ABSTRACT

With the presence of heavy metals in water posing a threat to human, animal, and environmental safety, monitoring technologies are a vital tool in determining remedial action, and future water policy. The comprehensiveness, cost-effectiveness, sustainability, and time requirements of monitoring technologies determine how likely institutions are to use them. Scientists, engineers, activists, and policymakers need accurate information to understand the scale of heavy metals contamination and develop future policies. The need to establish the importance of using monitoring technologies, and suggest policy changes, while understanding the world’s diverse needs, capabilities, and current situation on handling heavy metal pollution. The social, political, and economic consequences of heavy metal contamination demands holistic decision actions.

INTRODUCTION

Water is life. There is no safety of human or environmental health without the assurances of clean water. One of the United Nations’ sustainable development goals is to "Ensure availability and sustainable management of water and sanitation for all". A major element of achieving this goal is - reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halting the propagation of untreated wastewater and substantially increasing recycling and safe reuse globally. A nation’s ability to meet this goal is determined by factors such as:

- Differences in their resources
- Technical capacities
- Status of the economy
- Quality of institutions and political systems and processes
- Weak market demand for monitoring technologies
- Technological lock-in to current infrastructure

One pollutant of concern is heavy metals, which are particularly hazardous to humans and the environment. However, traditional testing methods for aqueous heavy metals are both effective and timely intensive, making their use very prohibitive. A government cannot regulate what it is not aware of. The goal of this research is to make the case for there being an engineering need for innovative aqueous heavy metal detectors, and why such technologies will drive the development of policy and the more likely realization of those UN goals across the world. This research will also provide recommendations to overcoming the barriers to wider adoption of monitoring technologies.

SOCIAL & ECONOMIC RISKS

The lack of water monitoring technologies used in developing nations means that large numbers of people consume water contaminated with heavy metal levels far exceeding World Health Organization guidelines, from Nigeria, to Cambodia, to Bangladesh. Sources of heavy metals contamination into water include:

- Industrial activity
- Improper disposal
- Agriculture
- Nuclear power
- Urban runoff

Heavy metals are absorbed by humans through contaminated water and vegetables grown in said water. They are carcinogens that target multiple human organs, even at very low levels. Negative health effects of heavy metal ingestion are particularly pronounced in children, who absorb them much faster than adults. The localized nature of pollution can disproportionately affect those of lower socioeconomic status, such as the Flint, Michigan crisis. Around the world, people who live in areas of strong heavy metals pollution have little to no access to healthcare which could catch and mitigate/reverse the damage to one’s body.

The entire world’s economic loss due to heavy metals poisoning is estimated between $726-1152 billion in 2012. These costs are associated with control measures for aqueous heavy metals will turn around as a net savings when factoring in health care, lifetime earnings, tax revenue, special education, attention deficit hyperactivity disorder, and the direct costs of crime. It would cost an estimated $1 trillion over the next 50 years to adequately clean up US households of heavy metals poisoning sources. Children who have safe drinking water are found to have higher lifetime earnings and quality of life. A reveal of heavy metals contamination can increase nearby housing prices, and affected areas have to spend millions of clean water and medical care for those affected. Willingness to pay for reduction in heavy metals risk is a common research figure in many regions of the world, used to gauge future technology adoption likelihoods.

MONITORING TECHNOLOGY

There are several major issues with current water monitoring technology:
- It is not continuously sampling. There is no capability for real-time knowledge of heavy metals levels in water.
- It is cost prohibitive
- Some technologies can only test for one element at a time
- Equipment requires highly specialized training to use
- Sensitivity detection range and minimum-maximum detection levels
- Slow speed of results
- Portability

Traditional analysis of heavy metals in water include ICP-MS, ICP-OES, and AAS. These are very large pieces of lab equipment that cannot be installed outside, cost a lot, requires extensive special knowledge to use, the user must have "some" idea of the sample’s constituents if testing more than one element at a time, and it only analyzes at one point in time. For these reasons, novel technologies have been developed to address one or more of the bullied concerns.

Table 1: Comparing cost and sensitivities of different novel monitoring technologies. From top to bottom: ANDalyze Inc. Heavy Metals sensors, FREDSense Asrec, Appealng Products, Inc. Chemplex test GHH-01, Appealng Products, Inc. Colorimetric test HM34, Hach EZ2600 series analyzers, REX Real Time Purity

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Cost</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>2ppb-3ppm</td>
<td>&lt;$2500, &lt;$8/test</td>
<td>Pb Cu U Hg Zn Cd</td>
</tr>
<tr>
<td>2.5-15ppb</td>
<td>&lt;$5000, $20/consumable</td>
<td>As In development: Mn Cu Ni</td>
</tr>
<tr>
<td>Lowest 10ppb</td>
<td>$9.95</td>
<td>Pb Hg Cd Zn Co Cu Ni</td>
</tr>
<tr>
<td>Lowest 250ppb</td>
<td>$34.95</td>
<td>Pb Hg Cd Th Less so Cu Zn Fe</td>
</tr>
<tr>
<td>&quot;Lower ppb range&quot;</td>
<td>$30000-50000</td>
<td>Cu As Cd Hg Zn Pb</td>
</tr>
<tr>
<td>Lowest 2 ppb</td>
<td>$150000</td>
<td>Mg U</td>
</tr>
</tbody>
</table>

Hach’s EZ2600 series machines analyze continuously in real time. However, different models are needed to test for different heavy metals. ANDalyze handheld sensors are cheap and portable but are engineered as a “complement” to traditional lab testing. FREDSense’s field kit offers fast turn-around for results and are easy to use. The company advertises its technology as a viable option where cost is a major factor in adopting monitoring technology.

REX uses X-Ray fluorescence and carbon aerogels. It is in its late stages of development, and with its newest update, produces continuous results every hour.

There are also novel technologies still in production and not on the market yet. Nanolyst is working on something involving artificial intelligence with cell phone connectivity, however this project is highly secretive as of now. Radcon will use inductively coupled plasma made from air or nitrogen to match ICP-OES in results quality with improved simplicity and cost. Despite the fact concentrations of heavy metals in water are often unacceptable at any level, the detectable limits in these technologies are often higher than regulatory limits. The disadvantage of many detection methods is that there may be interference caused by analyte components, masking the characteristics of the element of concern. Also, if an element is detected, it can be difficult to remove from the sensor to find the next or any remaining elements in solution. This becomes the technical challenge for many of the sensors listed. In continuous operation with near real time sampling, the automated cleaning of the measuring element is a critical step for precise results.

POLICY

A nation’s ability to pass and uphold its water policies is a reflection of current and practical circumstances, the strength of state institutions, and the level of trust people have in their government. Nations like Bangladesh, Mexico, Chile, and Saudi Arabia set their drinking water lead levels at 50 ppb, well above the World Health Organization’s recommendation of 10 ppb, which is a policy copied into the laws of countries like Germany, the Netherlands, Australia, and South Korea, as well as Nigeria, India, China, Israel, Iran, and South Africa. The superpower Canada has drinking water lead levels at 5 ppb. Some nations do not have water policies easily accessible online, such as Haiti, Bolivia, and Indonesia. The United States has a relatively unique 15 ppb lead “action level”, the law being an order to fix what is currently broken, rather than a definitive hard cap on pollutant levels like most other nations researched. US Executive and legislative controls are shown to be ineffective in curtailing water pollution. There is also a lack of private-public collaboration when it comes to US adoption of water technologies. The public’s ease of access to water policy is important to consider, so research was done not only on global water heavy metal policies, but how easily information could be found online.

CONCLUSION

Technologies for monitoring heavy metals are crucial for generation of data and development and implementation of policy. The lack of capacity for widely available water monitoring technologies causes socioeconomic and health risks. Although considerable progress has been made in last couple of decades, our study shows that research is still ongoing to develop much needed water monitoring technologies that can release reliable and accurate results at low cost within a day, hours, or nearly real-time, depending on the application.

Engineered solutions must be combined with institutions which understand the risks of heavy metals, and have the ability to invest in monitoring technology, and a public ready to accept policy changes. It is believed that an increased collaboration between public and private sector will create a positive feedback loop, where the private sector is encouraged by the public sector to develop technologies, which in turn will lead to better info to dictate better policy, allowing more people to live healthier lives.

It is through these measures that progress society to the ultimate goal of universal and equitable access to safe and affordable drinking water for all.

REFERENCES


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A REVIEW OF HEAVY METALS WATER DETECTION TECHNOLOGIES AND GLOBAL POLICIES

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