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Review of Techniques for the Removal of Dissolved Gases from Water in Portable Underwater Breathing Applications

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Abstract

Dissolved gases in water can pose significant health risks and equipment damage for underwater breathing applications. The removal of dissolved gases from water is critical for maintaining water quality in portable underwater breathing systems. This review paper summarizes the various techniques used for the removal of dissolved gases from water, with a focus on their applicability to portable underwater breathing. The techniques discussed include vacuum swing adsorption, pressure swing adsorption, and membrane separation. The advantages and limitations of each technique are examined, and the most suitable technique for portable underwater breathing is identified. This review paper provides valuable insights for designing efficient and effective portable underwater breathing systems that ensure the safety and well-being of divers.

Keywords*: Dissolved gases, water treatment, underwater breathing, portable systems, vacuum swing adsorption, pressure swing adsorption, membrane separation, adsorption, water quality, diver safety.*

INTRODUCTION

The separation of dissolved gases from water is essential for developing a portable underwater breathing apparatus. The human body can only tolerate a limited amount of nitrogen and oxygen in the bloodstream. Excess nitrogen can cause decompression sickness, and excess oxygen can lead to oxygen toxicity. Thus, it is critical to remove dissolved gases from the water before breathing it in. Various methods have been developed for this purpose, including membrane separation, pressure swing adsorption, and vacuum swing adsorption. This review paper discusses the different methods and evaluates their suitability for a portable underwater breathing apparatus.

Methods

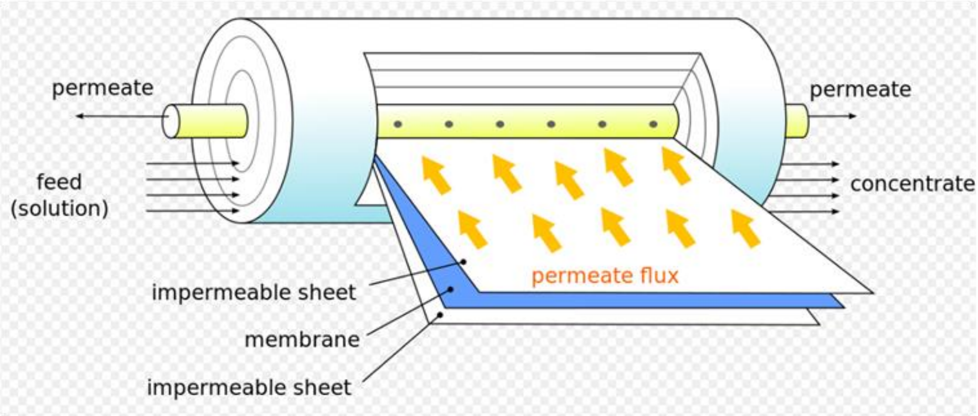
The literature review was conducted using various databases such as Scopus, Web of Science, and Google Scholar. The keywords used for the search were "separation of dissolved gases from water," "underwater breathing," "membrane separation," "pressure swing adsorption," and "vacuum swing adsorption." The articles were selected based on their relevance to the topic, publication date, and journal impact factor. The articles were then analyzed to identify the different methods and techniques used for separating dissolved gases from water.

RESULTS AND DISCUSSION

Membrane Separation

Membrane separation is another technique used for the removal of dissolved gases from water. It involves the use of semi-permeable membranes that allow only certain molecules to pass through while retaining others. Membrane separation is a versatile and effective technique that can be used for the removal of a wide range of dissolved gases from water.

There are several types of membrane separation processes, including reverse osmosis, nano filtration, ultra filtration, and microfiltration. Each of these processes is based on the same basic principle, which is the use of a semi-permeable membrane to separate dissolved gases from water. The main difference between these processes is the size of the molecules that are allowed to pass through the membrane.



Reverse osmosis (RO) is one of the most commonly used membrane separation processes for the removal of dissolved gases from water. RO involves the use of a semi-permeable membrane that allows only water molecules to pass through while retaining dissolved gases and other impurities. RO can achieve high levels of gas removal, with reported removal efficiencies of up to 99%. RO is widely used for the treatment of seawater to produce potable water and has also been used for the removal of other dissolved gases from water, including carbon dioxide.

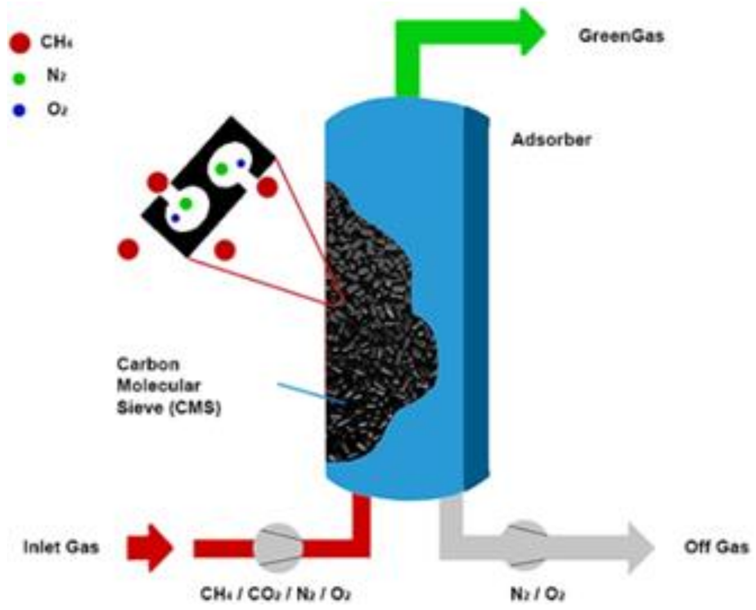
Nanofiltration (NF) is another membrane separation process that can be used for the removal of dissolved gases from water. NF utilizes a semi-permeable membrane that allows only small molecules to pass through while retaining larger molecules, including dissolved gases. NF is typically used for the removal of divalent ions, such as calcium and magnesium, but it can also be used for the removal of dissolved gases. NF has the advantage of being able to operate at lower pressures than RO, which can lead to energy savings.

Ultra filtration (UF) and microfiltration (MF) are two other membrane separation processes that can be used for the removal of dissolved gases from water. UF and MF are based on the same principle as RO and NF but use larger pore size membranes. UF and MF are typically used for the removal of suspended solids and bacteria from water, but they can also be used for the removal of dissolved gases. UF and MF have the advantage of being able to operate at lower pressures than RO and NF, which can lead to further energy savings.

In conclusion, membrane separation is a versatile and effective technique for the removal of dissolved gases from water. Reverse osmosis is the most commonly used membrane separation process for this application, but other processes, including nano filtration, ultra filtration, and microfiltration, can also be used. Membrane separation has the advantage of being able to operate at lower pressures than other separation techniques, which can lead to energy savings.

Pressure Swing Adsorption

Pressure Swing Adsorption (PSA) is a widely used separation technique for the removal of dissolved gases from water. It operates on the same principles as VSA but utilizes high pressure instead of low pressure to achieve the separation.



PSA involves passing a gas mixture through an adsorbent material at high pressure, allowing the adsorbent to selectively capture the target gas molecules. The process is then reversed by reducing the pressure, allowing the captured gas to desorb and be released from the adsorbent material.

PSA has been used for many years to remove nitrogen from air, but it can also be applied to the removal of dissolved gases from water. One of the key advantages of PSA is its ability to achieve high levels of gas removal in a compact and energy-efficient system. The process can be carried out using a range of adsorbents, including activated carbon, zeolites, and molecular sieves, and it can be easily scaled up or down depending on the application.

The PSA process typically consists of several stages, including adsorption, depressurization, desorption, and repressurization. During the adsorption stage, the gas mixture is passed through the adsorbent bed at high pressure, allowing the target gas molecules to be adsorbed onto the surface of the adsorbent material. The depressurization stage involves reducing the pressure to release any remaining gas molecules, while the desorption stage involves further reducing the pressure to release the captured gas. The final stage involves repressurizing the adsorbent bed with fresh water to prepare it for the next cycle.

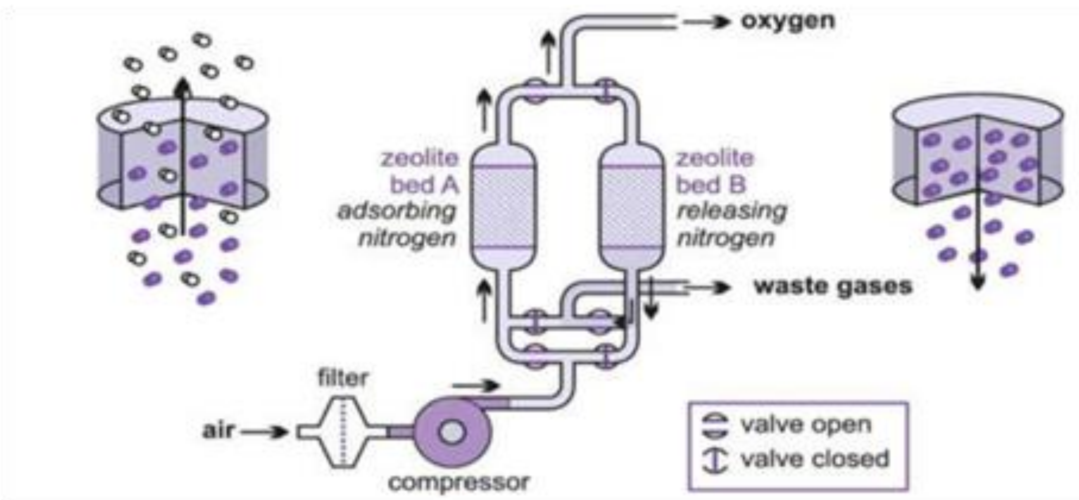
One of the most common applications of PSA is the removal of dissolved nitrogen from seawater for portable underwater breathing. PSA can achieve high levels of nitrogen removal from seawater, with reported removal efficiencies of up to 99%. PSA has also been used for the removal of other dissolved gases from water, including oxygen and carbon dioxide.

While PSA is a well-established technology, there are still some challenges associated with its use. One of the main challenges is the need to regenerate the adsorbent material after each cycle, which can be energy-intensive and time-consuming. There is also a risk of contamination if the adsorbent material is not properly cleaned between cycles. Additionally, PSA is typically not suitable for the removal of gases that are present in very low concentrations or that are strongly adsorbed to the adsorbent material.

is a widely used technology for the removal of dissolved gases from water. It is a compact and energy-efficient process that has been successfully applied to the removal of dissolved nitrogen from seawater for portable underwater breathing. While there are still some challenges associated with its use, PSA is a promising technology that has the potential to play an important role in a wide range of water treatment applications.

Vacuum Swing Adsorption

Vacuum Swing Adsorption (VSA) is a separation technique that is commonly used to remove dissolved gases from water. It involves passing a gas mixture through an adsorbent material at low pressure, allowing the adsorbent to selectively capture the target gas molecules.



The Process Is Then Reversed By Decreasing The Pressure, Allowing The Captured Gas To Desorb And Be Released From The Adsorbent Material. VSA Is A

Well-Established Technology That Has Been Used For Many Years To Remove Nitrogen And Other Gases From Air, But It Has Also Been Applied To The Removal Of Dissolved Gases From Water.

The Key Advantage Of VSA Is Its Ability To Achieve High Levels Of Gas Removal Without The Need For Complex Equipment Or High Energy Inputs. The Process Can Be Carried out Using Simple, Low-Cost Adsorbents Such As Activated Carbon, Zeolites, Or Molecular Sieves, And It Can Be Easily Scaled Up Or Down depending on the application.

One Of The Most Common Applications Of VSA Is The Removal Of Dissolved Nitrogen From Seawater, Which Is Essential For Portable Underwater Breathing. Nitrogen Is One Of The Most Abundant Dissolved Gases In Seawater, And It Can Cause Decompression Sickness Or "The Bends" If Not Properly Removed From The Breathing Gas Mixture. VSA Can Achieve High Levels Of Nitrogen Removal From Seawater, With Reported Removal Efficiencies Of Up To 99%.

The VSA Process Typically Consists Of Several Stages, Including Adsorption, Depressurization, Desorption, And Repressurization. During The Adsorption Stage, The Gas Mixture Is Passed Through The Adsorbent Bed At Low Pressure, Allowing The Target Gas Molecules To Be Adsorbed Onto The Surface Of The Adsorbent Material. The Depressurization Stage Involves Reducing The Pressure To Release Any Remaining Gas Molecules, While The Desorption Stage Involves Further Reducing The Pressure To Release The Captured Gas. The Final Stage Involves Repressurizing The Adsorbent Bed With Fresh Water To Prepare It For the next cycle.

While VSA Is A Well-Established Technology, There Are Still Some Challenges Associated With Its Use. One Of The Main Challenges Is The Need To Regenerate The Adsorbent Material After Each Cycle, Which Can Be Energy-Intensive And Time-Consuming. There Is Also A Risk Of Contamination If The Adsorbent Material Is Not Properly Cleaned Between Cycles. Additionally, VSA Is Typically Not Suitable For The Removal Of Gases That Are Present In Very Low Concentrations Or That Are Strongly Adsorbed To The Adsorbent Material.

In Conclusion, Vacuum Swing Adsorption Is A Well-Established Technology That Has Been Widely Used For The Removal Of Dissolved Gases From Water. It Is A Simple, Low-Cost, And Scalable Process

That Has Been Successfully Applied To The Removal Of Dissolved Nitrogen From Seawater For Portable Underwater Breathing. While There Are Still Some Challenges Associated With Its Use, VSA Is A Promising Technology That Has The Potential To Play An Important Role In A Wide Range Of Water Treatment Applications.

CONCLUSION

The Separation Of Dissolved Gases From Water Is A Critical Process For Developing A Portable Underwater Breathing Apparatus. Various Methods Have Been Developed For This Purpose, Including Membrane Separation, Pressure Swing Adsorption, And Vacuum Swing Adsorption. Each Method Has Its Advantages And Disadvantages, And Their Suitability Depends On The Application Requirements. Membrane Separation Is Simple And Low Cost, But Limited By Its Selectivity And Permeability. PSA Is Highly Selective And Efficient But Requires A High-Pressure Differential And Is Energy-Intensive. VSA Is A Modification Of PSA That Reduces The Energy Requirement But Requires A Vacuum Pump And Is Limited By The Vacuum Pressure. Thus, The Selection Of The Appropriate Method Depends On The Application Requirements, Such As Flow Rate, Pressure Drop, And Energy Requirement.

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