Lack of Clarity Around Policies, Data Management, and Infrastructure May Hinder Efficient Use of Reclaimed Water Resources in the United States.

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Abstract

Water reuse in the United States is growing in popularity as communities face new and increasing water supply concerns. As wastewater treatment technologies progress, the potential for reuse of reclaimed wastewater (treated effluent from municipal wastewater treatment plants) expands, and is more likely to be implemented with increasing water scarcity and availability challenges. The progression of water reuse in the United States depends on the development of an effective policy environment that describes and promotes appropriate reuse practices. We conducted a holistic critical review of the water reuse policy environment in the United States to identify how policy specifics and recommended practices may affect the implementation of water reuse for non-potable applications. In this work we consider state-level water reuse policy, generation and management of data from projects and research, and development or adaptation of treatment technologies and distribution infrastructure as important aspects of water reuse practices. We find several commonalities and divergences between different state policies that may hinder the development of reclaimed water resources in regions facing diverse water scarcity challenges. There are many lessons to be learned and implemented from existing policies and future innovation in this field will require a multi-pronged, collaborative approach.

Keywords

water reuse, reclaimed water, environmental policy

1 Introduction

Global water scarcity concerns can motivate communities to seek non-traditional potable and non-potable water sources. Once traditional local water sources have been allocated, municipalities often look to interbasin transfers, water conservation measures, desalination, and/or water reuse to meet current and future water demands.[?] Water reuse is a phenomenon that occurs unintentionally in current water disposal and supply systems (e.g., de facto reuse)[?,?] and can be engineered to provide a local, secure, reliable water supply, especially for non-potable demands because they typically reqire lower quality water.[?] In the context of this discussion, we use the term "reclaimed water" to refer to treated effluent from a municipal treatment plant that is at an appropriate quality for reuse and "recycled water" as effluent that has been both treated and reused.[?,?,?] One of the greatest challenges to municipal non-potable water reuse in the United States is fragmentation between regulations and policies outlining appropriate water reuse practices and the existence of discrete, decentralized authority structures.[?,?] Through this work, we provide a brief overview of current water reuse policy in the United States and propose more dedicated approaches to data and knowledge sharing and infrastructure development. We also identify local water reuse projects in states without explicit policy and consider how the absence of policy may incentive local behaviors. Using an inclusive definition of "policy" that includes formal legislation, regulations, department guidelines, or policy statements, we identify 36 U.S. states that have some level of water reuse policy and examine patterns and trends in how individual states define appropriate water reuse. The U.S. government, National Research Council, and numerous non-profit and academic institutions have reviewed the administrative, legal, and regulatory barriers to water reuse.[? ? ? ? ? ?] We complement this discussion by providing an overview of existing state policies and propose potential research questions based on trends and observations found within these policies.

This work considers water reuse policy from three perspectives: the written policy (legislation, regulations, guidelines), management of data and operational knowledge from water reuse projects, and the advancement of water recycling technology and infrastructure. Each of these factors contribute to a holistic policy environment that clearly defines appropriate use of recycled water resources and promotes improved management practices and future development.

2 Policy Analysis

Writing effective policy related to public and environmental health requires diverse considerations and can often be an iterative process where successes and failures of past management practices inform future policies. These challenges exist not only in the United States, but globally, as nations seek to effectively manage reclaimed water resources.[? ? ?] In the absence of federal regulations or guidance beyond the U.S. Environmental Protection Agency's *Guidelines for Water Reuse*, individual states developed water reuse legislation, regulations, and guidelines as early as the mid 20th century, and today we estimate that 36 states have some policies that allow or promote the reuse of reclaimed water as treated wastewater from a central treatment facility. Our analysis is not meant to comprehensively report the details of individual state policies, but rather capture common attributes and differences. We perform this examination by searching existing internet databases,[?] recycled water literature,[?] government sources,[?] individual state websites, and contacting regional EPA representatives.

2.1 Review of State Policies

The initial source we used to examine state policies is the EPA *Guidelines for Water Reuse*,[?] which identifies 11 categories of water reuse and includes a data set of state legislation and regulations that was accurate as of the date of publication in 2012. This resource includes some links to state regulations and provides an initial outline of states for which we should expect to find updated policies. After an extensive internet search for primary documentation from state websites and existing public databases, like the WateReuse Association's State Policy and Regulations Map,[?] we confirmed the results of this review with representatives from the 10 EPA Regions via email and made adjustments based on their responses. We examined the details of water reuse policies using the primary documents collected from each of the 36 states, which are described in SI 1.

First, we categorized states based on the different types of end uses they allowed for water recycling and the level of treatment required for those end uses. We used 40 CFR Part 133 - Secondary Treatment Regulation to define secondary treatment water quality requirements and National Pollutant Discharge Elimination System (NPDES)[?] definitions to define primary and advanced treatment. Primary treatment involves the removal of material that can be settled out by gravity using screening, comminution, grit removal, and sedimentation. "Preliminary" treatment is also a common way to describe this level of treatment. Secondary treatment is defined first by specific water quality indicators and secondly by treatment processes (e.g., activated sludge basins). Effluent is expected to have a monthly average of less than 30 mg/L biochemical oxygen demand (BOD), less than 30 mg/L suspended solids, and a pH between 6 and 9 (40 CFR Part 133). In cases where states describe water treatment as "secondary treatment" or activated sludge treatment or similar terminology but outline water quality indicators more stringent than 40 CFR Part 133, that level of treatment was classified as "advanced" for the purposes of this study. Tertiary, or advanced, treatment is any treatment beyond the secondary level. Some common advanced treatment technologies include filtration, adsorption of organics, or denitrification. If a state categorizes treatment levels in a way that is inconsistent with the EPA in the National Pollutant Discharge Elimination System (NPDES) Permit Writers' Manual,[?] we categorized their treatment level based on the EPA definitions.

We then performed a thematic analysis of these documents to identify common features between state policies and unique characteristics that different states consider to be significant enough to include in written policies. For this process, each state's policies were examined for common features that were defined through manual inductive coding of the text. Features that appeared to be at odds with other state policies or EPA guidelines were noted and we maintained an aggregate count of states with common features. A description of the policy terminology identified in this process is included in SI 2.

2.2 Observations

While each state has developed its own unique water reuse framework, there are also several core attributes that exist across different states (Table 1). The holistic motivation (stated or unstated) behind each state's policy can generally be sorted into those that are intended to encourage conservation of freshwater through the use of reclaimed water and those that are intended to efficiently dispose of treated wastewater. These different motivations can influence specific attributes found within the policy such as the level of treatment required before reuse and approved methods of application. Many of the most common attributes in existing policy are related to the protection of public health and limiting public exposure to potential contaminants in recycled water. Beyond the policy motivations, the specific details within state policies largely influence it effectiveness, enforceability, and accessibility. Overly stringent policy may serve as a barrier to water reuse and place unnecessary burdens on municipalities or potential recycled water users, a concern that Maryland specifically addresses with the language in their guidelines purpose statement.[?] Alternatively, if policy is written with vague or unclear language or published in a format that is difficult to access and enforce, it may be ineffective in protecting human health and the environment.[?]

Specific policy attributes also reveal different degrees of focus on regulating reclaimed water suppliers or end users. Policies addressing treatment and monitoring specifically apply to the municipal body that is treating and distributing reclaimed water, while requirements on application methods, storage, public notification, and setback distances are more likely to affect end-users. Whether these policy attributes focus on the producer or end user, they holistically work together to protect against unwanted human exposure. Different end uses also place different burden on suppliers and users of reclaimed water. If water is applied to an area with a high degree of public exposure, the end users may have a greater responsibility for public notification and detailed requirements on application methods.

In some instances, a lack of statewide legislation has served as motivation for cities and/or counties to take initiative on developing projects and guidelines. For example, the city of Hays, Kansas reuses approximately 25% of its effluent from its Chetolah Creek Water Reclamation and Reuse Facility for irrigating sports complexes and golf fields,[?] even though they have no state-wide water reuse policies. Across the state of Tennessee, there are at least 5 cities (Murfreesboro, Franklin, Pigeon Forge, Spring Hill, and Smyrna) that permit water recycling.[?, ?, ?, ?] These locally driven reclamation projects in states without explicit regulations or guidelines are a testament to individual community's autonomy over water supply and provide evidence for innovation and governance in the absence of policy motivators. Furthermore, the existence of local water reuse projects in the absence of state policies raises the question of how local ordinances or regulation may interact with

Table 1: List of states with common features in their water reuse policies. Definitions of terms are included in SI 2.

Policy Attribute	**Number of States**	**States**
Legislation	1	LA
Regulations	23	AL, AZ, CA, CO, DE, FL, ID, IL, IN, IA, MA, MT, NE, NC, OH, OK, OR, SC, TX, UT, VA, WA, WY
Department Guidelines	12	GA, HI, MD, MN, ND, NH, NJ, NM, NV, PA, RI, WI
Setback Distances	27	AL, AZ, CA, CO, DE, FL, GA, HI, ID, IL, IN, MA, MD, NC, NH, NM, NV, OH, OK, OR, PA, RI, TX, UT, VA, WA, WY
Post-Secondary Treatment	33	AL, AZ, CA, CO, DE, FL, GA, HI, ID, IL, IN, LA, MA, MD, MN, MT, NC, NE, NH, NJ, NM, NV, OH, OK, OR, PA, RI, TX, UT, VA, WA, WI, WY
Application Methods	22	AL, AZ, CA, CO, DE, FL, GA, HI, IL, LA, MD, MT, NC, NM, OH, OK, OR, PA, TX, VA, WA, WY
Monitoring	26	AL, AZ, CA, CO, FL, GA, HI, ID, IL, IN, LA, MD, MT, NC, NE, NJ, NM, OH, OK, OR, PA, TX, UT, VA, WA, WY
Public Notification	29	AZ, CA, CO, DE, FL, GA, HI, ID, IL, IA, NE, MD, MA, MN, MT, NC, NH, NM, NV, OH, OK, OR, PA, RI, TX, UT, VA, WA, WY
Storage Requirements	15	DE, FL, GA, IL, MD, MN, MT, NC, NH, NM, NV, OH, OK, TX, VA
Blending	4	AZ, FL, ID, OR
Direct Potable Reuse	2	AZ, WA

state and federal policies, and at what level are policy initiatives most effective? In the same way that we see states adapting to limited federal oversight, localities and sub-state authorities are innovating and adapting even in the absence of state policies, and may in turn accelerate state-level action.

An underlying theme across states in their approach to water reuse is the protection of human and environmental health. In some cases, human and environmental safety regulations are detailed and rigorous, while others are more vague. One example of this phenomenon is irrigation of pasture land. Our analysis identifies six states that require higher levels of treatment for water applied to pasture for lactating animals than non-lactating animals (Alabama, Arizona, California, Idaho, New Mexico, Ohio, Washington). Additionally, in line with U.S. EPA guidelines, Florida, New Jersey, and Pennsylvania require a 15-day waiting period between irrigation of pasture land and providing access to lactating animals[?] and the state of Delaware requires 1 year of time to pass before allowing access to lactating animals (Delaware Administrative Code, Title 7, 7101 Regulations Governing the Design, Installation and Operation of On-Site Wastewater Treatment and Disposal Systems, 6.3.2.3.6.11.2). Even among states that require the same treatment *processes* for reuse for irrigating pasture land (i.e., secondary treatment with disinfection), they may monitor different water *quality indicators* (e.g., fecal coliform versus total coliform) and have different standards for those indicators. For the case of irrigation of pasture land where lactating animals will have access, Utah limits fecal coliforms to 14 CFU in any single 100 mL sample (Utah Administrative Rules Title 317, Rule 13: Approvals and Permits for a Water Reuse Project), while Arizona requires less than 800 CFU in any single 100 mL sample (Arizona Administrative Code Chapter 11, Article 3. Reclaimed Water Quality Standards). The motivation behind these specific policies are not stated, but they are likely motivated by the desire to avoid environmental bacterial infections like mastitis in lactating dairy cows that may lay down in wet grass.[?] We find that these fine levels of distinctions are not always described for other end uses and sometimes only vague language is used to differentiate between different level of public exposure. Several states require different degrees of treatment based on expected public exposure however, they do not explicitly distinguish between "high" and "low" exposure end uses (e.g., Colorado, Maryland, Wyoming).

Some states reference each other's policies and technical reports as validation for setting treatment standards for reuse, which leads to uniformity in a few specific cases. For example, Idaho references California's Alternative Treatment Technologies report, which matches commercially available water treatment technologies with different water quality standards[?] (IDAPA 58.01.17). The state of Minnesota uses the same water quality and treatment indicators and matching end uses as California, and directly references California's regulations in their water reuse permitting policy[?] (California Water Resource Control Board Title 22, Chapter 3).

Even with some states cross-referencing other state or federal recommendations, there is still a broad range of treatment requirements for water reuse in different states. Some of the most commonly allowed non-potable end uses are for irrigation and industrial purposes such as manufacturing or cooling at power generating facilities (Figure 1). From our review of state policies, we found that states permit water reuse for irrigation of processed food crops or non-food crops based on levels of treatment that range from primary treatment (for land application) to advanced treatment with disinfection. Treatment requirements for irrigation of food crops or industrial purposes have less variability with requirements ranging from secondary treatment with disinfection to advanced treatment with disinfection. The fact that irrigation of processed food crops and non-food crops is the most widely permitted, may be the result of the endurance of land application practices that have historically served as means of waste disposal with the added benefit of providing irrigation and fertilizer for crops land. In comparison, the use of treated wastewater for industrial or power generation or for irrigation of food crops purposes requires intentional policy and infrastructure changes that are a comparatively new adaptation and may have greater instances of human exposure.

These dissimilarities between state policy terminology and specifications reveal a lack of agreement on how to best protect public and environmental health and safety and may lead to some states being overly stringent regarding treatment and monitoring requirements, setback distances, and/or public notification, while others may take a more hands-off approach. These discrepancies introduce several key questions. What degree of uniformity should we expect and strive for in water reuse policy? How do we balance

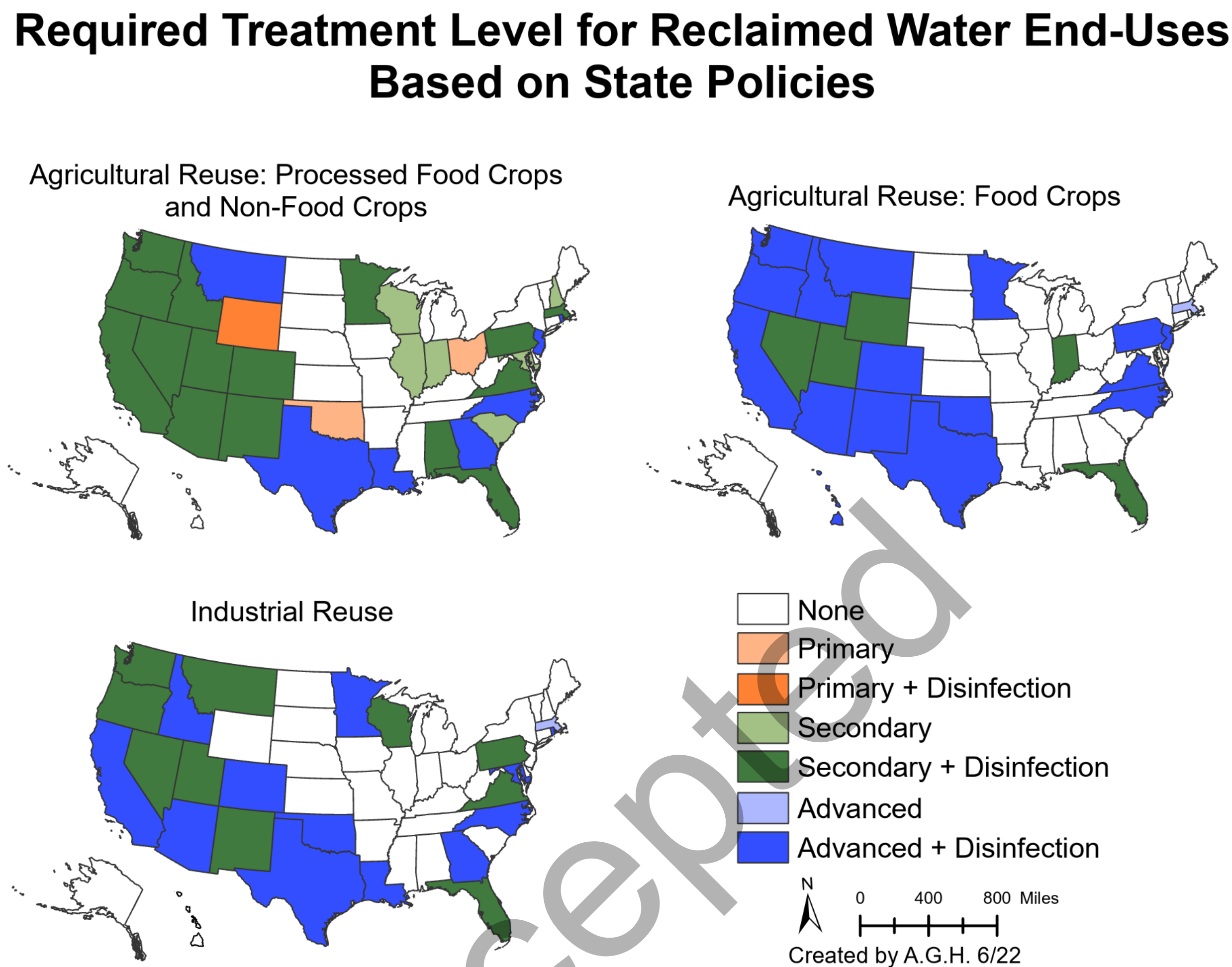

Figure 1: Map of the level of wastewater treatment required before reuse in each state with non-potable water reuse policies for agricultural reuse and industrial reuse including power plant cooling.

detailed, stringent water quality requirements while encouraging broader innovative water reuse?

In light of these dissimilarities and larger policy questions, it is worth recognizing that making general policy recommendations is challenging because water reuse concerns are often highly localized. Soil quality, specific pollutants of concern, county or state-level policies, potential human contact concerns, watershed allocations and return flow considerations, and the history of water supply projects in the area can all contribute to or detract from successful implementation of a project.[?,?] Developing new water reuse policies and adapting existing policies requires thoughtful balancing of the role of federal regulations, state policies, and local authority, and certainly requires continued research on water quality concerns to inform effective policies that protect human health while promoting sustainable water resource management.

3 Improving data collection, management, and sharing

Another challenge that is not clearly addressed in existing water reuse policy is the management of data generated by water reuse projects and new knowledge produced through academic and industry research. These information sources can provide critical data to inform operations and policy development. Researchers, practitioners, and regulators are all in positions to generate new data or knowledge and use data or knowledge from other bodies to inform their actions. In the absence of federal mandates and oversight, the collection of data on existing recycled water projects is limited. The Clean Watershed Needs Survey collects some data on "recycled water distribution systems",[?] The WateReuse Foundation has compiled a database, published by the Department of Energy, of water reuse facilities,[?,?] and individual states (e.g., California, Florida) provide publicly available annual reports on water reuse that can be useful within their specific contexts;[?,?] however, these limitations on current nationwide water reuse data create challenges for transparency, accountability, and benchmarking.

Interactions between researchers, policy makers, and practitioners have a number of feedback loops around water reuse data and knowledge. Practitioners can generate data from existing systems related to treatment processes, distribution systems, public acceptance, and successful practices. Across the hundreds of existing water reuse projects in the United States, there is a wealth of data and knowledge that can inform academic research and experimentation and provide essential background for new policy developments. Researchers can help in the development of best practices and treatment recommendations to inform decisions around different wastewater treatment levels and end uses. From the data and knowledge gathered and generated by practitioners and researchers, policy makers can then develop guidelines and regulations that are data-informed and practical. At the same time, policy can be written in such a way to promote the generation and sharing of new data, which we see at the federal level in environmental agencies such as the Energy Information Administration within the Department of Energy or the Clean Watershed Needs Survey as mandated by the Clean Water Act.

The scale at which data are collected, managed, and published is another policy question that must be considered. Data from existing projects are generated at a number of scales and can be aggregated to different geographic and organizational scales, presenting opportunities for innovative research along with responsibilities to collect, manage, and distribute these data.[?,?] For example, Florida reports water reuse data at the county level, water district level, and by Department of Environmental Protection district.[?] Each of these scales may be more or less convenient for reporting purposes, but each lacks a spatial association with specific reclaimed water facilities and end users. Alternatively, in the EPA's Clean Watershed Needs Survey and WateReuse Association database, specific wastewater treatment plants are identified, but these sources include no information on end uses. These data serve a purpose and provide some information for data users, but challenges remains in determining the spatial and temporal scales that are most beneficial for interested bodies including operators, regulatory bodies, consumers, and researchers.

Water reuse is typically a localized practice and heavily dependent on unique community conditions. A relevant question for practitioners is whether or not knowledge and data from a single project are transferable to other projects. What are insights that can be drawn from existing projects and what data are too location-specific to have value outside of their context? Questions of what water quality is required for different end uses, considering human health, can be transferable between different contexts if the level of human exposure is similar. However, issues around water reuse in agriculture can affect soil and groundwater quality differently given different physical conditions.[?,?,?] Specific contaminants might be more common in source water for one reclaimed water facility and not another. We have the potential to accelerate effective water reuse practices if we can draw generalizable knowledge from existing water recycling projects, but this is not an easy question to answer and is a challenge across may engineering disciplines.

4 Advancing technology and infrastructure

Many of the issues around recycled water data management also apply to the treatment technologies and infrastructure that *are being used* and *can be used* to facilitate water recycling. The United States is currently in a position where some states have developed water reuse policies requiring stringent treatment processes beyond the capacity of many or all of their current wastewater treatment facilities (e.g., Minnesota, Texas). Other states may have relatively advanced wastewater facilities, but have minimal treatment requirements before reuse (e.g., Ohio, Wisconsin). Analogous to a "demand pull" or "technology push", which are used as explanations for innovation in technology, with some limitations,[?] these policy and technology or infrastructure incongruities may motivate further innovation in the water reuse sector. State policies may act as a "policy pull" by creating a demand for more advanced wastewater treatment infrastructure, motivating municipalities to improve existing treatment facilities or construct entirely new water recycling facilities given sufficient financial resources. We may see this policy pull play out within the state of Minnesota where water reuse for industrial purposes like closed-loop cooling in power plants requires water treated with advanced treatment methods and disinfection,[?] but as of the 2012 Clean Watershed Needs Survey, there were no wastewater treatment facilities within the state that treated wastewater to that level.[?] This policy incongruity may be the result of Minnesota copying their water reuse policy from California, which has 13 municipal wastewater facilities with advanced treatment processes and disinfection.[?] The converse may also be true that as treatment technologies advance, they may motivate states to develop more stringent wastewater treatment regulations, known as a "technology push". An example where this push may occur is the state of Ohio, which has over 500 treatment facilities using advanced treatment technologies with disinfection of wastewater and currently has limited water reuse policy, only allowing land application of reclaimed water, which is primarily presented as an alternative disposal method for treated wastewater (Ohio Administrative Code Rule 3745-42-13).[?] This balance between "policy pulls" and "technology pushes" and similar policy frameworks have been studied in the context of innovation and adoption of renewable energy technologies that exist within a market, but may also have influence over municipalities and water utilities.[?,?]

One place we may be seeing this "technology push" in action, is in public universities, which, though they are partially funded and governed by state governments, often have the flexibility and autonomy to influence their surrounding communities and develop innovative technologies and practices that can support widespread technology adoption. For example, both the University of Connecticut and Emory University use treated wastewater for non-potable end uses on their respective campuses and can serve as case studies for newer water reuse technologies.[?,?] Combining academic research with practical applications can help demonstrate the efficacy of these technologies while simultaneously advancing operational knowledge. Universities can also partner with local utilities for reuse projects. For example, the University of North Carolina-Chapel Hill was the motivation behind the city of Chapel Hill developing a recycled water system in 2009.[?] The University paid for 25% of the construction costs for the facility and uses reclaimed water to irrigate on campus.[?]

One way the tension between policy and technology plays out is that some states specifically mandate treatment processes with few or no related water quality indicators whereas others outline detailed water quality indicators (Figure 2). Water quality based standards represent a departure from the Clean Water Act's technology based standards and are more similar to the Clean Air Act which determines Ambient Air Quality Standards.

Pairing of water quality with technology standards requires in-depth testing and analysis of commercially available treatment technologies. The California State Water Resources Control Board has done some work to assimilate these two approaches and match commercially available treatment technologies with recycled water quality requirements in their Alternative Treatment Technology Report for Recycled Water.[?] Additionally, the detail and specificity of water quality indicators are constrained by monitoring capabilities. The advancement of water quality monitoring is not just an issue for water reuse, but presents an example of potential sharing of knowledge and technology between the traditional wastewater treatment industry and water reuse.

Infrastructure and technology considerations naturally include a number of economic factors that can influence the feasibility of new water reuse projects and sustainability of existing projects. Across the United States, there are examples of municipalities choosing to build entirely new water recycling facilities,[?] while others retrofit and expand existing wastewater treatment plants;[?] there is a wide range of costs associated with either new construction or retrofitting different treatment trains.[?] For small non-potable reuse projects, the cost of constructing new distribution lines may make up a majority of the total costs of a project,[?] but in other cases advanced treatment processes may dominate total costs.[?] Pricing reclaimed water to internalize these costs while balancing affordability is the subject of a growing body of literature from academic, professional, and regulatory bodies.[?,?,?,?] The state of Louisiana, for example, has directly addressed this issue by requiring that the cost of reclaimed water (including transportation) be less than alternative potable water supplies in certain contexts (LA Rev Stat § 30:2396). Based on market forces, pricing reclaimed water below potable water is a common practice, but makes it very challenging to recover capital and operational costs of reclaimed water systems.[?]

Excerpt from Illinois Design Standards for Slow Rate Land Application of Treated Wastewater

Section 372.400 Degree of Treatment Required Relative to Application Area

A) Agricultural Areas

Agricultural or forested areas that do not have public access shall provide at a minimum a two cell lagoon system or a mechanical secondary treatment facility

B) Urban Areas

Urban parks, forest preserves and golf courses and other areas with public access shall utilize as a minimum two cell lagoon system with tertiary sand filtration and disinfection or a mechanical secondary treatment facility with disinfection

Excerpt from North Carolina Administrative Code Reclaimed Water Effluent Standards

15A NCAC 02U .0301 RECLAIMED WATER EFFLUENT STANDARDS

(a) Reclaimed ater treatment processes producing an effluent quality prior to storage, distribution, or utilization that meets the parameter limits listed below shall be classified as Type 2:

(1) monthly average five-day biochemical oxygen demand (BOD5) of less than or equal to 5 mg/L and a daily maximum BOD5of less than or equal to 10 mg/L;

(2) monthly average total suspended solids (TSS) of less than or equal to 5 mg/L and a daily maximum TSS of less than or equal to 10 mg/L;

(3) monthly average ammonia (NH3-N) of less than or equal to 1 mg/L and a daily maxi imum NH3-N of less than or equal to 2 mg/L;

(4) monthly geometric mean Escherichia coli (E. coli) or fecal coliform level of less than or equal to 3/100 mL and a daily maximum E. coli or fecal coliform level of less than or equal to 25/100 mL;

(5) monthly geometric mean Coliphage level of less than or equal to 5/100 mL and a daily maximum Coliphage level of less than or equal to 25/100 mL;

(6) monthly geometric mean Clostridium perfringens level of less than or equal to 5/100 mL and a daily maximum Clostridium perfringens level of less than or equal to 25/100 mL; and

(7) maximum turbidity of 5 Nephelometric Turbidity Units (NTUs).

Figure 2: Excerpts of state policies describing different reclaimed water requirements for different classes or end uses. Illinois standards are based on "degree of treatment" compared to North Carolina which is based on an "effluent standard."

5 Conclusions and path forward

Technical advancements in water reuse can be hindered by unclear water reuse policies and limited sharing of operational data and knowledge. Our analysis finds that many utilities have adapted existing infrastructure, policy, and data to fit the needs of water reuse projects, even though this interpretation is a departure from their original purpose. As these reuse practices saturate water supply portfolios, we see the development of new technologies and policies that are specifically devoted to water recycling. Clear water reuse policies, readily available water data and operational guidelines, and devoted infrastructure can help facilitate reuse by lowering barriers that may halt local progress. However, each individual utility faces unique challenges and has particular resources available for the implementation of water recycling projects.

There are a variety of factors that may motivate a municipality to consider recycled water as an alternative to traditional freshwater sources.[?] Many western states face severe water scarcity and are innovators in reclaimed water policy, data sharing, and technology. However, water reuse can also be motivated by specific local water challenges, protection of groundwater resources (e.g., Maryland), or concerns over the water quality effects of discharges (e.g., Oregon, Illinois). With a diversity of motivations comes a diversity of approaches to water reuse from a technical and regulatory perspective. Improving management of reclaimed water resources will require cohesive efforts in developing effective water reuse policies, data management and sharing plans, and advancement of treatment technologies and related infrastructure. Progress towards some of these goals is being made by a group of collaborators under the National Water Reuse Action Plan (WRAP) facilitated by the U.S. EPA. The actions outlined in this plan include many of the issues we raise in this analysis, with on-going work through partnerships between NGOs, governing bodies, researchers, and practitioners.[?] WRAP is a valuable contribution to the discussion around water recycling and can help address many of the practical barriers that stand in the way of widespread water reuse and recognizes the distinct different bodies that must contribute to the advancement of these projects. Our work complements some of the WRAP actions specifically Action 2.1: Compile Existing State Policies and Approaches to Water Reuse. Some of the policy shortcomings we identify in this work may also be achieved through WRAP actions like Action 3.1: Compile Existing Fit-for-purpose specifications, Action 5.2: Identify Water Quality Monitoring Practices for Reuse Applications, among others. We hope that our analysis can serve as independent validation for some of the WRAP actions and stimulate greater engagement from seemingly distinct academic communities.

A wide spectrum of water reuse policies, infrastructure, and data management may signal a lack of understanding and clarity around the best use of reclaimed water resources in the United States. A lack of clear guidance can unnecessarily burden local decision makers and may have far reaching impacts on environmental and human health.[??] Without proven scientific recommendations from scientists and researchers regarding water quality standards for different end uses, policy makers are left to develop water reuse guidelines and regulations that may be arbitrarily strict or lenient. These issues must be addressed by researchers with diverse expertise including engineering, toxicology, public health, and others. Effective policy should be detailed enough to satisfy public health needs in a variety of circumstances, but also flexible enough for utilities to understand and adapt to their unique context. By considering the interactions between water reuse policy at multiple governance scales, the generation and management of operational data, and adaptation and development of new water reuse technologies and infrastructure, we can identify the most pressing management gaps and progress in our utilization of valuable non-traditional water resources.

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Supporting Information Available

The following files are available free of charge.

- SI 1- Table of state policy sources: list of sources used for policy review
- SI 2- Description of policy terminology

383 # TOC Graphic