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Electrochemical Oxidation For Wastewater Treatment

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Abstract: Electrochemical oxidation (EO) as electrochemical method is unique by three aspects. The first is that is the most versatility process in water treatment area and covers: various industrial effluent treatment including, amongst others, distillery, agrochemical, pulp and paper, textile dyes, oilfield and metal plating wastes; hazardous effluent treatment including hospital wastes; removal of pathogens and persistent, pharmaceutical residues and biological from municipal wastewater treatment plant; removal of organic micro - pollutants such as pesticides and heavy metals such as arsenic and chromium from water. Another aspect is that EO is complementary with most other methods: chemical or electrochemical, and is often combined with one or more of them. And finally, this procedure is the most interdisciplinary of all. It includes: material science, (micro)biology, (electro)chemistry, environmental protection, water supply systems, etc Many human activities result in the production of wastewater. Usually, physical, chemical and biological processes are successfully combined for the treatment of municipal wastewater, attaining good removal efficiencies. However, some industrial processes introduce anthropogenic recalcitrant pollutants in wastewater that are quite difficult to remove or degrade using conventional means and that should be removed due to their hazardousness

Keywords: Electrochemical, Wastewater Treatment, Oxidation, Environmental

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INTRODUCTION

It may come as a surprise to find that wastewater treatment has only been around for a very short period. Ancient Roman cities often had sewers to get rid of odorous water, but it wasn't until the 19th century that major metropolitan areas realized they needed to cut back on the pollution they released into the environment via their spent water. By 1850, people were so dense that even though there was enough fresh water and the surface waters could naturally purify themselves over time, deadly disease outbreaks were regular. Pathogenic bacteria in the contaminated water were identified as the source of these epidemics. Everything that goes on at a wastewater treatment facility is identical to what happens in a natural body of water like the ocean, lake, river, or stream. A wastewater treatment plant's job is to hasten this cleaning process that occurs naturally. Using the most cutting-edge biological, physical, chemical, and mechanical methods, wastewater collection and treatment have evolved into a refined science. Because of this, the purity of our drinking water and the public's health are more safeguarded than ever before.[1]

Wastewater treatment, in its most basic form, employs proven technologies to enhance the quality of wastewater before it is discharged into recipient water bodies. Typically, wastewater is drained in a central, isolated place before being subjected to a series of treatment operations. Whether a wastewater treatment facility employs a biological, chemical, or physical technique, it will fall into one of many broad categories. For the elimination of wastewater's biodegradable organic contaminants, biological technology is often used since it is the most cost-effective treatment method. Despite this, the presence of poisonous and refractory substrates in the wastewater would effectively foil the biological treatment process since these substrates are possibly impeding the bioactivity of microorganisms. Among the many methods available, remediating industrial wastewater by the use of an electro-chemical oxidation process has captured the interest of many researchers. Electrochemical oxidation techniques have been demonstrated to date to be a useful choice for the removal of refractory organic compounds from a wide range of wastewater types. When compared to alternative physiochemical methods, which just induce phase transition of the pollutants in issue without any chemical destruction taking place, electrochemical oxidation is superior in its ability and efficiency to reduce organic molecules from different types of wastewater.[2]

Water Pollution Control Legislation

Environmental protection falls under the purview of Environment Canada, a department of the federal government. The Environmental Protection Act is a piece of Canadian legislation that sets broad environmental protection policies. When it comes to protecting Ontario's natural resources, nobody does more than the Ministry of the Environment. To fulfill its mission, it must take on the responsibility of ensuring access to clean water and reducing pollution. The Ministry of the Environment enacted the Ontario Water Resources Act to ensure that its goals regarding water quality could be realized. Together, the OWRA and the many regulations enacted under it establish the legal framework for environmental management.[3]

The Wastewater Services Division of the Environmental Services Department of the City of Guelph is responsible for the management of wastewater, storm water, and water quality in the region it covers. The WSD is in charge of running the Hanlon and Wellington Street West Wastewater Treatment Plant and ensuring it complies with MOE treatment regulations. In addition to these prerequisites, the city has implemented legislation through the Sewer Use By-law (1996)-15202 that is unique to the city's wastewater operation. Wastewater generators discharging into the city's sewage collection and treatment system must adhere to the quality and quantity criteria set out in this Bylaw.

The Ontario Ministry of Environment (MOE) and the Municipal Engineers Association of Ontario (MEAO) are collaborating on further legislation, namely the Ontario Ministry of Environment Industrial Strategy for Abatement program, in addition to these pieces of law. Plans for dealing with spills into systems, creating an industrial inventory, and conducting an audit of enforcement operations are all part of the program. In addition to posing substantial health dangers to the general public and wastewater treatment workers, some wastewater contaminants, mainly from industrial sources, can severely disrupt the different wastewater process processes. At its source, the MISA program aims to reduce and regulate industrial wastewater emissions.[4]

WASTEWATER TREATMENT PROCESS

A process is, by definition, a set of related steps or transformations. Most modern water treatment plants use a variety of methods to improve water quality. The wastewater treatment procedures include collecting, cleaning, and finally disposing of any contaminants that were found.[5]

i. Wastewater treatment may be broken down into four categories: physical, mechanical, biological, and chemical.

ii. Tanks and other structures built to confine and control the flow of wastewater to facilitate the removal of impurities are examples of physical techniques of treatment.

iii. Machines, both basic and complicated, are used in mechanical treatment methods.

iv. Bacterial and microbial activity constitute biological treatment approaches that are crucial in the elimination of contaminants that cannot be efficiently performed by other means.

v. The incorporation of chemicals into the treatment process at varying stages improves the effectiveness of the overall procedure and allows for more targeted therapy.

DESCRIPTION OF PROCESS OPERATIONS

The reader should be acquainted with the jargon and slang used in the wastewater treatment industry to fully grasp the process activities described here. The following parts provide a more in-depth look into wastewater treatment and have been written in a way that should make it easier for readers who are unfamiliar with the area to make sense of the terminology they'll encounter. These words and phrases are introduced in bold italics and defined in Section 9.0 Glossary of Terms.[6]

i. Collection System

The collection system, often known as the sewage system, is a network of pipes used to dispose of the millions of gallons of wastewater produced daily. There are three main kinds of sewage pipe, each designated for a different kind of wastewater flow: sanitary, storm, and mixed. The City of Guelph has a dual-sewer system, which means that its sanitary and storm sewers are kept entirely separate. The wastewater treatment facility receives the sewage system's overflow. The city's storm system is connected directly to stormwater management systems strategically placed in newer and planned-for-development regions. Stormwater is emptied straight into the river in the city's more established neighborhoods. When there is a lot of rain or snow, the flow through the storm or combined sewers that are linked to treatment facilities is substantially greater than usual.

ii. Preliminary Treatment

Debris such as wood, rags, and plastics are found in the influent that is sent to treatment facilities. Not only does the flow include organic waste from domestic, commercial, and industrial water consumption, but also sand, eggshells, and other coarse inorganic particles. Large objects and dense inorganic matter in the wastewater flow may be removed by preliminary treatment.

To filter out the trash, wastewater treatment plants utilize mechanical screens made of parallel bars or stepped plates positioned at an angle in the flow of wastewater. Debris is raked off the bars mechanically, and the resulting screens are cleansed, compacted to eliminate excess water, and then buried in a landfill. The pipes and downstream equipment in the treatment plant are spared from obstruction and/or damage if these materials are removed. Aerated pipes are used to decrease the wastewater flow to 0.3 meters per second once the screening process is complete.[7]

iii. Anaerobic Digestion

Raw sludge, also known as primary sludge, and primary effluent were the products of primary treatment, the first step in the wastewater treatment process. In terms of biochemical oxygen demand, each product has its own set of physical qualities and organic strength that set it apart from the others. To further treat these products, secondary treatment techniques are often used, and these processes are biological. Large, oxygen-free containers called digesters receive the sludge that was created during primary settling. Within this system, anaerobic bacteria use the sludge's organic content as a food source, emitting carbon dioxide and methane gas as waste products. By changing the original sludge's properties, these anaerobic bacteria increase its dewaterability for subsequent processing and stabilize the raw or primary sludge.

The biological activity of the anaerobic bacteria is maximized by maintaining optimal circumstances for the duration of the digesting phase (usually 15–28 days). To keep the organic material in the digester tank in touch with the bacteria and to avoid the development of a scum blanket, the contents of the tank are heated to a constant 35 to 37 degrees Celsius and stirred.

iv. Activated Sludge

The main effluent that goes untreated because it overflows the primary settling tanks contains organic material that has certain properties. The main effluent's murky appearance is due to the presence of these organic materials, which are dissolved and finely split suspended or, colloidal particles. During primary treatment, the organic matter that was dissolved in the influent will still be suspended in the liquid. Due to their tiny size and low mass, the current colloidal particles do not settle out during initial treatment. Increasing the retention duration of the wastewater in the main tanks in an attempt to remove these colloidal particles is neither practicable nor practical. Longer periods of detention would lead to septic conditions in the settling tanks, reducing the effectiveness of solids removal.[8]

v. Chemical Treatment

Most wastewater contaminants may be effectively removed by basic and secondary treatment procedures, but other pollutants need specialized kinds of treatment. To this end, phosphorus is one particularly worrying contaminant. Wastewater treatment plants often release phosphorus-laden effluent into nearby waterways. If this phosphorus isn't removed, it might have a devastating effect on these bodies of water. For healthy plant development, phosphorus is a crucial element. Human waste, detergents with phosphate additions, and corrosion control agents used in water supplies and industrial outputs are all potential phosphorus sources. High levels of phosphorus in receiving waters might upset the delicate biological balance of those waters by encouraging an overabundance of algae and aquatic plants. The eutrophication process in the receiving body of water may be hastened by the rapid decrease in water quality.[9]

ELECTROCHEMICAL OXIDATION PROCESS

Wastewater from a variety of industries, including textile production, landfill leachate, simulated wastewater, olive production, paper production, and industrial paint production, all include contaminants that may be degraded using an electrochemical oxidation process. Figure 1 depicts the electrochemical reactor used in laboratory studies. The conceptual schematic of an electrochemical reactor for wastewater treatment is shown in Figure 2. The reactor consists of a cathode, an anode, and an electrolyte, all powered by a direct current (DC) power source (a medium that provides the ion transport mechanism between the anode and the cathode necessary to maintain the electrochemical process).[10]

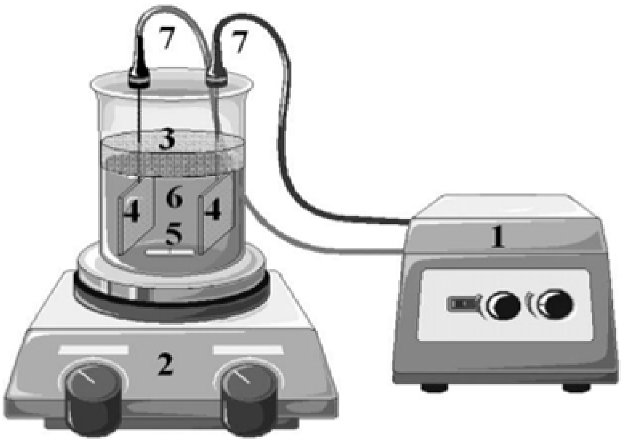

Figure 1: The electrochemical reactor in the laboratory experiments.

- DC power supply,
- magnetic stirrer,
- cover,
- electrodes,
- magnetic bar-stirrer,
- wastewater and
- electric wire

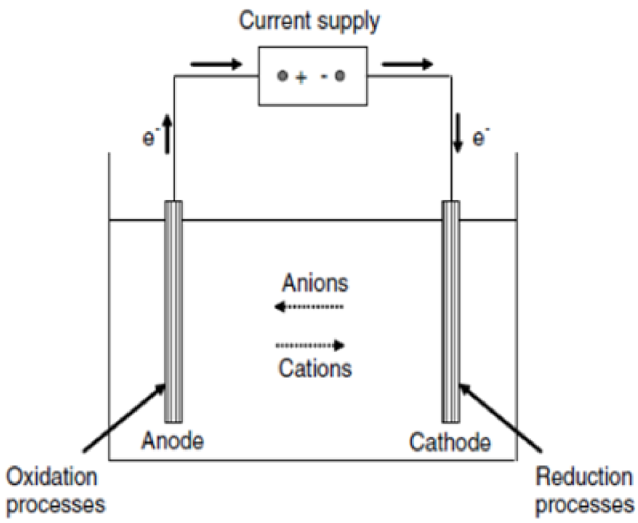

Figure 2: Conceptual diagram of an electrochemical reactor

CURRENT SCENARIO: SCARCITY IN TERMS OF QUANTITY AND QUALITY

It's possible that river quality decline, groundwater depletion, and water allocation conflicts in which some groups benefit at the cost of others are all symptoms of physical water shortage. 1.2 billion people have little access to clean water because they reside in regions where the supply is inadequate. They also predict that another 1.6 billion people live in places with "economic water scarcity," where water resources available are ample compared to water usage but there is a lack of investments in the rising water demand. Roughly 2.8 billion people, or more than 40% of the global population, are thought to reside in river basins where severe water shortage is a reality. In addition, several upcoming events are likely to make this scenario much worse. The first is the growing number of people in the globe; there are presently 7.04 billion people on the planet, and that number is expected to expand to 8.2 billion by the year 2030.[11]

One prevalent misconception is that groundwater is uncontaminated and untouched by pollution. Aquifers hold around 97% of the world's unfrozen freshwater and provide almost a third of the world's population with drinking water, making groundwater pollution significantly more dangerous. More than a billion people in Asia rely only on groundwater for their daily water needs. In addition, groundwater has played a crucial role in the development of irrigated agriculture across the world. Because of this, groundwater pollution poses a significant risk to the long-term health of the environment and the human population. Some sections of the globe now consider access to clean water to be a luxury.

COMMON WATER TREATMENT METHODS

It is common to practice cleaning water using a combination of different methods, including physical treatments such as filtration and sedimentation, biological processes such as slow sand filters or activated sludge, chemical processes such as flocculation and chlorination, and electromagnetic radiation such as ultraviolet light.[12]

i. Physical Methods

This category encompasses techniques for bettering or treating wastewater that rely only on physical phenomena, without resorting to any sweeping chemical or biological alterations. Coarse screening, for instance, may be used to get rid of bigger entrained materials, while sedimentation is another example. Sedimentation is achieved by allowing physical events associated with the settling of solids by gravity to take place. The wastewater is stored in a tank under calm circumstances for a while, during which time the heavier materials sink to the bottom, and the "clarified" effluent is drained away. One of the most popular physical treatment techniques is sedimentation; another is aeration, which involves physically introducing air, often to supply oxygen to the wastewater. Filtration is another physical phenomenon exploited in therapy. In this setup, wastewater flows through a filter media, which traps and removes solids. Using sand filters to further remove entrained particles from treated wastewater is one such example.

ii. Chemical Methods

Chemical treatment involves the use of chemicals or the application of chemical processes to the water supply to enhance its quality. Chlorination is the chemical process that has the widest range of applications. Chlorine is used to destroy germs since it is a powerful oxidizing agent. The water is treated with a variety of chemicals, including those that cause neutralization, coagulation, precipitation, oxidation, and disinfection. Another oxidizing agent used to remediate dirty water is ozone, a disinfectant that works by breaking down contaminants. These oxidizing chemicals interfere with the bacterial growth process, making the water safe to drink. Neutralization, a chemical procedure, is often employed in the treatment of industrial effluent. The pH of the water is brought back to a neutral state by adding either an acid or a base. Lime is a typical base that is utilized in this procedure because of its effectiveness in neutralizing acid wastes.

iii. Biological Methods

The goal of the biological water treatment method is to biochemically break down the wastewater and stabilize the final product using microorganisms like bacteria. There are two branches of the biological water treatment method: the aerobic and the anaerobic branches. Sludge is fermented at a set temperature in the absence of oxygen during the anaerobic phase, while microorganisms devour the organic matter and help convert it to carbon dioxide during the aerobic process. Another aerobic method for treating wastewater is composting, which involves combining the sludge with carbon sources like sawdust. The waste is broken down into carbon dioxide, water, and other byproducts, and more microorganisms (sludges) are produced. Lastly, it may be necessary to provide therapy to eliminate offensive smells, slow down biological activity, or kill harmful microorganisms.[13]

iv. Electrochemical Techniques in Water Treatment

Electrochemical therapy shows promise as a treatment option owing to its high efficacy, cheap maintenance cost, little labor need, and quick outcomes. Using an electric current flowing via electrodes in a reactor, electrochemical treatment purifies wastewater. Electrochemical therapy involves the passage of contaminated water between electrodes, where oxidation and reduction processes may take place either indirectly or directly.

A further mechanism through which electric current may be used to eliminate organic contaminants is the production of oxidizing groups, such as HOCl. Industrial uses of electrochemical technology include the efficient removal of organic molecules from water that has been used for other purposes. Irons, silicates, humus, dissolved oxygen, and discoloration may all be eliminated using EC.

v. Nanotechnology and Water Treatment.

Nanotechnology, the controlled manipulation of matter on length scales smaller than 100 nm, has the potential to usher in a plethora of novel materials and devices that exploit the special phenomena only possible at such small dimensions. This is because of the nanoscale's high reactivity due to its large surface-to-volume ratio. Richard P. Feynman, an American physicist, is widely credited for coining the term "nanotechnology." Recent developments show that many concerns relating to water quality might be fixed or considerably ameliorated by utilizing nanoparticles, nanofiltration, or other products coming from the development of nanotechnology.

One area where nanoparticles are likely to have a big impact is water filtration. The usage of nanotechnology in the water and wastewater treatment industries has expanded to include a wide range of applications. Nanotechnology has the potential to influence three distinct areas of water applications: treatment and cleanup; sensing and detection; and pollution prevention. Nanotechnology has the potential to contribute to the long-term quality, availability, and viability of water resources via treatment and remediation methods, such as the use of improved filtering materials that permit more extensive water reuse, recycling, and desalinization. Particularly intriguing within the field of sensing and detection is the pursuit of better and more sensitive sensors for detecting trace amounts of biological and chemical pollutants in the environment, particularly water. Using nanotechnology for water and wastewater treatment will undoubtedly allow for the reuse of hitherto unsuitable water sources including brackish water, seawater, and another effluent. [14]

7. Groundwater –A Major Source of Drinking Water

Groundwater is still a viable alternative to augment the ever-increasing demand for water as surface water supplies continue to fall short of meeting the needs of human activities. There are numerous nations where people must rely on polluted groundwater for drinking, farming, and industry. This is a major concern in many countries. Historically, groundwater has been utilized as a source of drinking water throughout the globe, and even now, more than half of the global population relies on groundwater for their own life. Groundwater's worth comes from not just the fact that it is abundant and easy to get, but also the fact that it is of consistently high quality and so provides for a great water supply. But rising population and industrialization, along with a lack of understanding to live in peace with nature, have resulted in water quality deteriorating and leading to water pollution.

Water intended for human consumption should be devoid of potentially harmful substances, including bacteria, viruses, and other microorganisms, as well as excessive amounts of minerals. Because groundwater has more opportunities to interact with different minerals in geologic layers, it often contains more dissolved components than surface water does. Even though groundwater typically has very low concentrations of suspended and organic matter, it may have significant concentrations of minerals such as calcium, magnesium, sodium, potassium, iron, aluminum, manganese, chloride, sulfate, carbonate, bicarbonate, etc. When levels of contaminants in groundwater rise to unsafe levels, such as those for human consumption, we say that the water is contaminated. A wide variety of hydrological, physical, and biological variables contribute to groundwater quality.[15]

CONCLUSION

Wastewater treatment by electrochemical oxidation process was established in a laboratory scale for many years. However, electrochemical oxidation technologies have not reached real application maturity in commercial scale perhaps due to the limitation of comparatively high capital investment and the cost of electricity supply. Consequently, operating cost reduction and efficient electrode materials manufacturing are the main problems need to be overcome before the site-scale accomplishment of electrochemical oxidation in wastewater treatment.

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