Diminishing the Impact of Wastewater on Treatment Infrastructure and the Environment: **White Paper**

Aging wastewater treatment infrastructure and the sheer abundance of wastewater produced in the United States have created an urgent need for alternative treatment methods outside of centralized public and private wastewater treatment systems. Traditional centralized wastewater treatment infrastructure collects wastewater from residential, commercial and industrial producers, transports the wastewater to an off-site treatment facility and discharges the treated effluent, usually far from the point of origin (Hophmayer-Tokich, 2006). For decades, this infrastructure has grown increasingly inadequate to meet the wastewater treatment demands of our society. Contaminants found in wastewater exacerbate the effects of age and impede treatment facilities' efficiency and effectiveness. In addition to a variety of emulsions and chemical mixtures such as paints and pesticides, wastewater can also contain contaminants, such as non-toxic siloxane surfactants found in many toiletries and cleaning products, that build up on facility equipment over time, causing further damage and thus accelerating the deterioration of machinery. Alternative wastewater treatment solutions alleviate a portion of the stress put on centralized treatment infrastructure while producing an oftentimes cleaner, safer effluent.

As our wastewater treatment infrastructure ages, the pipes and facilities we rely on become less able to accommodate treatment demands and meet quality sanitation expectations. According to EPA estimates, there are approximately 500,000 miles of publicly owned sanitary sewers with a similar expanse of privately owned sewer systems (EPA, 2015). The National Pollutant Discharge Elimination System (NPDES) permit program categorizes this network of sewers into sanitary sewer systems (SSSs) and combined sewer systems (CSSs). While an SSS collects and transports domestic, commercial and industrial wastewater in one pipe and storm water and ground water in a separate pipe, a CSS collects rainwater runoff, domestic sewage and industrial wastewater into one pipe (EPA, 2016). Although these systems vary from city to city, age is a significant concern for both types. "The construction of wastewater treatment facilities blossomed in the 1920s and again after the passage of the Clean Water Act in 1972," (EPA, 2015), and some of the earliest sewer pipes were installed in the late 19th century (Economic Development Research Group, Inc., 2011). In Philadelphia, some of the city's pipes date back even farther to 1824 (Philadelphia Water Department, 2017). As many wastewater lines average almost a century old in age, particularly in communities with CSSs, this network of pipes is rapidly approaching the end of its life expectancy, which is generally assumed to be about 100 years (EPA, 2015). The EPA emphasizes the scope of this age problem: Data suggests that by 2020, up to half of the assets in our sewer systems may be beyond the midpoint of their useful lives (EPA, 2015). With systems in dire need of repairs and advancements, aging and neglected infrastructure cannot properly manage vast amounts of wastewater at the speed and caliber users demand.

In addition to time, siloxane surfactants used in many everyday products for consumer and industrial use intensify the aging of centralized wastewater treatment equipment. Applied Technologies, an architectural and engineering firm specializing in water and wastewater, explains, “Siloxanes are most widely used in the cosmetics industry,” and are also popular in the food industry and plastics manufacturing. These compounds are a part of our daily lives, from bathing to doing laundry to printing newspapers (Applied Technologies, 2009). As more and more consumer and industrial products follow the trend of containing siloxanes, concentrations of siloxane compounds in the wastewater stream also increase. While siloxanes are non-toxic in terms of consumption, their harm lies in damage to treatment equipment such as cetrifuges, agitators and degassers. In “Emergence and Fate of Siloxanes in Waste Streams: Release Mechanisms, Partitioning and Persistence in Three Environmental Compartments”, civil engineer Sharon Surita states that siloxanes typically adhere to solids in a waste stream due to their low solubilities. She continues, “Siloxanes are released from the solid phase (biomass) during anaerobic decomposition processes which result in release of the bound siloxanes . . .” (Surita, 2015). Just like fat can clog an artery, siloxanes can form deposits on equipment that impede efficiency and require maintenance time to remove.

Most alarming, the deterioration of our nation’s wastewater treatment infrastructure poses direct threats to public health. In March 2017, the American Society of Civil Engineers graded the United States’ overall wastewater treatment infrastructure as D+ on an academic-style grading scale of A-F (American Society of Civil Engineers, 2017). According to the ASCE Committee on America’s Infrastructure, the following criteria are taken into consideration in order to determine an infrastructure grade assessment: capacity, condition, funding, future need, operation and maintenance, public safety, resilience and innovation. Wastewater infrastructure’s D+ grade falls at the top end of the “Poor, At Risk” rating and at the low end of the “Mediocre, Requires Attention” rating, and is slightly improved from the previous 2013 report’s D grade (American Society of Civil Engineers, 2017). This infrastructure insufficiency contributes to the discharge of an estimated 900 billion gallons of untreated sewage into our waterways each year (Economic Development Research Group, Inc., 2011). According to the U.S. Geological Survey, the average American uses about 80 to 100 gallons of water each day, which equates to 29,200 to 36,500 gallons of wastewater produced per person each year (U.S. Geological Survey, 2016). This large volume of wastewater can sometimes overwhelm the capacity of a sanitary or combined sewer system or treatment facility and result in an overflow of raw sewage. In fact, the EPA estimates that a minimum of between 23,000 and 75,000 sanitary-sewer overflows (SSOs) happen each year, and these figures do not account for particularly concerning combined-sewer overflows (CSOs) (EPA, 2016). The EPA explains, "CSOs are remnants of the country's early infrastructure. In the past, communities built sewer systems to collect both stormwater runoff and sanitary sewage in the same pipe . . . CSOs contain not only stormwater, but also untreated human and industrial waste, toxic materials and debris. This is a major water pollution concern for cities with CSSs," (EPA, 2016).

In "Impacts of Sanitary Sewer Overflows and Combined Sewer Overflows on Human Health and on the Environment: a Literature Review", the Office of Water Programs at California State University, Sacramento explores the potential endangerment of public health by combined sewer overflows. CSOs tend to take place after rainfall, as the combined system must handle surges of stormwater in addition to sanitary sewage from domestic sources. The report states, "Although combined sewer overflows are not desired, they are expected events. When wet weather-induced hydraulic loads exceed the capacity of a wastewater treatment plant, excess flow in the CSS is directed around the treatment plant and directly discharged to receiving waters through a CSO outfall . . . Combined sewer overflows regularly release untreated sanitary sewage into lakes, rivers, streams, bays, estuaries and coastal waters of the United States. Those waters are used as drinking water sources, recreational waters and habitat for fish and shellfish used for human consumption," (Office of Water Programs, California State University, Sacramento, 2008). Overflows are an inevitable and alarmingly precarious result of our wastewater treatment infrastructure as it stands today. Without the proper, modern infrastructure to support present-day water consumption and stormwater drainage, overloaded wastewater treatment facilities not only fail to meet treatment demands but also directly release hazardous wastes back into water sources in a vicious cycle of contamination.

Moreover, municipal government spending on wastewater infrastructure does not keep up with treatment needs. As acknowledged in the American Society of Civil Engineers' publication "Failure to Act: The Economic Impact of Current Investment Trends in Water and Wastewater Treatment Infrastructure", "Water infrastructure in the United States is clearly aging, and investment is not able to keep up with the need. . . Even with increased conservation and cost-effective development of other efficiency methods, the growing gap between capital needs to maintain drinking-water and wastewater treatment infrastructure and investments to meet those needs will likely result in unreliable water service and inadequate wastewater treatment," (Economic Research Group, Inc., 2011). Without proper investments put into updating and expanding our wastewater treatment infrastructure, the consequences of sewer system deterioration and overload remain a present threat. The Environmental Finance Center at the University of North Carolina, Chapel Hill's analysis of Congressional Budget Office data for the "Public Spending on Transportation and Water Infrastructure, 1956-2014" explores modern investment trends. According to this data, during the past four decades, public spending on operations and maintenance has steadily grown while capital expenditures have fluctuated and declined. The Center explains, "For several years until 1980, public spending was split almost evenly between capital expenditures (to build or replace water and wastewater systems) and operations and maintenance of the systems . . . Currently, governments spend twice as much on operations and maintenance of their systems than on capital expenditures to rehabilitate, replace or expand existing assets or install new infrastructure," (Environmental Finance Center, University of North Carolina, Chapel Hill, 2015). Perhaps most significant for state and municipal governments, the research highlights a critical gap in spending to combat infrastructure shortcomings: By 2014, local and state governments accounted for 96 percent of all public spending on water and wastewater utilities – Federal government spending accounted for only four percent (Environmental Finance Center, University of North Carolina, Chapel Hill, 2015). Overall, today's diminished public spending on capital infrastructure allocates a grossly insufficient amount of funding to expand our wastewater treatment infrastructure and meet growing treatment needs.

Ultimately, the more gallons of wastewater produced and discharged to a sewer system, the more wear and tear pipes and wastewater treatment equipment incur. The natural deterioration of our wastewater treatment infrastructure combined with the sheer abundance of wastewater entering the sewer system each day and a lack of government spending on capital infrastructure have resulted in an urgent need to lessen impacts on existing systems. Sustainable technologies that recycle wastewater for industrial, commercial and residential use and produce cleaner byproducts are in high demand to combat the growing inadequacy of centralized treatment facilities. By processing wastewater for reuse or direct discharge outside the sewer system, these technologies bypass reliance on antiquated, over-capacity infrastructure, which provides benefits for the end user as well as governments at the state and municipal levels and their communities.

Several sustainable technologies at work in the wastewater treatment world remove pollutants relatively thoroughly and yield cleaner byproducts, which helps limit the types of contaminants and materials that are discharged to water sources. When utilized in a decentralized system, whereby wastewater is collected, treated and discharged/reused at or near the point of generation (Hophmayer-Tokich, 2006), these sustainable technologies also diminish the strain of wastewater on centralized treatment infrastructure. In its report "Primer for Municipal Wastewater Treatment Systems", the EPA defines and explores some of these advanced methods, including nitrogen control, biological phosphorus control, coagulation-sedimentation and carbon adsorption. Nitrogen in the form of ammonia can be a dangerous wastewater effluent since it is toxic to some aquatic life and can stimulate the excessive growth of algae. Through nitrification, "nitrifying bacteria present in wastewater treatment can biologically convert ammonia to the non-toxic nitrate," which effectively removes toxicity (EPA, 2015). Phosphorous control is often needed before discharging wastewater effluent to prevent the excessive growth of algae as well. The EPA explains, "Phosphorous removal can be achieved through chemical addition and a coagulation-sedimentation process" or through suspended growth systems whereby bacteria trap phosphorous within solids that are removed entirely from the effluent (EPA, 2015). One manner of removing such solids is coagulation-sedimentation. In this method, solids heavier than water settle out of the wastewater by gravity. With the addition of chemicals such as alum, lime or iron salts, smaller particles can become heavier or clump together to settle faster. However, “This process produces a chemical sludge, and the cost of disposing this material can be significant,” (EPA, 2015). Finally, in carbon adsorption, wastewater effluent passes through a bed of activated carbon granules that removes more than 98 percent of resistant, trace organic substances. Adding to the method’s sustainability, the carbon can be removed, cleaned and reused (EPA, 2015). Used in many common aerobic and anaerobic wastewater treatment processes, these methods take wastewater treatment quality to a level beyond the minimum wastewater treatment facility requirements. Overall, the report proposes, “In various combinations, these processes can achieve any degree of pollution control desired. As wastewater is purified to higher and higher degrees by such advanced treatment processes, the treated effluents can be reused for urban, landscape and agricultural irrigation, industrial cooling and processing, recreational uses and water recharge and even indirect augmentation of drinking water supplies,” (EPA, 2015). As the EPA suggests, wastewater treatment methods that yield a clean, safe effluent can provide additional benefits that extend far beyond protecting water sources. However, many of these processes are not routinely implemented in centralized wastewater treatment facilities. State and local governments and the business at work in their communities must instead turn to alternative treatment sources to achieve a level of sustainable and beneficial wastewater treatment.

One such alternative wastewater treatment source is the membrane bioreactor (MBR), a popular choice for municipal, commercial and industrial wastewater treatment alike. As defined by the Institute of Electrical and Electronics Engineers (IEEE), “A membrane bioreactor (MBR) is a biologically active piece of wastewater treatment equipment using a suspended growth bioreactor and a membrane process such as microfiltration or ultrafiltration,” (Engineering360, 2017). While filtration can take place inside or outside of the bioreactor itself, all MBR processes utilize two techniques—biological treatment and membrane filtration. In biological treatment, microorganisms break down organic contaminants, and in filtration, the remaining contaminants and residual materials are filtered out through a membrane (Engineering360, 2017). The overall characteristics of the MBR treatment process provide significant advantages over standard centralized treatment. According to VA Tech WABAG, a leading engineering company in the water treatment field, “The two major benefits of the MBR process are substantially reduced land and space requirements and the reclamation of water (permeate) of excellent quality, which is a valuable source for higher demand reuse applications,” (Klegraf et al., 2007). Moreover, MBRs “exhibit high removal efficiency, better effluent quality and the ability to remove a number of contaminants such as nitrogen, phosphorus, bacteria and suspended solids,” (Engineering360, 2017). In addition to these performance advantages, most MBRs require minimal maintenance to function efficiently. GE Power & Water asserts that MBR systems are simple to operate and require very little operator attention. In fact, according to GE, “Typical operator requirements for an MBR for a small community would average less than one hour per day,” (Bernard et al., 2012). While MBRs are a relatively new technology, advancements in engineering and wastewater treatment have resulted in more capable and efficient MBR systems that are better suited to serve municipal communities and their assets.

Developed with innovative technology to help meet today's demanding water, conservation and sustainability needs, the OxyShark® Wastewater Reclamation (OWR) system is a multi-celled, submerged fixed-film bioreactor capable of processing hundreds of thousands of gallons of wastewater each day. According to Auto Laundry News, an average tunnel car wash uses approximately 48,000 gallons of water per day, a 100-room-occupancy hotel laundry service uses about 3,000 gallons per day and an average sit-down restaurant uses 5,800 gallons per day (Brochard, 2011). OxyShark provides sustainable wastewater treatment on location, allowing users to circumvent municipal or private facility treatment, thereby reducing costs and overall strain on aging infrastructure. Moreover, the system's modular design and build ensures a functional fit in most applications, even in restrictive spaces. This capability provides further versatility for retro-fitting existing sites, an optimal choice for applications that seek to add their own wastewater treatment system or upgrade or replace existing processes. Key site applications for the OxyShark system include any operation that begs a solution for fast and efficient wastewater treatment, such as food processing, housing developments, car washes, breweries, dry cleaners, commercial laundry, public and private schools, airports and more.

The OxyShark system utilizes a natural and biological process to produce a clean effluent that operators can immediately and safely reuse or discharge into a body of water or land application. OxyShark harnesses oxygen and beneficial, waste-consuming bacteria as opposed to standard filtration or the addition of chemical agents to process influent wastewater. Within the OxyShark system, a compact media provides a large surface area on which these bacteria grow. While the system houses thousands of square feet of media, OxyShark has a small footprint, as small as four and a half feet by 10 feet for a single unit. As influent water passes through the media, the bacteria consume waste materials such as surfactants, oil, grease, chemicals and organic matter. According to a third-party pilot study conducted in 2015, OxyShark effectively removes up to 97 percent of BOD5 pollutants and 97 percent of surfactants from wastewater, far exceeding environmental regulation requirements. The OxyShark system is also fully capable of processing surfactants without resulting in damaging buildup in the media or system housing. Moreover, unlike suspended growth systems, the bacteria within OxyShark media can withstand damaging chemical spikes like chlorine bleach and maintain an adequate microbe population that will continue to process the organic pollutants.

Time is a crucial factor in the treatment of wastewater, as daily water use is a necessity in most any operation. Rate of treatment affects operators who produce wastewater continually and/or require water to complete service functions such as industrial cooling and processing, washing, fire protection, irrigation, recreational use and other processes that can be adequately conducted with treated effluent (EPA, 2015). With the use of an OxyShark system, users can complete the wastewater treatment process in as little as two to four hours, up to 10 times faster than traditional biological wastewater treatment alternatives. The ability to process wastewater and immediately reclaim a clean effluent for reuse within a matter of hours permits a site to maintain operations without concern of surpassing government environmental compliance or health and safety requirements. In addition, OxyShark's treatment process yields minimal to no byproduct, or sludge. Traditional bioreactors produce a sludge byproduct that must be removed in order for the system to function at optimal efficiency. Because the OxyShark system does not require frequent maintenance due to waste sludge, operators further reduce time in the treatment cycle.

OxyShark's advanced and natural technology provides a sustainable alternative to the deteriorating wastewater infrastructure already in place across the United States. In addition to private businesses, OxyShark provides municipalities the opportunity to diminish the impact of wastewater on centralized infrastructure through a variety of publically owned applications, including airports, schools and housing developments. These applications all can benefit from the ability to effectively manage wastewater for reuse or direct discharge while reducing sewage fees. Over the past several years, the Federal Aviation Administration (FAA) has encouraged efforts toward recycling, reuse of materials and waste reduction in airports. According to the FAA, the main sources of airport wastewater include aircraft maintenance hangars, where water is used in the service and repair of aircraft, and flight kitchens, where the food served on passenger airplanes is prepared. The FAA encourages airports to develop and implement a sustainable waste management plan, and OxyShark is a viable method for enacting wastewater management efforts (FAA, 2013). Moreover, airports are highly trafficked areas, providing a perceptible opportunity for a municipality to reinforce its identity and commitment to improvement to residents and visitors alike. Public schools offer another avenue by which a municipality can lessen strain on its centralized wastewater treatment infrastructure. With industrially stocked kitchens, restrooms, locker rooms, science laboratories, landscaping and athletic fields, public schools require a substantial amount of water to maintain a safe, attractive and functional environment for their students. The town of North Reading, Mass., realized the potential stress this water usage presents, and today North Reading Public Schools processes the wastewater from its combined middle/high school at a wastewater treatment facility with a membrane bioreactor (North Reading Public Schools, 2017). Other municipalities can follow suit to decrease the amount of wastewater processed through a centralized sewer system and reap the cost and reuse benefits of sustainable treatment.

Last, the use of sustainable wastewater treatment alternatives like OxyShark in public housing developments presents dual benefits for a community. Historically residing in lower-income neighborhoods, public housing tenants and individuals who live below the poverty line are significantly impacted by rising water and sewage rates. These increased costs affect a municipality's availability of affordable housing, as is the case in New York City. According to New York City's University Neighborhood Housing Program, the rate for water and sewer service in New York City has nearly tripled in the past 15 years, from $3.37 per 100 cubic feet in the year 2000 to $9.57 per 100 cubic feet in 2015. The report continues, "The impact has been especially felt in housing with larger apartments occupied by lower income households in New York City neighborhoods, making this issue impossible to ignore when addressing housing affordability," (University Neighborhood Housing, 2015). As this report explores, water consumption and sewage needs are consequential costs that must be factored in to providing affordable public housing. With that being said, a decentralized treatment option such as OxyShark not only minimizes sewer costs but also permits water to be reused for non-potable activities. The wide range of reuse possibilities includes flushing toilets, supplying fire hydrants, washing cars and streets, watering lawns and landscape assets, completing construction and maintenance projects and other non-potable purposes (The National Academies of Sciences, Engineering, and Medicine, 2015). All in all, the use of an OxyShark system in public housing developments can assist lower-income individuals and families by minimizing sewage costs while alleviating strain on centralized treatment infrastructure.

Reducing the environmental impact of wastewater treatment and disposal is key to keeping water sources clean and safe while diminishing overall costs to residents, business owners and local and state governments. It is estimated that over the next 20 years, more than 56 million new users will be connected to centralized wastewater treatment systems, a growth that will require at least $271 billion to meet current and future demands (American Society of Civil Engineers, 2017). Solutions to address our ever-expanding wastewater treatment needs while raising our nation's infrastructure grade are in a higher demand than ever. Sustainable technologies like OxyShark are poised to help deliver a solution. No matter the application – commercial, industrial or municipal – OxyShark's revolutionary system is making wastewater treatment affordable, efficient and clean. Aligned with many municipalities' increased focus on "green" initiatives, OxyShark grants users opportunities to reuse water, a precious resource especially in areas prone to drought. OxyShark also delivers safe direct discharge to water sources without negative impacts on the surrounding environment and wildlife. This ability to recycle and reuse water while protecting natural resources is an invaluable advantage of sustainable wastewater treatment technology like OxyShark with benefits that extend far beyond the end user. Altogether, the sustainable OxyShark process allows operators to be good stewards to their communities while our nation continues to address its outdated and overworked centralized wastewater treatment infrastructure.

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