IEEE SA STANDARDS ASSOCIATION

IEEE planet positive 2030

Strong Sustainability by Design

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

RIVERS AND LAKES

An initiative supported by the IEEE Standards Association

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Strong Sustainability by Design

This Compendium has been created by committees of the IEEE Planet Positive 2030 Initiative supported by the IEEE Standards Association (IEEE SA). The IEEE Planet Positive 2030 Initiative community is composed of several hundred participants from six continents, who are thought leaders from academia, industry, civil society, policy and government in the related technical and humanistic disciplines. At least one hundred seventy members of this community from about thirty countries have contributed directly to this Compendium and have worked to identify and find consensus on timely issues.

The Compendium's purpose is to identify specific issues and recommendations regarding sustainability and climate change challenges to achieve "Planet Positivity" by 2030, defined as the process of transforming society and infrastructure by 2030 to:

- Reduce Greenhouse Gas (GHG) emissions to 50% of 2005 GHG emissions by 2030.
- Significantly increase regeneration and resilience of the Earth's ecosystems.
- Be well on the path to achieving net zero GHG emissions by 2050 and negative GHG emissions beyond 2050.
- Continue to widely deploy appropriate technology as well as design and implement new technological solutions in support of achieving technological solutions designed and deployed to achieve "Planet Positivity."

In identifying specific issues and pragmatic recommendations, the Compendium:

- Provides a scenario-based challenge (how to achieve "Planet Positivity by 2030") as a tool to inspire readers to get engaged.
- Advances a public discussion about how to build from a "Net Zero" mentality to a "Net or Planet Positive" ("do more good," that is, doing "more" than "don't harm") societal mandate for all technology and policy.
- Continues to build a diverse and inclusive community for the IEEE Planet Positive 2030 Initiative, prioritizing the voices of indigenous and marginalized members whose insights are acutely needed to help make technology and other solutions more valuable for all. Of keen interest is how to encourage more in-depth participatory design in these processes.
- Inspires the creation of technical solutions that can be developed into technical recommendations (for example IEEE SA recommended practice for addressing sustainability, environmental stewardship and climate change challenges in professional practice, IEEE P7800™) and associated certification programs.
- Facilitates the emergence of policies and recommendations that could potentially be intraoperative between different jurisdictions (e.g., countries).

By inviting the general public to read and utilize *Strong Sustainability by Design*, the IEEE Planet Positive 2030 community provides the opportunity to bring multiple voices from the related scientific and engineering communities together with the general public to identify and find broad consensus on technology to address pressing environmental and social issues and proposed recommendations regarding development, implementations and deployment of these technologies. You are invited to Join related IEEE activities, such as standards development and initiatives across the organization.

- For further information, learn more at the IEEE Planet Positive 2030 Initiative website
- Get in touch at: PlanetPositive2030@ieee.org to get connected to and engaged with the IEEE Planet Positive 2030 community.
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Strong Sustainability by Design was created in two versions ("draft" and this current edition) that were iterated over the course of two years. The IEEE Planet Positive 2030 Initiative follows a specific consensus building process where members contributing content identify specific potential issues and proposed recommendations.

Membership

IEEE Planet Positive 2030, an initiative supported by the IEEE Standards Association as part of the Industry Connections Program, Sustainable Infrastructures and Community Development program (SICDP), currently has more than four hundred experts involved, and remains eager for new voices and perspectives to join in this work.

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RIVERS AND LAKES

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RIVERS AND LAKES

Future Vision

It is 2030.

Key technology developments, policy implementations, and perhaps most difficult of all, the focus of humans have together resulted in the regeneration of the ecosystems of the world's rivers and lakes. Inspired to address the many problems brought about by an exploding population engaged in unsustainable environmental practices, people chose to come together. They chose to imagine what was possible, and as a result, achieved the victories in these areas that all experience today.

Access to clean potable water has been democratized across cultural and economic divides. Water-use rights and access to water have expanded even as water waste has dramatically dropped.

The world's commercial agriculture businesses have diversified. Crops include more regionally appropriate "less thirsty" crops, decreasing the demand for agricultural irrigation, as well as diminishing the runoff from pesticides, fertilizers, and other nutrient pollutants into neighboring rivers and lakes. The need for flow diversion via dams and other artificial means has also decreased. In response, freshwater ecosystems have rebounded with an increasing number of healthy plant and animal species.

Pollution from Earth's manufacturing facilities and urban infrastructure is significantly reduced. New technologies, bolstered by educational and media efforts, have addressed physical, chemical, and biological pollutants at their source, bringing back a biological diversity not seen in generations. The world's urban areas have made significant progress in integrating natural ecosystems into their urban developments. Parks, woodlands, rivers, and lakes have an expanded natural presence within their boundaries, helping to reduce the effects of climate change.

Human influences on water's temperature and flow direction affected the natural water and land interaction in the past, disrupting its chemical makeup, affecting the diversity of flora and fauna, of which, and this is the ironic and salient point, humans are included. Many humans viewed themselves as occupants, settlers, even conquerors of this planet, using its resources to fulfill their needs and desires. This attitude shifted when more of Earth's people recognized that all are indigenous planet Earth members, reliant on its rich diversity of species to survive. They began to realize that as much as species depend on a healthy habitat for their survival, habitats rely on each other too. And as people knew the importance of their cardiovascular health, they also began to recognize the sacred importance of Earth's lungs and heart and made better efforts to understand it for their own good. People all around the world recognized they needed to become a responsible species.

This shift was inspired by science and the realization that the Earth's "wetlands store about five times more CO_2 than forests and as much as 500 times more than oceans" (Duke University, 2022). The shift represented a significant turning point for humans as they began to consider nature as something to care for (rather than to dominate). Before this, over centuries, humans drained wetlands, treating them as obstructions or undesirable swamps and attempting to claim as much inhabitable land as possible for agriculture and settlement purposes. Renowned novelist and journalist, Annie Proulx elegantly reflected on this with respect to the early settlement of North America:

> *The original occupants of the continent knew the rivers and swamps, the bogs and lakes, as they knew the terrain and one another. But for most English settlers and European newcomers' nature consisted of passive and inanimate substances and situations waiting*

> *to be used to human advantage.* ***Preservation and care of nature were not what they had come for***. (Proulx, 2022)

Regarding the North American continent, for example, over the decades in the short history of its settlement by non-Indigenous people, according to the U.S. Environmental Protection Agency (EPA), there were approximately 220 million acres of wetlands in the area comprising the continental United States in the 1600s, and by 2009, roughly half of that was gone (U.S. EPA, "Wetlands;" Dahl & Allord, 1997). This is not isolated to the North American continent. A United Nations (UN) report cited a source revealing even more stunning data: Worldwide "some 85 percent of wetlands present in 1700, were lost by 2000, many drained to make way for development, farming or other 'productive' uses." While evidence suggests the rate of losing wetlands is slowing, we lost 1% of the world's wetlands by 2023; however, "the good news is, people now know how to restore these wetlands at a scale that was never before possible and in a way that both stops the release of carbon dioxide and re-establishes the wetland's carbon dioxide storing capacity" Dahl & Allord, 1997; Duke University, 2022; NSW Government, 2019).

It was with this knowledge, and in the spirit of pioneer conservationist Rachel Carson, that collectively, Earth's riverbanks and lakes now enjoy regeneration.

Today, in 2030, our water planet predictably spins on its axis propelling winds in opposite directions above and below its equator, driving surface and deep ocean currents affecting temperature changes across this azure and tawny sphere. Evaporation occurs. Clouds form. Storms develop. Rain falls. Watershed commences, and water's journey back to the sea begins. Like blood vessels, rivers and lakes work with the ocean and the atmosphere to pump water around the globe. It's the Earth's cardiovascular system: life imitating life (Baratto, 2020). Along its way, water runoff enlivens and enriches ecosystems on a mass scale beginning in the Lilliputian world of a phytotelmata, ending in an estuary that slow dances with its ocean partner to the tune of the tides. In between, millions of species of flora and fauna, including humans, now live symbiotically and sustainably with our planet, surviving and thriving in habitats naturally created in an amalgam of water and land, adapting to temperature and gravity forces compelling water along its way.

Introduction

Human population growth and its impacts on the Earth's river and lake ecosystems are considered. The scope, "Rivers and Lakes," references the Earth's freshwater systems, including rivers, streams, creeks, wetlands, and groundwater. The impacts of urbanization, commercial farming and manufacturing, resulting pollution types, and the overall impacts occasioned by climate change are explored.

Issue 1: Water access rights are becoming increasingly complex, especially with transboundary waters

Background

Waterways naturally and unforgivingly flow across geopolitical borders. Historically, around the globe, most species evolved near a reliable clean source of water. Times have changed such that water may no longer be reliable, and what water there is may be beyond the control of a given society or species. Typically, the upstream societies or human legal policy arrangements retain water access to the potentially disastrous detriment of all others. Where there is little water upstream, there may be none downstream, or where there may be plenty of water upstream, the controlling societies may use most of it to establish, sustain, and grow their economies that may be ruinous to downstream needs. Conversely, a controlling community may redirect an overflow of water to avert a local disaster only to convey the disaster to downstream communities.

Water access rights are centuries old. Colonization activities empowered governments to control access for whatever purpose they prioritized (Mwanza, 2018). Today, water access control, from a global perspective, ranges from full public access to government regulated to private access. Each of these approaches is nuanced; for example, private access may be further restricted by either riparian or prior appropriation access rights (NALC, "Water Law"). Then there is the consideration of groundwater versus surface water. It's complicated (NALC, "Water Law").

Humans control access to many clean water sources through legal arrangements impacting numerous species, not just humans.

The core challenge, then, is how do we equitably share fresh water, the lifeblood of this planet among all its inhabitants? This challenge is a policy one. The future of transboundary waters largely depends on the collective efforts and cooperation among countries sharing these water resources. Securing the future of transboundary waters requires a cooperative, inclusive, and long-term approach (Wouters, 2013). In 2010, the UN adopted resolution 64/292 recognizing the human right to water and sanitation, rallying the international community to action, especially in support of developing nations (UNDESA, "Water for Life"). As of 2020, one in four people on this globe still did not have access to safe drinking water (Ritchie & Roser, 2021).

Recommendations

1. **Build on the water usage knowledge of indigenous peoples and other societies.** Consult Indigenous peoples regarding their knowledge of water usage that may have been passed along, and societies that have taken steps to rectify and improve equitable water access for all. In addition, consider the guidance in the UN report, "The Human Rights to Water and Sanitation in Practice" (UNECE, 2019).
2. **Mission local organizations with championing clean water access and protection.** Such organizations should be contextually aware and aligned around key water regions. Organizations should be linked within and across nations to improve decision-making, goal-setting, and knowledge sharing.

3. **Practice international cooperation.** Strengthening collaboration and dialogue among countries sharing transboundary waters will be vital. This cooperation could involve the establishment or enhancement of international agreements, joint commissions, or other mechanisms for effective management and conflict resolution (UN 2023 Water Conference).
4. **Integrate water resources management.** Adopting integrated approaches to water resources management can help improve the equitable and sustainable use of transboundary waters. This approach involves considering the needs of various sectors, such as agriculture, industry, and ecosystems, while balancing social, economic, and environmental objectives (Wouters, 2013).
5. **Continue efforts to improve approaches to agriculture that make more efficient use of water while minimizing pollutants**. This effort is vital considering that agriculture uses globally 70% of freshwater (freshwater withdrawals) and contributes toward polluting the freshwater through nutrient pollution (UN FAO, 2011).
6. **Use modeling tools to aid in decision-making.** Explore the use of "serious gaming" modeling tools to help engage stakeholders in decision-making exercises (Wikipedia, "Serious Game;" Angarita et al., 2016).
7. **Explore the concept of location specific water standards**. Explore clean water standards targeted at, and appropriate for, specific communities, encompassing the native species of the region. Local context is important.
8. **Develop a water-forecasting process.** Devise a weather-forecasting approach that better evaluates water impact to aid communities/states in better forecasting long-term water availability and its capacity to support community viability as populations grow. For example, the use of satellite and thermal technology could evolve to aid "in both monitoring and measuring both surface and groundwater extractions, and consumptive use" (Wheeler, 2021).

Case studies

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

1. Serious Gaming as a Tool to Model and Communicate Considerations for Water Resource Management

   Serious games, such as "SimBasin,"[1] may hold promise in helping communities improve their approach to water management within given water basins. With SimBasin, "the engine allows to easily create a simulated multiplayer basin management game using WEAP water resources modeling software (SEI, 1992–2015), to facilitate the communication of the complex, long term and wide range relationships between hydrologic, climate, and human systems present in river basins, and enable dialogue between policy-makers and scientists" (Angarita et al., 2016). The game was used in Columbia, applicable to the Magdalena-Cauca River Basin (Craven et al., 2017). It was also tried in Thailand for the Upper Nan River Basin (Gunathilake, 2020).

[1] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

2. Water Scarcity and Agriculture

   The Food and Agriculture Organization (FAO) of the UN has engaged in a program titled, “Coping with Water Scarcity—the Role of Agriculture,” based on its framework for agriculture and food security (UN FAO, 2012). The program focused on Egypt, Jordan, and Lebanon. The FAO indicates their program is having success per a separate 2020 evaluation of the project in Lebanon:

   > *FAO projects made positive impacts on their beneficiaries, in terms of enhanced capacity, higher productivity and increased income. The impact was greater when the interventions addressed institutional, policy and cross-sectoral issues as in the case of forest management, statistics and vocational training projects.* (UN FAO, 2020)

Further resources

1. Guest Blogger for the Internationalist. “Navigating Rough Waters: The Limitations of International Watercourse Governance.” *The Internationalist* and *International Institutions and Global Governance Program* (blog), *Council on Foreign Relations*, 2 Sept. 2020.
2. “Nebraska and Colorado Face Off Over Water.” *AP News*, 18 May 2022.
3. NPR Staff. “Water Wars: Who Controls The Flow?” *NPR All Things Considered*, 15 June 2013.
4. Meshel, Tamar, and Moin A. Yahya. “International Water Law and Fresh Water Dispute Resolution: A Cosean Perspective.” *University of Colorado Law Review* 92, no. 2 (18 Mar. 2021).
5. “Potential Problems with Cross-Border Water Issues: The U.S. and Canada in the 21st Century.” In *Canada and the New American Empire*. University of Victory, CA: Center for Global Studies and CBC News World.
6. Singh, Shashwat. “The American Southwest’s Water Crisis, and Why Canada May Have the Solution.” *Glimpse from the Globe.* 10 Jan. 2022.

Issue 2: Humans treat water as an endless resource that causes unnecessary waste

Background

To those living in the developed world, water can seem limitless, just a turn of a knob away. This easy and ready water access in some societies triggers wasteful habits, which could run the gamut, from letting water run in a sink while brushing teeth or washing dishes, to the obsession of watering residential grass in pursuit of idyllic green lawns. The problem extends beyond individual household waste. Water overuse and waste happen in agricultural, commercial, and industrial settings too. Where it is plentiful and inexpensive, there will be a tendency toward neglectful water spillage and runoff. Even where water is scarce, in less developed countries, water rights owners or those with means to pay for the water may feel entitled to water use as if it is a limitless resource. Notably, the challenge may have more to do with developing and implementing workable policies and regulations that incentivize sustainable usage. An example is the 1980 Groundwater Management Code in Arizona.

It is projected that even as "the U.S. water supply decreases, demand is set to increase." Specifically, "On average, each American uses 80 to 100 gallons of water every day, with the nation's estimated total daily usage topping 345 billion gallons—enough to sink the state of Rhode Island under a foot of water" (Heggie, 2020). As the population increases, water stress will increase accordingly. Progress is happening with simple technological creations such as effective household greywater capture systems that might affect greater impact with broader adoption (Heggie, 2020; Gelt, 1993; Boano et al., 2020).

Recommendations

1. **Support maintenance of old infrastructure, such as leaky pipes.** Old fixtures should be replaced with new, efficient ones, and installation of water-efficient fixtures and appliances should be incentivized (U.S. EPA, "Statistics and Facts").
2. **Encourage use of water-efficient technologies** (Federal Energy Management Program, "Water-Efficient Technology Opportunities"). Ongoing innovation in this area is needed; therefore, promoting imaginative study, experimentation, and entrepreneurship may help to continue to raise the bar. For example, where appropriate, advocate for more use of greywater technology to capture and reuse household water from laundry, bath, and kitchen usage to be applied toward nonedible landscape vegetation (Gelt, 1993; Boano et al, 2020).
3. **Form new water use habits**. Inclusive campaigns could help people from all generations, backgrounds, and roles to reverse the power of old habits (e.g., such as learning to run dishwashers only when full). With an eye to the future, especially focus on building new habits with children (U.S. EPA, "Water Sense for Kids"). Leaders and influential managers should be empowered to use water conservation means in commercial buildings (U.S. EPA, "Commercial Buildings"). The role cultural values play should also be considered, while inspiring new values for beauty. One option would be to encourage the use of plants that conserve water rather than growing grass lawns. Outdoor water use should be limited (Karlamangla, 2021).
4. **Examine the potential for using water markets to help determine a fair price for water that encompasses all stakeholders** (Wheeler et al., 2017; Young, 2021). Water markets, like any market,

can help manage scarce resource usage by assigning appropriate value to it. Be mindful, however, that capital markets are human centric. Today's water markets may trend more toward agricultural benefits, weighing the water value against crop value. To benefit all of society, such markets should continue to broaden their participation to encompass all water users, attributing a fairness factor that considers the importance of the water to each stakeholder, beyond just humans, balancing seasonal, environmental, economic, and safety factors, to name a few (Ritcher, 2016). New technologically applied ideas may be of help to further promote/market/educate, increase accessibility, and assure equitable and inclusive participation among all stakeholders, including nonhumans (corporate, policy, community).

Case studies

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1. Water Management in San Diego County, USA.

   San Diego County, California, has actively managed its water resources for many years. Its leaders were especially motivated to rectify their water situation during a drought period in the 1990s. Their approach incorporates a combination of water rights access, appropriate pricing, infrastructure (aquifers, stopping leaks, and desalination plants), and educating their constituents, including both industry and households about common-sense water conservancy practices. Today, when other California residents need to make major adjustments to reduce water consumption, San Diego County inhabitants are less impacted given they have already been conditioned for water scarcity (Naishadham, 2022).

2. Balancing the Use of Water Through Water Trading Markets—Australia

   Water trading markets in Australia have exhibited reasonable success as a means to balance the use of water as a scarce resource among competing parties. The market approaches vary by the water rights being traded (e.g., access entitlement, allocation, irrigation, and delivery). The markets accommodate both economic and climate demands (Australian Government, DCCEEW; Hughes, 2021).

Further resources

1. Dalin, Carole, Yoshihide Wada, Thomas Kastner, and Michael J. Puma. "Groundwater Depletion Embedded in International Food Trade." *Nature* 543 (Mar. 2017).
2. "Excessive Water Use." City of Show Low, Arizona.
3. James, Barry. "Overuse Leading to Food Shortages, Study Warns: Less Water, and Less to Eat. *New York Times*, 18 Oct. 2002.
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9. Water Science School. "Total Water Use in the United States." USGS, U.S. Department of the Interior. 8 June 2018.[2]
10. Water Science School. "Trends in Water Usage in the United States, 1950 to 2015." USGS, U.S. Department of the Interior. 18 June 2018.

[2] "Thermoelectric power and irrigation remained the two largest uses of water (in the USA) in 2015, and total withdrawals decreased for thermoelectric power but increased for irrigation."

Issue 3: Community overexpansion can overtax water resources, whereas the scaling effect, while seemingly efficient from a financial sense, may have the unexpected impact of overtaxing available water resources

Background

As populations grow in various countries, the pressure for already scarce water resources increases accordingly. The surrounding infrastructure on which people rely to sustain themselves in various regions needs to scale to meet the demand of ballooning populations. Notably, "according to the World Health Organization (WHO), between 50 and 100 liters of water per person per day are needed to ensure that most basic needs are met, and few health concerns arise" (UN Water Decade Programme). Community planners should accommodate such a fundamental requirement. Compounding this basic infrastructure demand in water-stressed regions is the competition for water among a community's flora and fauna, human residents, and businesses, including agriculture and electricity production where that applies. The aggregate of all water-consuming parties amplifies the potential for disaster in such areas (Derla, 2016).

Recommendations

1. **Develop more detailed planning tools. Build and use better planning models that incorporate a richer set of variables inclusive of the surrounding species, the stakeholders.** For example, the use of "serious gaming" modeling tools should be explored to help engage stakeholders in decision-making exercises (Wikipedia, "Serious Game;" Angarita et al., 2016).
2. **Consult stakeholders extensively about the impact of proposed community growth on water availability**. **Consult local Indigenous communities, as well as local research universities and nongovernment organizations (NGOs), to advise on environmental impacts.** Those impacts should reflect not just that of human projects on the environment, but rather the converse, the impact of a potentially damaged environment on the community. Also, the UN should be partnered with, using the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to devise methods for the public, businesses, and local governments to understand and apply its guidance (Brondizio at al., 2019).
3. **Build an extensive knowledge base on water scarcity and its causes as well as potential flooding.** Leverage, on a global scale, the UN and other nations to identify regions of increasing water scarcity, breaking down that scarcity by its cause at local situational levels: natural, water diversion, pollution, industrial/commercial usage, and so on (all the issues listed in this chapter). Then the effect can be modeled as human-controlled water scarcity culprits are scaled down (Wada et al., 2016).
4. **Communicate to the public about water consumption by industry. Educate the general population on the effect of scaling, as well as on how to balance water needs with enterprise.** Bigger is not necessarily better.

Case studies

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1. River of Life Project—Kuala Lumpur

   Kuala Lumpur invested more than $1 billion via its "River of Life" project to clean and revive its Klang River with the intent to balance the area's natural resources with economic development. The city has been transformed by these changes:

   > *Restoring river habitat and ecological processes not only enhanced the quality of the human experience, it also added resilience to local economies.* (Schneider, 2018)

2. Smart Growth—New Jersey, USA

   Evidence shows that "smart growth," applying environmental conservation principles, can increase property values within communities that apply them. Conservation Tools Org discusses these principles and successful use cases in its paper, "Economic Benefits of Smart Growth and Costs of Sprawl":

   > *This impact assessment compares two possible growth plans for New Jersey, one in which growth is managed according to the State Development and Redevelopment Plan, and one in which it continues according to historical trends.* (WeConservePA, 2012)

Issue 4: City infrastructure detracts from healthy river and lake ecosystems

Background

Cities have a "profound relationship" with rivers and lakes. Infrastructure development "affects both the quantity and quality of water by changing the natural flow of stormwater runoff in a watershed. When rain hits impervious surfaces such as roofs, streets, and parking lots, it flows off in large quantities, carrying pollutants it picks up from the surfaces. The runoff's increased quantity and speed erode stream channels and destabilize [sic] their banks, while pollutants harm plants and wildlife in rivers, streams and bays" (U.S. EPA, "Smart Growth and Water"). But it is not only the functional aspects of city infrastructure that matter to rivers and lakes. Now, rivers and lakes also serve as sources of pride for cities and their urban dwellers as leaders invest to build infrastructure that enhances the beauty of the waterfront and that invites people to use these bodies of water for recreational purposes. "A good waterfront development considers diversity, community engagement, safety and security, environment and sustainability" (Hussein, 2014).

Our opportunity is to invest in city infrastructure that enables rather than detracts from healthy river and lake ecosystems by minimizing barriers, elevating natural systems, and advocating for sustainable practices.

Recommendations

1. **Consider the ecosystem needs of rivers and lakes, not only to maintain their functionality and their beauty but also to help improve the health and safety of urban dwellers**. To do this, building an infrastructure to support sustainable rivers and lakes and to minimize human-made pollution is essential.
2. **Implement "green Infrastructure" within and around cities.** Such infrastructure includes technologies that manage storm water safely, effectively, and sustainably using "natural infrastructure" and "techniques that protect, restore, and replicate natural systems." It might also mean "[r]estor[ing] floodplains, and preserv[ing] wetland forests through conservation programs." These programs might include things such as energy efficiency, water access, and green walks along the waterfront (Hussein, 2014).
3. **Create more "public greenspaces" in cities.** "Urban greenspaces" help reduce air, water, and noise pollution, and they may offset greenhouse gas emissions through CO_2 absorption. As it relates to the health of river and lake ecosystems, "Urban greenery also provides storm water attenuation, thereby acting as a measure for flood mitigation" (Lee et al., 2015).
4. **Consider initiatives to create and protect healthy watersheds** (U.S. EPA, "Initiatives to Create and Protect Healthy Watersheds"). This consideration should be an integral part of a holistic infrastructure planning process. Organizations such as the EPA partner with local states to encourage "holistic protection of aquatic ecosystems" (U.S. EPA, "Initiatives to Create and Protect Healthy Watersheds") This alliance results in joint efforts to employ such things as monitoring and assessment approaches, goal development, transparent communication with the public, and strategic habitat protection partnerships (U.S. EPA, "Initiatives to Create and Protect Healthy Watersheds"). When used as part of a coherent strategic planning process, all of these may inform how best to approach modifications to city infrastructure or future planning for such infrastructure.

5. **Retrofit/renovate industrial riverfront infrastructure for long-term sustainable use.** Retrofit out-of-date industrial riverfront properties, while including plans for the future use of the space by keeping in mind not only the human desire for "live, work, play" (Tierney, 2013) but also the ecosystem's needs. The ecosystem itself, the river, should play an equally important role as the human stakeholders in the planning process.

Case studies

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1. Huangpu River Development—Shanghai

   Shanghai is experiencing a renaissance devised through development along the Huangpu River with the river as the centerpiece:

   > *The urban regeneration of the Huangpu riverfronts plays a key role with no less than 120 kilometers of waterfront transformation intended to eliminate polluting industries, create a continuous open public space, to make new ecological connections, to reuse industrial heritage, and to add new landmarks. More than 50 kilometers of new waterfronts have been already implemented.* (den Hartog, 2021)

2. Sabarmati Riverfront Redevelopment—Ahmedabad, India

   In Ahmedabad (India),

   > *"the closure of mills along the Sabarmati Riverfront caused unemployed laborers to form large informal settlements along the riverbed, creating unsafe and unclean living areas and reducing the flood management capacity…In response, the city created a development corporation to reclaim 200 hectares of riverfront land on both sides and paid the project costs through the sale of 14.5 percent of the reclaimed land, while the rest of the riverfront was transformed into public parks and laborers resettled through a national program*. (World Bank, 2016)

3. Riverfront Project—Omaha, Nebraska, USA

   In Omaha, Nebraska, "The Riverfront" project "became the first in Nebraska to earn an "Envision" award for sustainability," with a "Platinum sustainability rating." The project transformed downtown Omaha along the Missouri River by connecting three parks near the city's downtown core.

   > ***Preserving undeveloped land and remediating a brownfield.*** *To preserve undeveloped land, one hundred percent of the project has been located on previously developed areas. The Lewis and Clark Landing, representing approximately 41% of the site, is located on a brownfield site where a lead smelting and refinery company operated for decades. A response action to install a geosynthetic clay liner was started in the late 1990s to cap the contaminated soils and was fully completed in 2016.* ("Omaha, Nebraska's Riverfront Revitalization Project," 2021)

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Issue 5: Excess fertilizer, pesticide, and animal waste pollute water sources and increase the chances for toxic harmful algal blooms (HABs)

Background

Humanity has been applying fertilizer and pesticide to crops for ages. There is a limit, however, to how much of it the waterways can filter before it impacts us and our surrounding environment (University of Oxford, 2013; PennState Extension, 2022). A U.S. EPA "assessment found that 48% of water quality impairment in American surface waters is attributable to agriculture" (Nosowitz, 2021). This problem isn't just an agriculture challenge, but also a household cultural problem. In the United States, household lawns may be the largest crop. "Lawns comprise over 150 000 km^2 of land in the US, an area larger than that of any irrigated crop" (Groffman et al., 2016) As a result, people are overfertilizing. In lakes and ponds, the result is increasing algal blooms. Here are some quotes from a few different sources:

> *"Using lots of fertilizer wouldn't necessarily be a bad thing if all of it was used by the crops. Unfortunately, most of it isn't."* (Ritchie, Roser, & Rosado, 2022)
>
> ***"[L]ess than half of the nitrogen we apply to our crops is actually taken up by them. The rest is excess that leaks into the natural environment."*** (Lassaletta et al., 2014)
>
> *"Nutrient pollution is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer,* ***causing excessive growth of algae."*** (NOAA, 2023)

Apart from occurring naturally, toxic algal blooms can be caused by the flow of nutrients like nitrogen and phosphorus into the lake ecosystem. These nutrients may originate from fertilizers used in agriculture and through household use of chemicals and so forth.

HABs "occur when colonies of algae—simple plants that live in the sea and freshwater—grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal" (NOAA, 2016).

Costs to the economy include healthcare costs for affected human beings, as well as to tourism and to mitigate the damage. There is also a cost to marine life (Florida Dept. of Health, "Harmful Algae Blooms"). Effective sustainable farming practices are evolving. They balance the objectives of a healthy environment and economic profitability with social and economic equity (UC SAREP, 2021).

Recommendations

1. **Consider natural, native solutions to let nature repair nature.** For example, it's been known for many years that some native grasses, such as switchgrass, serve as filters. "Grassy riparian buffers, either alone or in a forested buffer system, trap or transform sediments and plant nutrients before they enter streams. Native grasses might also be used in contour filter strips that can retain 50–70% of nutrients, pathogens, and sediment" (Schnabel, 1999).

2. **Reduce the use of pesticides and chemical fertilizer in crop production.** Use regenerative farming (University of Missouri Center for Regenerative Agriculture) or, at minimum, crop rotation. These practices can reintroduce natural nutrients from a crop back into the soil for future crop benefit. This approach can also reduce the need for fertilizers and pesticides. Research has already made progress in identifying food crops that require less fertilizer.

3. **Use financial incentives or disincentives to avert the overuse of fertilizers**. For example, continued evolving and popularizing the use of water quality trading (WQT) is needed. Much like voluntary carbon markets (VCMs) use greenhouse gas (GHG) offsets traded among carbon producers to achieve lower carbon output to meet policy goals, WQT enables waterway nutrient polluters to achieve something similar. Its advantage is in attracting private capital market investment toward infrastructure required to clean the water. It brings together key stakeholders (e.g., government, nongovernment, agriculture, private industry, and capital markets) to achieve water quality policy goals such as the 1972 Clean Water Act in the United States (Chesapeake Bay Foundation, "Water Quality Trading;" U.S. EPA, "Water Quality Trading").

4. **Continue to develop, evolve, and deploy sustainable agriculture practices**. "Growers may use methods to promote soil health, minimize water use, and lower pollution levels on the farm" (UC SAREP, 2021).

5. **Improve the efficiency of fertilizer application.** Use new advances in science, both in analyzing the results of applications (e.g., plant sap analysis; Barrera, 2021) and in exploring the viability of using super-absorbent polymer (SAP) technology:

   > *Besides improving water use efficiency of soil, SAPs are also used for controlled release of fertilizers. It is reported that about 40–70% of nitrogen (N) and about 80–90% of phosphorus (P) in conventional fertilizers cannot be absorbed by crops due to their high solubility in water and high diffusivity to the surrounding environment.* (Chang et al., 2021)

6. ***Encourage minimizing "manicured" lawns.*** Promote ways to encourage a natural residential lawn and disrupt the pursuit of an unnatural manicured lawn that requires more chemical treatment—potentially significant irrigation—to maintain it. Growing native species encourages and supports a healthy habitat for surrounding indigenous flora and fauna. For households unwilling to switch to a natural lawn, suggestions to mow at taller heights that "can reduce pest problems, such as weeds, insects, and diseases" (Clear Choices Clean Water, Indiana, "Fertilizer and Water") are useful. Landscaping services should be mindful of and better educated about over fertilizing and should provide more natural means of pest control.

7. **Implement sustainable algae management practices.** These practices and viable technologies include increasing the level of oxygen in lake water through technologies like aeration, educating and encouraging households to reduce the use of detergent, algae control using ultrasonic waves, judicious use of aquatic herbicides, and the potential use of nanobubble technology (Temesgen, 2017). These tactical approaches should be advertised to the community as clearly temporary and requiring pairing with more natural strategic solutions. Such tactics should avoid leaving the community with the sense that temporary remediation solves the underlying problem to the point where they lose interest.

8. **Monitor water and communicate water quality in real time**.

Case studies

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1. Remediation of the Pleasant Valley Branch of the Pecatonica River, Wisconsin, USA

   The Pleasant Valley Branch of the Pecatonica River in Wisconsin managed to reduce sediment and chemical runoff by proactively engaging stakeholders to rally around a solution. That solution included government agencies, NGOs, and farmers (voluntarily) applying a SNAP PLUS program (Soil Nutrient Application Planner) to identify "hot spots" and assess appropriate remediation. They managed to reduce the phosphorus pollution by 40%, which improved the health of the fish and other species reliant on the river as their habitat; it also dramatically reduced the algae growth in downstream waters. Thus, they incorporated a sustainable management model by introducing an automated sampler mechanism along the river (Into the Outdoors, 2017; Environmental Trading Network).

2. Building the Future of Freshwater Protection

   Lake George Association—The Jefferson Project: Building the Future of Freshwater Protection.

3. Impacts of climate change on coastal blooms

   The National Centers for Coastal Ocean Science (NCCOS) are working to monitor and address the impacts of climate change on coastal blooms: Monitoring and Event Response (MERHAB).

4. Algal Blooms—Root Causes

   Moleaer's nanobubble technology is used for various purposes, including for treating the root cause of algal blooms.

Further resources

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16. U.S. Environmental Protection Agency (EPA). "Harmful Algal Blooms." Nutrient Pollution. Last updated 25 Aug. 2022.
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Issue 6: Water flow diversions disrupt critical ecosystems

Background

The human need for energy, irrigation, transportation, household, and industrial products often alters the natural flow of rivers and streams through construction and deforestation. Modification of the natural environment has a detrimental impact on rivers and lakes by either increasing or impeding the natural flow of water, by increasing pollutants in the water, and/or by disrupting the natural processes of interconnected ecosystems.

The land area through which water naturally flows is called a *watershed*. Any human modification to the watershed interrupts the natural flow of water, including modifications humans make every day such as construction ranging from dams and irrigation channels to buildings and dwellings to roadways and parking lots. Disturbing the watershed by building structures such as parking lots can dramatically increase rainwater runoff, resulting in increased volumes of water, which results in flooding and erosion. Construction is not the only culprit, though. Other uses of the land, such as harvesting materials like lumber, impact the natural flow of water. When the natural flow of water is interrupted, the receptacles of the water, such as streams, rivers, and lakes, are impacted. When trees are removed for human use, the natural process they play in our ecosystem is disrupted too. For example, trees facilitate the natural rivers in the sky. They do this by absorbing and then releasing water into the atmosphere that travels "hundreds or even thousands of miles away," feeding rivers and lakes across the world. Other impacts can range from increases in water flow, where barriers are reduced, which results in flooding and erosion, to the polluting of water as pollutants are collected during flow. When humans introduce barriers within the natural watershed, as water flows, it can pick up contaminants and pollutants, which impact rivers and lakes downstream.

The fact that people have made choices over centuries to alter natural water flows without understanding their impact on other species also affects humans in the long run. For example, one study finds a correlation of human disease increases with the 20th-century construction of two large dams in Egypt (Derr, 2021). Regarding dams, numerous articles and studies provide evidence of their disrupting nature, but it is prudent to ask whether dams could be used in other ways that benefit other species as well as humans. Alternative sources of energy are needed to relieve dependency on fossil fuel, and dams provide such a choice. Of course, there are trade-offs. Each action by any species on Earth affects others, sometimes negatively. It's a dance! And like a "dance," troupes must work in unison to achieve harmony.

Recommendations

1. **Examine the appropriate timing of dam water releases to balance the needs of multiple stakeholders** (Chen, 2018). The impact of dam creation on the habitat of the native species that are important to maintaining the sustenance of the surroundings should be considered.
2. **Employ more permeable construction materials for infrastructure to minimize water flow impact.** For example, studies have trialed the use of permeable pavement for roadways or walkways that has the potential for improving water flow disruption (USGS, 2019).

3. **Effectively use AI to assess the life cycle of a dam—from design to end-of-use.** Use artificial intelligence based on trusted data models to aid in assessing the motivations and the impact of building a dam, even its removal. Alternative approaches may reveal themselves.
4. **Take a systems approach including the need for irrigation, potential types of crops when assessing the need for an irrigation dam.** Determine, when the motivation for a dam is for irrigation, whether more appropriate crops could grow in a region that would lower or minimize the demand for water from the irrigation channels. An example is in Arizona where local alfalfa farmers are looking at substituting their usual non-native alfalfa with a native plant, guayule, that has uses in the latex market.

Case studies

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1. Dam Removal—Selune River, France

   France has been making concerted efforts to reduce the river flow diversions of its dams by scientifically researching and applying approaches. A major dam was removed from the Selune River with acknowledged success:

   > *"The way the river has been reborn is such an important message, a message of hope," says Roussel. "Just when you think that everything is going wrong with the environment, sometimes you can get a sign, a concrete example of nature reclaiming its territory. And I think that's really comforting."* (Dekimpe, 2022)

2. Dam Modification to Support Atlantic Salmon Population—Poutes Dam, France

   Another dam, the Poutes Dam was retained but lowered by nearly two thirds with modifications to both its operational structure and schedule to provide a migration path for the declining Atlantic salmon population. This project is still in progress but with encouraging results so far (Dekimpe, 2022).

3. Dolphin Population Decline in the Ganges River—Assam, India

   In Assam, a state in India, the Xihu (river dolphin) population is in serious decline in the Ganges River, which is partly attributable to dams that restrict the dolphins' movements. Being at the top of the food chain, these dolphins help maintain the health of the rivers they inhabit. Any indication of their population decline is a sign of an unhealthy river (Swinton & Gomez, 2009; Guha, 2022).

4. Environmental Flows—Human and Environmental Water Needs Study, USA

   A 2017 study from the *University of Washington School of Aquatic and Fishery Sciences*) provides some hope of a possible positive compromise addressing this problem, "Designing flows to resolve human and environmental water needs in a dam-regulated river":

   > *One of the most promising approaches to **integrating human uses into the larger scope of ecological sustainability** is the concept of environmental flows, or the provision of water within rivers to support positive ecological outcomes while maintaining the water needs of human society.* (Chen & Olden, 2017)

5. Large Dam Study

   Another promising example of compromise is described in this *Scientific American* article, "We Can Make Large Dams More Friendly to the Environment," which provides some hope of a possible positive compromise addressing this problem (Chen, 2018).

Further resources

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Issue 7: Growing water-intensive crops in arid zones accelerates water scarcity

Background

The agriculture industry is incentivized to grow crops that provide the greatest yield for their investment and available resources. In some cases, the crops require more water than the local ecosystem is natively capable of providing.

Thirsty crops: It's an economic problem:

> *"When growers are producing things, they think in terms of what income can you generate per unit of water, so a crop that doesn't use as much water per acre, might not generate much income."* ~George Frisvold, Researcher, Univ of Arizona Dept of Agricultural and Resource Economics. (Mysofski, 2022)

For example, the United States produces almonds largely in California and Arizona, two water-stressed areas. Almonds natively grow in the Mediterranean region, and they do require a great deal of water. This crop, therefore, may no longer be practical from a water usage perspective. The issue becomes more complicated when intricate dependencies are unveiled about crops grown at scale to fulfill the demands of the entire vertical food industry from farm to wholesale to industrial to commercial to consumer.

This 2016 article in the Austin American-Statesman (updated in 2018), "5 Reasons Farmers Grow Thirsty Crops in Dry Climates," reveals a great deal about the problematic relationship specifically in the United States between agriculture and water. Here are some key snippets:

> *"**Corn's production value is higher than that of soy or wheat**, making it an attractive choice for farmers to plant. But corn also demands more water."*
>
> *"**Most of the corn grown in America goes to fatten up livestock**. It's also **used in starch, corn oil, beverage and industrial alcohol, sweeteners such as corn syrup, and fuel ethanol**.*
>
> *"**Irrigated land is worth more** than non-irrigated land in low-rainfall regions."*
>
> *"Farmers have a choice: **Fully irrigate or risk losing** the lease to a neighbor who's willing to do so."*
>
> *"Farmers who want to cut irrigation to conserve water only qualify for **dryland insurance policies that don't compensate** them nearly **as much** as an irrigated policy."*
>
> *"**Farmers** often purchase the equipment using **loans**. **To pay down the debt**, they **need to keep up production**, which usually **means irrigating**."* (Wise, 2018)

Recommendations

1. **Educate and incentivize the agricultural industry regarding growing native crops** (i.e., farmers need to avoid planting water-thirsty crops in water-stressed regions). For example, an Arizona alfalfa and cotton farmer is learning to grow and develop a market for guayule (pronounced "why-YOU-lee"), a desert shrub plant that provides a natural rubber useful for latex and other similar products (USDA, 2009; Allhands, 2021).
2. **Educate the public on the water stress impact of their product choices.** For example, consider developing a reliable measure of water intensity. Then the water intensity information could be added to food product labels.
3. **Educatevize and incentivize the public to consider locally sourced foods as well as a variety of protein sources.** Incentivize the public to look more at the advantages of locally sourced foods, where possible, as well as at alternative sources of protein to aid in rebalancing the demand across protein choices. The cattle and dairy industry, however, should be supported through this transition, that is, in fairness to their business investment, both their financial and sweat equity. Support for this industry during this transition can help bolster greater support and avoid blowback that could undermine such efforts. One way to improve incentivization is to use tokens layered on blockchain technology to open access to a broader population that wishes to participate in affecting such changes (Guo, 2022).
4. **Consider crop selection for a particular location a "systems" problem.** Develop ways to educate societies on how to improve the valuing of water and other environmental resources when analyzing the costs/benefit of growing a crop in a particular area/land—in addition to weather, time to market and so on. The intent is to improve the decision-making of crop selection with more accurate and inclusive resource cost and benefit information.
5. **Pair advanced moisture sensors with AI to improve water management system options**.[3]
6. **Minimize the water requirements for irrigation.** Consider alternative forms of irrigation, such as drip irrigation to improve the water efficiency in plant growth, especially when paired with native crops (Smith & Freemark, 2016).

Case studies

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1. Crop Water Intensity and Natively Resilient Crops

   Extensive evidence exists that farmers are aware of the issue of crop water intensity and are taking measures to address it. They are looking at farming crops natively resilient to the local climate extremes, and they are seeking a market for them. Farmers then become market-makers as opposed to merely growing crops in the most cost-effective manner to meet existing world consumer demand:

[3] Evja provides solar-powered agriculture water management system. See https://www.evja.eu/#features.

Some farmers are also starting to grow crops based not on what faraway foreign consumers already demand, but raising animals and crops which thrive on increasingly arid lands, and then create a demand for those commodities abroad. (Elbein, 2021)

Accelerating such activity requires more financial help that supports farmers in this pivot. Programs such as the Environmental Quality Incentives Program (EQUIP) aim to do just that with participation from the National Resource Conservation Stewardship (NRCS). Also, the United States has passed recent legislation to further encourage and support such endeavors by way of bill S.1251, the Growing Climate Solutions Act. (U.S. Senate Bill S.1251)

2. Water Reclamation from Wastewater—Israel

   Being an arid nation with a growing population, Israel has improved water reclamation from wastewater to upward of 85% and has learned to employ drip irrigation to enrich its agriculture (Smith & Freemark, 2016).

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[4] Reveals the important awareness of thirsty crops in resolving cross-border water sharing between Canada and the United States.

[5] Discusses water problems in India's agriculture.

Issue 8: Physical trash / plastics pollute freshwater ecosystems and play a significant role in ecosystem degradation and destruction

Background

A steady stream of physical trash ends up in rivers and lakes. A significant amount is generated by people's processes in disposing of end-use materials in their homes, such as plastic, cardboard, paper, building materials, abandoned items, and illegally dumped items.

Single-use plastics are a particularly toxic form of trash pollution. Unlike cardboard, paper, and many metals, their biodegradability has a particularly long lifespan. Additionally, they are often physically harmful to plants, animals, and humans.

The continuing single-use economy exacerbates the problem (Plastic Action Centre, "Here's Where the World's Plastic Will End Up, by 2050).

Regional, cultural, and economic differences complicate the issue further, leading to the need for a multifaceted approach.

Recommendations

1. **Transition from single-use resource economies to sustainable, regenerative, and circular economies appropriate for areas of differing physical, cultural, and economic development.** Tactics for such a transition should be tailored to the specific physical, cultural, and economic context of each area and be based on strategies developed around education, local partnerships, policies, regulations and incentives, and research and development of technological solutions.
2. **Educate populations globally and locally through primary, highly visible private, government, and media channels to change the principle worldview of societies.**
3. **Develop and improve waste disposal technologies that have a more modest, minimal, impact on the air, land, and water environments.**

Case studies

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1. Ganga River Water Quality—India

   Three start-ups are taking different approaches to improving and protecting India's Ganga River water quality. One uses autonomous robot, or ro-boat, technology to monitor and clean the river surface waters. Another focuses on the capture and repurposing of the flower pollution contributed by the historical religious floating floral arrangements. Still another monitors the river bed pipeline using ultrasound to alert whenever oil leaks are detected (Pal, 2017).

2. Cross Border Waterway Contamination—Balkan

   Balkan nations try yet struggle to coordinate the prevention of trash from entering shared waters. Often trash landfills are inappropriately located next to waterways, compounding the problem (CBS News, 2021).

3. Menhaden Return to the Coast of New Jersey, USA

   Humpback whales and one of their food sources, Menhaden, have returned to the shores of New Jersey, a reflection of prior long-term policy-driven efforts to clean the waterways feeding the US coastal areas:

   > *"There is still a lot of ongoing research to determine why they're here, but certainly we're seeing the long-term benefits of action taken in the 1970s like the Clean Water Act and the Marine Mammal Protection Act," said Brown, a Rutgers doctoral candidate and head researcher for the advocacy group Gotham Whale.* (Fallon, 2022)

Further resources

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5. Gray, Brian, Jennifer Harder, and Karrigan Bork. "Implementing Ecosystem-Based Management." *Duke Environmental Law & Policy Forum* 31 (2021).
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Issue 9: Chemical and hazardous waste adversely affects river and lake ecosystems

Background

Hazardous waste from commercial and private sources adversely affects the world's river and lake ecosystems, leading to ecosystem degradation and destruction, loss of biodiversity, and increasing human food and water insecurity.

The U.S. EPA characterizes hazardous waste threats according to four broad categories: ignitability, corrosivity, reactivity, and toxicity (U.S. EPA, "Defining Hazardous Waste).

> ***Ignitable waste*** *can catch fire spontaneously or burn easily. Examples include charcoal lighter fluid, gasoline, kerosene, and nail polish remover.* ***Corrosive wastes*** *can cause a chemical action that eats away materials or living tissue. Battery acid is an example.* ***Reactive waste*** *can react with air, water, or other substances to cause rapid heating or explosions. Acids that heat up rapidly and spatter when mixed with water are examples.* ***Toxic wastes*** *can cause illness or death. Some such wastes are more dangerous than others. Exposure to a small concentration of a highly toxic chemical may cause symptoms of poisoning. Pesticides, cleaning products, paints, photographic supplies, and many art supplies are examples. (NASD, "Disposal of Hazardous Household Waste)*

Waste with these characteristics is introduced into Earth's river and lake ecosystems from both commercial and private sources.

Commercial sources include manufacturing across a wide range of industries; mining activities (Ecowatch, 2012); commercial agriculture; and construction. Introduction of their hazardous waste byproducts into rivers and lakes results from inadequate disposal technology, water runoff, groundwater (Desjardins, 2015), acid rain, and illegal dumping.

Residential sources consist of the products consumers buy. Hazardous residue from these products enters rivers and lakes through runoff, groundwater, and illegal dumping (Denchak, 2023).

Management of hazardous wastes includes management at the source, disposal technologies, cleanup technologies, and infrastructure developments.

Recommendations

1. **Increase communication about hazardous waste disposal.** Increase education around, and public exposure to, messaging regarding the environmental hazards of pouring oils, antifreeze, paint, solvents, cleaners, preservatives, and prescription drugs down household and storm drains.
2. **Treat the hazardous waste problem at the source.** The treatment at the source approach is the most efficient means of dealing with hazardous waste. This approach includes employing disposal technologies, public education, and engagement.

3. **Improve and/or replace traditional disposal technologies such as landfills, incineration, and chemical treatment.** Further technologies must be developed, such as bioremediation, encapsulation, plasma arc technologies, thermal desorption, ion exchange, and electrochemical remediation.
4. **Design groundwater and freshwater "friendly" infrastructure.** Examples are inert permeable paving systems that manage surface runoff by allowing rainwater to be introduced into groundwater. Roads, driveways, sidewalks, and other urban infrastructure can be developed that allow for more direct introduction of rainwater into the ground and groundwater. Current concrete production has a high carbon footprint cost. Asphalt paving is fossil oil and gas resource intensive. Both additionally channel various forms of pollution into freshwater ecosystems (Venditti, 2022).

Case studies

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1. Microbubble Technology to Clean Up Pollution in Water Bodies

   A way has been found to clean up polluted lakes using a microbubble solution that attracts viruses and bacteria ("A Man from Peru, Bright Side).

2. Transport of Contaminants in Groundwater—Case Study Collection

   "Case Studies in Groundwater Contaminant Fate and Transport" is a collection of case studies that focuses on "natural processes that control the fate and transport of contaminants in groundwater rather than on active remediation methods." (Bekins, 2018)

3. Waste in Lake Malawi, Malawi

   A paper, "The impacts of waste dumping in Lake Malawi," reveals "the challenges and dangers that occur due to waste dumping globally and how individuals, water species, and even the water itself are affected." This paper is about an important lake in the African nation, the Republic of Malawi. It considers local context, sharing "what the local inhabitants are saying about this issue, and their recommendations for improving the condition of the lake." (Tsuro, 2021)

4. Cleanup of the Lower Duwamish River, Seattle, Washington, USA

   The National Oceanic and Atmospheric Administration (NOAA) runs a Damage Assessment, Remediation, and Restoration Program (DARRP) wherein they publicly share documented activity of projects. In this example, "Lower Duwamish River," DARRP information is being shared about the progress in the cleanup of the Lower Duwamish River in Seattle, Washington, USA (NOAA, "Hazardous Waste").

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Issue 10: Raw human sewage pollution causes degradation of river and lake ecosystems

Background

While land and water can naturally treat sewage, everything has a capacity. Where humans have concentrated in growing population areas, if no separate sewage treatment mechanisms are in place, then the nearby natural waterways are likely polluted with human sewage.

Sewage from outdated treatment plants and growing populations pollutes rivers and lakes worldwide (American Rivers, "How Sewage Pollution Ends Up in Rivers"). Medicines, household cleaners, biologic waste, and a host of other pollutants make their way into water supplies, damaging ecosystems and threatening public health. Changing or conflicting policies exacerbate the problem (Flavelle, 2020). Climate change only worsens the problem (Kruzman, 2022).

Recommendations

1. **Provide extensive education around all aspects of sewage to raise public awareness** (SAS, "Get Learning").
2. **Rebuild infrastructure in light of local climate change parameters/forecasts such that the infrastructure is resilient.**
3. **Effectively deploy filtration and other sewage/wastewater treatment technologies as appropriate to the location.** Deploy and further develop advanced filtration technologies such as membrane bioreactors, moving bed biofilm reactors, integrated fixed-film activated sludge, granulated activated carbon, and oxonation.

Case studies

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1. Marine Conservation—UK

   Grassroots UK organization, Surfers Against Sewage (SAS), is an education program that not only teaches sustainable practices but also provides teach-the-teacher workshops (SAS, "Get Learning"). From a handful of activists to a nationwide movement, over the last 30 years, Surfers Against Sewage has grown into one of the UK's most successful marine conservation and campaigning charities.

2. “Stop, Don’t Flush That” Campaign by the Water Environment Foundation (Water Environment Foundation, 2013)

   WEF members work to solve the non-dispersibles problem. Perpetrators mucking up the system are known as “non-dispersibles,” which currently means anything other than human waste and toilet paper that is flushed down the toilet.

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Issue 11: Invasive species threaten freshwater ecosystems

Background

Invasive species are "non-native (or alien) to the ecosystem under consideration and … introduce causes or are likely to cause economic or environmental harm or harm to human health" (USDA NISIC, "What Are Invasive Species?)." Freshwater ecosystems are being threatened by invasive species because of the climate changing and human introduction of non-native species. These invasive species in some cases thrive due to being introduced into an ecosystem with no predators along with a substantial source of accessible food allowing them to prosper and outcompete other species.

With warmer temperatures in rivers and lakes, the native species are shifting and migrating to cooler environments, and they are being replaced by invasive species that can better adapt to the warmer water. These invasive species pose serious challenges to the entire ecosystem. Furthermore, the native species that cannot move to tolerable areas face possible extinction.

Recommendations

1. **Create strategies to prevent the introduction of invasive species.** "Once invasive species become established and spread, it can be extraordinarily difficult and costly to control or eradicate them" (NWF, "Combatting Invasive Species") To curtail the spread of invasive species, preventive measures should be deployed such as:
   a) Enforcing strict boat cleaning rules at boat ramps and docks preventing species from transferring from one body of water to another
   b) Educating fisherman on releasing live bait into bodies of waters
   c) "Creat[ing] monitoring systems for detecting new infestations (NWF, "Combatting Invasive Species")"
2. **Use scientifically defensible methods to identify freshwater aquatic species at high risk of becoming invasive species.**The focus should be specifically on the 'import processes' and those who import fish or plant species for home aquarium use. Policies and methods are needed to prevent accidental introduction of such species into river and lake ecosystems (Nature Conservancy, "Great Lakes Aquatic Invasive Species).Another focus area is the accidental transport of aquatic species in ships' ballast water as well as on the hulls of ships.
3. **Focus preventative measures on waterway connections**. "The places where waterways connect are vulnerable to the movement of aquatic invasive species. Both natural and artificial connections pose a risk for the transmission of such species." By focusing on these connections, we can protect them and stop the two-way movement of aquatic and invasive species" (Nature Conservancy, "Great Lakes Aquatic Invasive Species).

4. **Employ mitigation and removal strategies for invasive species in freshwater bodies when preventative strategies are not effective.** Some strategies are:

   a) Moving rapidly to remove newly detected invasive species (Nature Conservancy, "Great Lakes Aquatic Invasive Species).

   b) Encouraging mitigation strategies like the hunting/harvesting of non-native species

5. **Promote public education campaigns about the problem of invasive species and engage the public to help**. Campaigns like "Don't Move a Mussel" should be considered. Such a campaign includes "general information and outreach materials to increase awareness of invasive species issues" (USDA, "Public Awareness Campaigns"). In addition to using billboards, technology should be employed to help through online and social media campaigns.

6. **Consider using remote-sensing technologies (from an airplane or drone) to determine the potential effects and locations of invasive species** (Lake George Association, "Invasive Species").

7. **Take care when introducing new species into freshwater ecosystems while trying to control non-native species growth.**

Case studies

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1. Invasive Species Management

   "Understanding population-level responses to removal and immigration rates are essential aspects of invasive species management." (Weber et al., 2016)

2. Invasive Phragmites on Beaver Island in Lake Michigan

   Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands. A report from the Michigan Natural Features Inventory demonstrates success of early detection and subsequent removal in minimizing the impact of the invasive phragmites on Beaver Island in Lake Michigan. (Higman et al., 2019)

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Issue 12: Engineering education lacks sufficient ecological literacy content

Background

Universities train engineers into specialties, be it chemical, civil, electrical, mechanical, software, or other areas of expertise. All are grounded largely in mathematics, physics and other sciences. Gaps in ecoliteracy knowledge contribute to human mistakes, unintended and unanticipated consequences, based on designing and implementing narrowly scoped engineering solutions that address misunderstood problems (Schultz-Bergin, 2021). The participating engineers from the spectrum of engineering disciplines, as well as the stakeholders involved across an expanse of project sizes, mega-industrial to residential, could improve their understanding of local environmental trade-offs by having engineers and stakeholder participants better trained on Earth's natural system behavior.

> *Human technologies developed over the past several hundred years have tended to be extractive, leaving the biosphere increasingly degraded as they have expanded. Imagine technology that is instead designed to function as an integral part of the Earth's living systems. (Institute for Regenerative Design and Innovation)*

Recommendations

1. **Encourage schools of engineering to modify their curricula to incorporate ecoliteracy as foundational throughout their courses.**
2. **Educate children on ecoliteracy.** Continue to build and deliver more early education for children in elementary, middle, and high schools that ground them in understanding and appreciating how humans both integrate in and influence their surrounding environment.
3. **Engage business in ecoliteracy education.** Encourage local businesses to not just donate funds to local environmental NGOs but also to encourage, engage, and incentivize their employees to donate their time toward such efforts.

Case studies

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1. Hands-on Education at Riverside Intermediate School, Fishers, Indiana, USA

   An effective way to improve planet stewardship is by local community "hands-on" education. Educators need more community involvement. The Riverside Intermediate School in Fishers, Indiana, a part of the Hamilton Southeast (HSE) school district, uses its proximity to nature to help students better interact with it. HSE succeeds by engaging the community to support raising goats and chickens on the school property, so the children, as well as community residents, gain appreciation for these farm animals. (Muljat, 2023)

2. Centre for Regenerative Design & Engineering for a Net Positive World, Bath, UK

   University of Bath in England has a Centre for Regenerative Design & Engineering for a Net Positive World. "We offer global research leadership in regenerative design and engineering, co-evolving solutions with societal, cultural, ecological, and economic co-benefits." (University of Bath Center for Regenerative Design & Engineering for a New Positive World.)

Further resources

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   This new understanding of nature as a self-organized, self-regenerating system extends, like a fractal, from a single cell to the global system of life on Earth. The conventional view of nature as a machine has encouraged many in our culture to view the Earth as a material resource with no intrinsic value, available to be exploited purely for humanity's needs. (Lent, "Is Nature A Machine—Or a Self-Governing Fractal System?")

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Issue 13: Freshwater ecosystems face multiple challenges

Background

The future of freshwater biodiversity is a topic of great concern and importance. As human activities continue to impact our environment, freshwater ecosystems face a multitude of challenges that threaten their biodiversity (Su et al., 2021). Some key factors affecting freshwater biodiversity include habitat loss and degradation, pollution, climate change, overexploitation of resources, and the introduction of invasive species. These factors not only lead to the decline in species populations but also disrupt the delicate balance of freshwater ecosystems (Dodds, Perkin, and Gerken, 2013).

Recommendations

1. **Conserve and restore habitats.** Efforts should be focused on protecting and restoring critical habitats, such as wetlands, rivers, lakes, and streams. By preserving these habitats, we can provide safe havens for a diverse range of species. Management can help improve the equitable and sustainable use of transboundary waters. This approach involves considering the needs of various sectors, such as agriculture, industry, and ecosystems, while balancing social, economic, and environmental objectives (Meli et al., 2014).
2. **Adopt sustainable practices in water management.** This crucial need includes reducing pollution from industries and agricultural activities, implementing efficient irrigation systems, and promoting responsible water consumption (Eros, Hermoso, and Langhans).
3. **Prevent the introduction and spread of invasive species in freshwater ecosystems.** Effective monitoring and control programs can help prevent the negative impacts of invasive species on native biodiversity (Neumann, 2020).
4. **Develop and implement strategies to help freshwater ecosystems adapt to climate change.** This approach may involve creating protected areas, implementing habitat restoration projects, and promoting water conservation (Combes, 2003).
5. **Promote and support collaboration among governments, organizations, scientists, and local communities.** This cooperation is essential to the success of conservation efforts.
6. **Increase awareness and education about the importance of freshwater biodiversity.** This effort can also help drive positive change, including reducing the chances of conflict and violence among people over scarce resources.[6]

[6] Largest river and wetland restoration initiative in history launched at UN Water Conference, March 2023, UN Environment Programme.

Case studies

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1. River Danube Restoration, Romania

   Restoration of a portion of the Danube River in Romania. Efforts continue to reconnect the Garla Mare marshland to the Danube, restoring the natural river floodplains by removing dykes. The expectation is improved biodiversity such as migratory birds, better flood control, and improved freshwater quality. (WWF, 2010)

2. Cross-border Collaboration in Water Management—Eastern Africa

   Collaboration among countries and organizations in Eastern Africa, especially inclusive of input from women, are improving water conditions. There is increased awareness and education on the importance of hygiene, trees, and animal management on the creation and maintenance of clean freshwater, and the impact on the surrounding flora and fauna. (Indakwa & Wamba, 2021)

3. Recovery from Freshwater Biodiversity Loss

   "Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan." (Tickner et al., 2020)

4. Freshwater Biodiversity in the Western Ghats, India

   "The status and distribution of freshwater biodiversity in the Western Ghats, India." (Molur et al., 2011)

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