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A REVIEW OF PARAMETERS, PERFORMANCE MODELS, AND APPLICATIONS OF BIOFILTRATION TECHNOLOGY IN REDUCING H_2S COMPOUNDS IN THE AIR

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ABSTRACT

High-quality air is essential for human survival. The present-day has a negative effect on air quality. Air contamination from the harmful compound H_2S is an important problem. The primary source of H_2S discharges is the oil and gas industry, where it is a by-product of resource harvesting and processing. Further sources of H_2S discharges into the atmosphere include mining, waste management, and fossil fuel burning. H_2S generates a malodorous scent resembling that of decayed eggs, which can prompt respiratory discomfort and irritation in humans and animals. At elevated concentrations, it may induce toxicity and even fatalities. Biofiltration is one of the latest remarkable technological advances for mitigating this issue. This method employs microorganisms to convert H_2S into less harmful compounds. Biofiltration offers the major benefit of low operational expenditure and minimal environmental impact. This paper contributes to our comprehension of the microbial parameters, designs, models, applications and processes that affect biofilter efficiency. Diffusion-based biofiltration models show greater efficacy in design systems. Furthermore, advances in media, including the use of hollow cylindrical particles, have increased the efficiency of biofiltration. Sulfur-oxidizing microorganisms, such as Thiobacillus sp., play a pivotal role in decreasing H_2S compounds. It is crucial to regularly monitor and regulate moisture levels, pH, temperature, and nutrient content to secure optimal and consistent biofiltration performance. The technology's effectiveness and stability heavily depend on precise control of these parameters. Biofiltration technology is hailed as a promising approach to manage H_2S compounds, safeguard air quality, and preserve human health and the environment.

Keywords: *air quality, biofiltration, H_2S, sustainable industry, waste*

INTRODUCTION

Air is the most important factor in life, However, in this contemporary era, urban and industrial expansion, along with advancements in transportation, have led to a shift in air quality. The once-fresh air has turned dry and polluted as a result of air pollution caused by many modes of transportation and other human activities. Changes in air quality can be attributed to air pollution as well as alterations to normal air composition, specifically the infiltration of pollutants (gasses and small particles/aerosols) into the atmosphere in significant amounts for an extended period. This can adversely affect the lives of humans, animals, and plants. It is imperative to address these factors to mitigate their impact (Ismiyati *et al.,* 2014). Vallero (2008), in his book entitled "*Fundamental of Air Pollution,*" he Air pollution is defined as the presence of any foreign substances or pollutants in the air that can cause harm to human health or well-being. Moreover, these pollutants can produce other adverse environmental effects. In order to support human and other forms of life, air must possess certain specific properties.

There are several air contaminants that are seriously harmful to health i.e. CO, NOx, SOx, and H_2S. As an example, the extraction of petroleum (petroleum refineries) involves both the usage and the manufacturing of numerous chemicals, many of which lead to the release of air pollutants, wastewater, or solid waste. The resulting pollutants usually encompass VOC, carbon monoxide (CO), sulfur oxide (SO,), nitrogen oxide (NO), particles, ammonia (NH,), hydrogen sulfide (H2S) and metals, acids, and various harmful organic compounds. These harmful substances can stimulate breathing resulting in irritation and inflammation. In this study, several studies have been conducted in an effort to reduce and manage various air pollutant compounds that can cause air pollution or pollution. (Ragothaman and Anderson, 2017).

A volatile compound known as hydrogen sulfide (H_2S) is frequently observed in a variety of industrial and natural processes, including waste processing, the paper industry, and biological processes such as decay. H_2S a poisonous and unpleasant-smelling gas, and its emission must be controlled Protecting the environment and human health (Smith, 2015). The compound is toxic to microorganisms and also has a corrosive effect on concrete and steel. The gasses generated by different industrial procedures are principally accountable for worldwide environmental issues, for instance, air pollution and acid rain. Acidic mine drainage is another critical environmental concern in areas where it is not expediently managed. The H_2S contamination can be controlled by means of biochemical, chemical, and physical methods; yet, it will require quite high costs, large energy input, and the effect of Mishandling of hazardous waste may result in the production of additional, possibly even more hazardous waste. Therefore, it is crucial to dispose of hazardous waste properly and safely to prevent environmental contamination and public health risks. Bio filtration is one of the biological techniques that can be chosen in eliminating the H_2S compounds since it has an economical advantage that is significant compared to other air pollution control technologies (Rattanapan and Ounsaneha, 2011). Biofiltration techniques have gained popularity in recent decades as an effective and environmentally acceptable approach to reducing H_2S emissions (Koe, 2010).

A technique called biofiltration enables microorganisms to convert a contaminant into a molecule that is safer. In H_2S case, certain microorganisms can change H_2S for being sulfur and sulfur dioxide, both are significantly less harmful and odorless (Li *et al.*, 2018). This technique has several advantages compared to traditional pollution control methods, of which advantage is lower operational costs and smaller environmental impact (Chen *et al.*, 2012). It is reinforced by Kennes and Veiga, (2001), the process is energy and cost efficient, and it can run at ambient temperatures and pressures, which are advantages over standard pollution control methods. Moreover, this technology also has potential to produce alternative products that can be reused such as sulfur that can be used in various industrial applications (Zhang *et al.*, 2016).

In a study by Rattanapan and Ounsaneha (2011), biofiltration was able to remove more than 90% of the concentrated H2S found in air, making it a cost-effective and efficient method. Therefore, many researchers are researching superior biofiltration techniques and compounds. Biofiltration efficiency is affected by many factors, including temperature, moisture content, pH level, flow velocity, and the physical structure of the system. In summary, the biofiltration process is used to remove hydrogen sulfide.

Nevertheless, there are challenges that should be addressed to generate H_2S biofiltration techniques more efficiently and practical. For instance, the efficiency of H_2S removal can reduce over time due to sulfur build up in the biofilter (Zhang et al., 2016). Furthermore, operational conditions i.e. temperature, humidity, and H_2S concentration can affect the biofilter performance (Jones *et al.*, 2014).

Several studies published in 2020 have contributed to the knowledge and understanding of biofiltration for H_2S removal. For instance, a study by Zhang *et al.* (2020) investigated the performance of a biofilter packed with activated carbon for H_2S removal from biogas. The researchers found that the biofilter achieved high removal efficiencies even at low H2S concentrations. They also observed that the presence of other sulfur compounds in the biogas had a significant impact on the biofilter performance.

Another area of advancement in biofiltration technology is the development of novel microbial consortia for enhanced H_2S removal. Microorganisms play a crucial role in biofiltration by oxidizing H_2S to less harmful compounds such as sulfate. Researchers have been exploring the use of genetically modified microorganisms or microbial consortia with enhanced H_2S degradation capabilities. A study published in Environmental Science & Technology by Zhang *et al.* (2021) about "Enhanced Hydrogen Sulfide Removal in Biofilters Using Engineered Microbial Consortia" demonstrated the successful application of engineered microbial consortia for improved H_2S removal efficiency.

A study published in Chemical Engineering Journal by Wang *et al.* (2022), integration of biofiltration and adsorption for hydrogen sulfide removal: performance and mechanism investigated the synergistic effects of biofiltration and adsorption and provided insights into the mechanisms underlying their combined performance. In conclusion, biofiltration technology for the removal of H2S has seen significant advancements in recent years. The optimization of biofilter media, development of novel microbial consortia, and integration with other treatment technologies have all contributed to improved efficiency and effectiveness. These advancements have the potential to enhance the sustainability and cost-effectiveness of H2S removal processes in various industries.

Development of Biofiltration Process Technology in H_2S Removal

In recent years, biofiltration has been developed to effectively control odors, including H_2S emissions in dilute waste gas streams. Despite the proven efficiency, practicality, and simplicity of this gas cleaning technology, design and operational parameters, as well as the microbial processes involved, have not been well defined in Europe. Specifically, several studies have reported on the details of controlling H_2S using biofiltration. Biofilter design is mainly based on "rule of thumb" criteria, which is often too conservative. Consequently, accurately predicting the performance of the system and maintaining optimal conditions for odor control efficiency is difficult. Conducting an operational study is necessary not only to demonstrate the system's effectiveness but also to encourage advancements in biofiltration usage and the development of new biofilter systems.

Shareefdeen *et al.*, (2011), this paper presents a detailed account of the experimental protocol used to design the biofilter media, the pilot-scale biofilter production, and the collection of performance data. The basic material used was hollow cylindrical particles made with specified building components, which were then supplemented with nutrients and microorganisms. Multiple sets of media samples with different compositions were prepared and assessed during the evaluation process. The mixing ratio of nutrients was modified to attain the required amount. A biofilter pilot plan unit, depicted in Figure 1, was constructed, packed with new media, and installed in the pumping station for data collection in the field. The unit consists of a biofilter column, humidifier, diaphragm pump, gas compressor, rotameter, and OdaLog (App-Tek International Pty Ltd, Australia). The OdaLog device has been developed specifically for the wastewater sector to detect H_2S emissions from pumping stations and other equipment, such as trolleys and manometers. The device's H_2S (hydrogen sulfide) performance data is generated based on the time that it remains within different containers (EBRT), which is defined as the ratio of the media volume to the volumetric air flow rate. Technical abbreviations will be explained in their first use.

Figure 1. Pilot Plant Scale Biofiltration Equipment. Source: Shareefdeen *et al.*, (2011)

Currently, biofiltration is a complex process that involves a range of physical, chemical, and biological phenomena. It is renowned as one of the most popular and efficient technologies for the removal of pollutants. The biofiltration process consists of two stages. Firstly, pollutants are transferred from the air stream into the liquid and adsorbed onto a solid medium. Secondly, these pollutants are degraded by microbes found in the liquid phase or on packaging materials. The biofiltration process can include the components shown in Figure 2. A novel biofiltration system for controlling H_2S emissions incorporates *Thiobacillus thioparus* CHll that is immobilized using Ca-alginate as

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pelleted packaging material. This innovative biofiltration system efficiently reduces H_2S emissions (Rattanapan and Ounsaneha, 2011).

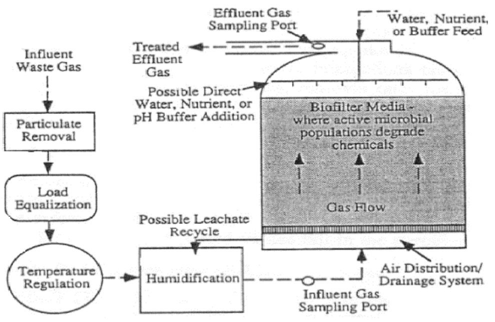

Figure 2. Illustration of Biofiltration Process Source: (Rattanapan and Ounsaneha, 2011).

In the study conducted by Rattanapan and Ousaneha (2011), the biofiltration process operates by guiding contaminated gas through a biofilter, whereby pollutants are transported to the biofilm and utilized as a carbon and energy source by microbes. Technical abbreviations will be introduced at first use. A standardized format will be observed, including commonplace academic sections with discreet titles and unambiguous wording. Objectivity will be enforced by removing subjective evaluations unless evident. Hedging will be applied to express positions on topics. Sentences will have grammatical correctness, and there will be no redundancy. Citation markers will be linked to an organized reference list using a regular citation style. The microbial species predominantly used in H_2S biofiltration are *Thiobacillus* sp., capable of H_2S degradation for energy and the production of sulfuric or sulfuric acid. Concise, logical, and transparent information will be conveyed through causal relationships between statements, with no ornamental or figurative language. Choosing the appropriate biofiltration media, i.e. natural or synthetic, is a crucial step in establishing a successful biofiltration process. In addition, several optimization factors have been identified for biofiltration operations, including maintaining an optimal water content of between 20 and 60% by weight, and keeping the pH near neutral since microbial growth is highest in these conditions. In addition, several optimization factors have been identified for biofiltration operations, including maintaining an optimal water content of between 20 and 60% by weight, and keeping the pH near neutral since microbial growth is highest in these conditions. Deviations from these conditions significantly affect the efficiency of the biofiltration process. Thirdly, it has been observed that the most effective temperature for biofiltration in terms of removal efficiency is comparable to the temperature at which microbial inoculation works best. Moreover, due to the fact that the H2S removal process necessitates only a small quantity of nutrients, it is possible to utilize commercial fertilizers or secondary waste from wastewater treatment plants to supplement the nutrients required.

The study examines the removal of H_2S through down-flow biofiltration, utilizing sulfide-oxidizing bacteria extracted from concentrated latex waste. The study evaluates a biofiltration system employing pure cultures of sulfur-oxidizing bacteria, which are immobilized on granular activated carbon (GAC) to remove H_2S. The research demonstrates that the efficiency of H_2S removal is more than 98%, even at high concentrations (200-4,000 ppm). The system has a maximum elimination capacity of about 125 g H_2S/m3 of GAC per hour (Rattanapan and Ounsaneha, 2011).

Biofiltration has gained recognition as an efficient technology for eradicating hydrogen sulfide (H_2S), a leading compound responsible for odor in the airstream of municipal wastewater treatment facilities. H_2S is both toxic and corrosive, in addition to possessing a distinctive scent. In their study, Shareefdeen *et al.,* (2011), it is postulated that biofilters containing novel filter media are being implemented in a nearby pumping station situated in University City, Sharjah, UAE. Information concerning the removal proficiency of H_2S is gathered and used for H_2S modeling and kinetic analysis. A study on H2S dispersion is then conducted, based on dispersion models (gaussian and US-EPA AERMOD) as well as outlet concentration predictions. Installing biofilters at pumping station locations can significantly reduce H_2S levels in the University community while also improving air quality, according to the study.

The method of work employed in the publication "Advanced simulation of H_2S scavenging process with triazine at different depths of gas well" is as follows:

1. The triazine-based H_2S scavenging process is mathematically modeled. This model takes into account the effects of triazine concentration, H_2S concentration, and gas well depth on H2S scavenging effectiveness.

2. Experimental data are used to verify the mathematical model. The mathematical model can accurately estimate H_2S scavenging efficiency, according to validation.

3. To optimize the H_2S scavenging process with triazine, mathematical models are applied. Optimization revealed that increasing the triazine concentration and decreasing the gas well depth can improve H_2S scavenging efficiency.

4. The simulation findings reveal that temperature and pressure affect the H_2S scavenging process using triazine. The efficiency of H_2S scavenging increases with rising temperature and decreases with increasing pressure.

5. The simulation findings reveal that the triazine-based H_2S scavenging process is a

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complex process controlled by numerous parameters. The simulation results can be utilized to optimize the triazine-based H_2S scavenging process (Subramaniam *et al.*, 2018).

Design and Biofiltration Process Model in H_2S Removal

In the biofilter model used by Shareefdeen *et al.*, (2011), Pollutants in the gaseous phase are transported to the biofilm through diffusion and are then degraded throughout the depth of the biofilm, which has been formed on the medium particles. The removal of pollution is influenced by two processes, namely diffusion and reaction. In the case of the zero-order reaction as postulated, either of these processes limits the overall removal. If the rate of diffusion is slower than that of reaction, the transfer process will be restricted. Similarly, a restricted reaction takes place when the reaction rate is slower than the diffusion rate. The equation is as follows:

Zero order = Reaction Limited

$Cout = Cin - K_0\,(EBRT)$

Where, the concentration of incoming air pollutants is Cin (kg.m-3) and the concentration of outgoing air pollutants is Cout (kg.m-3). The zero-order reaction rate constant is k0 (kg.m-3.s-1).

It is known that diffusion limits the overall removal of biofilm during the diffusion process. According to the restricted diffusion model, pollutants achieve maximum biodegradation in the biofilm at a depth less than the actual thickness of the biofilm, which implies that the biofilm is not entirely active. The gas phase concentration equation for this example is provided:

$Cout = Cin\,(1- \beta_1 \frac{EBRT}{\sqrt{Cin}})^2$ Where,

$$\beta_1 = A_S \sqrt{\frac{k_0 f(X_V) \cdot D_{H_2S,W}}{2m}} \; ; \quad f(X_V):$$

diffusivity ratio of compounds in the biofilm to water, H_2S W D: Diffusivity of hydrogen sulfide in water ($m^2 \cdot s^{-1}$), and m: The dimension of pollutants' Henry's constant.

The 'Ottengraf and van den Oever' models, extensively used by researchers and environmental professionals to describe performance data and construct biofilter systems, are founded on this principle.

Experimental procedure used by Shareefdeen *et al.*, (2011) The pilot-scale biofilter production series and collection of H_2S performance data demonstrate the development of new biofilter media. Since the experimental data are used to determine kinetics and models, new media and experimental setup are created. Hollow cylindrical particles are generated as the medium's basic material using specified building components and then Coatings of nutrients and microbes. Several sets of media

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samples are prepared and evaluated, each one containing a different composition. The nutrient mixing ratio is changed to coat the required amount of nutrients.

Biofilter model used by Yang and Allen (1994;2012) in *Biofiltration Control of Hydrogen Sulfide* is experimental allowance which is carried out using Dual tower experimental biofilter system. The laboratory experimental biofilter system is illustrated by Figure 3.

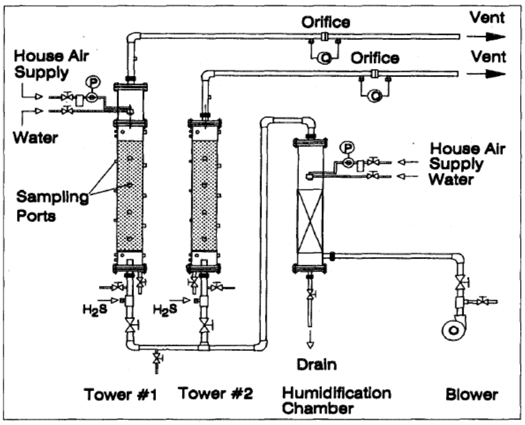

Figure 3. Schematic of the biofilter system
Source: Yang and Allen (1994)

System in Figure 3 comprises two parallel filter columns. Separate operation and control of two vertical biofilter towers. A 1.2 m high transparent rigid acrylic tube with an internal diameter of 0.15 m is connected to the biofilter bed material. Each column is filled to a height of 1.0 to 1.1m with the necessary compost. To achieve homogeneous incoming gas dispersion, the biofilter material is packed and supported by a filter plate. Sampling and measurement points for compost and gas sampling, as well as pressure and temperature measurements, are positioned along the acrylic column. A fan (Gast Regenair model R3105-1) in the humidification chamber regulates the temperature. Incoming air is humidified by passing through a packed spray chamber. Throughout the process, a relative humidity in the range of 95 to 100 percent is routinely and consistently maintained.

One of the biofiltration processes explained in the book of *Fundamental of Air Pollution* is a Model of biofiltration without a liquid phase to treat vapor phase pollutants. Air transports vaporized contaminants upwards through a porous medium (e.g. compost) containing microbes engineered to eliminate specific contaminants. Waste is heated at the bottom of the system to increase partitioning into the gas phase. Microbes in the biofilm surrounding each compost particle break down the contaminants into simple chemicals, which are then converted into carbon dioxide and water vapor. Figure 4 gives an overview of the process.

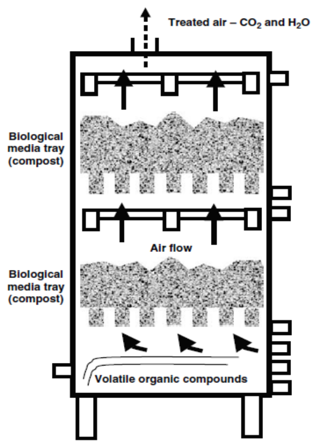

Figure 4. Biofilter Process without Liquid Phase (Source: Vallero, 2008)

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A. Biofiltration Mechanism and Performance in H_2S Removal

Microorganisms can degrade H_2S in three ways: assimilation, mineralization and sulfur oxidation. The H_2S produced by assimilation is insufficient to achieve a high enough removal efficiency from the very large flue gas stream. Microorganisms degrade H_2S by oxidation, resulting in the release of energy and the formation of sulphuric acid. When sulfide is completely oxidized to sulfate, the highest energy is released (according to equation (1)).

$$H_2S + 2O_2 \rightarrow SO_4^{2-} + 2\,H^+ \quad (\Delta G^{0'} = -798.2\ kJ/rxn) \qquad (1)$$

$$HS^- + \tfrac{1}{2}\,O_2 + H^+ \rightarrow S^0 + H_2O \quad (\Delta G^{0'} = -209.4\ kJ/rxn) \qquad (2)$$

$$S^0 + H_2O + 1\tfrac{1}{2}\,O_2 \rightarrow SO_4^{2-} + 2H^+ \quad (\Delta G^{0'} = -587.1\ kJ/rxn) \qquad (3)$$

$$\tfrac{1}{2}S_2O_3^{2-} + \tfrac{1}{2}\,H_2O + O_2 \rightarrow SO_4^{2-} + H^+ \quad (\Delta G^{0'} = -409.1\ kJ/rxn) \qquad (4)$$

As shown in Eq. (2) - (4), Sulfide oxidation occurs in stages, with elemental sulfur as an intermediate product, and in oxygen-limited conditions oxidation can only proceed to elemental sulfur, producing less energy. Sulfur can be stored inside or outside the membranes of cells. As shown in equation (4), other reduced sulfur compounds, such as thiosulphate, can also be oxidized and release energy.

The desired bacteria used in biofiltration to convert H_2S to S0 should have several basic characteristics: reliable conversion of H_2S to S0, minimal nutrient input, and easy separation of S0 from biomass. Chemolithotrophic sulfide oxidizers (also known as colorless sulfur bacteria) have diverse morphological, physiological and ecological characteristics and are able to grow chemically on reduced inorganic sulfur compounds such as sulfide, sulfur and thiosulphate, and in some cases organic sulfur compounds such as methanethiol, dimethyl sulfide and dimethyl disulphide. Sulfur bacteria include many genera such as *Acidithiobacillus*, *Achromatium*, *Beggiatoa*, *Thiothrix*, *Thioplaca*, *Thiomicrospira*, *Thiosphaera*, and etc. The genus *Thiobacillus*, one of the most studied groups, consists of several gram-negative and rod-shaped species that use the oxidation of sulfide, sulfur and thiosulphate for energy and growth. (Rattanapan and Ounsaneha, 2011).

Bacteria in the genus *Thiobacillus* appear to have superior H_2S removal efficiencies than other sulfide-oxidizing bacterial species due to their lower food requirements and ability to grow using H_2S as an energy source. *Thiobacillus* species are the most commonly used bacteria in H_2S biofiltration. *Thiobacillus* sp. use only carbon dioxide as a carbon source when biodegrading H_2S. It has been found that no typical carbon

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source inhibits its growth and it is expected to influence the oxidation of most sulfides via the sulphite oxidase pathway. These bacteria can grow in a variety of conditions. Acidic conditions are examples of stressful conditions. Acidophilic bacteria prefer a pH close to 7 and acidophilic bacteria thrive at low pH, allowing efficient H_2S oxidation over a wide pH range. This point shows that this genus appears to be superior due to lower nutrient requirements, allowing a reduction or elimination of the early lag phase and an improvement in H_2S removal efficiency while maintaining stable operation (Rattanapan dan Ounsaneha, 2011).

Suwardin (2005) asserts that biofiltration technique is one of proper alternatives to be developed in removing gas pollutants. This technique utilizes the ability of microbial activity to degrade pollutant compounds. Its current application is not restricted to odor reduction; it has also been developed as a method for the control of air pollution. The power of micro-organisms and the renewal of the filter medium utilized limit the effectiveness of this procedure. Using palm fiber and solid rubber waste as fixed bed media is an option that should be further investigated. Hence, it is envisaged that biofiltration techniques can be used by agriculture-based enterprises to decrease air pollution by harnessing the potential of existing microbial strains and industry waste. Figure 5 demonstrates the reactor used.

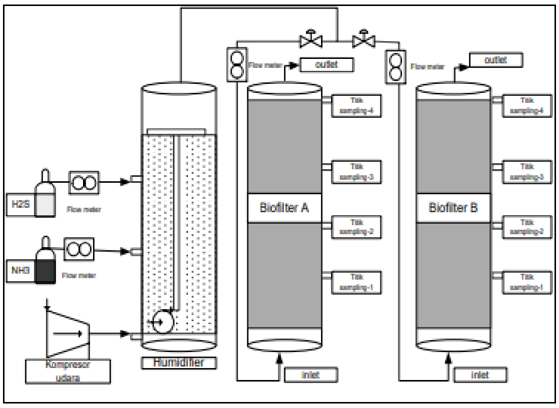

Figure 5. There are two continuous biofilter reactors made of cylindrical flexible glass

Source: Suwardi (2005)

B. Parameter Affecting Biofiltration in H_2S Removal

Biofiltration is a commonly used method to remove hydrogen sulfide (H_2S) from various sources, both industrial and domestic. The process relies on a biological filter medium, which is colonized by microorganisms that oxidize H_2S, resulting in a harmless byproduct. However, the efficiency of H_2S removal through biofiltration depends on various parameters, such as the type of filter media, nutrient supply, pH, temperature, and flow rate.The study of Singh *et al.* (2020), provides a thorough examination of the important factors affecting biofiltration in H_2S removal, with an emphasis on recent research in this area:

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1. Filter Medium

The type of filter medium used in biofiltration systems is a critical parameter that affects the efficiency of H_2S removal. Different filter media have varying surface areas, porosity, and chemical properties that influence the attachment and growth of microorganisms. For example, activated carbon, zeolites, and ceramic filters have been shown to be effective in H_2S removal, but they have different advantages and disadvantages. Activated carbon has a high surface area and can adsorb H2S, but it can also clog quickly and require frequent replacement. Zeolites have a high cation exchange capacity and can retain H_2S, but they can also be more expensive and have limited availability. Ceramic filters have a high mechanical strength and can withstand high temperatures, but they can be more difficult to regenerate.

2. Flow Rate

The flow rate of the influent also affects the efficiency of biofiltration in H_2S removal. The optimal flow rate depends on the type of filter medium and the specific application. In general, a higher flow rate can lead to higher H_2S removal efficiency, but it can also cause the filter medium to become clogged more quickly. For example, a flow rate of 1-5 m/h has been recommended for activated carbon filters, while a flow rate of 5-10 m/h has been recommended for zeolite filters.

3. pH

The pH of the influent also plays a critical role in biofiltration in H_2S removal. The optimal pH range for H_2S oxidation by microorganisms is typically between 6.5 and 8.5, although some studies have reported that H_2S can be oxidized at pH values as low as 5.5. A pH outside of this range can lead to reduced H_2S removal efficiency and the growth of non-oxidizing microorganisms.

4. Temperature

The temperature of the influent also affects the efficiency of biofiltration in H_2S removal. The optimal temperature range for H_2S oxidation by microorganisms is typically between 25°C and 45°C, although some studies have reported that H_2S can be oxidized at temperatures as low as 15°C. A temperature outside of this range can lead to reduced H_2S removal efficiency and the growth of non-oxidizing microorganisms.

5. Nutrient Supply

The nutrient supply is another critical parameter that affects the efficiency of biofiltration in H_2S removal. Microorganisms require a source of carbon, nitrogen, and other nutrients to grow and oxidize H_2S. The type and amount of nutrients added to the biofilter can affect the growth and activity of the microorganisms, as well as the H_2S removal efficiency. For example, some studies have

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used glucose, peptone, and other organic compounds as nutrient sources, while others have used wastewater or other industrial effluents as a source of nutrients.

Research Findings of Biofiltration Technique in H_2S Removal

Morgan and Noyola (2006) discover that mixing filter material in compost biofilters can improve hydrogen sulfide (H_2S) removal from biogas. The filter material employed in this investigation is compost mixed with wood chips, and changing the media boosted H_2S removal by up to 50%. The researchers also discover that mixing the material minimizes pressure drop across the biofilter, which can boost system efficiency. According to the findings of this research, mixing filter media in compost biofilters can be an efficient strategy to boost H_2S removal from biogas. This can be advantageous for biogas producing plants since H_2S is a hazardous gas that can cause health problems as well as damage to equipment.

Study of Shareefdeen *et al.*, (2011) shows a kinetic study on the H_2S removal from biofilter media. The best data is shown by a first-order model. Kinetic constants are and then to develop correlations of Cout = Cin exp(−0.055 * EBRT). This correlation can be used for the prediction of output concentrations and to assess biofilters filled with new material. The experimental data are as follows accord well with the model when compared to the expected concentrations using correlation. The University City dispersion effect as a research object is then determined using a simple Gaussian dispersion and an AS-EPA AER-MOD model with and without biofilters. According to the H_2S dispersion data, installing a biofilter at the pumping station will dramatically reduce H_2S levels and provide clean air for the University City population.

To evaluate the kinetics and the best theoretical model fit to the experimental data, the average concentrations at each of the four EBRTs are examined (Table 1). The H_2S removal kinetics in the biofilter are determined from the average concentrations (Cin and Cout) and the EBRT data.

Table 1. Average concentration in each EBRT tested

EBRT (s)	Cin (ppm)	Cout (ppm)
20	3,33	1,00
30	9,84	1,30
45	9,17	0,981
60	13,7	0,597

In this research, wind speed concentration calculations are performed to investigate the impact of H_2S dispersion from a pumping station in the city of the university. First, for two conditions, a basic Gaussian model is used: (1) H_2S dispersion out of the chimney without the use of a bio-filter, and (2)

H_2S dispersion with the use of a biofilter. In both circumstances, the average wind speed is considered 3 m/s and the atmospheric level has moderate stability. In the first example, It is assumed that the gas stack (without a biofilter) releases 100 parts per million of hydrogen sulfide. In the second example, It is assumed that a concentration of 1.5 ppm H_2S is released at the biofilter outlet. The removal rate is 98.5%. According to experimental and correlation data, the biofilter filled with new media can remove H_2S by 98.5%. By comparing the results of the two treatments, it can be shown that the H_2S concentration, which is greatly lowered at wind speed, exhibits the low values at all 7 location sites utilized as test samples. The biofilter has the potential to reach a maximum downwind concentration of 0.0023 ppb. The AERMOD model is utilized with the currently accessible meteorological database to extract the data.

In the investigation conducted by Rattanapan and Ounsaneha (2011), it was revealed that H_2S removal efficiency exceeds 98% even at elevated concentrations ranging from 200-4,000 ppm. Moreover, the maximum elimination capacity recorded is approximately 125 g H_2S /m3 of GAC /hour. The media used for biofiltration is critical to the effectiveness and success of the H_2S biofiltration process. Currently natural components have been employed in the media, which have advantages When compared to synthetic media, natural media offers superior nutrition for the growth of bacteria used in biofilters. Since inert synthetic packaging materials are typically utilized, biofiltration using water vapor and a steady supply of nutrients must be provided. There is also study combining natural and synthetic media.

Results that are not much different are shown by Yang and Allen (1994;2012), H_2S removal efficiency shows a consistently high value of 99.9%. One of the things that influences the efficiency of H_2S removal is the water content, which if it is reduced below 30%, the efficiency of H_2S removal decreases proportionally. A moisture content of 35% or more is required for optimum efficiency. To maintain constant control efficiency, biofilter systems must be run at or below their maximum loading capacity. To ensure compliance with the system's maximum loading capacity, it is imperative to adjust the waste gas flow rate to achieve optimal reduction of H_2S for varying incoming concentrations. For limiting H_2S emissions with a biofilter system, the following optimal operating parameters are recommended: temperature: 25-50°C, nutrients have a pH of 3.0 and a sulfate content of 25 mg-S/g. The retention time for pollutants is 15 seconds.

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Figure 6. P H_2S Changes Before and After Biofiltration

Duan et al. (2007) examined the combined impact of adsorption and biodegradation of biologically activated carbon (BAC) on H_2S bio trickling filtration. The results demonstrate that the presence of BAC effectively enhanced the efficiency of H_2S removal. Specifically, the H_2S removal efficiency increased from 60% to 95% as the concentration of BAC increased from 0 to 10 g/L. At low BAC concentrations, it was found that H_2S is predominantly eliminated through adsorption onto BAC, while at high BAC concentrations, biodegradation became the dominant process. The research suggests that combining BAC adsorption with biodegradation can be an effective method for eliminating H_2S from gas streams.

Recent research has been a comparison of the durability of biofilters and ADBRs for removing H_2S and VOCs from the air. The study discovers that both technologies are effective in removing the H_2S and VOC; however, the ADBR is stronger to the changes in operating conditions. This study also discovers that the ADBR is more effective to remove H_2S and VOC in the low concentration. The ADBR is similar to biofilter, yet both of them use different packaging materials such as ceramic or plastic beads. A nutrition solution is irrigated into the packaging material, allowing it to maintain a moist environment and supply nutrients for microorganisms. ADBRs can start up faster and are more resistant to changing operating conditions than biofilters. ADBRs, on the other hand, can be more expensive to operate and maintain than biofilters. According to the findings of this research, biofilters and ADBR are excellent technologies for eliminating H_2S and VOCs from the air. ADBR, however, is more resistant to changes in operating circumstances and more effective in removing H_2S and VOC at low concentrations. As a result, ADBR may be a preferable alternative for applications with changing operating circumstances or low influent concentrations (Lebrero, 2010).

Based on Omri *et al.*, (2013) with a removal effectiveness of more than 99%, biofilters can successfully remove H_2S gas from wastewater. A biofilter's bacterial community is varied, containing many different species. The biofilter's primary bacterial species are *Alcaligenes faecalis, Pseudomonas aeruginosa,* and *Bacillus subtilis*. These organisms are renowned for their capacity to break down H_2S gas. The bacterial community in the biofilter is also found to be adaptable to fluctuations in the concentration of entering H_2S gas in this research. This demonstrates that biofilters can be used to treat wastewater containing varying quantities of H_2S gas. According to the findings of this research, biofilters are a viable technique for wastewater odor treatment.

Alinezhad et al. (2019) conducted a study comparing the technical and economic feasibility of chemical scrubbers and biofiltration for removing hydrogen sulfide (H_2S) and ammonia (NH3) from wastewater treatment plants. Results indicated that chemical scrubbers are the better choice for removal efficiency when considering these two compounds. However, if the primary priorities are capital and operational costs, then biofiltration may be the more cost-efficient option.

Research findings of Zarei *et al.*, (2019), on modeling the Efficiency of Hydrogen Sulfide Removal from Biogas in Biofilters Using Multiple Linear Regression and Support Vector Machines, Biofilters are air pollution control devices utilizing living organisms to remove pollutants from a gas stream. In this research, biofilter is used to hydrogen sulfide from biogas. Models of biofilter removal efficiency are constructed using multiple linear regression (MLR) and support vector machines (SVM). Using study results demonstrating that the MLR and SVM models may accurately predict biofilter removal efficiency. The SVM model, on the other hand, is shown to be more accurate than the MLR model. According to the findings of this research, SVM is a promising method for modeling biofilter removal efficiency.

Zhang *et al.,* (2021) carry out an economic assessment of a A biogas purification system that has been developed to eliminate H_2S and siloxane from biogas. The research explores the financial viability of various biogas purification systems intended for removing H_2S and siloxane. Biogas purification systems that use a combination of chemical absorption and membrane filtering are the most cost-effective. This system has a low operating cost and can remove H_2S and siloxane to acceptable levels. Biogas purification systems that use a combination of chemical absorption and membrane filtration are the most cost-effective. This system has a low operating cost and can remove H_2S and siloxane to acceptable levels. The chemical absorption system is capable of extracting H_2S from biogas but not siloxane. The membrane filtration system can remove siloxane From biogas; however, it is ineffective in the removal of H_2S. The combination of these two

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technologies can reduce H_2S and siloxane levels in biogas to acceptable levels.

CONCLUSION

Based on the information presented, biofiltration technology is widely acknowledged as the optimal solution to mitigate H_2S pollution from the atmosphere. The concomitant use of biofiltration with adsorption treatment technologies has produced significant synergistic effects that have resulted in enhanced efficiency. Furthermore, scientific advancements in the development of novel microbial consortia and media have considerably facilitated the removal of H_2S with greater efficacy.Key factors for achieving effective biofiltration performance consist of moisture levels, temperature, nutrient supply, flow rate and pH. These essential parameters, in combination with suitable media and microbial strains, are capable of optimizing the biofiltration process to reduce H_2S emissions. In conclusion, when optimized using the above-mentioned important factors, biofiltration technology is considered the most efficient technique for eliminating airborne H_2S.

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