Critical Issues Related to Recycling of Waste Waters for Multiple Applications

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Abstract

Optimizing the use of over 2 trillion gallons/day (10 billion tons/day) of water is becoming a critical issue with the rapid growth in the population and industrial activities. Water is the most essential item for all operations including human day to day activities. Sources of water for potential reuse can include municipal wastewater, industry process and cooling water, storm water, agriculture runoff and return flows, and produced water from natural resource extraction activities. These sources of water are adequately treated to meet “fit-for-purpose specifications” for a particular next use. "Fit-for-purpose specifications” are the treatment requirements to bring water from a particular source to the quality needed, to ensure public health, environmental protection, or specific user needs. Hence it is important to develop new technologies to treat and recycle the wastewaters in a safe and economical way and also develop real-time monitoring system for the operations including monitoring the water quality at all levels of supplies, treatment and recycling operations.

1. Introduction

Earth is covered with 75% of water but 97.5% of that is salt water (oceans) and only 2.5% is fresh water to drink. With the growth in the population there is rapidly increasing amount of water used for domestic, commercial and industrial operations amounting to over 2.4 trillion gallons per day. An average American uses 100 gallons to 175 gallons of water per day. Agriculture alone can consume 75 to 90% of the region’s available fresh water. Source of fresh water supply includes ground water, rainfalls, reservoirs and rivers.

Water reclamation (also called **wastewater reuse or recycling**) is the process of converting wastewater into water that can be reused for other purposes. Reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater (i.e., groundwater recharge). Reused water may also be directed toward fulfilling certain needs in residences (e.g. toilet flushing), businesses, and industry, and could even be treated to reach drinking water standards. This last option is called either "direct potable reuse" or "indirect potable" reuse, depending on the approach used.

Reclaiming water for reuse applications instead of using freshwater supplies can be a water-saving measure. When used water is eventually discharged back into natural water sources, it can still have benefits to ecosystems, improving streamflow, nourishing plant life and recharging aquifers, as part of the natural water cycle.

Reusing wastewater as part of sustainable water management allows water to remain as an alternative water source for human activities. This can reduce scarcity and alleviate pressures on groundwater and other natural water bodies. Another potentially positive aspect is the nutrient content in the wastewater, which might reduce the need of other fertilizers.

Drawbacks or risks often mentioned include the content of potentially harmful substances such as bacteria, heavy metals or organic pollutants (including pharmaceuticals, personal care products and pesticides). Irrigation with wastewater can have both positive and negative effects on soil and plants, depending on the composition of the wastewater and on the soil or plant characteristics. [6]

Water/wastewater reuse, as an alternative water source, can provide significant economic, social and environmental benefits, which are key motivators for implementing such reuse programs. Specifically, in agriculture, irrigation with wastewater may contribute to improve production yields, reduce the ecological footprint and promote socioeconomic benefits. These benefits include:[28][19]

- Increased water availability
- Drinking water substitution - keep drinking water for drinking and reclaimed water for non-drinking use (i.e. industry, cleaning, irrigation, domestic uses, toilet flushing, etc.)
- Reduced over-abstraction of surface and groundwater
- Reduced energy consumption associated with production, treatment, and distribution of water compared to using deep groundwater resources, water importation or desalination
- Reduced nutrient loads to receiving waters (i.e. rivers, canals and other surface water resources)
- Reduced manufacturing costs of using high quality reclaimed water
- Increased agricultural production (i.e. crop yields)
- Reduced application of fertilizers (i.e. conservation of nutrients, reducing the need for artificial fertilizer (e.g. soil nutrition by the nutrients existing in the treated effluents))
- Enhanced environmental protection by restoration of streams, wetlands and ponds
- Increased employment and local economy (e.g. tourism, agriculture).

1.1. Barriers to implementation of Recycling Wastewaters

There are issues related to recycling of wastewaters and some the important issue are as follows:

- Full-scale implementation and operation of water reuse schemes still face regulatory, economic, social and institutional challenges.
- Economic viability of water reuse schemes.
- Costs of water quality monitoring and identification of contaminants. Difficulties in contaminant identification may include the separation of inorganic and organic pollutants, microorganisms, Colloids, and others.
- Full cost recovery from water reuse schemes - lack of financial water pricing systems comparable to already subsidized conventional treatment plants.

Psychological barriers, sometimes referred to as the "yuck factor" can also be an impediment to implementation, particularly for direct potable reuse plans. These psychological factors appear to be closely associated with disgust, specifically pathogen

Recycle (reclaimed) water is considered safe when appropriately used. Reclaimed water planned for use in recharging aquifers or augmenting surface water receives adequate and reliable treatment before mixing with naturally occurring water and undergoing natural restoration processes. Some of this water eventually becomes part of drinking water supplies.

A water quality study published in 2009 compared the water quality differences of reclaimed/recycled water, surface water, and groundwater. Results indicate that reclaimed water, surface water, and groundwater are more similar than dissimilar with regard to constituents. When detected, most constituents were in the parts per billion and parts per trillion range. DEET (a bug repellant), and caffeine were found in all water types and virtually in all samples. Triclosan (in anti-bacterial soap & toothpaste) was found in all water types but detected in higher levels (parts per trillion) in reclaimed water than in surface or groundwater. Very few hormones/steroids were detected in samples, and when detected were at very low levels. Haloacetic acids (a disinfection by-product) were found in all types of samples, even groundwater. The largest difference between reclaimed water and the other waters appears to be that reclaimed water has been disinfected and thus has disinfection by-products (due to chlorine use).

A 2005 study titled "Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed Water" found that there had been no incidences of illness or disease from either microbial pathogens or chemicals, and the risks of using reclaimed water for irrigation are not measurably different from irrigation using potable water.

A 2012 study conducted by the National Research Council in the United States of America found that the risk of exposure to certain microbial and chemical contaminants from drinking reclaimed water does not appear to be any higher than the risk experienced in at least some current drinking water treatment systems, and may be orders of magnitude lower.[38] This report recommends adjustments to the federal regulatory framework that could enhance public health protection for both planned and unplanned (or de facto) reuse and increase public confidence in water reuse.

The main potential risks that are associated with reclaimed wastewater reuse for irrigation purposes, when the treatment is not adequate are the following:

1. contamination of the food chain with microcontaminants, pathogens (i.e. bacteria, viruses, protozoa, helminths), or antibiotic resistance determinants;
2. soil salinization and accumulation of various unknown constituents that might adversely affect agricultural production;
3. distribution of the indigenous soil microbial communities;
4. alteration of the physicochemical and microbiological properties of the soil and contribution to the accumulation of chemical/biological contaminants (e.g. heavy metals, chemicals (i.e. boron, nitrogen, phosphorus, chloride, sodium, pesticides/herbicides), natural chemicals (i.e. hormones), contaminants of emerging concern (CECs) (i.e. pharmaceuticals and their metabolites, personal care products, household chemicals and food additives and their transformation products), etc.) in it and subsequent uptake by plants and crops;
5. excessive growth of algae and vegetation in canals carrying wastewater (i.e. eutrophication);
6. groundwater quality degradation by the various reclaimed water contaminants, migrating and accumulating in the soil and aquifers.

To address these concerns about the source water, reclaimed water providers use multi-barrier treatment processes and constant monitoring to ensure that reclaimed water is safe and treated properly for the intended end use. In the ever-evolving technology landscape, the ability to adopt quickly the technology, both treatments can be a major asset.

1.2. History

From the beginning of the Bronze Age (ca. 3200–1100 BC), domestic wastewater (sewage) has been used for irrigation and aquaculture by a number of civilizations including those that developed in China and the Orient, Egypt, the Indus Valley, Mesopotamia, and Crete (Andreas et al. 2018). In historic times (ca. 1000 BC−330 AD), wastewater was disposed of or used for irrigation and fertilization purposes by the Greek and later Roman civilizations, especially in areas surrounding important cities (e.g., Athens and Rome). In more recent times, the practice of land application of wastewater for disposal and agricultural use was utilized first in European cities and later in USA. Today, water reclamation and reuse projects are being planned and implemented throughout the world. Recycled water is now used for almost any purpose including potable use. This paper provides a brief overview of the evolution of water reuse over the last 5,000 years, along with current practice and recommendations for the future. Understanding the practices and solutions of the past, provides a lens with which to view the present and future.

1.3. Engineered Wastewater Treatment Systems

The development of modern methods of sewage treatment can be traced back to the mid nineteenth century in England and Germany. The large population in London and the limited area available for treatment in sewage farms, broad irrigation, or intermittent filtration led to renewed interest in more intensive methods of treatment before discharging the treated effluent to land and hence to freshwater bodies. Methods of treatment that were used included large septic tanks, contact beds, and trickling filters. Where sufficient land was available intermittent sand filters were also used.

1.4. Changing Views of Water Reclamation and Reuse

Many things have changed in the water reclamation and reuse field in the contemporary period (1900 AD-present), but especially so during the last three decades. One of the most relevant changes is the recognition of the importance of reclaimed water in an integrated water resources management plan. Reclaimed water has become a new, additional, alternative, reliable water supply source right at the doorstep of metropolis for numerous uses in the diverse environment. This approach has even been recognized by the United Nations through the World Water Development Report 2017 (UNESCO, 2017) focusing on wastewater as a resource. Moreover, successful stories on water reuse have expanded the frontier from agricultural and landscape irrigation and restricted urban uses to a variety of uses including potable reuse (Crook, 2010; Mujeriego, 2013; Tchobanoglous et al., 2014).

1.5. World Health Organization (WHO)

The World Health Organization has recognized the following principal driving forces for wastewater reuse:

1. increasing water scarcity and stress,
2. increasing populations and related food security issues,
3. increasing environmental pollution from improper wastewater disposal, and
4. increasing recognition of the resource value of wastewater, excreta and greywater.

Water recycling and reuse is of increasing importance, not only in arid regions but also in cities and contaminated environments.

Already, the groundwater aquifers that are used by over half of the world population are being over-drafted. Reuse will continue to increase as the world's population becomes increasingly urbanized and concentrated near coastlines, where local freshwater supplies are limited or are available only with large capital expenditure.[11][12] Large quantities of freshwater can be saved by wastewater reuse and recycling, reducing environmental pollution and improving carbon footprint.[9] Reuse can be an alternative water supply option.

1.6. EPA Guidelines

Water reuse (also commonly known as water recycling or water reclamation) reclaims water from a variety of sources then treats and reuses it for beneficial purposes such as agriculture and irrigation, potable water supplies, groundwater replenishment, industrial processes, and environmental restoration. Water reuse can provide alternatives to existing water supplies and be used to enhance water security, sustainability, and resilience.

Water reuse can be defined as planned or unplanned. Unplanned water reuse refers to situations in which a source of water is substantially composed of previously used water. A common example of unplanned water reuse occurs when communities draw their water supplies from rivers, such as the Colorado River and the Mississippi River, that receive treated wastewater discharges from communities upstream.

Planned water reuse refers to water systems designed with the goal of beneficially reusing a recycled water supply. Often, communities will seek to optimize their overall water use by reusing water to the extent possible within the community, before the water is reintroduced to the environment. Examples of planned reuse include agricultural and landscape irrigation, industrial process water, potable water supplies, and groundwater supply management.

1.7. Water Reuse Regulations in the United States

EPA does not require or restrict any type of reuse. Generally, states maintain primary regulatory authority (i.e., primacy) in allocating and developing water resources. Some states have established programs to specifically address reuse, and some have incorporated water reuse into their existing programs. EPA, states, tribes, and local governments implement programs under the Safe Drinking Water Act and the Clean Water Act to protect the quality of drinking water source waters, community drinking water, and waterbodies like rivers and lakes. Together, the Safe Drinking Water Act and the Clean Water Act provide a foundation from which states can enable, regulate, and oversee water reuse as they deem appropriate.

1.8. US Geological Survey (USGS)

What is continuous real-time water quality (RTWQ)?

Real-time water quality refers to in-stream water-quality measurements made available on the web in real-time. Water-quality measurements are recorded in time intervals as small as 5 minutes to hourly and are often referred to as continuous. These time-dense (continuous) stream data are made available on the Web in near real-time (updated 4-hour intervals or less) (available at http://waterdata.usgs.gov/nwis). Providing these data in real-time informs the user of stream conditions for various uses and public safety.

Real-time water quality information is made possible because of improvements in sensor and data recording technology since the first in-stream sensors were developed in the 1950-60s to directly measure or compute concentrations of many water-quality constituents. Sensors that measure water-quality properties or constituent concentrations are available for specific conductance, pH, water temperature, turbidity, dissolved oxygen, and nitrate. Sensors also are available that measure portions of the electromagnetic spectrum (light) that indicate adsorption or scatter (turbidity, chlorophyll, nitrate, and fluorescence) or sound (acoustic Doppler technology,). In-stream chemical analyzers and portable field laboratories for nitrate and phosphorus also are available. Many additional new sensors are being developed as the need for these data increase.

1.8.1. What are these measurements?

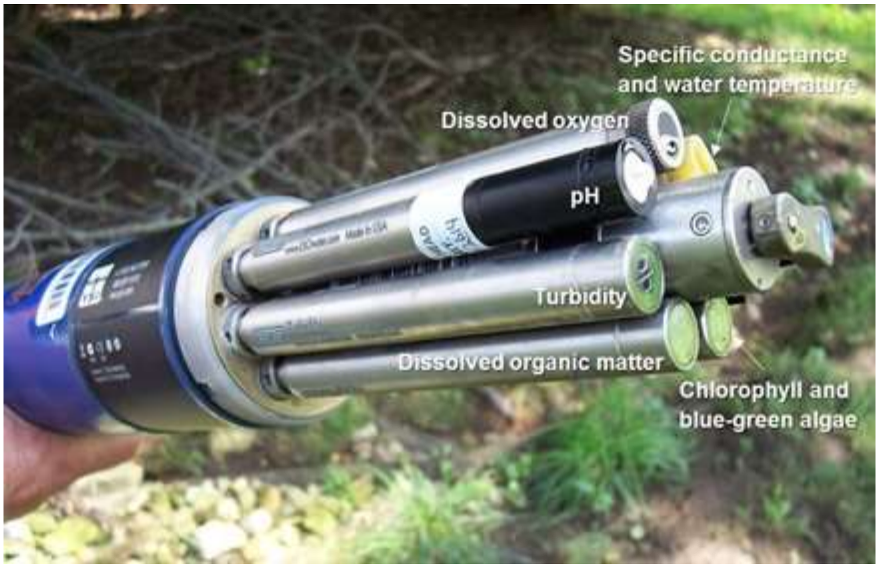

Figure 1. Probes used by USGS for monitoring

Multi-parameter monitor used to record water-quality measurements.

- **Water temperature** is measured using a thermistor and reported as degrees Celsius. Temperature is an important measurement for habitat and recreation and affects the rates of chemical and biological processes.

- **Specific conductance** is a measure of the capacity of water to conduct an electrical current at a standardized temperature of 25 degrees Celsius and is reported in microsiemens per centimeter. It is affected by the types and amounts of dissolved substances in the water. Water that has no dissolved solids has a specific conductance of 0. This measurement is used to estimate the concentrations of dissolved solids or salts (salinity) in water. Large daily variations are possible in estuaries or other locations affected by tidal interactions of fresh and salt water.

- **pH** is a measure of how acidic the water is and is reported in standard units. It is an important indicator of water quality because it directly affects water treatment, chemical reactions, and basic functions of plants and animals.
- **Dissolved oxygen (DO)** concentration (reported in milligrams per liter) in surface water is a significant factor in chemical reactions and the survival of plants and animals in the water. It is related primarily to exchange with overlying air, photosynthesis by algae and plants in the water, and respiration of aquatic organisms. Extended periods of time with low dissolved oxygen (less than 5 milligrams per liter) can cause fish and other aquatic organisms to perish.
- **Turbidity** refers to the cloudiness or murkiness of the water and is reported as nephelometric turbidity units (NTUs) or formazin nephelometric units (FNUs). The larger the turbidity is, the more murky the water appears. Turbidity is caused by suspended particles, primarily clay, silt, organic matter, and microscopic organisms. Turbid water is not necessarily harmful, but the particles or sediments can also cause problems. Sediment can negatively affect aquatic life (clogging fish gills). Particulates and especially organics can contribute to low DO. Metals, bacteria, and toxic organics can be adsorbed on particles and particles can be coated with metals oxy-hydroxides.
- **Nitrate i**s a common form of nitrogen and is important because it affects plant growth and, in excess, contributes to eutrophication and human health concerns. It is measured in milligrams per liter. Nitrate usually is measured with an instrument that is separate from the multi-parameter monitor.
- **Chlorophyll** is the green molecule in plant cells essential for photosynthesis and is often used as an indicator of algal biomass in water. Chlorophyll sensors rely on fluorescence, which is the emission of light by a substance that has absorbed light. Measurement units include relative fluorescence units (RFU) and micrograms per liter (ug/L). Chlorophyll sensor data provides information on relative patterns but need to be related to laboratory-measurements to provide information about actual chlorophyll concentrations. Large daily variations in sensor measurements that are not related to chlorophyll concentrations may occur due to changing light and temperature conditions, which affect the fluorescence response of algal cells.

Sensors are becoming more common for recording other water-quality measurements such as dissolved organic matter, chlorophyll, and blue-green algae.

1.8.2. Why continuous and real time?

Continuous real-time information is a vital asset that helps safeguard lives and property and ensures adequate water resources for a healthy economy. Continuous real-time water-quality data are needed for decisions regarding drinking water, water treatment, regulatory programs, recreation, and public safety. Additionally, increased data-collection frequency provides an improved understanding of factors that affect water quality.

Advances related to monitoring technology are enhancing our understanding of water-quality issues. These advancements include, for example, innovation and new water-quality sensors, monitors (multiple sensors in a single probe), data recorders, and transmission equipment. In-stream water-quality sensors provide continuous measurements (typically, every 5-60 minutes) of water-quality conditions that may vary widely over short periods of time, such as before, during, and after storms or during tidal fluctuations. When these data are available in real time, water management officials can be notified of these changes and are able to respond by altering treatment or collecting additional data. Additionally, real-time measurements for temperature, conductance, and turbidity can be statistically related to other important properties, such as indicator bacteria that are more costly and difficult to monitor and analyze. Continued development, testing, and deployment of a new generation of real-time sensors for water quality have the potential to greatly increase the level of information available.

Advantages of continuous and real-time data:

- USGS real-time water-quality data are available to everyone on the Internet.
- The time-density of continuous data improves our knowledge and understanding of relations between water quality and changes in hydrology, geology, and land use.
- Increased data-collection frequency provides an improved understanding of factors that affect water quality.
- Continuous data provide richer data sets for developing tools and models for extending observed water quality to unmeasured streams and enables development of better management tools for ensuring stream quality protection.
- Notification of water resource managers in real time, eliminating delay between sample collection and lab analysis may be critical for warning the public for recreation or for water treatment.
- Real-time data can decrease time and costs associated with manual sampling.
- Continuous data provide better measures of water quality relative to water-quality criteria compared to a few samples collected during a year.
- Continuous data measure water quality changes at night and during storms when samples are seldom collected and when storm events can have major effects on concentrations and loads.

2. Objectives

Overall objective is to investigate the potential of recycling wastewaters for reuse with the challenges identified. The specific objectives are as follows:

(1). Identify the sources of wastewaters and potential applications

(2). Critical issues related to recycling of wastewaters for various reuses and the need for developing rapid treatment methods.

(3). Real-time monitoring issues related to water quality and recycled waters

3. Literature review

3.1. Sources of Wastewaters

Sources of water for potential reuse can include municipal wastewater, industry process and cooling water, stormwater, agriculture runoff and return flows, and produced water from natural resource including oil extraction activities. Also, another area is in chemical industries and also hydraulic fracking. These sources of water must be adequately treated to meet “fit-for-purpose specifications” for a particular next use.

3.2. Reuse

Recycled wastewater can be used in multiple applications.

3.2.1. Water Reuse in Contemporary Times (1900 AD-Present)

The advent of twentieth century brought significant technological and scientific innovations along with a significant growth in the implementation of wastewater treatment plants (WWTPs) that could handle large volumes of wastewater for direct discharge to waterways and the ocean. These plants were adopted widely by most of the major urban centers around the globe, as they were compact and did not require large areas for treatment compared to sewage farms (Metcalf and Eddy Inc., 1991; Jimenez and Asano, 2008; Lazarova et al., 2013). However, with the construction of mechanized WWTPs and discharge to rivers or the ocean, interest of reclaiming nutrients and organic matter to fertilize and improve soil characteristics diminished. In the latter part of the twentieth century and the first part of the twenty-first century, water reclamation and reuse has regained popularity because of population growth, urbanization, the growth of megacities, climate change, the increasing need for water in a variety of applications, and because of the development of water reclamation technologies able to produce water of almost any quality desired including water of quality equal to or higher than drinking water.

The purpose is to consider modern water reuse practice. Subjects considered include: (a) the importance of modern technology, (b) changing views of water reclamation and reuse; (c) water reuse applications; (d) review other non-domestic sources of wastewater for reuse; (e) understanding and quantifying unplanned potable reuse, (f) health and environmental issues; and (g) review development of water reuse criteria. Emerging trends in water reuse and future challenges in water reuse are considered in the following two sections, respectively.

"Fit-for-purpose specifications” are the treatment requirements to bring water from a particular source to the quality needed, to ensure public health, environmental protection, or specific user needs.

(a). Environmental restorations

The use of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow is called "environmental reuse". For example, constructed wetlands fed by wastewater provide both wastewater treatment and habitats for flora and fauna.

(b). Groundwater recharge

It includes aquifer recharge for drinking water use; Augmentation of surface drinking water supplies; Treatment until drinking water quality.

(c). Agriculture

There are benefits of using recycled water for irrigation, including the lower cost compared to some other sources and consistency of supply regardless of season, climatic conditions and associated water restrictions. When reclaimed water is used for irrigation in agriculture, the nutrient (nitrogen and phosphorus) content of the treated wastewater has the benefit of acting as a fertilizer. This can make the reuse of excreta contained in sewage attractive.[7]

The irrigation water can be used in different ways on different crops:

- Food crops to be eaten raw: crops which are intended for human consumption to be eaten raw or unprocessed.
- Processed food crops: crops which are intended for human consumption not to be eaten raw but after treatment process (i.e. cooked, industrially processed).
- Non-food crops: crops which are not intended for human consumption (e.g. pastures, forage, fiber, ornamental, seed, forest and turf crops).[21]

There can be significant health hazards related to using untreated wastewater in agriculture. Wastewater from cities can contain a mixture of chemical and biological pollutants

(d). Potable

Perhaps the most important future trend in the field of water reuse, especially in large metropolitan areas, is potable reuse (PR). As the name implies, PR involves the reuse of wastewater for human consumption following various treatment interventions. It should be noted that the US EPA acknowledged the importance of and highlighted the increased interest in pursuing potable water reuse, in its recently issued 2017 Potable Reuse Compendium (US EPA and CDM Smith, 2017) as a supplement the previously published Guidelines for Water Reuse (US EPA/USAID, 1992; US EPA, 2004, 2012). There are two types of planned PR: (a) indirect potable reuse (IPR), and (b) direct potable reuse (DPR).

Indirect potable reuse

Indirect potable reuse (IPR) means the water is delivered to the consumer indirectly. After it is purified, the reused water blends with other supplies and/or sits a while in some sort of storage, man-made or natural, before it gets delivered to a pipeline that leads to a water treatment plant or distribution system. That storage could be a groundwater basin or a surface water reservoir.

Direct potable reuse

Direct potable reuse (DPR) means the reused water is put directly into pipelines that go to a water treatment plant or distribution system. Direct potable reuse may occur with or without “engineered storage” such as underground or above ground tanks. In other words, DPR is the introduction of reclaimed water derived from domestic wastewater after extensive treatment and monitoring to assure that strict water quality requirements are met at all times, directly into a municipal water supply system. Direct potable reuse is also called "toilet to tap”.

(e). Irrigation

Irrigation of public parks, sporting facilities, private gardens, roadsides; Street cleaning; Fire protection systems; Vehicle washing; Toilet flushing; Air conditioners; Dust control.

(f). Commercial

Irrigation of public parks, sporting facilities, private gardens, roadsides; Street cleaning; Fire protection systems; Vehicle washing; Toilet flushing; Air conditioners; Dust control.

(g). Domestic

Can be used for Vehicle washing; Toilet flushing; Air conditioners and as external coolants.

(h). Industrial (Chemical and Petroleum)

There are multiple applications such as Processing water; Cooling water; Recirculating cooling towers; Washdown water; Washing aggregate; Making concrete; Soil compaction; Dust control.

This will also include the oil and gas industries where recycled water is used for hydraulic fracking and also extracting oil from formations.

3.3. New Technologies

3.3.1. Wastewater Treatment

Some important technological developments that have brought about the renewed interest in wastewater reclamation include: the availability of reliable microfiltration, ultra-filtration, and reverse osmosis membranes; the use of ozone coupled with biological filtration, low, medium, and high energy UV disinfection; high energy UV advanced oxidation. These treatment processes can now be used to remove acute toxicity (e.g., microorganisms) and chronic toxicity (e.g., chemical constituents). Further, because multiple treatment processes are now available for any given constituent, the multiple barrier concept, which involves the use of redundant treatment processes or other activities, in parallel or series, is applied to reduce the risk from a given constituent (e.g., pathogenic microorganisms). In addition, instrumentation and monitoring equipment have also contributed to the reliability of advanced water treatment facilities.

Microbial Fuel Cell

CIGMAT is working on developing microbial fuel cell (MFC) to treat both oily wastewater and salty wastewater in multi chamber MFCs.

3.3.2. Real-Time Monitoring

Point-to- point versus Along the Length Monitoring

Figure 2 Schematic of Monitoring (a) Point-to-Point and (b) Along the Length

Current monitoring by the USGS is done point to point along the pipeline. There could be accumulation of contaminants around the measuring probes, also there could be fungus growth around the probes. Also, in addition to the water quality, the pipeline infrastructure also needs to be monitored. New two probe real-time monitoring technology has been developed to that can be used to monitor the not only the water quality along the length also the changes in the measuring probes and also the condition including corrosion along the pipelines.

4. Conclusions

New technologies that are now being implemented as well as those under development will help with the conventional and advanced wastewater treatment. Combining advanced treated water with desalinated water will be an attractive option in megacities. New scientific breakthroughs will lead to enhanced understanding of the significance of criteria found in both water and wastewater and their significance to human health. New regulations will be needed to reflect this enhanced biological and chemical understanding. To meet future water resource management and water reuse challenges effectively, cities must embrace the one water concept. Based on this study following conclusions are advanced:

(1). It is important to real-time monitor the quality of the wastewaters before, during and after treatment. It is important to identify the parameters to be monitored.

(2). There is a need to not only monitor the water quality frequently and real-time but also the condition of the infrastructure including the pipelines. Compare the point-to-point measurements with the along the length measurement using the new technologies with quick data analyses and results.

(3) Develop new treatment methods for easy adoption in the field. Test and evaluate the potential of using microbial fuel cell for treating wastewaters.

5. Acknowledgement

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