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AI Based Water Treatment using Graphene Nano-Material

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***Abstract*— Increasing population and industrial growth, combined with climate change, led to global water problems. The graphene-based membrane materials that are used for water purification using Artificial Intelligene(AI). Graphene-based membrane materials are believed to be the advanced materials for the water treatment process because of their atomic thickness and tunable functionalities. The effect of membrane fabrication techniques and operating conditions on the separation and membrane fouling mechanisms are discussed in depth. To extend the applications of graphene membranes, more attention should be paid to the water permeability and membrane selectivity in long-term operation at conditions similar to those in the field for performance analysis using AI. While literature reviews have mainly concerned the ability of graphene materials to adsorb water contaminants, there is very limited updated information by artificial intelligence, related to its sieving properties. Moreover, the literature lacks a comparative discussion of graphene-based membranes with other hybrid membrane materials. Thus, a profound understanding of graphene-based membranes is much needed to unlock the potential for graphene materials using Artificial Intelligence(AI).**

Keywords: - Graphene-based membranes ,Multiple layer membrane materials, Nano Particles and Water Treatment Process,Artificial Intelligence.

I. INTRODUCTION

Single-layer graphene, as an iconic two-dimensional (2D) material, has drawn much scientific attention in recent decades. Because of its ultrathin thickness and outstanding mechanical properties, graphene with artificial pores has been demonstrated to have great potentials in many engineering applications, such as effective hydrogen gas separator, next-generation energy storage or supercapacitor building and high-resolution DNA sequencing. Given the potential imminent global water scarcity crisis, another important application for nanoporous graphene is energy-efficient water desalination. Equipped with nanoporous 2D material membranes like graphene, the reverse osmosis (RO) water desalination process can expect 2–3 orders improvement in water flux compared with traditional polymeric membranes. In RO, the geometry of nanopores in 2D materials plays a determinant role in water desalination performance. In general, a large pore that allows high water flux is likely to perform poorly in rejecting ions; a small pore that rejects 100% undesired ions, on the other hand, usually have limited water flux. Thus, an optimal nanopore for water treatment is expected to allow as high water flux as possible while maintaining a high ion rejection rate.Therefore, to discover the optimal graphene nanopore for water treatment, an efficient nanopore screening method with a fast nanopore water treatment performance predictor (performance predictor in short) is needed. Inspired by the recent success of deep learning and reinforcement learning, we create an AI framework consists of the combination of the state-of-art deep reinforcement learning algorithm to solve this challenge.

II. METHODS OF WATER TREATMENT

1. **Primary treatment:** solids and sediment are removed from the water (and then sent to landfill or incinerated). About 60% of solids are eradicated.
2. **Secondary treatment:** common biodegradable contaminants are lowered to safe levels. The wastewater is aerated and bacteria is used to consume nutrients and organic materials. About 90% of all solids and organic material are eradicated.

3. **Tertiary treatment:** the quality of the water is raised to domestic and industrial standards. Chemicals are used to remove any remaining bacteria, viruses and microorganisms. The water can then be discharged back into the environment.

III. GRAPHENE NANO MATERIALS FOR WATER PURIFICATION

Graphene is a two-dimensional (2D) 1-atom-thick planar sheet of sp^2-bonded carbon atoms. This material shows amazing physical, mechanical, thermal and optical properties, which have been highlighted in most areas of science and engineering.The sp^2 bonds and the involved electron configuration are the main reasons for the ultra-high mechanical strength and elasticity, tunable electronic band gap, excellent thermal (5300 W mK^{-1}) and electrical conductivity (2000 S cm^{-1}) and room-temperature Hall effect of graphene.Its hardness is over 30 times higher than that of diamond and 200 times higher than that of steel.

Regarding water separation, graphene possesses an atomic thickness, assuring its high fluid permeability and thus energy/cost efficiency. In addition, there is good potential for size-selective transport through the nanopores of a highly robust graphene layer or 2D nanochannels between adjacent stacked graphene sheets. The fabrication of graphene-based membranes for desalination is also straightforward.

Graphene can be used for the construction of treatment membranes in various forms, such as pristine graphene, GO and reduced GO (rGO). Pristine graphene is a single 2D layer of carbon atoms organized in a hexagonal pattern. Layered oxygenated graphene sheets, that is, those including oxygen functional groups, such as epoxides, carboxyls, hydroxyls and alcohols, on their basal planes and edges, are called GO. In this structure, the isolated pristine domains are confined by the continuous oxidized domains. Through reduction processes, such as chemical reduction, electro-reduction, thermal annealing, flash reduction and enzymatic reduction, GO is converted to rGO with some residual oxygen and structural defects.

IV. EXPERIMENTAL MULTI LAYER GRAPHENE TREATMENT MEMBRANE

Despite the significant advantages of monolayer graphene membranes, especially in terms of water permeability, the fabrication of leak-free, large-area monolayer graphene membranes with controlled pore density and size on the industrial scale is challenging. One solution for this challenge is the fabrication of desalination membranes based on stacked GO nanosheets. These nanosheets are highly stackable, mainly due to their structure, a single-atom-thick layer with a lateral dimension reaching tens of micrometers. Durable interlayer hydrogen bonds hold the GO sheets together to form a stable freestanding membrane. Moreover, GO nanosheets can be produced on a large scale with low cost via chemical oxidation and the ultrasonic exfoliation of graphite. This method promises the cost-efficient and industrially applicable fabrication of stacked membranes. Finally, 2D graphene offers not only extraordinary chemical and thermal stabilities but also superior flexibility and solution processibility.

GO sheets can be arranged as highly ordered films with 2D nanochannels between two adjacent graphene sheets. In this structure, the 2D channels enable the permeation of water while rejecting undesired solutes. In addition, the presence of oxygen-containing functional groups, such as carboxyl groups, on the GO nanosheets enables functionalization and thus enables related charge-based interactions with water pollutants. Such promising features make multilayer GO structure an ideal candidate for the production of advanced ionic and molecular sieving membranes for desalination

V. AI CAN PROTECT WASTEWATER TREATMENT PLANTS

1. AI IDENTIFIES FILAMENT UPSETS TO DETECT AND AVOID ISSUES.

Filaments are bacteria and fungi that can be both positive and negative. Positively, they can add stability to the floc structure. Negatively, they can cause foaming and bulking.

When it comes to the wastewater treatment process, AI can address sludge expansion problems and help in improving aeration and pump efficiency. AI testing platforms, such as the one we've developed at opseyes, are trained on thousands of sludge images. This means they can spot issues with human-level accuracy, but at computer-level speeds.

2. AI PREDICTS EQUIPMENT FAILURES WITH SENSOR DATA FROM MOTORS.

By controlling the daily flow, and monitoring the systems and automation processes of a water treatment process, AI can improve operational efficiency and reduce costs.

Machine learning algorithms are able to identify abnormal sensor behavior and so provide an early warning of asset degradation or failure. AI technology can also warn of leaks, bursts, and pollution incidents and – by monitoring areas such as the energy consumption of equipment – can predict when maintenance is required.

All of this allows Plant Managers, Wastewater Directors and Wastewater Operators to make much faster fact-based decisions.

3. AI PREDICTS FUTURE EFFLUENT QUALITY.

Effluent quality can provide a basis for a WWTP's management decisions when it comes to minimizing microbial risks and optimizing operations.

However, monitoring effluent quality remains a big challenge for all WWTPs – especially at a time when more stringent wastewater effluent limits and regulations are being implemented.

Imagine if you could predict the effluent quality in real time? Gone would be the days of infrequent and inaccurate measurements, large operational costs and incorrect management decisions.

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4. AI ANSWERS OPERATOR QUESTIONS ABOUT PROCEDURES.

'Grab sampling' has commonly been used by wastewater operators to get some visibility over what's going procedurally. However, this method requires ongoing labor and only provides a snapshot of conditions, not a real-time one.

Automating the sampling process with AI allows operators to identify patterns and trends. What's more, a powerful AI testing platform can provide recommendations and analysis to managers in a plant, helping them understand what's going on and what needs to be done. All without them having to slow or stop operations.

Plant Managers don't have the hassle of sending samples to a lab or secondary location, while the sludges that are continually tested don't change in composition as they no longer have to travel from plant to lab for processing.

5. AI FINDS PREVIOUSLY HIDDEN ISSUES WITHIN LARGE DATASETS

Having data is one thing. Knowing how to use it is another.
Data scientists and experts can be expensive, and the required skill set to understand and process the data from a WWTP is rare.
This is a challenge for water treatment process which collect a relatively large amount of data with instruments from both influent and effluent streams. Enter AI.
AI applications can extract the data, process it, and make sense of it. Operational cost savings and predictive maintenance. This is crucial at a time when water treatment process face strict emission restrictions, and increased regulations around energy efficiency and resource recycling

VI. OBJECTS AND ADVANTAGES OF THE INVENTION

The objects of the present invention are: to provide a AI monitoring system for a fresh water or waste water treatment facility that backs up facility operators and aids in preventing catastrophic failures of the process and the maintenance of effluent water quality within selected parameters and that further calculates and predicts failures, problems and undesirable situations from correct or incorrect data inputs that might not be predicted by an operator without aid of the monitoring system; to provide such a monitoring system that can be used with a plurality of facilities, each with different concentrations of pollutants and each being remote from the others; to provide such a monitoring system wherein data from all types of sensors at a facility is transmitted over secure, constantly on communicator systems to a computer of the monitoring system; to provide such a monitoring system wherein the monitoring computer includes a module, a pattern recognition module, a statistical module, a search function module, an optimization module and an expert system module to fully analyze data inputs, disregard inputs that are apparently in error, predict operation parameters and effluent quality parameters, predict undesirable future events and situations based upon historical patterns, provide a probability distribution of likely future effluent and in-process quality parameters, constantly search data and probability results to find events that may occur that trigger threshold alarms and provide an analysis and recommendation as to what steps can be taken to optimize the process in the future based upon an optimization of present status; to provide such a monitoring system that sends out alarms to persons in response to the threshold alarms; to provide such a monitoring system wherein alarms are sent on a hierarchal basis depending on severity of any projected problem to different persons or to persons who can best handle a particular problem with recommendations on how to avoid or reduce the severity of the problem; and to provide a process for using the AI monitoring system in combination with waste water facilities.

VII. CONCLUSIONS AND FUTURE WORK

One of the most serious problems adversely affecting people around the world is insufficient access to clean and potable water and sanitation. This problem will expand in the coming decades as water scarcity begins to occur globally. To address this challenge, extensive research must be conducted to identify advanced novel methods of water purification at lower cost and with less energy. In addition, such technologies must be independent from the use of chemicals and must not impact the environment.

Graphene nanomaterials offer novel solutions for water purification and facilitate the development of advanced water purification membranes, especially for water treatment. Owing to its atomic thickness, assuring high fluid permeability and thus energy/cost efficiency, extraordinary mechanical stability and potential for size-selective transport, graphene is an ideal candidate for future membranes. Graphene-based membranes possess several fascinating advantages over conventional membranes. First, their raw material is graphite, that is, an inexpensive material that affords low membrane fabrication costs. Second, the fabrication procedure of graphene membranes, for example, the fabrication of GO membranes based on GO nanosheets, is quite simple and scalable and enables the technical readiness for scaling up membrane production. This kind of membrane can be further improved by engineering the spacing between the GO layers through the inclusion of different-sized cross-linkers. In addition, the membrane charge and thus the charge-based selectivity can be modified by functionalizing GO with various functional groups.

However, to close the gap between research at the lab scale and practice at the industrial scale, there are still some challenges that must be overcome. First, the selectivity of graphene multilayer membranes is mainly limited to large organic molecules and hydrated ions. Thus, the membranes can perform solely as ultrafiltration or NF membranes. To extend their applicability to desalination, that is, to obtain high salt rejection efficiency, the nanochannel size must be tailored in the subnanometer range. Moreover, if water treatment is the target application, realistic salt concentrations and thus solvated ion concentrations should be considered. At the moment, the studied membranes are able to offer the efficient removal of low amounts of salt of a few tens of mM , which is not applicable for large industrial scales. Accordingly, the design and modification of

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graphene-based membranes should be properly done and, in fact, revolutionized. Considering the high surface area/mass ratio of graphene nanomaterials, this goal could be met by advanced design strategies of, for example, membrane modules exposing large surface areas or by the insertion of negatively charged functional groups, maximizing the electrostatic repulsion with ions. As mentioned earlier, at the moment, the developed graphene membranes can be employed solely as NF membranes, not to reduce seawater salinity to drinking water standards, but to treat mildly brackish feed water. However, by coupling with RO, the membranes can be used in water treatment. In addition, future research is required to thoroughly comprehend the transport mechanism of water and solutes in such membranes. In parallel, other potential separation mechanisms in addition to sieving must be explored. In this regard, it is necessary to create multifunctional graphene membranes with exceptional antifouling, adsorptive, antimicrobial, and photocatalytic properties. Moreover, for application in environmentally benign and green applications, the long-term stability of graphene membranes in aqueous systems should be improved. This feature can be tracked by ecotoxicological characterizations to guarantee the effective application of graphene membranes and minimize the risks related to possible relevant adverse health and environmental effects. In addition, the mechanical strength and durability of graphene membranes is still a challenge that restricts their practical application. In this regard, employing potential supports for graphene membranes or incorporating them into a host matrix could be a solution. Last but not least, the large-scale, controlled production of graphene membranes for industrialization is still a challenge and needs further study to be realized.

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