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Editorial

Towards Zero Liquid Discharge

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Editorial

Zero Liquid Discharge (ZLD) is an ambitious wastewater management strategy to purify wastewater by subjecting it to a chain of treatments so that 80-90% of wastewater is recovered and recycled within the industry. ZLD thus prevents the risk of environmental pollution associated with wastewater discharge and maximizes the efficiency of water usage, thereby striking the balance between exploitation of freshwater resources and preservation of aquatic environment. Until now, ZLD was generally characterized by energy intensive high cost unviable proposition [1].

In recent years the challenges of water scarcity and pollution of aquatic environments has revived global interest in ZLD. More stringent regulations, rising expenses for wastewater disposal, and increasing value of freshwater are driving ZLD as an essential option for wastewater management. The global market for ZLD is estimated to reach an annual investment in the range of $100-200 million, growing rapidly from developed countries in North America and Europe to emerging economies such as India and China [2,3].

Stricter regulations for wastewater disposal and increased awareness of public for environment are the primary driver for ZLD. ZLD avoids negative environmental impacts of wastewater discharge and reduces the corresponding public concerns.

Although ZLD has been practiced in the European Union, Australia, Canada, Middle East, and Mexico [2-5], examples from the United States, China, and India are highlighted, as they represent the major ZLD markets with the largest populations and economic power.

The United States

The birth of ZLD dates back to the 1970s when the increased salinity of the Colorado River led to a regulatory mandate of ZLD for nearby power plants. Today, power plants remain the major domain of ZLD implementation in the U.S., where Flue Gas Desulfurization (FGD) wastewater and cooling tower blow down are treated and recycled using ZLD technologies. Among the 82 ZLD plants listed in a survey in 2008 [6], more than 60 plants were associated with the power industry; the rest were distributed across areas such as electronics, fertilizer, mining, and chemical industries.

The U S EPA recently revised the existing regulations on wastewater discharge from thermal power plants [7]. The new guidelines sets the limits on the level of toxic metals and other harmful pollutants in wastewater discharged from power plants. Compliance with these tighter wastewater discharge standards provides new regulatory incentives for ZLD installation in U S power plants.

China

Rapid economic development and urbanization have led to rising water consumption and rampant pollution in China. In response to this great challenge, China recently announced a new Action Plan to tackle water pollution, aiming to largely improve the quality of local water resources and ecosystems by 2020 [8]. This plan, enforced by the central government, emphasizes rigorous control of pollutant discharge and promotes water recycling, thereby providing regulatory support for ZLD installation.

As in US, the power industry is an important contributor to the Chinese ZLD market. Although coal-fired power plants provide more than 70% of the total electricity generated in China [9], 65-84% of water-intensive thermal power plants operated by the five largest state-owned companies are located in regions that suffer water scarcity. This sharp conflict between energy demand and water deficiency makes ZLD one of the few sustainable solutions at the energy-water nexus in China. However, no data is available on the overall ZLD installation in Chinese power industry.

The recent boom of the coal-to-chemicals industry in China generates another promising market for ZLD application. coal-to-chemicals industry, utilizing coal to produce raw materials for chemical production, consume a considerable amount of freshwater but are often located in water-stressed areas, such as Inner Mongolia where ample coal reserves and environmentally sensitive grassland coexist. As a consequence, ZLD is mandatory at coal-to-chemicals plants in those areas to preserve both local water resources and ecosystems [10].

Several ZLD facilities are already installed or in the stage of design/construction at Chinese coal-to-chemicals plants, with a wide range of feed water salinities (2,000-16,000 mg/L of total dissolved salts, TDS) and treatment capacity (110-2300 m^3/hour) [11]. In addition, greater public awareness of water pollution may facilitate ZLD installations in China.

India

Facing a situation similar to that in China, India is taking aggressive actions to curb severe water pollution, including the holy river Ganga. The recent three-year target set by the Indian government, known as the “Clean Ganga” project, imposes stricter regulations on wastewater discharge and compelling high-polluting industries to move towards ZLD [12].

In 2015, the Indian government issued a draft policy that requires all textile plants generating more than 25 m^3 wastewater per day to install ZLD facilities [13].

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Dyeing plants in the city of Tirupur had already implemented ZLD in 2008, which recovered not only water but also valuable salts from textile wastewater for direct reuse in the dyeing process. According to a recent technical report, the ZLD market in India is valued at $39 million in 2012 and is expected to grow continuously at a rate of 7% from 2012 to 2017. In India, textile, brewery, power, and petrochemical industries are the major application areas for ZLD installations [14].

ZLD Technologies

Earlier ZLD systems were based on thermal processes, where wastewater was typically evaporated in a brine concentrator followed by a brine crystallizer or an evaporation pond. The condensed distillate water is collected for reuse, while the residual solids are either sent to a land fill or recovered as valuable salt by products. Such systems require considerable energy and capital investments.

Later, Reverse Osmosis (RO) [15], a membrane-based technology widely applied in desalination, has been incorporated into ZLD systems to improve energy and cost efficiencies. However, RO can be applied only to feed waters with a limited salinity range. Accordingly, other salt-concentrating technologies that can treat higher salinity feed waters, such as Electrodialysis (ED) [16], Forward Osmosis (FO) [17], and Membrane Distillation (MD) [18], have emerged recently as alternative ZLD technologies.

Environmental Impacts

Despite the main goal of ZLD to reduce water pollution and improve water sustainability, application of ZLD also results in unintended environmental impacts. Some of the factors which have environmental impacts are: solid waste disposed in landfills may result in leaching of chemicals into groundwater [19]. ZLD consumes large amounts of energy, leading to significant emission of Green House Gases (GHG). Introducing technologies with higher energy efficiency, such as RO, will significantly reduce the GHG emission. In addition, emerging ZLD technologies that can utilize renewable energy (e.g., waste heat, solar energy, geothermal energy) enable further reduction of GHG footprint of ZLD systems.

In summing up, ZLD implementation is growing globally as an important wastewater management strategy to reduce water pollution and augment water supply. However, high cost and intensive energy consumption will remain the main barriers to ZLD adoption.

Future growth of the ZLD market will heavily rely on stricter environmental regulations on wastewater discharge which will push high-polluting industries toward ZLD. In addition intensified freshwater scarcity, caused by both climate change and freshwater over exploitation, will encourage ZLD implementation.

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