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Water Reuse – Where are we Heading?

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We find ourselves at a unique time in history where population expansion and exponential growth in urban density are leading to water demand far outstripping water supply. This is further compounded by global warming and climate change, creating anomalies in weather patterns and resulting in severe drought, floods and disease. Although these challenges have always been with us through the centuries, nowhere has it hit civilizations with the ferocity and frequency that we are experiencing today. This places even more emphasis on the need to fast forward our technological solutions and to anticipate problems before they surface. Three areas which will or should have some bearing on the way we resolve environmental problems now and in the future are Emerging Contaminants of Concern, Sustainability and Smart Infrastructure.

Emerging Contaminants of Concern

Emerging contaminants of concern, both chemical as well as microbial, are emerging because they are either new or have not been a problem in the past but have since been found to be. The connecting thread is that these contaminants pose some health risk but which has yet to be confirmed and regulated due to insufficient information or evidence. From a treatment perspective, emerging contaminants continue to remain a challenge in several aspects. One lies in the analytical detection of these micro pollutants at trace levels; the other is in the removal of these contaminants from wastewater and potable water. Our understanding of their presence in the environment is only as far as our capability in detection is evolving. Sensitivity and accuracy of measurements need to be continuously pushed to the limits while quality assurance, quality control and standardized protocols have to be pursued rigorously to ensure a comprehensive basis for comparison. Many of the emerging contaminants are currently measured using discrete water samples processed in the laboratory with high end analytical instruments. The trend, however, is to aim for real-time or online detection of target contaminants in water systems, especially those which carry serious health risks. The ability to detect such contaminants in real-time will allow for rapid response measures to counteract threats, whether accidental or intentional. There is still plenty of scope for development in this area but progress has been promising.

In addition to detection methods, treatment methods also need to be improved as not all emerging contaminants can be effectively removed with current technology. Application of new materials in treatment processes offer new opportunities while the combination of different treatment approaches allow for more efficient and more complete removal, although with varying degrees of success. Ultimately, the aim is to reduce the concentrations of contaminants to levels which do not pose a risk to the environment. This begs the question as to what levels are suitable? For chemicals, the understanding of health risks to ecosystems and people inevitably seem to lag the production of emerging contaminants, and more needs to be done to pre-empt health risks rather than to respond on hindsight. Relevant bioassays on mixtures at environmentally relevant concentrations and time-scales should also be conducted to have a more realistic evaluation of risks.

With so many emerging contaminants surfacing, there is a need to continually update the target list of contaminants. As some contaminants are phased out from production, new ones are added for which health risks are less known. For example, the ubiquitous per fluorinated chemicals, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), have been removed from production in many countries in the 2000s due to potential health impacts related to carcinogenicity, developmental effects and bioaccumulation properties. They have since been replaced by shorter chain PFCS (e.g. PFBS, PFBA) which tend to be less hydrophobic and thus, less bioaccumulative. However, concerns have recently been raised about the safety of these shorter chain chemicals in the urban water cycle. Continued vigilance of emerging contaminants is necessary to ensure public safety and protection of the environment.

Sustainability

Sustainability is a term that has been used incessantly in recent years, underlining its importance in managing our scarce resources and preparing for the future. In the field of water reuse, sustainability champions the very reason for water reclamation which continues to make inroads into societies worldwide. Reclaimed water is still largely for industrial as well as indirect potable use but moving forward, can we reach the point where reclaimed water is used directly for regular, potable water supply? The technology is already there, but it may still be a question of overcoming public concern and residual unknowns, rather than technological constraints. We are seeing more and more countries facing severe water stress, exacerbated by climate change and it may be, that when push comes to shove, direct potable use of reclaimed water will have to be implemented. Whatever the reasons, the technology used should be of sufficient rigor to allay people's fears and simultaneously, there should be proper education and dissemination of information to the public to effect changes in mindset.

Water stress has precipitated the recycling of both grey and black water. A question which arises is whether one should opt for centralised versus decentralised treatment. Should treatment be done at source and if so, to what extent? There are advantages which include savings in cost of sewerage and water infrastructure but disadvantages in terms of economies of scale for treatment options and lack of quality control. Another problem is that of implementation. Many urban cities today face aging infrastructure in densely populated areas, making retrofitting and rehabilitation a tremendous challenge. Each place is unique and there is often, no one size that fits all. In new developments, however, there is excellent opportunity of integrating water and wastewater infrastructure into the urban design where recycling wastewater and reclaiming water are feasible. At the same time, recovery of energy at the household or building level from treatment processes would help close the loop and safeguard sustainability in the long term. More emphasis should be placed in R&D where there is not only removal of target contaminants but also a substantial reduction in footprint, carbon emissions and costs. With greater treatment efficiency and energy recovery, water reclamation can be a viable solution that can greatly enhance water resilience.

Smart Infrastructure

An upcoming trend that can significantly transform and enhance the resilience of the urban water system is the coupling of sensing, modeling and data analytics. However, for this to happen fruitfully there has to be synergy between environmental engineers and data scientists. Sensor networks and online data monitoring, coupled with numerical modeling and artificial intelligence, offer real opportunities to develop smart water-infrastructure systems. These systems can provide real-time information for rapid response and problem solving. If robotics can be integrated as part of the solution package, this could facilitate even faster response times to fix problems. Many novel and innovative solutions lie at the interface or nexus of different disciplines and these can be developed by active collaboration between partners. One can imagine, for example, a scenario where a failed pipe system could be detected, and automatically patched up using sensor controlled robots delivered through the network. Internet technology also opens up avenues for communicating data from sensor networks, with convenient application tools that can be accessed everywhere.

The integration of decentralized treatment options for wastewater recycling coupled with smart sensing and control are real possibilities in the future. It is not inconceivable to envision an integrated smart system for water usage, recycling and reclamation at a household level. Online sensing and feedback provide quality control and safety, while data mining and artificial intelligence can help to optimize methods. With these technologies in place, the goal of sustainability in the urban water cycle can be achieved. We look forward to receiving your research contributions to this effort.