats addressed by the Act that could fall under this category include - the accumulation of plastics, trash, and microplastics, waste carbon dioxide accumulations, adverse soil health conditions, erosion, and sedimentation. The presence of plastics can negatively affect aquatic life. The most visible impacts of plastic debris on aquatic life are the suffocation on, ingestion of, and entanglement of various species by the debris (IUCN, 2023).

Certain plastic products also leach toxic compounds as well as organic carbon into water (Romera-Castillo et al., 2018), sources, which further affect aquatic ecosystems. According to the US EPA, most aquatic trash comes from 'land-based activities' (EPA, 2023) including domestic waste when garbage has not been properly disposed of. Among the top forms of plastic found during the 2017 coastal cleanup project included straws and takeout containers (National Oceanic and Atmospheric Administration, 2018).

As plastic is weathered down, it is broken up into smaller pieces forming microplastics. Microplastics include large plastic debris, microbeads, and microfibers. Microbeads are tiny abrasives, usually polyethylene, found in wash-off cosmetics, cleansers, and toothpaste (Sulpizio, 2022). Microfibers are tiny pieces of thread and fibers that break off clothing. Plastic particles can enter water bodies through littering, poor sewage treatment, and runoff. Aquatic animals tend to mistake plastics for food. With the inability to digest microplastics, aquatic animals feel less hunger as the plastics accumulate in the stomach. Eventually, animals die due to lack of nutrients and starvation. Research also suggests that accumulation of microplastics in humans exerts localized particle toxicity by inducing or enhancing an immune response such as inflammation (Wright & Kelly, 2017).

Image: Ocean cleanup device collecting trash in the Atlantic Ocean
Source: The Guardian

BIOLOGICAL THREATS

Biological threats originate from sources like bacteria, pathogens, and algae. The Act addresses nutrient release and eutrophication, including harmful algal blooms, as a threat to water quality (NOAA 2019). These blooms are caused by the excess runoff of nutrients into lakes and rivers, creating anoxic environments in the water which causes aquatic life to suffocate.

STRUCTURAL THREATS

Structural threats relate to hydrologic alterations, such as restricting tidal flow, erosion and sedimentation, and karst, sinkholes, and land subsidence. For example, coastal erosion in Louisiana has involved a change in the shape of both the region's coastline and negatively affected its marsh ecosystems.

The U.S. Geological Survey estimates that Louisiana has lost approximately 1,900 square miles of its coast since 1932 and much of this erosion is in its wetlands, leading to a loss in the wetland ecosystem (NOLA Ready, n.d.). Coastal erosion is a natural phenomenon but is exacerbated by sea level rise.

Environmental justice is a persistent challenge integrated within each category of the aforementioned threats. Certain communities are adversley impacted by threats to their water sources. The following case study investigates one such community.

Interacting Water Quality Threats and Environmental Justice : A case study of Chesapeake Bay

This estuary, the largest in the United States, borders 6 states and has a watershed that is home to 18 million people (NOAA, n.d.). Chesapeake Bay also borders multiple EPA regions and has hundreds of tributaries each with different characteristics, scoring, and biotic indices. This sets the scene for complex water quality issues that interact with and amplify one another.

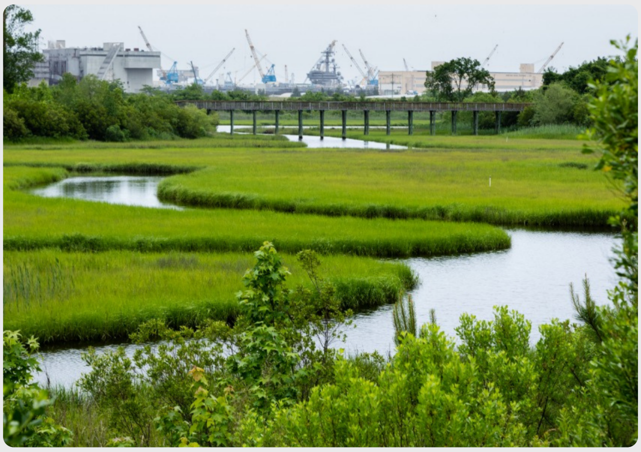


Image: Paradise creek, a seemingly pristine-looking river in Portsmouth with many water quality issues such as chemicals from nearby toxic waste sites hidden below the surface.

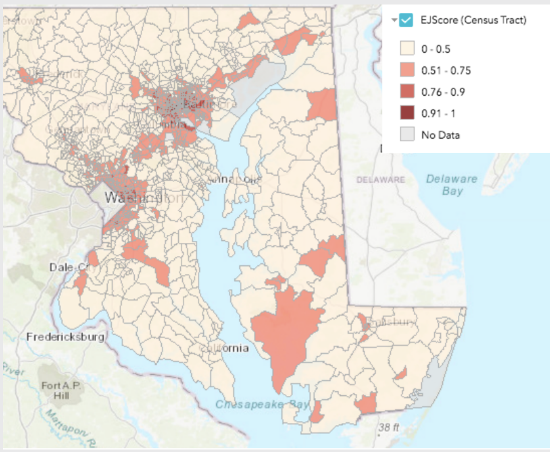


Image: Outline of Chesapeake Bay with areas highlighted in red showing regions with low environmental justice scores.

Images Sources: Will Parson, Chesapeake Bay Program, and Maryland's School of Public Health

All of the four mentioned categories of water quality threats are prevalent in Portsmouth, a city at the south end of Chesapeake Bay with a predominantly black population (Brown, 2022). Portsmouth also has one of the highest rates of deaths due to cancer and asthma in Virginia and on top of that, people of color and lower-income populations here are more likely to live near a Superfund site than 99% of the U.S. (Brown, 2022). Portsmouth is an example of how critical environmental justice considerations are to water quality issues. Safe water is not only limited but also inequitably distributed across the U.S.

PHYSICAL - Research by the University of Pennsylvania has shown that the vast majority of microplastics that make their way into the rivers of the Chesapeake Bay and persist in local waters. Microplastics have a long residence time, act as transport vectors for toxins, and absorb VOCs. These microplastics will travel up the food chain causing issues such as inflamed lung tissue and leading to cancer in humans.

BIOLOGICAL - Fertilizers have high concentrations of nitrates that runoff into the upper Melville Pond in Portsmouth and lead to the formation of algae blooms, depleting the oxygen content in the water body, making the water inhabitable for fish and many other forms of aquatic life. Fertilizer contamination also has adverse impact on human health. If water is ingested, it can lead to headache, diarrhea, and kidney and liver damage in some cases. Exposure to such water may also lead to skin rashes and irritation. In 2017 because of algae blooms, people were advised to not fish or do any water activity. (Brown, 2022)

CHEMICAL - Peck Iron and Metal Superfund Site - Twice a day, when the tide comes in, the water of Paradise Creek rises over one of the worst toxic waste dumps in America and all the industrial toxins, metals, and radioactive materials get washed downstream into the community. This includes cadmium and radium, which are both radioactive in nature, and PCBs. This contamination can harm human health by causing PCBs accumulating in fat-rich tissues such as the liver, brain, and skin.

STRUCTURAL - Sea Level Rise and Flooding - The superfund site 'Peck Iron and Metal' is vulnerable to hurricanes, flooding, and sea level rise (Brown, 2022). Such flooding can transport toxins the Superfund site into the creek via surface water migration pathways. Such toxins can include cobalt, which causes asthma, and chromium, which is cancer-causing. When floods occur, these chemicals then seep into nearby communities, harming the local pop.

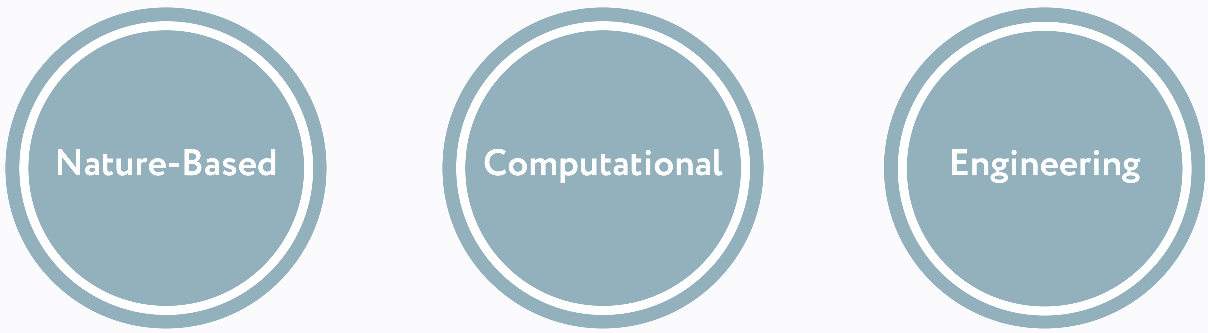
PROPOSED SOLUTIONS

H. R. 873 mentions by name 11 specific solutions that projects should prioritize to address water quality. They are:

- Mechanical Harvesting
- Aquatic Muck Dredging
- Living Shorelines
- Living Seawalls
- Cultivation of Aquatic Species, such as seaweed, seagrass, kelp, clams, oysters, and mussels.
- Artificial Intelligence
- Quantum Information Science (QIS)
- Distributed Ledger Technology (Blockchain)
- Robotics
- Nanotechnology
- Environmental DNA (eDNA)

For the purposes of this analysis, we further divided them in to Nature-Based, Computational and Engineering solutions.

THREE CATEGORIES OF SOLUTIONS



NATURE-BASED SOLUTIONS:

MECHANICAL HARVESTING AND AQUATIC MUCK DREDGING

Mechanical harvesting is the method of removing aquatic vegetation, such as weeds or algae, from water bodies using specialized machinery, to control the excessive growth of aquatic plants and maintain water clarity. It is considered a quick and effective way to remove nuisance macrophytes and improve recreational use and aesthetics in shallow lakes. Neglecting any lingering or residual damaging effects, it not only removes from the water the unwanted plants but also the nutrients that encourage their growth (Aquamarine, 2023). Furthermore, mechanical harvesting allows for immediate use of the water after harvesting and has no potential long-term consequences to the ecosystem. This method improves the use of recreational water, opens up navigation in waters overgrown with plants, and optimizes irrigation flow and water drainage. Additional prospects of this method include the opportunity for sport and commercial fishing, greater flood control, and preserving potable water supplies (Kuanfu Chen, 2022).

Aquatic muck dredging is the removal of accumulated sediment, organic matter, and debris from the bottom of water bodies. Sedimentation is the accumulation of sand, silt, and other types of debris at the bottom of a water body. Muck, also known as sapric organic material, is an organic soil material where all the organic material is decomposed, precluding identification of plant forms. Muck creates uninhabitable conditions for benthic flora and fauna, releases gasses such as methane and hydrogen sulfide, and induces far-reaching ancillary ecosystem impacts. (Mark V. Hoyer, 2017)

Muck dredging is a fast, efficient solution for resolving these problems. It includes grab dredging with a clam-shell bucket, dragline dredging, and suction dredging. The collected sediments are transported to distant land disposal sites (Solitude Lake Management, 2023). Once the collected sediments or slurry is pumped into a settling basin, it is allowed to settle and the water can be pumped to an aquatic system, if it meets the water quality standards. For instance, muck dredging in Lake Trafford, Florida resulted in habitat improvements for fish (Florida Fish & Wildlife Conservation Commission, 2016).

LIVING SHORELINES AND LIVING SEAWALLS

Living shorelines provide a low-maintenance, cost-effective and eco-friendly solution to erosion control, wildlife habitat restoration, and coastal resilience. They are also referred to as nature-based, green, or soft shorelines (NOAA, 2023). A living shoreline is made of natural materials such as plants, sand, or rock, and is located along bays, rivers, and homes on the waterfront. It increases the natural appearance, improves water quality, stores carbon, replaces aging structures, and filters stormwater runoff and groundwater. The materials and maintenance of living shorelines cost less than hard shorelines, yet their installation fees are relatively higher (Center for Coastal Resources Management, 2023).

Living seawalls are structures that incorporate natural elements along with bioengineered structural components. It is designed to stabilize shorelines, mitigate erosion, and provide habitat for marine organisms while protecting against wave energy and coastal erosion (Truline, 2023). They typically consist of a combination of concrete or steel panels, and ecological features, including native coastal plant species like salt marsh grasses, mangroves, or oysters. These organisms in turn, contribute to biodiversity and the overall health of coastal ecosystems. (National Park Service U.S. Department of the Interior , 2021) A living seawall provides important information on the environmental benefits of adding surface area and mitigates research gaps (Fujio, 2019).

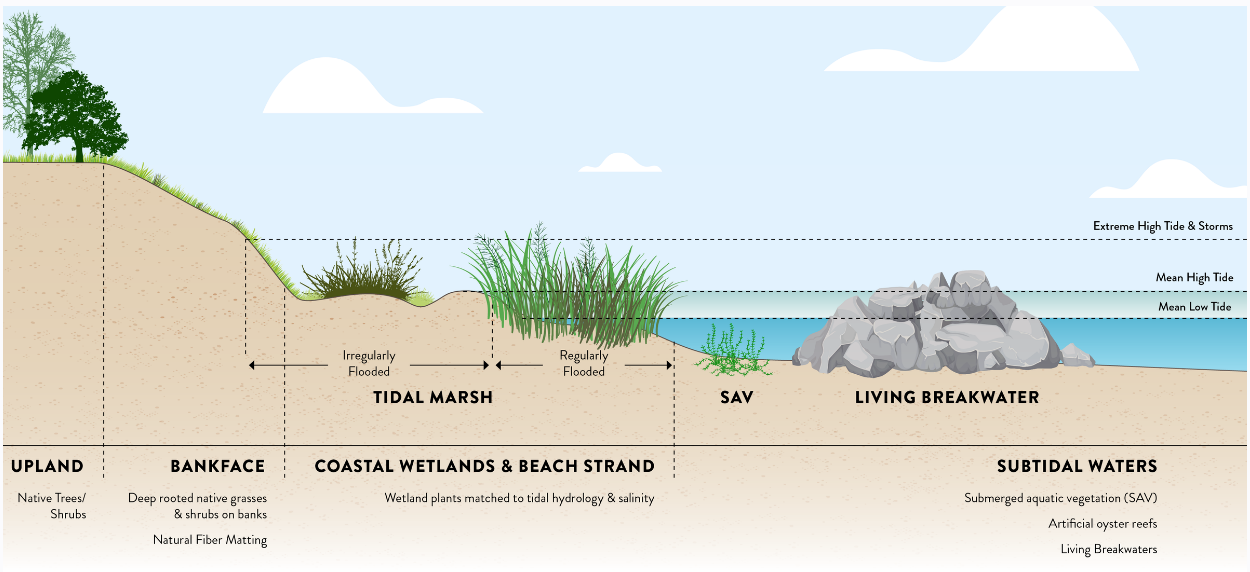


Image: An ideal living shoreline contains various natural components to increase coastal resiliency. Source: Texas General Land Office: Living Shorelines

Malibu Living Shoreline Project

The Malibu Living Shoreline Project (MLSP) aims to restore approximately three acres of sandy beach and dune habitat at Zuma Beach and Point Dume Beach. The living shoreline can stabilize the coastline and provide natural habitats for shorebirds and plants. Moreover, the project helps solve the sea level rise problem. Specialized plants that are naturally adapted to the beach will grow and trap sand that is transported by the wind and pushed ashore by waves. As vegetation grows, so will the dunes. Dunes can provide a natural defense against sea level rise and coastal storms. Native plants can also slow down the water flow, thus trapping sediments and nutrients and purifying the water. One year after the implementation of this project, a total of 28 avian species were observed within or adjacent to the restoration area. Restoration activities were performed in a 3.26-acre area, removed invasive vegetation, allowed growth of native vegetation and formation of sand hummocks along fence lines and in other areas of the site (Malibu Living Shoreline Project).

Image: Dune plantation as a Living Shoreline method at Zuma Beach and Point Dume Beach. Source: The Bay Foundation

Cultivation of Aquatic Species

The cultivation of aquatic species, including seaweed, seagrass, kelp, clams, oysters, and mussels, plays a crucial role in the absorption and filtration of excess nutrients and pollutants, thereby increasing the resilience of aquatic ecosystems and mitigating eutrophication. These species have unique characteristics that enable them to perform these functions effectively.For instance, seaweed cultivation can significantly decrease nitrogen and phosphorus levels, leading to improved water quality (Amir Neori, 2004). Similarly, seagrasses, such as Posidonia oceanica, have root systems that stabilize sediments leading to carbon sequestration and a positive impact on water clarity. Therefore, their cultivation not only increases the overall resilience of the coastal ecosystems but also offers valuable ecosystem services (Duarte, 2010).

For instance, Oysters provide water quality benefits and involve ecological processes for removal of nitrogen removal .Oysters can filter large quantities of water by filtering out sediments, algae particles and other suspended particles, resulting in cleaner waters.(Image below: process - a) Oysters can capture nitrogen from the algae and store the nutrient within it's shell (Image below: process - b). This process is referred to as assimilation and nitrogen once captured will be store in oysters until it dies and decomposes. Oysters act as nitrogen sinks and the process of harvesting oysters for nitrogen

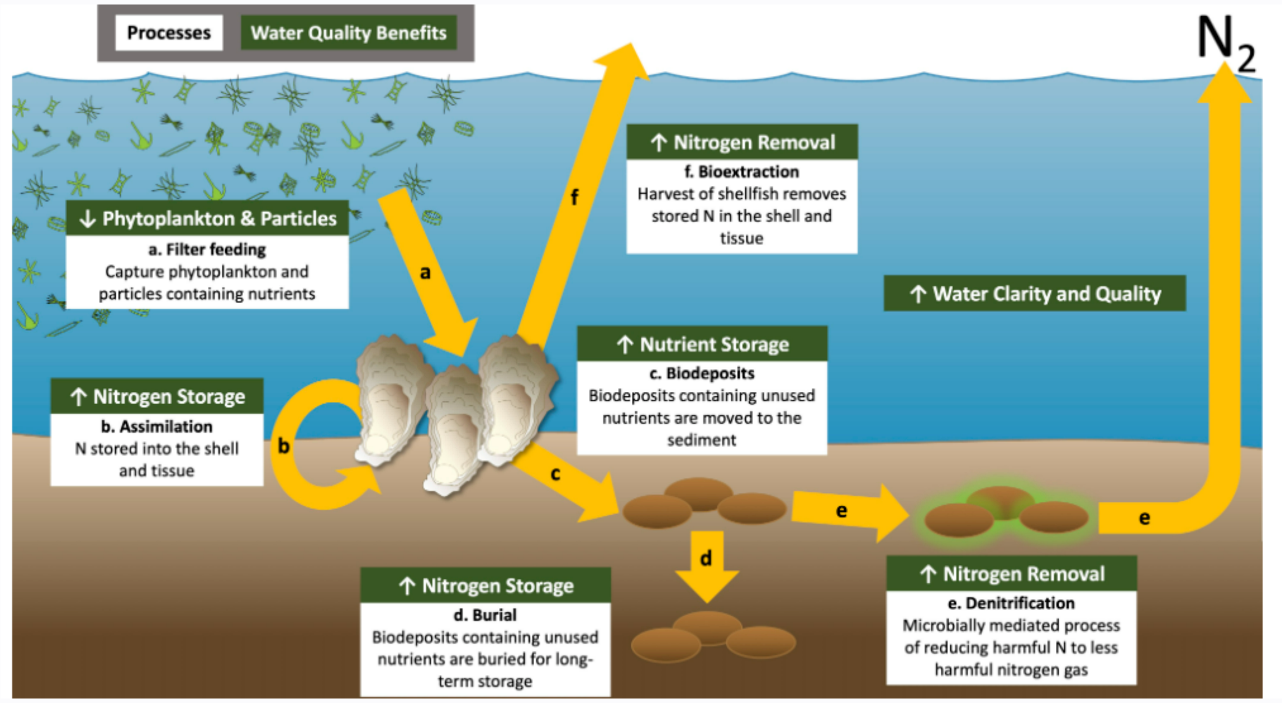


Image: Process of how oysters improve water clarity and nitrogen removal and their associated benefits
Source: University of Florida

removal is referred to as bio-extraction (Image above process - c). Oysters excretions generally contain nitrogen deposits. As they are heavy in size, these deposits tend to settle down next to oysters (Image above process - d). These deposits may get buried in sediments over time and thus act as nitrogen sinks. Deposits that settle on the surface often go through denitrification, which is a process to remove bioavailable nitrogen from the environment (Image above process - e).

COMPUTATIONAL

ARTIFICIAL INTELLIGENCE

Artificial Intelligence machines are designed to analyze and interpret data, learn from experience, make decisions, and solve problems in a way that mimics human cognitive abilities. Machine learning algorithms can greatly assist with water quality monitoring and prediction. AI and quantum information science are often used in tandem with one another to identify pollutants, bacteria, and harmful substances in water, while simultaneously assisting with water quality monitoring (Microsoft AI , 2023). AI has been harnessed in the development of a neural network capable of both detection and removal of dangerous bacteria, plastics, and other particles in water. While AI's applications are multiple, its implementation must account for the high capital investment at the beginning of its use and development. Additional barriers include the need for experts to maintain this technology. However, AI's ability to automate seemingly complex tasks is unequivocally useful and is easily scalable across water management systems (Richards, 2023).

The image below illustrates the working of artificial intelligence systems. These systems are provided with large datasets to learn patterns, AI technology has different sub-models- deep learning, predictive analytics, and cognitive computing- under machine learning to analyze patterns from the input data. Deep learning is a specific type of machine learning model that mimics biological neural networks in human brains to process information, identify patterns and use reasoning. Predictive analytics artificial intelligence systems are also Another model is cognitive learning, which can be used to analyze texts, images and speeches just like a human mind. Predictions within an artificial intelligence system are done by neural networks which are an integrated part of machine learning models. On the basis of data accessed and analyzed using machine learning models, the AI system can generate relevant data. The Clean Water AI case study illustrates how artificial intelligence systems are used in monitoring water quality. (CSU Global, 2021)

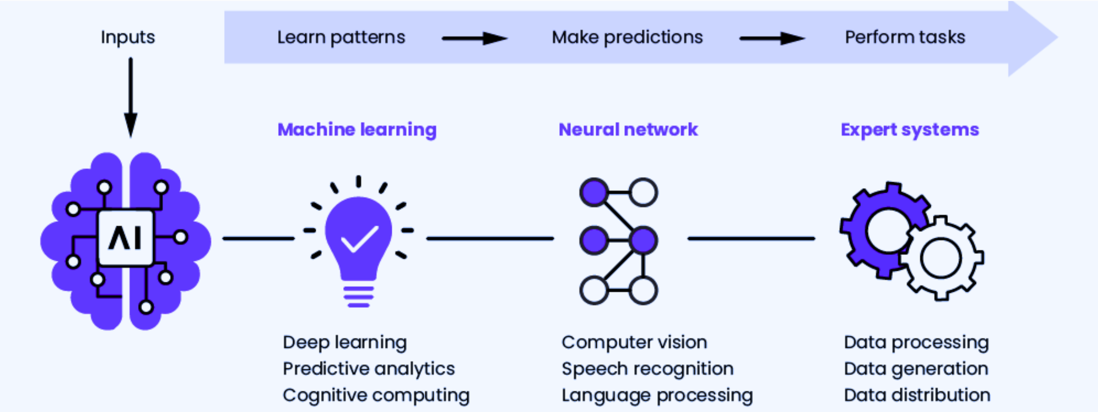


Image: Working Process of Artificial Intelligence systems
Source: Weka.io

Clean Water AI

Clean Water AI uses artificial intelligent models to detect contamination of water resources. The models are trained using a combination of deep learning and neural networks, which are used for image processing. With a combination of Internet of Things sensors placed at various locations in water resources, cities can monitor real-time data of water quality. The current model of Clean Water AI has been trained using a microscope and is able to detect species of bacteria in contaminated water resources. Clean Water AI has already built a prototype with a cost under $500. (Clean Water AI for drinking water safety)

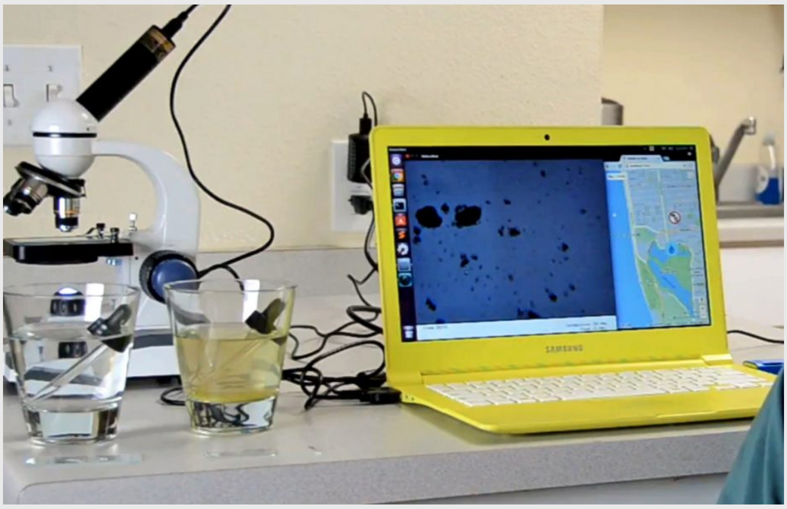


Image: Laboratory set-up of Clean Water AI
Source: Microsoft: Clean Water AI

QUANTUM INFORMATION SCIENCE

Quantum Information Science (QIS) revolutionizes water quality management using quantum computing and qubits for storage. QIS enhances analysis, improving water quality monitoring, resource management, and operational efficiency in treatment. Quantum machine learning predicts and detects issues accurately, processing complex datasets through qubits for early identification of contaminants (Lloyd S., 2014). It further optimizes the water cycle within watersheds, considering climate change and feedback loops. Quantum algorithms model intricate water system interactions, enhancing understanding of factors affecting water quality. This insight aids effective management, optimizing treatment processes, and resource allocation in water treatment processes (Giani, 2022).

DISTRIBUTED LEDGER TECHNOLOGY

Distributed Ledger Technology (DLT), otherwise known as blockchain technology, enables decentralized and secure record-keeping and transaction management. Water system management is used to track, manage, store, and share data across all agents within the network, without relying on a central authority (Wenjun Xia, 2022). Its efficiency and transparency of real-time data increase the response time for pollutant incidents and the detection of early pollution within the water bodies (Abu-Amara, 2022). However, the impacts of employing smart water systems go beyond the efficient management of water bodies. Its innovative, efficient, and scalable nature is found to improve the overall infrastructure of sustainable water systems. Nations can utilize this technology to store smart contracts, which are self-executing contracts with predefined rules encoded into the ledger, to automate various water-related processes and transactions, such as water trading, payments, and compliance (Kaushik, 2023).

ENGINEERING

ROBOTICS

Water-related robotic technology is designed to detect, measure and remove pollutants, plastics and harmful substances from water bodies. Robots are often used to inspect for leaks, blockages, or structural damage, reducing the risk of pollution incidents. Furthermore, robotics, such as sample collectors, mitigate the exposure of water experts and scientists to hazardous water bodies. This innovative remote monitoring, inspection efficiency, easy maintenance, and enhanced mapping capabilities has been proven to decrease the response times to water-related challenges (The Ocean Cleanup, 2023). These applications contribute to better water resource management, early detection of issues, and the preservation of water quality and ecosystems. Although the initial investment is considered relatively high, this technology reduces long-term costs and is scalable across diverse water (Stevens, 2011). For instance, robotic fish mimicry provides an innovative approach to water quality monitoring, utilizing bio-inspired design principles. These robotic fish can navigate complex environments, measure water parameters, and collect data without disturbing the aquatic ecosystem. (Kai, 2020).

NANOTECHNOLOGY

Nanotechnology is the manipulation and control of materials and structures at the nanoscale, typically in the range of 1 to 100 nanometers. Within water solutions, nanotechnology can improve water purification methods. It provides efficient and effective removal of physical, biological and chemical contaminants through nanomaterials, like nanoparticles, nanofibers, and nanocomposites that are engineered to have unique properties for adsorption, filtration, and catalytic reactions. These nanomaterials are designed to remove heavy metals, adsorption, filtration, and catalytic reactions (Ankit Nagae, 2020). These nanomaterials are designed to remove heavy metals, adsorb specific pollutants, and filter out impurities, bacteria, and viruses (NNI, 2023). It allows early bacterial detection and immediate feedback for water plant operators, thus reducing energy usage, and treatment expenses, while increasing their safety and environmental impacts (Keerti Jain, 2021).

Nanobots

Passive nanomaterials can be directed to move in particular directions and perform certain actions. Utilizing this behavior of nanomaterials of propulsion, multifunctionality, adaptation to environments, collective behavior, and communication, nanomaterials can function as robots. Nanobots are designed using nano-particles by introducing: propulsion, ability to move in a direction by consumption of a chemical fuel or under any external field; multifunctionality, the ability to perform certain tasks; Taxis, ability to respond to change in environmental stimuli; collective behavior, robots can form a chain to perform a specific task together; communication, nanobot, operate and exchange information with other robots (Urso et al., 2023).

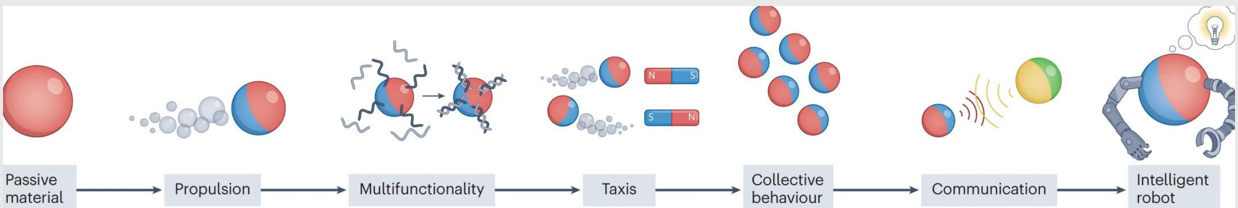


Image: Transition of a nanoparticle to an intelligent robot
Source: Smart micro- and nanorobots for water purification

These nanobots are used as a water remediation strategy. Under magnetism, AuTiO2 particles can function as nanomotors and adsorb microplastics on its surface. In a lab scale experiment. In the lab scale experiment, it was observed that nanobots are able to attract 67% of microplastics present in a solution (Wang et al.,2019).

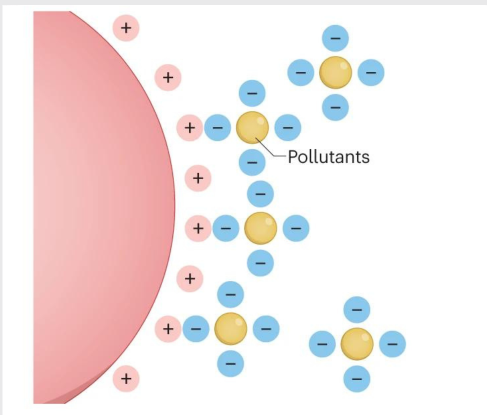


Image: Adsorption of pollutants on surface of nano-bots
Source: Smart micro- and nanorobots for water purification

ENVIRONMENTAL DNA (E-DNA)

Environmental DNA, commonly called eDNA, is DNA originating from the biological material emitted by organisms into their surrounding environment. eDNA can come from many sources, including excrement, carcasses, and even hair. It can consist of either mitochondrial or nuclear DNA (Miklos Balint, 2014). eDNA is particularly relevant in that it allows researchers to determine species distribution and spread in a rapid, and cost-effective way (Adam S. Smart, 2016). Since eDNA is detectable at such low levels, it is capable of finding species with small populations that are difficult to detect with traditional methods (such as snorkeling). Scientists have conducted experiments using this method in three ponds in the Czech Republic (Blabolil , 2022), demonstrating its effectiveness in detecting water quality and biodiversity.

Because of its efficacy and ease of use, eDNA has many benefits. Some of these include the early detection of invasive species, the improvement of biodiversity assessments, and the detection of rare or endangered species. When compared to traditional methods, eDNA was found to be more effective and more sensitive in detecting species than traditional survey methods. Furthermore, eDNA is cheaper in high-diversity regions and thus considered to be relatively cost-effective compared to traditional methods in large-scale biodiversity surveys of high-diversity areas. However, the cost-effectiveness of this method requires further case-by-case evaluation, as in many circumstances eDNA sampling is found expensive than is found expensive than traditional methods (Julija Fediajevaite, 2021).

CONTROVERSIES BEHIND THE PROPOSED SOLUTIONS

While innovative solutions to water quality issues may sound appealing, the solutions themselves are not perfect. While emerging technologies in general can be subject to controversies, there are also specific issues surrounding the use of artificial intelligence, nanotechnology, and aquatic muck dredging in water.

Artificial intelligence has associated controversies with biased data, as its decision-making processes are based off of an often skewed set of training data, which is generally based off of a small set of pollutants not necessarily representative of a larger water body. Nanotechnology can also pollute the water it aims to clean by breaking down, and finally aquatic muck dredging has been associated with both mechanical and biological issues, ranging from risks surrounding the introduction of bacteria into a water body to risks surrounding the release of toxic contaminants from mechanical dredging. Each of these controversies must be investigated and addressed as the feasibility of the bill is discussed. We explore some of the controversies in detail in the next sections:

CONTROVERSIES SURROUNDING ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) presents an innovative solution to water quality issues by offering a mechanism to monitor and assess water quality, but it isn't free of associated scientific issues and controversies. Some critics of using AI for water quality note that it does not differ greatly from existing water quality monitoring protocol; instead, it simply automates aspects of this protocol. The prospect of Artificial Intelligence running an entire water system may seem ideal, but controversies surrounding how to create "responsible AI" and eliminate bias among Machine Learning (ML) systems remain rampant. It is not yet clear if AI is always better than humans. While automation may appear optimal, cost/ benefit analyses should be performed to truly evaluate the optimal monitoring strategies (Richards et. al., 2023).

One of the concerns with Artificial Intelligence is training data bias. Machine Learning (ML) algorithms function by learning off of a set of data – if that training data is flawed or presents certain chemical biases, AI designed to clean water could effectively distribute fouled water. Issues with biased training data have yet to be solved. Researchers have attempted to determine whether ML algorithms are capable of overcoming bias. Their main findings suggest that a diversity of training data can help ML algorithms eliminate bias – but sourcing a diverse array of data can be difficult, which is why it is not yet clear whether AI is always better than humans (Zewe, A., 2022).

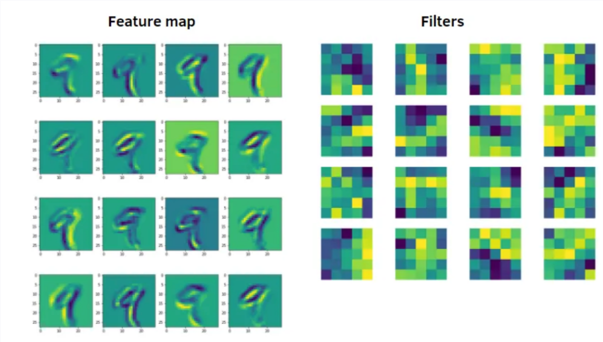


Image: medium.com, illustrated. by Eugenia Anello

Some AI algorithms also use a Convoluted Neural Network, otherwise known as a CNN, to make determinations about visual data. However, issues can arise with the CNN protocol, as it makes determinations about visual data by comparing pixels; two objects with similar pixel parameters thus may be easily confused (Eugenia, A. (2022). A visualization of the CNN technique can be seen above.

In the image above, pixel interpretations of the image are created - similarities between the pixel maps of different images are striking.

Expanded AI may increase the power intensity of data centers, and thereby water usage to cool those centers. While there may be benefits for water, costs for the environment due to emissions generated from powering data centers also exist. These emissions may end up negatively impacting anthropogenic climate change. Like any new technology, users of AI to resolve water quality issues must avoid the progress trap which can arise with the advent of new technological solutions. These solutions may create new problems that technology is not yet advanced enough to solve (Ibid).

CONTROVERSIES SURROUNDING THE USE OF NANOTECHNOLOGY

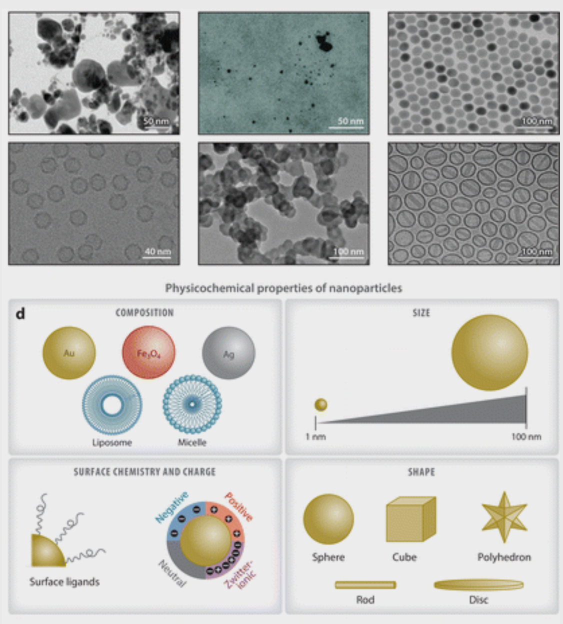
Nanotechnology may be a promising solution to some water quality issues, but it can also act as a pollutant. Nanotechnology can be used to purify water bodies; its uses thus far have included the collection of micro-plastics, as well as the separation and collection of chemicals and microbes from water.

Using nanotechnology to improve water quality is not without its controversies. Little consideration has been given to end-of-life retrieval with nanotechnology, but this issue is of utmost importance when introducing a new technology to any environment (Fajardo et al., 2022). Nanotechnology is made from nanoparticles that often break down in water, further exacerbating the difficulty of end-of-life retrieval. Furthermore, those nanoparticles can sometimes be toxic to aquatic organisms.

EXAMPLE OF NANOPARTICLE TOXICITY

One example of nanoparticle toxicity can be illustrated with two different kinds of nanoparticles: nanosilver and titanium dioxide. Researchers at the University of Arizona noted the potentially toxic impacts of nano-silver. Nano-silver may become toxic if it finds its way into wastewater, as it may kill the beneficial bacteria used to treat the wastewater. Nano-silver may also have potentially negative effects on zebrafish, a common aquatic organism (Asharani et. al., 2008). Titanium dioxide has also been associated with potentially negative impacts on aquatic organisms.

Additionally, biomagnification occurs as these particles travel up trophic levels (Ajith et al., 2021). Size, shape, and images of nanoparticles can be seen in the figure below. The figure demonstrates the size, of around 100 nanometers, of a nanoparticle. Nanotechnology has a long life cycle thus increasing the probability of consumption by marine life. Furthermore, several studies show that certain nanotechnology particles are likely toxic to humans (Fajardo et al., 2022).



Nanoparticles can be broadly organized into three different classes: (a) natural, (b) incidental, or (c) engineered nanoparticles. Nanoparticles from all of these classes can be made from inorganic or organic materials. Nanoparticles from nanotechnology can enter aquatic ecosystems and are easily absorbed by aquatic organisms. Some nanoparticles, like Ag visualized above, can be toxic in aquatic ecosystems. (source: Yang et. al., 2021)

CONTROVERSIES SURROUNDING THE USE OF AQUATIC MUCK DREDGING

Aquatic muck dredging (AMD) is another solution to water quality issues, where 'muck' is removed from the bottom of a pond or other water body, and transported to another location to be processed. AMD has both a mechanical and biological component; mechanical muck dredging involves the physical removal of muck from the bottom of a water body, while biological dredging uses bacteria to remove unwanted nutrients from the water. A case study in Vancouver Island, Canada, which demonstrates the risks and issues with mechanical aquatic muck dredging, can be seen below.

Controversies surrounding AMD use include issues associated with its lack of selective filtering—this can lead to ecosystem destruction, as keystone species may be removed during dredging. These are exactly the impacts that struck Alberni Inlet, seen below, when aquatic muck dredging was implemented. Another risk with AMD is that it may inadvertently release toxic substances or solids. Additionally, unwanted toxins may be released during the dredging process. Biologic dredging also introduces the potential of byproducts from microbial decomposition, and uncertainties surrounding potential microbial impact. In order to measure the success of the program, potential controversies and issues should be considered.

CASE STUDY: ALBERNI INLET, VANCOUVER ISLAND, CANADA


Image: vancouverisland.com

One study on Alberni Inlet in Vancouver Island, Canada, found that "aquatic muck dredging catalyzed the release of volatile solids and hydrogen sulfide that were trapped in the sediment - these were lethal to many organisms" (Snyder, 1976). In this case, a history of logging near an estuary had caused large scale cedar deposits on the bottom of the estuary. The dredging project aimed at remediating the water body instead caused massive fish kills of stickleback and shiner fish, and had catastrophic ecosystem effects. Ultimately, considerations for the consequences of dredging should be considered before implementing this solution to water quality.

MEASURING SUCCESS

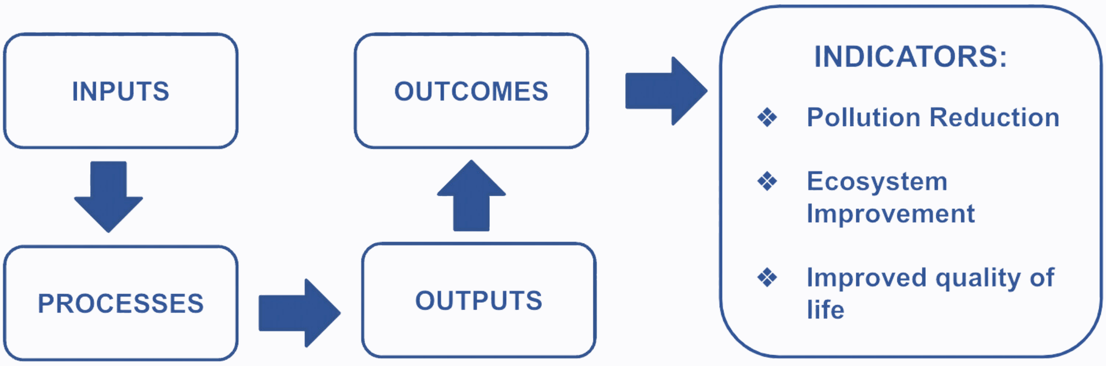


Image: Process chart of arriving to metrics/indicators for assessment and measurement of success.

In the context of the Act, the goal is to leverage emerging technologies for effective water quality improvement and sustainable practices. To measure the program's success, metrics play a pivotal role in guiding progress by quantifying the impact of innovative solutions and ensuring its alignment with the Act's objectives. This process follows the Input-Process-Output-Outcome framework. Inputs involve deploying innovative technologies and strategies, while the process involves their application, data collection, and analysis. This leads to specific outputs, such as precise pollutant data and enhanced fish habitats, driving the desired outcomes of 1) pollution reduction, 2) ecosystem improvement, and 3) practices focusing on improving quality of life. These indicators enable us to empirically evaluate the effectiveness of our solutions and their long-term impact.

By employing effective measurement techniques, we can assess the real progress and effectiveness of the eleven technologies examined. This promotes accountability, informs decision-making, and consistently enhances our approach to enhancing water quality.

Success Indicator 1: Pollution Reduction

Metrics to Measure Success:
The following four metrics can be used when measuring pollution reduction through implemented solutions:

1. Percentage reduction of key pollutants in targeted water bodies (e.g., nitrogen, phosphorus, heavy metals).
2. Improvement in water clarity and transparency, measured by turbidity levels.
3. Restoration and preservation of sensitive aquatic habitats, such as wetlands and coral reefs.
4. Reduction in the frequency and severity of harmful algal blooms and other pollution-induced ecological disruptions.

This can be further explained through the case study of the Yorkshire Combined Sewer Overflow (CSO) outlined below.

YORKSHIRE CSO PROJECT

In the pursuit of pollution reduction, the Yorkshire Combined Sewer Overflow (CSO) project underscores the potency of innovative technologies in achieving pollution reduction goals. During heavy rainfall or snowmelt, untreated water can discharge into waterways through CSOs, potentially causing pollution. To mitigate this, scientists have harnessed Artificial Intelligence (AI) and the Internet of Things (IoT) to proactively detect and remove blockages, averting overspills. To delve into specifics, the metrics encompass an array of technological interventions. Over 2,000 sensors are strategically placed across 55,000 km of sewers on CSOs (Yorkshire Partnership, n.d.). In this ongoing five-year endeavor (2020-2025), the anticipated outcome is a remarkable 50% reduction in pollution accidents. Rigorous analysis of an extensive 21,300 days' worth of data, covering 70 site pilots, substantiates the efficacy of the AI system. It identifies 88% of confirmed issues, showcasing 3-4 times greater effectiveness than existing methods. Furthermore, the achievement of a mere 3% false alarm rate, half of the current system's rate, attests to the enhanced efficiency of issue detection (Yorkshire Partnership, n.d.). The integration of AI, IoT, and real-time data analysis showcases a promising framework for proactive pollution management, resulting in cleaner water bodies and healthier aquatic ecosystems.

Success Indicator 2: Ecosystem Improvement

Metrics to Measure Success:
The following four metrics can be used when measuring ecosystem improvement through implemented solutions:

1. Increase in the abundance and diversity of fish populations, especially in vulnerable and endangered species.
2. Improvement in fish health, evidenced by reduced incidence of diseases and abnormalities.
3. Enhancement of fish habitat, gauged by the restoration and protection of critical habitats.
4. Tracking fish migration patterns to ensure successful spawning and breeding activities.

The pursuit of ecosystem improvement exemplifies the application of emerging technologies, as demonstrated by a case study in North Carolina involving transplanted oyster beds explained further.

TRANSPLANTED OYSTER BED IN NORTH CAROLINA

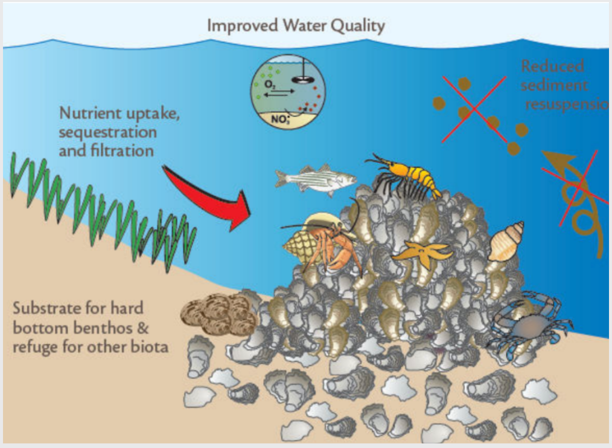


Image: Filtering particulate matter & nutrients by oysters as an example of ecosystem improvement
Source: (Ozbay, Reckenbeil, Marenghi, & Erbland, 2014)

This approach harnesses the intrinsic capabilities of oysters to enhance water quality by efficiently filtering particulate organic and inorganic matter, as well as nutrients, from the water column.

Furthermore, oyster reefs create hydrodynamic alterations that amplify the removal of particulate matter from aquatic environments (Nelson et al., 2004).

In the context of this case study, meticulous examination encompassed a ten-month data collection period. Key parameters, including Total Suspended Solids (TSS), were systematically measured both upstream and downstream of newly established oyster reefs, along with a control channel devoid of such interventions (Nelson et al., 2004). The findings underscore a notable reduction in downstream TSS concentrations at both the upland and lower creek sites, particularly evident within the initial months following reef establishment. This observation emphasizes the vital role of modest oyster reefs in significantly enhancing water quality, fostering improved habitat conditions, balanced nutrient levels, and decreased pollutant loads. Consequently, the ecosystem gains robustness and vitality, directly contributing to the augmentation of fish populations and species diversity.

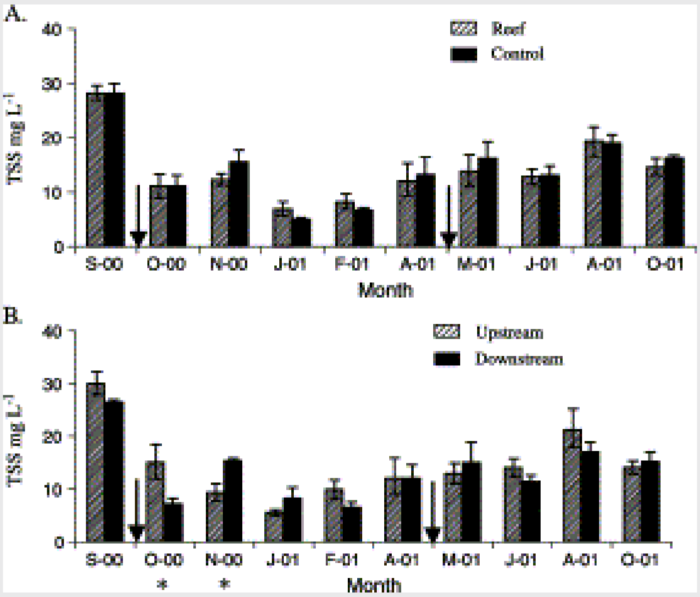


Image (on left): Mean TSS concentrations in the reef and control channels & upstream and downstream of reef placement at the upland site. Source: (Ozbay, Reckenbeil, Marenghi, & Erbland, 2014)

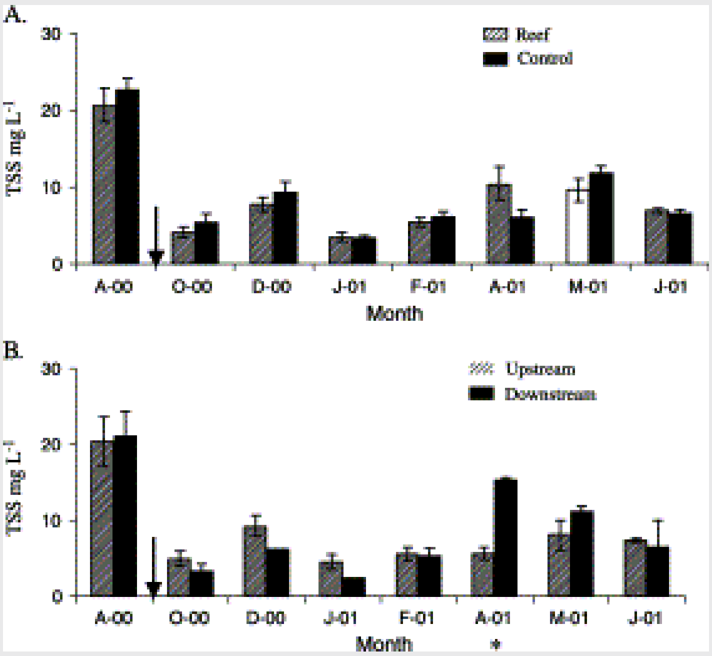


Image (on right): Mean TSS concentrations in the reef and control channels (A) & upstream and downstream of reef placement (B) at the lower creek site.
Source: (Ozbay, Reckenbeil, Marenghi, & Erbland, 2014)

Success Indicator 3: Practices focused on improving quality of life

Metrics to Measure Success:

The following three metrics can be used when measuring improvement in human health and quality of life through implemented solutions:

1. Assessment of clean water accessibility and affordability, especially in underserved and marginalized communities.
2. Monitoring and evaluation of health risks and harms over a longer period of time, including any decline in the risks
3. Verification of data transparency and accountability in resource allocation and benefits distribution among communities where health and quality of lif is most impacted by water quality.

Efforts toward improving human health must encompass not only technological innovation but also a commitment to equity and inclusion - catering to vulnerable populations who are at the most risk. To effectively measure this, a multi-faceted should be devised.

CONCLUSION

This analysis of H.R. 873, the Water Quality and Innovation Act, underscores the critical importance of addressing the multifaceted threats posed to water quality and the innovative technological avenues available to mitigate these challenges. An array of threats to water quality in the US, ranging from pollution and algal blooms to diminishing freshwater sources, endanger the ecological balance and human health.

H.R. 873 brings a new approach to improving water quality instead of using existing tools already developed by the EPA. Its provisions reflect an awareness of the urgent need to modernize water infrastructure, enhance pollution control measures, and promote sustainable water management practices.

By incorporating metrics, prioritizing robust research and development of emerging technologies, fostering collaborative partnerships, raising public awareness, and implementing continuous monitoring, we can effectively track progress, optimize water quality improvement efforts, and achieve the Act's goals of ensuring clean water resources for all. In sum, H.R. 873 could be a pivotal step toward safeguarding our water resources for current and future generations.

Image: Farmland and waterways in the Sacramento-San Joaquin Delta.
Source: CA Department of Water Resources

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