Identifying Workforce Education, Training, and Outreach Needs in Decentralized Wastewater and Distributed Water Reuse

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Abstract **Although decentralized wastewater and distributed water reuse professionals represent a key part of environmental public health and environmental engineering, an understanding of workforce challenges has remained elusive. Here we begin to address the critical need of understanding education, training, and outreach needs for decentralized wastewater and distributed water reuse. We specifically engaged professionals working in health departments and other government agencies, industry, academia, and nongovernmental organizations. We examined workforce characteristics related to education, training, and outreach. We found that 37% of decentralized wastewater and distributed water reuse professionals plan to retire within 5 years, approximately 25% of these professionals do not hold any type of certification, and education and training are insufficient to meet current workforce demands.**

We further report 10 problem statements associated with timely education, training, and outreach needs, which represent important opportunities for improving the practice of decentralized wastewater and distributed water reuse. Strategic education, training, and outreach activities are necessary to ensure workforce preparedness, to promote education with owners of onsite technologies, and to expand advanced training and translational research programs in decentralized wastewater and distributed water reuse. Our findings can specifically support decision making aimed at sustaining and advancing the decentralized wastewater and distributed water reuse workforce.

Introduction

Decentralized—or onsite—wastewater and distributed water reuse is a core part of environmental public health and environmental engineering, which is commonly managed by environmental health practitioners at the local level of government. In the U.S. alone, it is estimated that 1 in 5 households depend on septic tanks or some other form of decentralized (or onsite) wastewater treatment system. In the Houston–Galveston region of Texas, for example, more than 300,000 onsite wastewater systems exist (Houston–Galveston Area Council, 2023).

Decentralized systems are expected to become increasingly important and widespread in the future, as 1 in 3 newly built homes are using onsite systems in the U.S. (U.S. Environmental Protection Agency [U.S. EPA], 2021a). Historically, onsite systems have been used commonly in rural areas where centralized municipal water treatment is infeasible. Onsite systems could serve more communities in the future, however, as they have been identified as sustainable and affordable alternatives to centralized systems. Decentralized and distributed water reuse technologies are advancing, and the use of onsite systems is growing around the world across urban–periurban–rural gradients.

Decentralized wastewater and distributed water reuse professionals are responsible for delivering essential environmental public health services that aim to protect and promote the health of all people in all communities (Centers for Disease Control and Prevention, 2023). Properly functioning decentralized wastewater systems are crucial for protecting public health in small, rural, and periurban communities. Professionals in onsite wastewater and distributed water reuse contribute to the design, preparation, installation, operation, maintenance, and regulation of decentralized wastewater systems.

Without a competent and well-equipped workforce, however, decentralized wastewater programs can fail to deliver essential environmental public health services, and when this occurs, can also fail to protect public health and the environment. Over the past 20 years, the onsite wastewater and distributed water reuse workforce consistently has been noted as an issue of potential concern in environmental health and environmental engineering (Boepple-Swider, 2008; Converse, 2004; Deal et al., 2004, 2007; Grigg, 2009; Guvernator & Landaeta, 2020; Hacker & Binz, 2021; Olstein, 2005; Reid et al., 2007; Rupiper & Loge, 2019; Siegrist, 2014; Spirandelli et al., 2019; Struck, 2008).

In 2021, in response to these workforce concerns, the U.S. Environmental Protection Agency (U.S. EPA, 2021a, 2021b, 2021c) released three reports focused on workforce implications in decentralized wastewater. Important data gaps for the onsite wastewater workforce remain, including types of occupation, demographic characteristics, and strategies to improve education and training programs needed for jobs in the future (U.S. EPA, 2021b). In addition, The Water Research Foundation (2022) examined barriers and opportunities for onsite and distributed water reuse implementation in the U.S. by specifically embracing a "One Water in the 21st Century" approach that considers all urban waters (e.g., drinking water, stormwater, wastewater) as interconnected within a systems-based context.

Horizon scanning—a common tool in public health—presents a useful approach to identify emerging problems and needs in science, engineering, and health disciplines. The Understanding the Needs, Challenges, Opportunities, Vision, and Emerging Roles in Environmental Health (UNCOVER EH) initiative—led by the Centers for Disease Control and Prevention, the National Environmental Health Association (NEHA), and Baylor University—reported workforce characteristics (Gerding et al., 2019), identified practice-based research needs (Brooks et al., 2019), and provided recommendations to advance the practice of environmental public health (Gerding et al., 2020). A number of professional priorities were also identified related to hiring and retaining appropriately trained professionals (Brooks & Ryan, 2021).

Because education and training needs for decentralized wastewater and distributed water reuse remain poorly understood, the National Onsite Wastewater Recycling Association (NOWRA) and Baylor University launched the Needs for Onsite Wastewater Recycling Research (NOW-R^2) initiative with diverse partners. Partners included professionals in multiple disciplines who work within health departments, different segments of the industry, and academic educators and researchers. NOW-R^2 employed workforce assessment and horizon-scanning methods to examine decentralized wastewater education, training, and research needs by considering diverse practice perspectives in this field.

We report key findings from a web-based survey, which we anticipate can inform workforce development efforts in the future. Our findings from diverse perspectives and geographic regions represent an initial attempt to understand education and training needs for decentralized wastewater and distributed water reuse practitioners in the U.S. Furthermore, our findings can inform related activities in other countries.

Methods

To identify priority research needs in onsite wastewater, the NOW-R^2 survey followed a model used in previous horizon-scanning exercises (Boxall et al., 2012; Brooks et al., 2019; Fairbrother et al., 2019; Furley et al., 2018; Gaw et al., 2019; Gerding et al., 2019, 2020; Leung et al., 2020; Rudd et al., 2014; Van den Brink et al., 2018). We identified potential survey respondents through NOWRA membership or attendance at previous NOWRA meetings; State Onsite Regulators Association membership; National Association of Wastewater Technicians membership; and select NEHA members who work in this field. In addition, we conducted a review of the refereed literature, which identified corresponding authors who had published on decentralized wastewater. Thus, our group of potential survey respondents included professionals from a diverse array of academic institutions, government agencies, businesses, and nongovernmental organizations.

The NOW-R^2 survey was launched in 2021 and remained open for 6 weeks. Follow-up with respondents included five points of contact during the survey response period, following a standard internet survey delivery protocol (Dillman et al., 2014). The survey included multiple parts, was designed to take ≤30 min to complete, and respondents could choose to leave the survey at any time without completing it. Only fully completed responses were included in our analysis. Our study specifically followed established methods previously described by Gerding et al. (2019) and Brooks et al. (2019) and was approved by the Institutional Review Board at Baylor University.

The web-based survey consisted of multiple-choice and open-ended questions. Multiple-choice questions collected data on basic demographics, education and training, employment history, and other professional information about the survey respondents to understand the current status of the workforce. We also asked open-ended questions related to professional needs and challenges for the future of decentralized wastewater and distributed water reuse: "Within the next 5–10 years, what decentralized wastewater issues or challenges will require new or modified programs or technologies?" and "What resources or tools will you need to do your job in the future?"

By the end of the survey period, we received 454 responses from professionals across multiple sectors (e.g., academia, government, industry, nongovernmental organizations) and disciplines. We partitioned these open-ended responses into common themes, one of which was workforce education, training, and outreach. We examined 55 responses that were directly related to workforce education, training, and outreach needs for overlap. We then identified common problem statements, which are discussed in this article.

Results and Discussion

Demographics

Of the survey respondents, one half (50.2%) were at least 55 years of age. More specifically, the largest age group (26.7%) was 56–65 years. Overall, <1% of respondents were under 25 years and 7.9% represented the next-lowest age group bracket of 26–35 years. The majority of respondents (78.4%) self-identified as male. All categories of race were represented by decentralized wastewater professionals in the survey. The most frequently reported race was White (91.4%), followed by Asian (4.4%), Native American or Alaska Natives (2.0%), Black or African American (1.5%), and Native Hawaiian or Pacific Islander (0.7%). Furthermore, 4.2% of respondents reported being Hispanic. Increasing the diversity of the decentralized workforce represents a timely and important education and training opportunity.

Employment Characteristics

The results of our survey indicate that respondents are highly experienced in decentralized wastewater and distributed water reuse. The largest group of respondents reported >30 years of work experience in the industry (21.6%), and nearly one half (45%) had at least 20 years of experience (Figure 1). The second largest group of respondents, however, reported entering the profession only within the last 5 years (16.8%). Respondents in other age groups were fairly evenly distributed. The survey also asked professionals about their retirement plans; we found that 37.0% of respondents plan to retire within the next 5 years. This percentage is higher than the number of environmental health professionals (26.0%) who were asked the same question during the UNCOVER EH initiative, which only examined environmental public health professionals working in health departments (Gerding et al., 2019). Nearly one half of the professionals surveyed worked in the business sector (47.5%), while 34.9% were employed by governments at the federal, state, local, or territorial levels (Figure 2). The remaining professionals were employed by academic institutions (10.4%) or nongovernmental organizations (7.3%).

The decentralized wastewater and distributed water reuse workforce represents a variety of different occupations, which was reflected by the diversity of professionals who responded to the survey (Figure 3). The most commonly reported job types included engineer (15.4%), environmental health professional (13.0%), installer (12.2%), and designer (9.8%). The survey included, however, representation from all occupations in the industry, from educators and researchers to professionals focused on the design, installation, maintenance (including pumpers), and regulation of onsite systems. Moreover, onsite and distributed water reuse professionals earn a wide range of salaries. The three most common salaries reported were ≥$145,000 (9.9%), $95,000–$104,999 (9.5%), and $65,000–$74,999 (9.3%).

FIGURE **1**

Years of Experience of Professionals Working in Decentralized Wastewater and Distributed Water Reuse

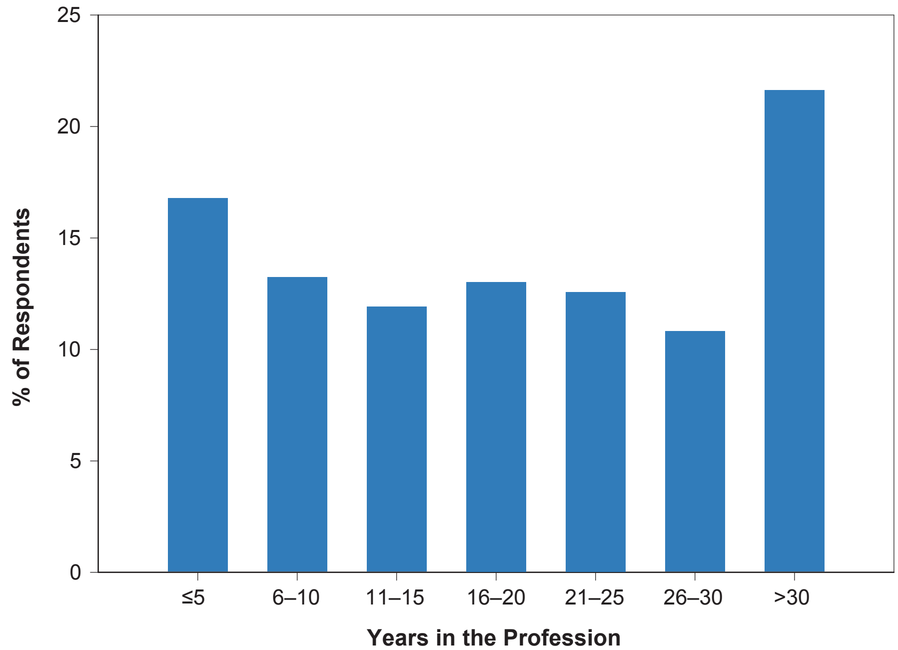
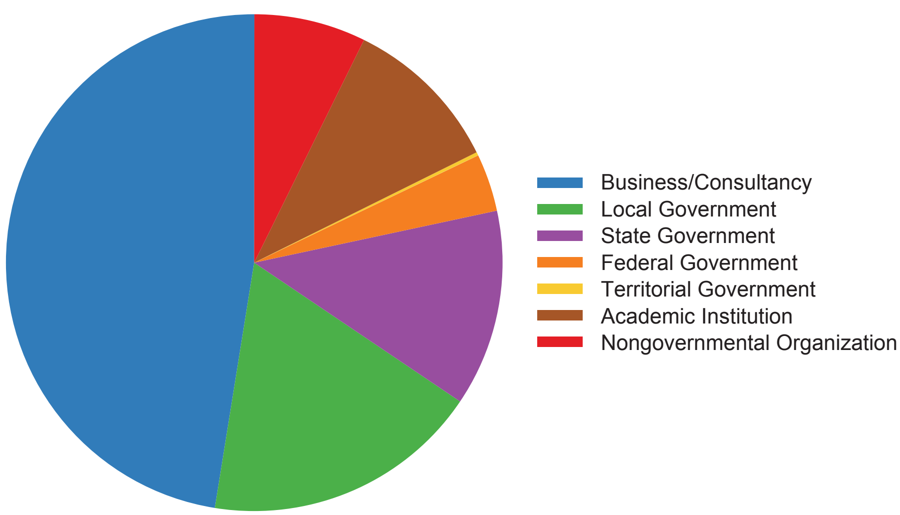


FIGURE **2**

Employers of Professionals Working in Decentralized Wastewater and Distributed Water Reuse

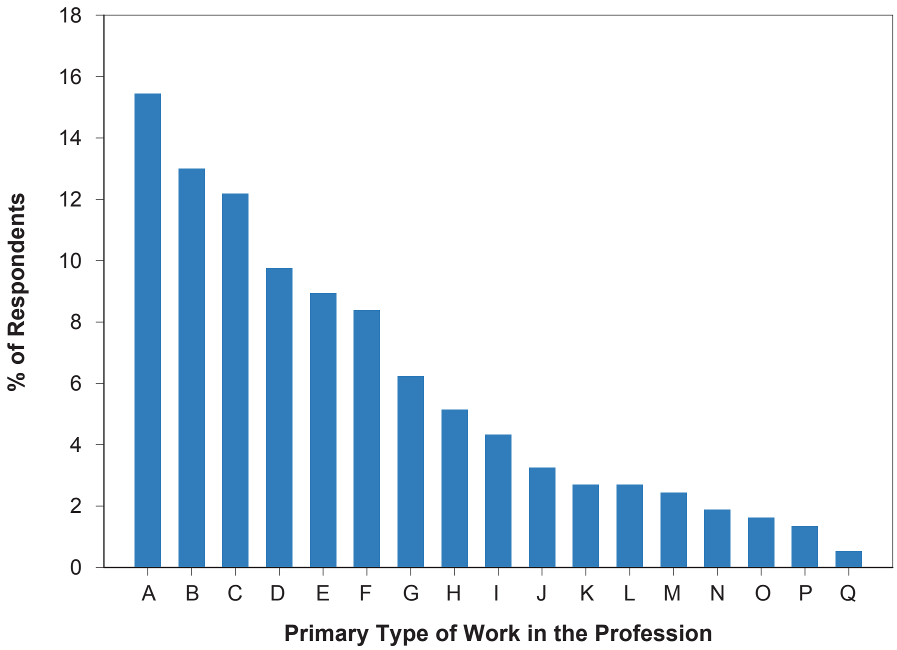


Education

Professionals in the decentralized wastewater and distributed water reuse workforce vary in their level of higher education attained. The

FIGURE 3

Primary Type of Work Performed by Decentralized Wastewater and Distributed Water Reuse Professionals



Note. A = engineer; B = environmental health; C = installer; D = designer; E = regulator at tribal, territorial, or state level; F = academic researcher; G = service provider; H = public inspector; I = academic educator; J = soil scientist; K = government researcher; L = soil evaluator; M = pumper; N = operator; O = private inspector; P = regulator at federal level; Q = funder.

most commonly reported degree attained was a bachelor's degree, reported by 32.8% of survey respondents. The next most common degrees were master's degree or equivalent (26.3%), high school diploma or GED (23.5%), doctoral degree or equivalent (10.8%), and associate degree (5.8%).

In addition to educational degrees, many professionals in decentralized wastewater are required to obtain credentials to do their work, including certifications and licenses. Our survey results indicated that 26.0% of respondents do not hold any type of certification. Of those certified, the majority are certified through the state government (58.4%), while other certifications are administered by local governments (13.9%) or professional associations (4.8%). Respondents reported a wide variety of certifications and licenses (Figure 4). The most commonly reported certifications include Certified Installer of Onsite Wastewater Treatment Systems (CIOWTS), Professional Engineer (PE), and Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS).

Continuing Education and Training

As part of the NOW-R[2] survey, we asked respondents four questions about their continuing education and training (Table 1). When asked about the frequency of completing continued education, 72.8% of the surveyed professionals reported completing continuing education annually, whereas others reported every 2- or 3-years (12.1% and 3.4%, respectively) or more than once per year (3.8%). Most respondents (64.0%) indicated that they had completed training within the last year, and over 90% completed training in the last 3 years. Over one half completed training in person (52.7%), while 39.3% completed training virtually. Although only 7.9% of respondents did not attend continuing education over the previous 3 years (2018–2020), this number increased to 36.0% in the past year and thus the lower numbers might have resulted from the global COVID-19 pandemic. The pandemic was specifically identified by 15.0% of respondents as precluding opportunities for continuing education (Table 1).

Problem Statements

From responses to open-ended questions related to future needs and challenges, we identified common themes and then developed 10 problem statements for workforce education, training, and outreach. These statements represent important opportunities for the practice of decentralized wastewater and distributed water reuse.

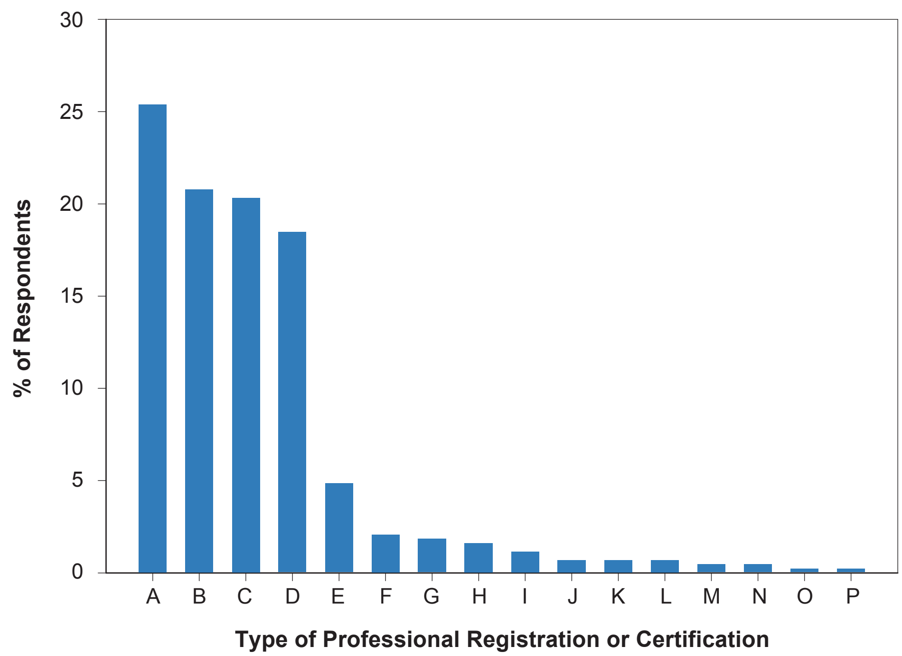
1. **There is a decline in the number of onsite wastewater professionals due to an aging workforce and retirements.**
   The onsite and distributed water reuse workforce consists of many highly experienced, long-term professionals who are retiring at increasing rates, especially over the next 5–10 years (U.S. EPA, 2021c). Almost one half of our survey respondents reported having at least 20 years of experience working in the profession. As noted previously, 37.0% of survey respondents indicated that they plan to retire within the next 5 years, which is greater than the reported percentage (26%) of environmental public health professionals working in health departments who plan to retire within the same period (Gerding et al., 2019). This anticipated high number of professionals planning to retire creates the problem of who will train new professionals in the future. The decline in professionals is an even larger issue given the fact that the field of decentralized wastewater is experiencing further growth, with 17 of 34 occupations designated as "Bright Outlook" jobs (U.S. EPA, 2021a). There already are a large number of existing onsite systems nationwide that require routine maintenance—and newer, more technologically complex systems are installed each year at increasing rates. The number of students studying environmental health alone in higher education, for example, is insufficient to meet this need (Brooks et al., 2019; Gerding et al., 2019).
2. **University-level programs in onsite wastewater that train new professionals and conduct critical research on decentralized systems are limited.**
   As noted during listening sessions held by the U.S. EPA at the 2018 NOWRA Mega-Conference and the 2019 NEHA Annual Educational Conference, increasing opportunities for onsite and distributed water

reuse education in universities, technical colleges, and community colleges are needed (U.S. EPA, 2021b). There appear to be few bachelor's degree programs that include concepts and principles in decentralized wastewater, which results in many professionals having to learn on the job and/or rely on continuing education training programs (U.S. EPA, 2021b). Respondents emphasized a need to foster college-track coursework to guide new professionals into the workforce. In addition to coursework, there is a need to expand research opportunities involving graduate students as well as the number of experts in the field who train students and conduct research specifically in decentralized wastewater.

3. **Continuing education classes do not consistently include hands-on, engaging, or effective best practices or educational techniques and often do not keep pace with the development of more advanced decentralized technologies.**
   Typically, training courses are provided by state- and national-level associations for continuing education credit, and the majority of respondents have received training in the past few years. U.S. EPA (2021a) recognized, however, that many continuing education classes use outdated curriculum and course materials, such that there is a need for improved communication and partnership between the private sector and educators to keep continuing education classes updated and effective. These observations are consistent with survey respondents, who emphasized that training programs must adapt as new technologies emerge and alter industry practices. Decentralized wastewater and distributed water reuse professionals are also concerned that continuing education classes are boring and ineffective. Training should be hands-on when possible and include testing and follow-up based on worker performance in the field.
4. **A shortage of education and training programs limits the number of qualified, certified, and experienced professionals in the onsite wastewater workforce.**
   Similar to other areas of public health in general—and environmental public health in particular (Brooks & Ryan, 2021; Gerding et al., 2019)—the onsite and distributed water reuse field appears to be experiencing a shortage of qualified workers in all stages of the life and planning of onsite systems (U.S. EPA, 2021c). Survey responses further reinforced this perception with many survey respondents expressing difficulty in finding properly educated people with the required credentials to fill entry-level roles. Training programs are especially important for workers in the private sector, who frequently may not receive formal higher education and instead often learn while on the job. Technical and community colleges might be effective in providing opportunities to expand relevant training program offerings (U.S. EPA, 2021c). Another problem arising from education and training programs is that public sector professionals might not hold the same credentials or licenses as private sector workers and vice versa, which could result in challenges with regulatory implementation within the decentralized wastewater and distributed water reuse field (U.S. EPA, 2021a).
5. **Recruitment of early-career professionals and awareness of employment opportunities in onsite wastewater is limited.**
   The aging workforce needs to be addressed with new hiring, career path promotion, and marketing of the industry and opportunities in multiple sectors. Current recruitment of new professionals, specifically at earlier career stages, is not meeting hiring demands across the nation. Recruitment efforts of new professionals might be limited because of a lack of awareness of career opportunities. Of 34 decentralized wastewater occupations that U.S. EPA (2021a) outlined, one half of these occupations were categorized as "Bright Outlook" jobs, and over one half (58%) of

FIGURE **4**

Certifications Held by Decentralized Wastewater and Distributed Water Reuse Professionals



Note. A = none; B = Certified Installer of Onsite Wastewater Treatment Systems (CIOWTS); C = Professional Engineer (PE); D = Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS); E = Certified Professional Soil Scientist; F = Certified Environmental Professional; G = Certified in Public Health (CPH); H = Certified Professional Geologist (PG); I = Professional Land Surveyor; J = Board Certified Environmental Engineer (BCEE); K = Board Certified Environmental Scientist (BCES); L = Certified Hazardous Materials Manager (CHMM); M = Certified Safety Professional (CSP); N = Healthy Homes Specialist (HHS); O = Certified Health Education Specialist (CHES); P = Certified Industrial Hygienist (CIH).

TABLE **1**

Continuing Education and Training of Decentralized Wastewater and Distributed Water Reuse Professionals

Survey Question and Response	Respondents (%)
Have you completed any training courses in the last year?	
Yes	64.0
No	36.0
How often do you typically attend continuing education?	
More than once per year	3.8
Annually	72.8
Every 2 years	12.1
Every 3 years	3.4
None	7.9
What type of training have you attended in the last 3 years?	
In person	52.7
Virtual/online	39.3
None	7.9
How was your continuing education affected by COVID-19?	
Not at all	20.7
No opportunity for continuing education	15.0
Attended virtual/online training	64.3

these occupations were also categorized as "Green Jobs" that include environmentally focused practices. Similar to other public health disciplines, however, small or rural communities often struggle with recruitment and retention due to challenges in offering competitive wages (U.S. EPA, 2021a). Recruitment efforts, therefore, must also improve the economic desirability of work in the profession.

6. **Public awareness of the importance of onsite wastewater systems and the sustainability benefits of decentralized technologies are limited.**
   Onsite wastewater systems are reliable and an economically advantageous alternative to centralized systems. When installed and maintained properly, these decentralized systems protect public health and the environment, particularly in rural or underserved areas and regions that are increasing wastewater reuse. For example, it is estimated that in the U.S., 1 in 5 homes use decentralized wastewater and 1 in 3 new homes employ onsite wastewater systems (U.S. EPA, 2021b). Despite the advantages and prevalence of onsite systems, public perception of the field remains uninformed, antiquated, and/or negative, and therefore this status needs improvement. The public appears largely unaware of why onsite wastewater treatment technologies are important to protect public health and the environment, or how onsite systems operate. Improving public awareness of onsite wastewater with a better understanding of its impacts and benefits can inform local decision making (U.S. EPA, 2020; The Water Research Foundation, 2022), especially given the diverse impacts of climate change on water resources and public health.
7. **In contrast to centralized systems, information on onsite wastewater recycling treatment locations, operational performance, inspection records, and system failures is not available in publicly accessible databases.**
   Survey respondents indicated that onsite and distributed water reuse data and information systems are not consistently accessible. In fact, a lack of available performance data for different onsite wastewater treatment technologies to address emerging threats has been identified previously as a practice-based research need (Brooks et al., 2019). In addition, a U.S. EPA memorandum of understanding (MOU) recently established the priority of providing accurate, up-to-date data and information on the use and performance of onsite systems (U.S. EPA, 2020). Subsequently, resources can be wasted due to an inability to effectively communicate within and among sectors. Development of effective information systems and data sharing would enable improved environmental management of onsite wastewater systems while improving communication and cooperation among decentralized wastewater professionals. Further, publicly available information on inspection reports and failing systems can be used in community health education programs to engage homeowners and businesses to promote better maintenance of their systems. Information systems might also create accountability for designers and installers to complete required inspections, and publicly accessible databases for surveillance data can support watershed-scale management and risk communication efforts.
8. **Users of onsite wastewater technologies do not have adequate access to training and other resources on proper use, operation, and maintenance of their systems.**
   Public information and online resources for owners of onsite wastewater treatment systems to directly interact with system technologies are not consistently available, or onsite system users are not aware of existing resources. Operation and maintenance resources would assist homeowners to maintain their systems, inform proper use such as avoiding flushing specific items into the treatment system, and recognize possible performance issues. One of the objectives of the U.S. EPA MOU is to better support homeowners by providing outreach and education materials on onsite technologies, such as the SepticSmart program (U.S. EPA, 2020), but the processes and prospects to accelerate doing so across states, tribes, and territories are not clear. In addition, NOW-R^2 respondents

suggest holding training sessions for property owners and training real estate agents to communicate the requirements of maintaining a septic system to potential homeowners. Mechanisms also need to be developed to afford service providers with opportunities to communicate with existing customers about different onsite wastewater treatment systems. For example, it is not clear the extent to which performance of decentralized wastewater and distributed water reuse technologies are specifically examined during housing inspections prior to completion of real estate transactions within and across states, tribes, and territories. Improving this process through public (e.g., local public health) and private (e.g., real estate lending and insurance) partnerships could provide a consistent mechanism to facilitate assessment and communication of system performance when property ownership changes through time.

9. **Consistent funding approaches and incentive programs for implementing best practices in the operation and maintenance of advanced onsite wastewater technologies are lacking at the local level.** Survey respondents specifically indicated a need for funding at both the state and federal levels to administer onsite programs. The 2020 U.S. EPA MOU established as a priority the pursuit of public and private funding options to help communities maintain systems (U.S. EPA, 2020). Funding for local programs, however, is not consistently available, and environmental public health delivery systems are not equitable within and among counties, states, tribes, and territories. Incentives are needed to establish improved structures to provide oversight and to assure continuing education for professionals.
10. **Lack of information exchange with other disciplines (e.g., medicine) and programs (e.g., environmental health disease tracking) limits opportunities to address emerging issues in onsite wastewater and distributed water reuse.** External partnerships with professionals outside of onsite and distributed water reuse are needed to successfully engage major issues in public health and environmental protection. Though previous efforts have called for strengthening of external partnerships (U.S. EPA, 2020), collaborative efforts and nontraditional partnerships are needed with disciplines that are not routinely engaging the onsite wastewater profession. For example, sharing with the medical community geospatially explicit information for failing decentralized systems can help identify potential causative relationships when increasing clinical rates of an illness (e.g., hookworm) are identified in local communities (McKenna et al., 2017). Partnerships with community health education specialists in health departments and joint programming at technical and education conferences of environmental science and engineering, public health, and rural and community medicine represent an opportunity to facilitate interdisciplinary exchange.

Conclusion

NOW-R^2 presents a unique opportunity to better understand current and future challenges and opportunities facing decentralized wastewater and distributed water reuse, which serves at least 20% of the U.S. population and is increasingly common around the world. After receiving input from more than 450 professionals with different backgrounds who are working in different sectors and roles within this field, we provide much-needed information on the demographics and professional characteristics of the U.S. onsite wastewater workforce. We further report 10 problem statements related to workforce education, training, and outreach—and offer perspectives to meet these needs.

We specifically identify common issues in the onsite and distributed water reuse workforce similar to those recently identified for the public health workforce in general through the Public Health Workforce Interests and Needs Survey (PH WINS). PH WINS suggests high turnover rates among public health workers—similar to the onsite wastewater industry—along with training needs and focused recruitment and retention efforts (Bogaert et al., 2023; McCullough & Robins, 2023). Our findings here similarly align with environmental public health workforce challenges identified during the UNCOVER EH initiative (Brooks et al., 2019; Brooks & Ryan, 2021; Gerding et al., 2019, 2020).

PH WINS, UNCOVER EH, and NOW-R^2 collectively identify a public health system in the U.S. that is understaffed, underfunded, and not equipped to address future challenges, which limits the effectiveness of delivering essential health services (McCullough & Robins, 2023). These workforce issues have been further exacerbated by the COVID-19 pandemic, as public health workers have spent at least 20% of their time on pandemic response activities regardless of their given sector, which limits their progress and productivity in other services (McCullough & Robins, 2023), including impacts on continuing education opportunities for decentralized wastewater professionals (Table 1).

Though robust workforce assessments have not been performed for the practice of environmental engineering, observations reported here suggest a need to understand the challenges and opportunities facing the broader water and wastewater engineering community, particularly as the One Water approach progresses at the global scale. Strategic education, training, and outreach activities are needed to ensure workforce preparedness, promote education with owners of onsite technologies, and expand advanced training and translational research programs in decentralized/onsite wastewater and distributed water reuse systems, particularly in the face of climate change and disasters. We anticipate our findings can specifically support decision making aimed at sustaining and advancing the onsite wastewater and distributed water reuse workforce, which is essential for protecting public health and the environment across the urban–periurban–rural gradient.

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References

Boepple-Swider, T.M. (2008). A regulator's perspective on workforce issues: Water and wastewater operators. *Journal AWWA*, *100*(8), 132–135. https://doi.org/10.1002/j.1551-8833.2008.tb09683.x

Bogaert, K., Papillon, G., Wyche Etheridge, K., Plescia, M., Gambatese, M., Pearsol, J.L., & Mason, A. (2023). Seven years, 3 surveys, a changed world: The state public health workforce 2014–2021. *Journal of Public Health Management and Practice*, *29*(Suppl. 1), S14–S21. https://doi.org/10.1097/PHH.0000000000001645

Boxall, A.B.A., Rudd, M.A., Brooks, B.W., Caldwell, D.J., Choi, K., Hickmann, S., Innes, E., Ostapyk, K., Staveley, J.P., Verslycke, T., Ankley, G.T., Beazley, K.F., Belanger, S.E., Berninger, J.P., Carriquiriborde, P., Coors, A., DeLeo, P.C., Dyer, S.D., Ericson, J.F., . . . Van Der Kraak, G. (2012). Pharmaceuticals and personal care products in the environment: What are the big questions? *Environmental Health Perspectives, 120*(9), 1221–1229. https://doi.org/10.1289/ehp.1104477

Brooks, B.W., Gerding, J.A., Landeen, E., Bradley, E., Callahan, T., Cushing, S., Hailu, F., Hall, N., Hatch, T., Jurries, S., Kalis, M.A., Kelly, K.R., Laco, J.P., Lemin, N., McInnes, C., Olsen, G., Stratman, R., White, C., Wille, S., & Sarisky, J. (2019). Environmental health practice challenges and research needs for U.S. health departments. *Environmental Health Perspectives*, *127*(12), Article 125001. https://doi.org/10.1289/EHP5161

Brooks, B.W., & Ryan, B.J. (2021). Building environmental public health back better. *Environmental Science & Technology Letters*, *8*(6), 443–444. https://doi.org/10.1021/acs.estlett.1c00391

Centers for Disease Control and Prevention. (2023). *Environmental public health and the 10 Essential Services*. https://www.cdc.gov/nceh/ehs/10-essential-services/index.html

Converse, J.C. (2004, March 21–24). *Challenges facing the on-site wastewater industry*. On-Site Wastewater Treatment X: 10th Individual and Small Community Sewage Systems Conference Proceedings (pp. 1–7), Sacramento, CA, United States. American Society of Agricultural and Biological Engineers. https://elibrary.asabe.org/abstract.asp?aid=15754

Deal, N.E., Buchanan, J.R., Farrell-Poe, K., Gross, M.A., Gustafson, D., Kalen, D., Lesikar, B.J., Lindbo, D.L., Loomis, G.W., Mechell, J., Miles, R., & O'Neill, C. (2007, Oct 20–24). *Speaking the same language: A glossary for the decentralized wastewater treatment field*. 11th Individual and Small Community Sewage Systems Conference Proceedings, Warwick, RI, United States. American Society of Agricultural and Biological Engineers. https://doi.org/10.13031/2013.23974

Deal, N.E., Lindbo, D.L., Tanner, J., & Hoover, M.T. (2004, March 21–24). *Cost analysis of developing and operating small training centers*. On-Site Wastewater Treatment X: 10th Individual and Small Community Sewage Systems Conference Proceedings (Paper # 701P0104, pp. 679–684), Sacramento, CA, United States. American Society of Agricultural and Biological Engineers. https://doi.org/10.13031/2013.15827

Dillman, D.A., Smyth, J.D., & Christian, L.M. (2014). *Internet, mail, and mixed-mode surveys: The tailored design method* (4th ed.). John Wiley & Sons Inc.

Fairbrother, A., Muir, D., Solomon, K.R., Ankley, G.T., Rudd, M.A., Boxall, A.B.A., Apell, J.N., Armbrust, K.L, Blalock, B.J., Bowman, S.R., Campbell, L.M., Cobb, G.P., Connors, K.A., Dreier, D.A., Evans, M.S., Henry, C.J., Hoke, R.A., Houde, M., Klaine, S.J., . . . Brooks, B.W. (2019). Toward sustainable environmental quality: Priority research questions for North America. *Environmental Toxicology and Chemistry*, *38*(8), 1606–1624. https://doi.org/10.1002/etc.4502

Furley, T.H., Brodeur, J., Silva de Assis, H.C., Carriquiriborde, P., Chagas, K.R., Corrales, J., Denadai, M., Fuchs, J., Mascarenhas, R., Miglioranza, K.S., Miguez Caramés, D.M., Navas, J.M., Nugegoda, D., Planes, E., Rodriguez-Jorquera, I.A., Orozco-Medina, M., Boxall, A.B., Rudd, M.A., & Brooks, B.W. (2018). Toward sustainable environmental quality: Identifying priority research questions for Latin America. *Integrated Environmental Assessment and Management*, *14*(3), 344–357. https://doi.org/10.1002/ieam.2023

Gaw, S., Harford, A., Pettigrove, V., Sevicke-Jones, G., Manning, T., Ataria, J., Cresswell, T., Dafforn, K.A., Leusch, F.D.L., Moggridge, B., Cameron, M., Chapman, J., Coates, G., Colville, A., Death, C., Hageman, K., Hassell, K., Hoak, M., Gadd, J., . . . Brooks, B.W. (2019). Towards sustainable environmental quality: Priority research questions for the Australasian region of Oceania. *Integrated Environmental Assessment and Management*, *15*(6), 917–935. https://doi.org/10.1002/ieam.4180

Gerding, J.A., Brooks, B.W., Landeen, E., Whitehead, S., Kelly, K.R., Allen, A., Banaszynski, D., Dorshorst, M., Drager, L., Eshenaur, T., Freund, J., Inman, A., Long, S., Maloney, J., McKeever, T., Pigman, T., Rising, N., Scanlan, S., Scott, J., . . . Sarisky, J. (2020). Identifying needs for advancing the profession and workforce in environmental health. *American Journal of Public Health*, *110*(3), 288–294. https://doi.org/10.2105/AJPH.2019.305441

Gerding, J.A., Landeen, E., Kelly, K.R., Whitehead, S., Dyjack, D.T., Sarisky, J., & Brooks, B.W. (2019). Uncovering environmental health: An initial assessment of the profession's health department workforce and practice. *Journal of Environmental Health*, *81*(10), 24–33. https://www.neha.org/workforce-and-practice-assessment

Grigg, N.S. (2009). Water and wastewater workforce stats—The case for improving job data. *Journal AWWA*, *101*(8), 67–78. https://doi.org/10.1002/j.1551-8833.2009.tb09945.x

Guvernator, G.C., IV, & Landaeta, R.E. (2020). Knowledge transfer in municipal water and wastewater organizations. *Engineering Management Journal*, *32*(4), 272–282. https://doi.org/10.1080/10429247.2020.1753491

Hacker, M.E., & Binz, C. (2021). Institutional barriers to on-site alternative water systems: A conceptual framework and systematic analysis of the literature. *Environmental Science & Technology*, *55*(12), 8267–8277. https://doi.org/10.1021/acs.est.0c07947

continued on page 28

References

continued from page 27

Houston–Galveston Area Council. (2023). *On-site sewage facilities*. https://www.h-gac.com/on-site-sewage-facilities

Leung, K.M.Y., Yeung, K.W.Y., You, J., Choi, K., Zhang, X., Smith, R., Zhou, G.-J., Yung, M.M.N., Arias-Barreiro, C., An, Y.-J., Burket, S.R., Dwyer, R., Goodkin, N., Hii, Y.S., Hoang, T., Humphrey, C., Iwai, C.B., Jeong, S.-W., Juhel, G., . . . Brooks, B.W. (2020). Toward sustainable environmental quality: Priority research questions for Asia. *Environmental Toxicology and Chemistry*, *39*(8), 1485–1505. https://doi.org/10.1002/etc.4788

McCullough, J.M., & Robins, M. (2023). The opportunity cost of COVID for public health practice: COVID-19 pandemic response work and lost foundational areas of public health work. *Journal of Public Health Management and Practice*, *29*(Suppl. 1), S64–S72. https://doi.org/10.1097/PHH.0000000000001656

McKenna, M.L., McAtee, S., Bryan, P.E., Jeun, R., Ward, T., Kraus, J., Bottazzi, M.E., Hotez, P.J., Flowers, C.C., & Mejia, R. (2017). Human intestinal parasite burden and poor sanitation in rural Alabama. *The American Journal of Tropical Medicine and Hygiene*, *97*(5), 1623–1628. https://doi.org/10.4269/ajtmh.17-0396

Olstein, M.A. (2005). Managing the coming brain drain. *Journal AWWA*, *97*(6), 60–67. https://doi.org/10.1002/j.1551-8833.2005.tb10911.x

Reid, S., Deal, N.E., Buffington, B., & Lindbo, D. (2007, October 20–24). *Updating North Carolina's education and training curriculum for onsite/decentralized wastewater treatment system operators*. 11th Individual and Small Community Sewage Systems Conference Proceedings, Warwick, RI, United States. American Society of Agricultural and Biological Engineers. https://www.doi.org/10.13031/2013.24001

Rudd, M.A., Ankley, G.T., Boxall, A.B.A., & Brooks, B.W. (2014). International scientists' priorities for research on pharmaceutical and personal care products in the environment. *Integrated Environmental Assessment and Management*, *10*(4), 576–587. https://doi.org/10.1002/ieam.1551

Rupiper, A.M., & Loge, F.J. (2019). Identifying and overcoming barriers to onsite non-potable water reuse in California from local stakeholder perspectives. *Resources, Conservation and Recycling: X*, *4*, Article 100018. https://doi.org/10.1016/j.rcrx.2019.100018

Siegrist, R.L. (2014, April 7–8). *Onsite and decentralized systems water and wastewater engineering: Course development and delivery experiences to fill a perceived void in higher education*. Innovations in Soil-Based Onsite Wastewater Treatment, Albuquerque, NM, United States. Soil Science Society of America Conference. https://www.soils.org/files/meetings/specialized/full-conference-proceedings.pdf

Spirandelli, D., Dean, T., Babcock, R., Jr., & Braich, E. (2019). Policy gap analysis of decentralized wastewater management on a developed Pacific island. *Journal of Environmental Planning and Management*, *62*(14), 2506–2528. https://doi.org/10.1080/09640568.2019.1565817

Struck, S.D. (2008, May 12–16). *Incentives for adoption of low impact development approaches on a larger scale*. 2008 World Environmental and Water Resources Congress, Honolulu, HI, United States. https://doi.org/10.1061/40976(316)38

U.S. Environmental Protection Agency. (2020). *Decentralized wastewater management memorandum of understanding among the U.S. Environmental Protection Agency and partner organizations*. https://www.epa.gov/sites/default/files/2020-09/documents/2020_mou_agreement.pdf

U.S. Environmental Protection Agency. (2021a). *Pipeline to a sustainable workforce: A report on decentralized/onsite wastewater occupations* (EPA-830-R-21-001). https://www.epa.gov/sites/production/files/2021-02/documents/career-pathways_report.pdf

U.S. Environmental Protection Agency. (2021b). *Education and training landscape: Providing a supply of talent for decentralized/onsite wastewater occupations* (EPA-830-R-21-005). https://www.epa.gov/system/files/documents/2021-09/education_training_landscape.pdf

U.S. Environmental Protection Agency. (2021c). *Building a decentralized wastewater training program* (EPA-830-B-21-002). https://www.epa.gov/system/files/documents/2021-10/decentralized_partnershipsguide.pdf

Van den Brink, P.J., Boxall, A.B.A., Maltby, L., Brooks, B.W., Rudd, M.A., Backhaus, T., Spurgeon, D., Verougstraete, V., Ajao, C., Ankley, G.T., Apitz, S.E., Arnold, K., Brodin, T., Cañedo-Argüelles, M., Chapman, J., Corrales, J., Coutellec, M.-A., Fernandez, T.F., Fick, J., . . . van Wensem, J. (2018). Toward sustainable environmental quality: Priority research questions for Europe. *Environmental Toxicology and Chemistry*, *37*(9), 2281–2295. https://doi.org/10.1002/etc.4205

The Water Research Foundation. (2022). *Implementing onsite and distributed water reuse systems in the United States: Literature review* (Project No. 5040). https://www.waterrf.org/system/files/resource/2022-11/DRPT-5040A.pdf