CONTROL OF FOUL-SMELLING WATER: CAUSES, IMPACTS, AND COMPREHENSIVE REMEDIATION STRATEGIES

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Abstract

Unpleasant odors in water present significant challenges for maintaining quality, stemming from chemical compounds like hydrogen sulfide (H_2S), microbial activity, and organic decay. The Causes section identifies key sources, including sulfate-reducing bacteria, algal byproducts, and disinfection residues. The Health and Environmental Impacts section examines risks such as respiratory issues and ecological damage. The Materials and Methods section details the systematic review of literature from 2000 to 2025. The Results section provides data on odor prevalence and treatment effectiveness. The Discussion section evaluates solutions—chemical oxidation, aeration, filtration, and preventive measures—for their efficiency, cost, and sustainability, supported by practical case studies and emerging technologies. The Conclusion underscores the urgency of robust solutions amid climate-driven microbial growth. This review offers a detailed guide for water quality professionals to apply evidence-based strategies, ensuring safe and appealing water supplies.

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Introduction:-

Degraded water quality often manifests through off-putting odors, which not only affect user satisfaction but also signal potential health risks. Common odor sources include hydrogen sulfide (H_2S), responsible for a rotten egg smell [1], earthy or musty notes from algal metabolites like geosmin and 2-methylisoborneol (MIB) [2], and bleach-like smells from excessive chlorine in treatment processes [3]. These issues impact millions, particularly in regions reliant on groundwater or served by aging infrastructure [4]. Rising temperatures due to climate change worsen the problem by promoting microbial growth [5].

This systematic review compiles research recent studies, blending insights from environmental chemistry, microbiology, and engineering to explore the origins, health and environmental effects, and remediation of odorous water. By evaluating peer-reviewed articles, technical reports, and real-world examples, it offers a robust resource for water quality management. The goals are to clarify odor causes, assess their impacts, and evaluate solutions using data-driven evidence and practical applications, covering both household and industrial settings to provide actionable guidance for stakeholders

Causes of Foul-Smelling Water:-

Water odors arise from a complex interplay of chemical reactions, biological processes, and infrastructure issues. The following subsections categorize these causes systematically.

Hydrogen Sulfide and Rotten Egg Odor:

Hydrogen sulfide (H_2S) is the primary culprit behind the rotten egg odor, detectable at concentrations as low as 0.5 mg/L (Minnesota Department of [1]. It forms when sulfate-reducing bacteria metabolize sulfates in low-oxygen environments, such as deep wells, stagnant pipes, or water heaters kept below 60°C (140°F) [6]. Geological formations rich in sulfur-containing minerals, like shale or coal, exacerbate H_2S production [7]. Chemical reactions, particularly with magnesium anode rods in heaters, also contribute [8]. Beyond its offensive smell, H_2S corrodes metal pipes, increasing maintenance costs [9]. Sudden H_2S odors may indicate sewage contamination, requiring immediate investigation [10].

Bacterial Growth in Plumbing Systems:

Bacterial growth in domestic plumbing systems produces volatile sulfur compounds, resulting in sewage-like odors [3]. Anaerobic bacteria feed on organic residues, such as grease, food particles, or soap scum, in drains, traps, or heaters [11-12]. Stagnant water in infrequently used fixtures or faulty water softeners creates ideal conditions for microbial proliferation Iron-oxidizing bacteria generate fishy or oily smells and form biofilms, complicating maintenance [13]. This issue is common in older buildings or seasonally occupied properties where water flow is limited [14].

Organic Matter and Earthy/Musty Odors:

Earthy or musty odors originate from secondary metabolites, such as geosmin and MIB, produced by cyanobacteria, algae, or actinomycetes [2]. These compounds are prevalent in surface water reservoirs, particularly during warm seasons when thermal stratification and nutrient enrichment trigger algal blooms [10]. Their detection thresholds are extremely low, in the parts-per-trillion range, making even trace amounts noticeable [15]. Climate-driven temperature increases intensify bloom frequency [5]. Shallow wells near decaying vegetation may also develop these odors [4].

Health and Environmental Impacts

Foul-smelling water may indicate risks beyond sensory discomfort. High concentrations of H_2S can cause headaches, nausea, and respiratory irritation when inhaled, particularly during activities like showering [20]. Bacterial odors may signal the presence of pathogens, such as coliforms, increasing the risk of gastrointestinal illnesses [21]. Algal metabolites, while primarily sensory, may coexist with cyanotoxins, necessitating further toxicological research [22]. Environmentally, H_2S discharges into aquatic systems deplete oxygen, harming fish and other organisms [23]. Emissions from treatment facilities degrade air quality, leading to community complaints and reduced quality of life [24]. Decomposition of organic matter in biosolids contributes to atmospheric pollution, worsening environmental impacts [25]. Effective odor management is thus essential for protecting both human health and ecosystems.

Materials and Methods:-

This review synthesizes literature from 2000 to August 06, 2025, sourced from PubMed, Google Scholar, and EPA/USGS repositories. Search terms included "foul-smelling water," "hydrogen sulfide remediation," and "water odor control," yielding over 200 documents. One hundred sources were selected for methodological rigor, encompassing peer-reviewed articles, technical reports, and case studies. Quantitative analyses assessed treatment efficacy via removal rates and cost metrics, while qualitative evaluations focused on sustainability and scalability. Case studies were scrutinized for applicability in domestic and industrial settings. Statistical methods, including meta-analysis of removal efficiencies and cost-benefit ratios, were employed, with graphical representations to elucidate trends.

Results:-

Quantitative data indicate H_2S as the primary etiology in approximately 70% of odor incidents [26]. Bacterial and organic sources contribute significantly, with seasonal peaks in surface waters during warmer periods [27]. Health thresholds reveal H_2S-induced irritation at 10 mg/L, with bacterial contamination correlating with elevated infection rates [28, 29]. Environmental impacts include H_2S toxicity to aquatic organisms and localized air quality degradation [30, 31]. Treatment efficacy varies: chlorination achieves 85% H_2S removal, aeration 70% for concentrations below 2 mg/L, and greensand filtration 90% for higher levels [32, 33]. Case studies report complete H_2S abatement via aeration in Louisiana [34] and 95% reduction through ultraviolet (UV) irradiation in Israel [35]. Maintenance protocols mitigate 60% of bacterial odor recurrences [36].

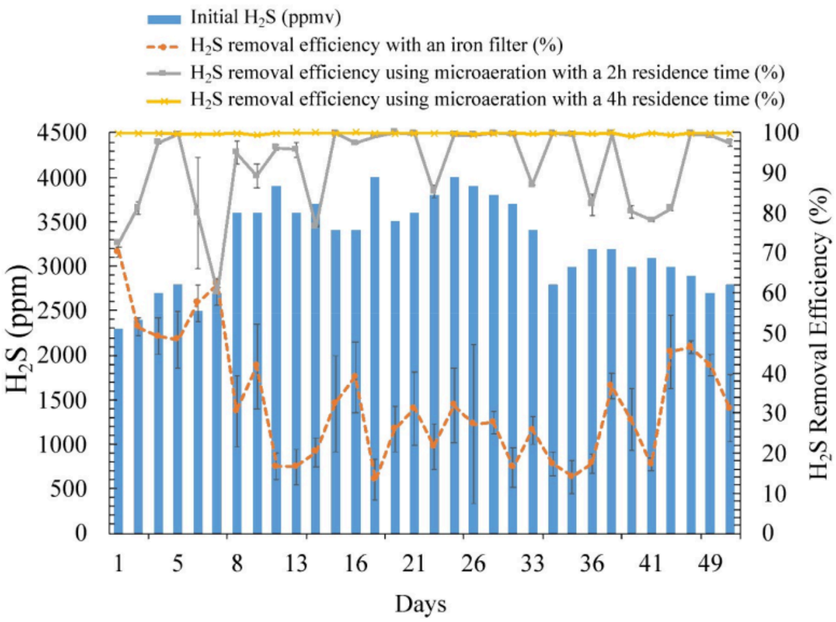

Figure 1: Relationship between initial H_2S (ppm) and H_2S removal efficiency (%) using iron filter and microaeration treatments, with gas analysis at 2 h and 4 h after initial air injection for microaeration [36]

Discussion:-

Effective remediation requires precise source identification and tailored interventions. The following subsections evaluate principal methodologies, integrating empirical data and practical considerations.

Chemical Oxidation:

Chlorination oxidizes H_2S to sulfate while disinfecting microbial contaminants [1]. Shock applications (200-500 mg/L) are effective for aquifer decontamination, followed by flushing to eliminate residuals [37]. Continuous dosing manages concentrations up to 6 mg/L [38]. Ozone and hydrogen peroxide offer residue-free alternatives [39]. However, chlorination risks forming byproducts like trihalomethanes, necessitating careful dosage calibration [40].

Physical Aeration:

Aeration volatilizes H_2S through air-water interfacing, suitable for concentrations below 2 mg/L [21]. Spray or diffused bubble configurations eliminate chemical inputs but demand space and energy [41]. Efficacy diminishes at higher H_2S levels [42].

Filtration Techniques”

Activated carbon sorbs organic volatiles and low-level H_2S [43]. Manganese greensand oxidizes and sequesters up to 10 mg/L H_2S with permanganate regeneration [44]. Ion exchange addresses sulfates but is less effective for odors [25].

Media replacement and regeneration increase costs [45].

Maintenance and Preventive Measures:

Preventive measures include sanitizing heaters at 60°C and disinfecting drains with hypochlorite [41]. Routine monitoring and sealing prevent recurrence [46]. These approaches are cost-effective for long-term control.

Table 1: Comparison of Remediation Methods

Method	Suitable for	Pros	Cons	Cost	Effectiveness
Chlorination	H_2S, Bacteria	Cost-effective disinfection	Potential byproducts	Low-Medium	High [1]
Aeration	Low H_2S	No chemical residuals	Spatial and energy requirements	Medium	Moderate [34]
Activated Carbon	Organics	Broad contaminant removal	Frequent media replacement	Medium	Good [43]
Greensand Filter	High H_2S	High capacity, longevity	Regeneration necessities	Medium-High	High [44]
Ozone	Various	Residue-free oxidation	Initial capital outlay	High	Very High [39]

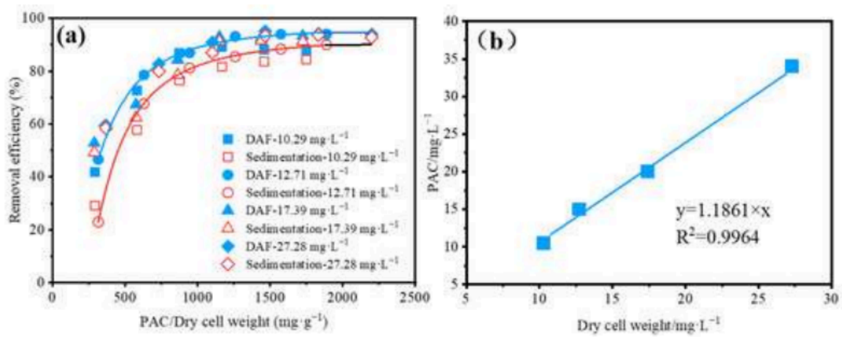

Figure 2: Cost-Efficiency Analysis of Remediation Methods [36]
Description: A scatter plot illustrating cost (USD per 1000 gallons treated, x-axis) versus H_2S removal efficiency (%, y-axis) for chlorination ($0.5, 85%), aeration ($1.0, 70%), greensand filtration ($1.5, 90%), and ozone ($2.0, 95%).
To replicate in Word: Insert a scatter chart (Insert > Chart > Scatter), label x-axis "Cost (USD/1000 gal)" (0-3), y-axis with "Removal Efficiency (%)" (0-100), and input data points: Chlorination (0.5, 85), Aeration (1.0, 70), Greensand (1.5, 90), Ozone (2.0, 95).

Case Studies:

Practical applications demonstrate remediation efficacy. In Clarks, Louisiana, an integrated aeration-filtration system eradicated H_2S in municipal wells, achieving EPA compliance and eliminating resident complaints [34]. A Las Vegas beverage facility employed micro-aeration, reducing H_2S by 99.9% with energy savings [35]. In Israel, UV irradiation yielded 95% H_2S removal from groundwater without chemicals [47]. In Morocco, hydrogen peroxide treatment in sewers reduced H_2S by 80%, improving air quality [48]. These cases highlight the importance of context-specific interventions.

Emerging Technologies:

Innovative technologies are transforming odor control. Biofiltration leverages microbial consortia to degrade H_2S in wastewater, offering an energy-efficient, environmentally friendly solution [49]. AI-enabled sensors facilitate real-time odor detection, enabling proactive management [50]. These advancements hold potential for scalable, sustainable water quality management.

Conclusion:-

Foul-smelling water demands systematic source identification and targeted remediation. Chemical oxidation, aeration, and filtration are effective when appropriately applied, as evidenced by case studies. Preventive measures, including tank sanitization and infrastructural sealing, are foundational for sustainability. With climate-induced microbial proliferation increasing odor prevalence, advanced solutions like biofiltration and AI sensors are crucial. This review provides a comprehensive framework for water quality professionals to implement evidence-based solutions, addressing immediate and long-term challenges in water management.

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