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MINI REVIEW

In Pursuit of Safe Drinking Water in the Texas-Mexico Border Region: A Matter of Social Justice

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CONFLICTS OF INTEREST
THERE ARE NO CONFLICTS OF INTEREST FOR ANY OF THE AUTHORS.

ABSTRACT:
The U.S.-Mexico border is populated by resilient families and characterized by environmental, social, economic, cultural, and epidemiologic inequalities. Person-in-environment perspectives and the need to embrace a new concept of environment to improve well-being of individuals and eradicate social conditions that undermine health are vital. One of the most innovative and promising mechanisms to improve water safety in underserved communities is the use of nanotechnology devices. The manuscript exposes the water scarcity, contamination and the health and social impacts in the Southwest border region and explores the use of Nanotechnology Enabled Water Treatment (NEWT) devices an alternative for water purification. These technologies will be portable, use less water treatment chemicals (i.e., chlorine) and electricity by employing nanophotonics for processes such as solar desalination. Nanotechnology seems to have the potential to address some of the pressing water safety and environmental needs. Caution, however, should be used when implementing nanotechnology especially when done with members of vulnerable populations. Community-engagement is crucial to inform scientists and researchers about the social needs through the use of participatory action research methods like focus groups, in-depth interviews and forums. The NEWT Project is an interdisciplinary, multi-institution nanosytems-engineering research center, consisting of an interdisciplinary research team of engineers, chemists, psychologists, social workers and community partners.

KEYWORDS: Water, Social Justice, Community Engagement, Colonias, Nanotechnology, U.S.-Mexico Border.

INTRODUCTION

Water in the Southwest Border Region

Water stress and scarcity are among the main problems that humanity is facing and will increasingly face in the future as a result of the multiple pressures from increasing exploitation and side effects such as pollution and environmental degradation, as well as social and political instability (Al-Weshah, Saidan, & Al-Omari, 2016). Safe drinking water is a basic need for human development, health, and well-being and is an internationally accepted human right (World Health Organization, 2002). The World Water Council estimates that by 2030, 3.9 billion people will live in "water scarce" regions, 1.1 billion people lack access to improved drinking water and 2.6 billion lack access to proper sanitation. In 2012, 12.6 million people died as a result of living or working in an unhealthy environment– nearly one in four of total global deaths (World Health Organization, 2016) and more than two million people die of diarrheal related disease annually, most often caused by waterborne infections, and the majority of these cases are children under the age of five (Pendergast & Hoek, 2011).

Additionally, when it comes to the availability and distribution of safe drinking water, social justice quickly arises as an issue of importance. In January

2014, the World Economic Forum announced that the water crisis is the number one global risk based on impact to society as a measure of devastation and that one in ten people worldwide lack access to safe drinking water and one in three lack access to a toilet (World Health Organization, 2015).

According to the 2006 Human Development Report, proper water management can be traced to poverty, inequality and unequal power relationships as well as flawed water management policies that exacerbate scarcity (UNDP, 2006).

Border communities are resilient and have confronted structural barriers ranging from governmental neglect to social isolation (Moya, Chavez Baray, Wood & Martinez, 2016). The U.S.-Mexico border region spans almost 2,000 miles from the Pacific Ocean to the Gulf of Mexico (Figure 1) and includes four U.S. states, six Mexican states, 44 U.S. counties, and 80 Mexican municipalities. The La Paz Agreement defines the border as the area within 62.5 miles of either side of the boundary. The border is home to approximately 13 million individuals, including 26 U.S. federally recognized Native American tribes. In some places, only a sign or a fence marks the border. In other places, the border is reinforced with barbed wire or tall steel fences. Although each nation operates under distinct legal and political structures as well as different health and environmental systems, the region is characterized by mutual dependence, with both sides sharing environmental, social, economic, cultural, and epidemiologic characteristics.

Figure 1: U.S.-Mexico Border map. Reprinted from www.borderhealth.org by the United States-Mexico Border Health Commission in cooperation with the Department of Geography and Spatial Application Research Center (SpARC) of the New Mexico State University by permission of the Unites States-Mexico Border Health Commission.

The "Healthy Border 2020 Program" and the "U.S.-Mexico Environmental Program: Border 2012" identified access to drinking water and sanitation services as one of the most salient physical and environmental determinants of health in the U.S.-Mexico Border region (Hargrove, Juárez-Carrillo & Korc, 2015). The intersection of water access, quality, sanitation and public health has been well documented in developing countries (VanDerslice, 2011; Fewtrell, Kafmann, Kay, Enanoria, Haller, & Colford, 2005; Gundy, Wright & Conroy, 2004).

According to the Texas Comptroller of Public Accounts Report, if the U.S.-Mexico border region were considered a state, the region would be comprised of the following characteristics: 1) rank last in access to health care; 2) second in death rates due to hepatitis; 3) third in deaths related to diabetes; 4) last in per capital income; 5) first in the number of school children living in poverty; and 6) first in the number of uninsured school children (Soden, 2006).

One of the most rapidly population growing regions of the United States of America is the Southwest. The Texas Water Development Board (Texas Water Development Board, 2012) projects that the water demand in Texas will rise by 22 % by 2060, from about 18 million acre-feet per year to about 22 million acre-feet per year, creating more challenges for water supply planners and communities. By 2060, urban areas are expected to have the largest increases in water demand due to increased municipal water consumption from rapid population growth (Venkataraman, Tummuri, Medina, & Perry, 2016).

The Rio Grande River supports an ecosystem of desert and aquatic life along its course, from Southern Colorado to the Gulf of Mexico. Unfortunately, the use of water for human consumption has greatly degraded the habitat of the river and its basin. Factors such as high salt content, high sediment load, inconsistent water flows, and the runoff of mineral mines and metal smelting wastes along the Rio Grande have negatively impacted this aquatic ecosystem (Rios-Arana, Walsh, & Gardea-Torresdey, 2004).

The presence of arsenic, copper, zinc, cadmium, lead, and nickel was confirmed in the water column and sediments of the Rio Grande in the El Paso Texas and Ciudad Juarez, Mexico border region. Concentrations of these elements were lower in the water column as compared to the levels found in the sediments. Zinc and lead were the elements most commonly present as dissolved and total recoverable metals in water and sediment samples. These values exceeded the freshwater chronic criteria and are sufficiently high to impact human health (Rios-Arana et al., 2004). Contamination of the environment with toxic metals, like mercury and arsenic, has been an important concern for decades. Human exposure to high mercury or arsenic levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages (Ray, Darbha, & Ray, 2008). Brain disorders, several of which have important environmental factors, are leading contributors to disabilities and morbidity that produce critical public health, societal and economic impacts. In addition, contamination of the air and water supplies in the vicinity of fracking operations has been linked to health impacts that include asthma, respiratory complaints, gastro-intestinal effects and nose bleeds (Cabrera, Tesluk, Chakraborti, Matthews, & Illes, 2016).

A study conducted by the School of Public Health's Department of Environmental Health at Harvard University found that millions of people residing in the United States are exposed to chemicals like polyfluoroalkyl and perfluoroalkyl in water. These chemicals in drinking water are known to affect immune function and can be extremely harmful to children and pregnant women (Hu & Olson, 2016).

The conditions and risks associated with water scarcity represent a real burden in the U.S.-Mexico border region, where the quality of life and socioeconomic indicators are impacted by environmental challenges. Contamination of drinking water is a key concern for public health. Microbial hazards make the largest contribution to waterborne diseases in developed and developing countries (World Health Organization, 2002). Nevertheless, chemicals in water supplies can cause serious health problems – whether the chemicals are naturally occurring or derive from sources of pollution. At a global scale, fluoride and arsenic are the most significant chemicals, each affecting perhaps millions of people. Many other chemicals can be important contaminants of drinking water under specific local conditions. Often, identification and assessment of health risks from drinking water relies excessively on analysis of water samples. The limitations of this approach are well identified, having previously contributed to the delay in recognizing arsenic in drinking-water as a significant health concern (WHO, 2007).

Population of interest: Community Dwellings or Colonias

The U.S.-Mexico Border is comprised of hundreds of *colonias*, which often have inadequate housing, roads, sewage systems, drainage, and lack a potable water supply (Figures 2 and 3). *Colonias* have both rural and urban characteristics, depending on their history, size, population density, location, community development trajectories cities, and are collectively home to well near a million residents (Barton, Ryder Perimeter, Sobel Blum, & Marquez, 2015; Lusk, Staudt, & Moya, 2012).

Figure 2: Tanks for water storage in San Elizario, Texas colonias. Photo courtesy of Eva M. Moya

Figure 3: Family members transporting and dispensing water for personal use in colonias. Photo courtesy of Maria Covernali, Familias Triunfadoras, Inc.

Colonia in Spanish means a community or neighborhood. The Texas Office of the Secretary of State defines a *colonia* as a residential area along the Texas–Mexico border that may lack some of the most basic living necessities such as potable water, septic or sewer systems, electricity, paved roads or safe and sanitary housing. There are 2,294 *colonias* in Arizona, New Mexico, and California; however, Texas has the largest *colonia* population and the largest number of *colonias* along the U.S.–Mexico border. According to the U.S. Census Bureau, about 96 percent of *colonia* residents are Hispanic (mostly of Mexican American descent), and the median age is 27 (Barton et al., 2015). There is a common misconception that most *colonia* residents are recent or first-generation immigrants. In reality, almost two-thirds of resident adults (over age 18) are U.S. citizens. Similar to the national rate, 94 percent of youths living in *colonias* are U.S. citizens (U.S. Census Bureau, 2015).

The spatial distance between these dwellings or other rural communities from potable water lines and the extensive plots of empty space between them makes the delivery of piped water a costly ordeal; these communities often endure lengthy waits for potable water to be delivered to their homes. Unfortunately, the decision to deliver water lies in the hands of local water boards. Water boards are quasi-government entities that deliver services to neighborhoods within districts, and the more developed and clustered the populations are, the more likely that water delivery services will be expedited. In the absence of sewage or adequate water supply, some community residents resort to the use of septic tanks, which often overflow and cause significant health and environmental risks to residents' health (Lusk et al., 2012).

Most of *colonia* residents continue to rely on water delivery trucks and store their water in reused drums or water tanks; however, this water typically has low levels of chlorine and sometimes contains coliforms, representing a health risk for users. Some of the most salient environmental and health conditions include water pollution, groundwater depletion, soil contamination, illegal outdoor burning, and infectious diseases, all of which transcend national boundaries (Grineski & Juarez-Carrillo, 2012).

Part of the Solution: Nanotechnology-Enabled Water Treatment

One of the most innovative options to generating cleaner drinking water is nanotechnology. Nanotechnology is a novel scientific approach that involves the use of materials and equipment capable of manipulating physical and chemical properties of a substance at molecular levels. A nanometer is a millionth of a millimeter and a single human hair is about 80,000 nanometers in width. In applications, such as the filtration of water, nanomaterials are able to filter out heavy metals and biological toxins (Condory, 2010). Chemical contaminants are removed from water through two processes. Contaminants can either be adsorbed onto nanoparticles (similar to the adsorption of dissolved organic compounds onto filters) or changed chemically via catalytic reactions, for instance, nitrate to nitrogen gas (Al Bahri et al., 2013). Nano-absorbents can be embedded in activated carbon filters or novel membranes, or have magnetic properties that allows for quick and effective recapture of the nanomaterials using magnetic fields (Jabbari et al., 2016). Microbial contaminants are not so much removed as they are deactivated similar to how copper surfaces kill bacteria. Copper or silver materials have proven anti-microbial properties and nanoparticles using these elements can be used to deactivate or destroy bacteria in contaminated water (Ruparelia et al., 2008).

Although no consensus has been reached about how to define nanotechnology, a great variety of application areas and products that contain nanotechnology already exist. Currently, over 1,800 consumer products are identified in the market, although many more products not labeled appropriately may increase this number and make nanotechnology an ubiquitous ingredient in consumer products today (Bertoldo, Mays, Poumadère, Schneider, & Svendsen, 2015; Kern, 2015).

In order to have faster and more efficient environmental remediation, more advanced detection and monitoring of nanomaterials and their deposition, along with more refined risk-assessment strategies, are needed (Patil, Shedbalkar, Truskewycz, Chopade, & Ball, 2015). Nanotechnology has the potential to revolutionize the environment, health, medical, agricultural and food industries, water purification, information technology, nutrition, energy production, and cognitive science with novel tools for the molecular management of diseases, rapid disease detection, and enhancing the ability of plants to absorb nutrients, among others means (Bertoldo et al., 2015; Ram, Vivek, & Kumar, 2014). Nonetheless, the risks derived from their use have not fully been determined.

Several concerns have emerged with regard to environmental contamination and health effects (Patil et al., 2015). Concerns for some nanotechnologies are mainly related with the (still unproven) assumption that nanomaterials are safe if chemically comparable to the same materials at different dimensions (Hess, 2010). However, it is alleged that materials at the nanoscale have different properties from the same materials at the micro or macroscale, and that their small size makes some nanomaterials more toxic than normal (Grimshaw, 2009). It has also been determined that nanomaterials have different chemical, physical, electrical, and biological characteristics than larger materials. Given these concerns, risks assessment techniques for ordinary materials may not be appropriate to determine nanomaterials' health and environmental risks (Davies, 2009). In addition, some nanomaterials can end up in the environment, invading drinking water and harming the health of humans and animals. Since they are highly durable, they will persist in the environment for some time (Patil et al., 2015).

Standard concerns about nanotechnology are primarily focused on two basic questions: 'Who controls the uses of nanotechnologies?' and 'Who benefits from the uses of nanotechnologies?' These questions are not unique to nanotechnologies, however, based on past experience with other technologies, these will need to be addressed (United States National Nanotechnology Initiative of the Nano.gov).

A recently formed National Science Foundation Engineering Research Center to design materials and safe systems to treat water using nanomaterials was formed. The research center is titled Nanotechnology-Enabled Water Treatment (NEWT). NEWT is an interdisciplinary, multi-institution Nano Systems-Engineering Research Center (headquartered at Rice University). The goal of NEWT is to apply nanotechnology to develop off-grid water treatment systems to treat drinking water and also industrial wastewater. NEWT is a joint effort by Rice University, Arizona State University, The University of Texas at El Paso, and Yale University. The primary objective of the research center is to develop technologies to safely use the properties that are unique to engineered nanomaterials. By doing so, reactors that are nanotechnology-enabled will be smaller, use less water treatment chemicals and electricity by employing nanophotonics for processes such as solar desalination (Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment, 2015).

While there are many water treatment technologies in use today, NEWT devices will use novel materials based on nanotechnology for cleaner, more efficient water treatment without adding chemicals to drinking water or producing large amounts of waste. When these devices reach production, they will be an immeasurable benefit to areas like neighborhood dwellings where infrastructure is deficient and municipal water treatment is limited. Current water treatment systems employ filters that need to be replaced periodically and use high pressure systems that require extensive maintenance while producing large volumes of waste water such as reverse osmosis, or condense the water vapor in the air which is only useful in high humidity environments.

Improving water treatment by utilizing nanotechnology could positively impact the world by providing low cost, safe, and efficient water treatment systems with minimal energy requirements (Westerhoff et al., 2016). This would allow rural and undeveloped areas that lack access to electricity to have access to treated water as well. It is vital that developed countries improve water treatment systems to fulfill the social imperative of providing clean water to less developed areas.

Research is currently focused on developing point-of-use systems that could be placed in a home to supply clean drinking water, and research is also being conducted to develop larger, centralized water treatment plants for community use. Another benefit of NEWT systems is the ability to develop made-to-order water treatment systems that will be tailored to the water contaminants unique to one area or another. Securing water supplies from biological agents may also be possible with NEWT technologies.

As part of the NEWT Project Safety and Sustainability Thrust, a team of scientists from the Departments of Social Work and Chemistry at The University of Texas at El Paso are conducting a cross-sectional study to explore community perspectives about water, sanitation, and nanotechnology feasibility and its use for water purification purposes. Using community-based participatory research methods and given the nature of the study, the research team will conduct focus groups and in-depth interviews. Focus groups are one of the most effective methods for engaging community members to tell their stories and for producing deeper understandings of community issues. Focus groups can reveal a wealth of detailed information and empower participants to address structural, social, and political factors affecting their communities (Liamputtong, 2011; Morgan & Krueger, 1998). In-depth interviews are a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular topic, program, or situation (Boyce & Neale, 2006). Data will be collected through two focus groups with approximately 12 community residents living in *colonias* and 12 in-depth interviews with key informants. Data analysis will be conducted using Miles, Huberman, and Saldaña (2014), Liamputtong (2011) and Morgan and Krueger (1998) protocols.

Recruitment of community participants will take place in two *colonias* in San Elizario, Texas and Sunland Park, New Mexico. Key informants (i.e., policy, decision makers, and water distributors) working in public and private organizations in the region in areas related to water provision and purification, health, and water technology serving the identified communities will be recruited. Participants will include male and female adults (18 years and older) representative of the communities' population and able to give voluntary informed consent for participation. Data collection procedures will take place between August and October, 2016. All materials and procedures will be produced and conducted in English and Spanish given the characteristics of the U.S.-Mexico Border population. Focus group participants will receive a $30 gift card as a stipend for their participation.

Community Engagement

Promoting public engagement in nanotechnology by offering interested citizens the opportunity to express their values and concerns and ask questions in planned exchanges with scientists, with the subsequent goal of enhancing community members' ability to play an active and constructive role in policy determination is essential (Toumey, 2006). Studies have demonstrated how community-generated information, local engagement and knowledge can advance scientific inquiry and contribute to sustainable environmental decisions (Fan, 2016).

Although efforts to involve stakeholders in science-related policy and decision-making are already taking place, criticism has emerged and suggestions have been offered. One of the critiques to upstream engagement strategies is that they are becoming a type of public participation experiment that is decontextualized and has no reference to public controversies, political participation demands, or individual concerns (Bogner, 2012). Upstream engagement refers to an approach in which exchange and mutual learning occurs before public attitudes are formed and substantial research has taken place (Kurath & Gisler, 2009; Kyle & Dodds, 2009). Several strategies have already been implemented as part of upstream engagement in nanotechnology including: focus groups, citizens' juries, deliberative workshops on nanotechnology and the environment, dialogues on the social ethical and legal aspects of nanotechnologies, information forums on nanotechnology, citizens' conferences, Nano Cafes and discussions on the implications of nanotechnology (Kyle & Dodds, 2009). All of these strategies have opened the possibility for a fruitful community engagement and discussion to the benefit of publics, policy makers, health professionals and societies (Pidgeon & Rogers-Hayden, 2007).

Upstream engagement has failed to be open and inclusive and little is known about how it can have any political effect (Bogner, 2012). Furthermore, analysis of existing nanotechnology projects determined that upstream engagement is dominated by academic, industrial, and government funding agencies with limited association to media and the public, limiting representativeness and ideas (Bogner, 2012; Wiek, Guston, Van der Leeuw, Selin, & Shapira, 2013).

Suggestions for improvement in public participation in nanotechnology have been offered. For example, a general suggestion stresses that the conditions, not just the opportunities for participation, must be created (Guston, 2014). Shortfalls in public engagement programs can be addressed by including community groups that are most likely to benefit from nanotechnology and also those traditionally excluded from participation in public deliberation such as minority groups and low socio-economic populations (Kyle & Dodds, 2009).

Kyle and Dodds propose that effective upstream engagement is conditioned upon the presence of a knowledgeable and involved public and on the commitment of government and researchers to substantiate their technological claims through providing open, responsible and debatable evidence. In order for this engagement to occur, social and political structures enabling these conditions must be created upstream. In this way, when risks start to emerge or when applications become possible, public engagement would be feasible. In order to achieve this, the same authors state that ethics and nanotechnology should develop concurrently within a framework of public awareness, information, and engagement (Kyle & Dodds, 2009). The social sciences have a salient role in the development of public participation and community engagement in nanotechnology because of their experience in public opinion, community mobilization processes, and their capacity for outreach for a more informed public debate (Macnaghten, Kearnes, & Wynne, 2005). Schmitz, Matyok, Sloam and James (2012) highlight an integral and interdisciplinary view of the skills social workers and practitioners will need to engage in practice that includes the natural and built environment. Social Workers are in a good position to help bring a paradigm shift toward compassionate and regulated use of natural resources (Burghardt, 2015) and serve as change agents and leaders to help guide interdisciplinary work to bring about societal change to protect the natural and built environment. Science and engineering make essential contributions to the knowledge base for promoting the public's health. Documentation of the realities and consequences of unhealthy infrastructure and environment for the public in terms of costs of individual services, lost productivity, and lower tax revenues, advocates and scholars can help others understand the importance of decisions about water, land use, jobs and industry, not only for health equality but also for the well-being of our society as a whole (Wing, 2016).

CONCLUSION

The Texas-Mexico border region faces multiple challenges in regards to safe drinking water, sanitation and environmental health, and these challenges are exacerbated for *colonia* residents. Exposure to harmful chemicals in water can pose serious health risks for adults and children. Providing people residing in *colonias* with the knowledge and tools to reduce health risks and prevent disease from contaminated or unsafe water should be a priority for all. Science and engineering make essential contributions to the knowledge base for promoting the public's health. Documentation of the realities and consequences of unhealthy infrastructure and environment for the public in terms of costs of individual services, lost productivity, and lower tax revenues, advocates and scholars can help others understand the importance of decisions about water, land use, jobs and industry, not only for health equality but also for the well-being of our society as a whole.

Although, nanotechnology is currently being utilized to generate clean water, many people are unfamiliar in the science behind it. Along with nanotechnology, water testing must be conducted to ensure people are not exposed to toxic chemicals and other health risks. Nanomaterials for clean, efficient water treatment are promising where infrastructure is deficient. It is imperative that community members get educated and participate in dialogues on the use of nanotechnology to ensure ethical and safe use.

Researchers must partner with the public to develop technologies that are accessible, available, affordable and accountable. The NEWT Project devices can greatly benefit communities with limited infrastructure. Our aim is to bridge science and community to bring about health and environmental improvements through nanotechnology, education and community agency. Protecting human lives and ensuring access to safe drinking water are human rights. Developing and applying nanotechnology for water treatment systems is NEWT's aim.

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