Use of GIS and Remote Sensing in Well Water Outreach

By Mahrukh (Anwar) Shaikh

What do Flint, Woburn, Camp Lejune, Hinkley, and Lanzhou have in common? It is the undeniable reality of how venerable our drinking water supply is to being contaminated. Since the start of the industrial revolution, mankind has been reminded again and again to be more careful and mindful of this precious resource.

When it comes to the presence of harmful contaminants in the drinking water, many are naturally occurring, while others are anthropogenic. Groundwater is no different. Whether it is the percolating rainwater that picked up the pesticides, or the naturally occurring arsenic in the bedrock through which the groundwater was flowing; the groundwater is prone to all sorts of harmful substances. Under the EPA’s Safe Drinking Water Act, the public wells are routinely tested and maintained, however the private wells are not covered under the drinking water act (Private Drinking Water Wells, 2017). Therefore, it is the responsibility of the private well owner to test and check their drinking well water. According to USGS, about “43 million people, or 15 percent of the Nation’s population use drinking water from private wells” (Contamination in U.S. Private Wells, 2016). Many barriers exist for a private well owner in having his/her water tested, which include lack of information, socio economic reasons, or just behavioral issues (Zheng, Y., 2017). What makes it even more complicated is that the quality of well water is “regional”. Take the example of Beryllium, a rare metal that occurs naturally in certain locations in Rhode Island bedrock and can cause health problems (Beryllium in Drinking Water Wells, 2013). Then there is even a greater concern regarding the naturally occurring arsenic in the bedrock. In New Hampshire, 39 percent of bedrock groundwater was identified as having at least a 50 percent chance of containing an arsenic concentration greater than or equal to 1 µg/L (Ayotte et al., 2012). In 2000, the Pew Environmental Health Commission published its landmark report, America’s Environmental Health Gap: Why the Country Needs a Nationwide Health Tracking Network, that identified the lack of a national, coordinated system that could track environmental health hazards, exposures, and health outcomes (Kearney et al., 2015). This led to the Congress approved funding to the Centers for Disease Control and Prevention (CDC) to develop the first national public health system that would assist in preventing diseases caused by environmental health threats. The CDC’s National Environmental Public Health Tracking Program was launched in 2002 (Katner et al., 2015). Addressing the drinking water quality issues and the illnesses arising from drinking water, many states launched their own programs especially aimed for the private well water communities. For example, Colorado initiated a Private Well Task Force (PWTF) and the Private Well Vulnerability Mapping (PW Vulnerability Mapping) project team around 2012. Over the next few years, with the collaboration of multiple agencies, an inventory of available well water quality data sets were put together to support intervention strategies that would improve the health of communities relying heavily on private wells for drinking water supply (Brown et al., 2015). The California Environmental Health Tracking Program developed an online application the Water Boundary Tool (WBT), a Web-based geospatial crowdsourcing application that can manage customer service boundary data for each public well system (PWS) in California and can track changes over time. It collects data on the geographic location of PWS customer service areas, which can then be linked to population and drinking water quality data. The CEHTP Water Boundary Tool (WBT) assists water systems in creating digital maps of the areas they serve and compiles these individual maps into a single statewide map (Wong et al., 2015). Louisiana used the funding from CDC to create the Unregulated Drinking Water Initiative (UDWI) in 2009, which laid the foundation for a surveillance system for tracking arsenic hazards, private well
drinking water use, and outreach planning. UDWI used different Environmental monitoring data sets, that includes the Louisiana Department of Health and Hospital's (LDHH's), Safe Drinking Water Information System (SDWIS), US Geological Survey's (USGS's), National Water Quality Assessment (NAWQA), USGS National Geochemical Survey (NGS), and EPA's Storage and Retrieval (STORET) Baseline Monitoring Project. The private well location and water use data included the Louisiana Department of Natural Resources (LDNR's) Strategic Online Natural Resources Information System (SONRIS) and a USGS's Domestic Well Water Use System. The Biomonitoring data was obtained from LDHH's Heavy Metal Surveillance Program (Katner et al., 2015). Similarly, New Hampshire Department of Health and Human Services (NH DHHS), and the New Hampshire Department of Environmental Services (NH DES) developed the New Hampshire Environmental Public Health Tracking (NHEPHT) Program to better understand the occurrence and levels of arsenic in the drinking water, and conducted a cooperative study to develop models using multivariate logistic regression modeling (“probability models”) for assessing the probability of arsenic in groundwater from wells at concentrations greater than or equal to 1, 5, and 10 µg/L (Ayotte et al., 2012).

All these programs rely on the use of a geographic information system and remote sensing, to put together all the data, and use it to not only develop strategies for betterment of water quality, and to identify which communities to outreach for, but also allow the private well owners access to obtain information and resources regarding their drinking water use. This is just a beginning. With time and more inter-agencies cooperation, these online geodatabases for water quality will expand their use even further.

References Cited:


Annotated Bibliography for Well Water Outreach
By Mahrukh (Anwar) Shaikh


In the State of Colorado, the private wells water quality test is the sole responsibility of the well owner. In order to protect these owners, a need for providing up to date and much needed quality issues was felt. The solution presented itself in form of a Private Well Task Force (PWTF) and the Private Well Vulnerability Mapping (PW Vulnerability Mapping) project team around 2012. Over the next few years, with the collaboration of multiple agencies, an inventory of available well water quality data sets were put together to support intervention strategies that would improve the health of communities relying heavily on private wells for drinking water supply. One major issue encountered was the protection of privacy of the well owners. For this, once the central data set was compiled and geo-coded to create data attributes that could be utilized by GIS software, sample results were then symbolized by individual points indicating the concentration and location across the state and these points were then slightly offset to protect privacy. To further protect the privacy, the point-level data were only available by request, via Colorado’s secure “Data Request System”, to local public health partners or other partner agencies and were not available on the public portal.


In Louisiana, privately owned domestic well water supplies are not regulated, or tested for contaminants under EPA’s Safe Drinking Water Act. Approximately 13% of Louisiana residents depend upon private domestic wells. Arsenic has been detected in the well water of some Louisiana communities, and may be a localized presence. To protect the well owners, Louisiana used the funding from Centers for Disease Control and Prevention (CDC) to create the Unregulated Drinking Water Initiative (UDWI) in 2009, which laid the foundation for a surveillance system for tracking arsenic hazards, private well drinking water use, and outreach planning. The Environmental monitoring data used for this are the Louisiana Department of Health and Hospitals (LDHH’s), Safe Drinking Water Information System (SDWIS), US Geological Survey’s (USGS’s), National Water Quality Assessment (NAWQA), USGS’ National Geochemical Survey (NGS), and EPA's Storage and Retrieval (STORET) Baseline Monitoring Project. The
private well location and water use data included the Louisiana Department of Natural Resources’ (LDNR’s) Strategic Online Natural Resources Information System (SONRIS), and a USGS’s Domestic Well Water Use System. Biomonitoring data were obtained from LDHH’s Heavy Metal Surveillance Program. While the results of this data evaluation are preliminary, they will assist Louisiana state agencies in prioritizing parishes for monitoring and outreach. Additional monitoring data for private domestic wells are needed. Future research will also include an analysis of spatial and temporal correlation of the samples.


The New Hampshire Department of Health and Human Services (NHDHHS), and the New Hampshire Department of Environmental Services (NHDES) developed the New Hampshire Environmental Public Health Tracking (NHEPHT) Program in 2011 using the funding from Centers for Disease Control and Prevention (CDC). The objectives of the program were to improve public health and provide detailed information on the probability of arsenic presence in bedrock of New Hampshire. It was suspected that a significant number of well owners were at risk for high arsenic levels. In order to better understand the occurrence and levels of arsenic in the drinking water, the NH DHHS, NH DES, and the U.S. Geological Survey (USGS) conducted a cooperative study to develop models using multivariate logistic regression modeling (“probability models”) for assessing the probability of arsenic in groundwater from wells at concentrations greater than or equal to 1, 5, and 10 µg/L. The probability models were developed from arsenic measurements in water from public and private wells as the dependent (or predicted) variable, and from a variety of geologic, geochemical, hydrologic, and land use data as the independent (predictor) variables.


In the Fall of 2010, the students taking The Environmental Studies Senior Seminar (ENVS 401) from the Middlebury College, Vermont, choose the theme for the current semester as “The Groundwater Resource: Global Concerns, Local Perspectives”. For this, the group focused on the occurrence of arsenic in the drinking water of especially the private well owners. The entire class was divided into three groups: The survey group, the spatial group and the policy group. The survey group collaborated with the Vermont Department of Health to evaluate the public’s knowledge of their well water. The spatial group was matched with Vermont geological survey, to investigate incidences of increasing arsenic well tests and determine relationship between bedrock and high arsenic to locate areas of concern. The policy group was paired with the State Senator Virginia Lyons to provide the community partner with information to advancing the policy discussions regarding private well water testing, and regulations in Vermont.

The use of GIS involved merging the five original well testing datasets into a single layer and placing it in a geodatabase. For all analyses ArcGIS 10.0 was used. High arsenic levels were found in small pockets throughout the state. The most notable collection of high arsenic results was in Rutland and Bennington counties. The findings and conclusions were all put together for the legislation in 2010-2011.

This article is about using the GIS for betterment of public health in regards to the illnesses arising due to the presence of low level contaminants in drinking water. In California, there are more than 8000 public water systems (PWSs), making the assembly of a database linking households to PWS difficult. Efforts began around 2008, when The California Environmental Health Tracking Program was started from the funding provided by the Centers for Disease Control and Prevention (CDC). The California Environmental Health Tracking Program developed the ‘Water Boundary Tool’ (WBT), a web-based geospatial crowdsourcing application that can manage customer service boundary data for each PWS in California and can track changes over time. It collects data on the geographic location of PWS customer service areas, which can then be linked to population and drinking water quality data. The CEHTP Water Boundary Tool (WBT) assists water systems in creating digital maps of the areas they serve and compiles these individual maps into a single statewide map. The WBT was designed for water system operators, local and state regulatory agencies, and government entities, and was launched in 2012. Since its launch, the WBT has collected service area boundaries for about 2300 individual PWS, serving more than 90% of the California population. Although the WBT data set is incomplete, it has already been used for a variety of applications, including fulfilling legislatively mandated reporting requirements and linking customer service areas to drinking water quality data to better understand local water quality issues. Development of this tool holds promise to assist with outbreak investigations and prevention, environmental health monitoring, and emergency preparedness and response.


It is estimated that approximately one in five New Hampshire wells have arsenic in excess of the U.S. EPA MCL of 0.01 mg/L, a class 1 carcinogen. It is an overwhelming issue to address as the private well owners, are solely responsible to have their water tested for arsenic. It is further complicated by the uneven distribution of arsenic in the bedrock. The only way to find out if one is drinking water with concerning levels of arsenic or not, is to have the water tested. But many private well owners, either do not know about it, or find the cost of testing to not be economical and then there are the behavioral issues. In order to address this, in 2012, Tuftonboro Conservation Commission Extensive outreach program was launched in a pilot study at the coastal town of Tuftonboro on the north shore of Lake Winnipesaukee (New Hampshire. The major intervention done was the outreaching followed by the distribution of water sample collection kits and then pickup and delivery of the water samples to a testing facility that was 70 minutes’ drive away. The samples were tested and the results were made available to the households by TCC, support from state agencies, and a research program at Dartmouth College. The project prompted more water tests at the state laboratory in one day than in the prior six years. This suggests that community-driven, collaborative efforts to overcome practical barriers can be successful at raising testing rates and ultimately improving public health.

This is an opinion paper that looks into the barriers and challenges of addressing the public’s protection from the presence of arsenic in their drinking water. Even though, the public water is managed by the EPA’s Safe Water Act, however, that leaves the communities of private well owners very vulnerable to the contamination and slow poisoning due to arsenic present in their drinking water. The barriers present are the uneven distribution of arsenic, socioeconomic and behavioral barriers. The author stresses that it is an ethical obligation of the environmental health professionals, physicians, water treatment specialists, hydro-geologists, and the community’s organizations and government to help with the mitigation and awareness issue of arsenic in drinking water to the public.


It was in 2000, when the Pew Environmental Health Commission published its landmark report, America’s Environmental Health Gap: Why the Country Needs a Nationwide Health Tracking Network, that identified the lack of a national, coordinated system that could track environmental health hazards, exposures, and health outcomes. In order to address that the Congress approved funding to the Centers for Disease Control and Prevention (CDC) to develop the first national public health system that would assist in preventing diseases caused by environmental health threats. This led to the launch of the CDC’s National Environmental Public Health Tracking Program (Tracking Program in 2002. This article evaluates the peer-reviewed articles that were published since the start of the Tracking Program (2002-2012) and spanned a broad variety of public health topics. The objective was to recognize the milestones, the challenges, and the recommendations proposed. The findings demonstrated progress in the areas of data linkage, data sharing, and network developing. The challenges identified were in establishing the connections between health and the environment, and included biomonitoring, public water systems and the data for the private well owners. The recommendations proposed were to use the data from the studies to better the policy making and use of electronic health records data for an improved public health management.