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UNVEILING BIOLOGICAL HAZARDS AMONG WORKERS HANDLING DRY SLUDGE AND MITIGATION STRATEGIES (REVIEW ARTICLE)

By

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Abstract

In Egypt, the accumulation of dry sludge in wastewater treatment plants stands as a persuasive challenge and presents a crucial hazardous domain within the realm of waste management sector. Accelerated population growth has parallel increase in wastewater generation that needs sustainable solutions. Workers handling dry sludge are exposed to a wide variety of occupational hazards among which the biological hazards due to direct dermal exposure or inhalation of air contaminated with microorganisms including bacteria, viruses, fungi and parasites. Therefore, dry sludge workers are at high risk of experiencing a broad range of adverse health impacts. Strict measures can control such exposure through engineering, medical and legislative means. Annual periodic medical examination should be performed to ensure general wellbeing and to detect early manifestations of infectious diseases, respiratory, gastrointestinal or skin disease. Proper handling and standardized regulations, establishing a comprehensive Work Plan, guidelines for sludge disposal, developing and implementing a "Site Safety" and "Health Sustained Strategic Plans" to eliminate exposure to such hazards. Egypt can adopt alternative methods for the best use of dry sludge and convert it to valuable resource to be incorporated in circular economy principles where the resource is fed back into the economy as a raw material with higher priority needs to be given to reuse and recycling. The diverse array of biological hazards facing dry sludge workers necessitates proactive measures of effective disinfection and stabilization of sludge such as by lime stabilization, heat treatment or thermophilic aerobic digestion prior to manual handling and strict adherence to safety protocols and practices to safeguard the .health and well-being of workers

Key words: Dry sludge handlers, Occupational exposure, Biological hazards, and Mitigation strategies

Introduction

The exponential growth of population and urban centers in Egypt has led to a parallel increase in wastewater generation. Consequently, the volume of dry sludge produced from wastewater treatment plants (WWTPs) has surged, straining the existing waste management infrastructure. Inadequate facilities, outdated treatment methods, and limited resources have contributed to the accumulation of sludge across the country. The circular economy framework encourages the recycling in the field of renewable energy and/or in agriculture reuse after a stabilization process, incineration, landfill, or others (Kacprzak et al., 2017).

Lately, growing worries have emerged regarding the handling of sewage sludge, stemming from environmental hazards triggered by the rapid growth of wastewater treatment facilities, with insufficient focus on managing the resulting sludge. Several challenges hinder efficient sludge management in Egypt. Insufficient funding and investment in modern waste treatment technologies often lead to outdated facilities incapable of handling the escalating sludge volume. Sludge drying involves extracting moisture from sludge as water vapor, contrasting with methods like thickening or dewatering, where moisture is eliminated as a liquid through purely mechanical processes. The generated sewage sludge typically constitutes a mere 1% to 2% of the treated wastewater volume, yet its management expenses commonly range from 20% to 60% of the total operational costs of the wastewater treatment facility (Sperling and Chernicharo ., 2005). This needs huge investments far above the available national budget. Workers may be exposed during manual handling, loading for transportation by trucks to a land application site where they are applied directly to the land using tractors, tank wagons, irrigation systems, or special application vehicles or through involvement in other manufacturing fields as cement or biogas production (Potential Risks To Workers Exposed to Class B Biosolids | NIOSH | CDC).

In the empire of waste management, handling of dry sludge represents a crucial yet risky facet of the process. In Egypt, the accumulation of dry sludge as a byproduct of wastewater treatment, poses environmental and health hazards when not managed effectively.

The sludge generated in developing countries significantly contrasts with that of developed nations due to varying levels of industrialization and public health standards. In developing countries, the metal and toxic content is usually much lower, while diverse range of pathogens is much higher in sludge in developing countries (Ujang and Henze, 2006).

Currently, a quite little attention is given to sludge management with lack of standardized local regulations and guidelines for sludge disposal, creating inconsistencies in management practices as it is adopted mainly from industrialized countries without any attempt to adapt it to local situations (Ghazy et al., 2009).

Moreover, the stigma associated with sludge as a waste product impedes the exploration of its potential as a resource for energy generation and agricultural use, leading to its improper disposal and accumulation in landfills. The steady increase in urbanization and industrial activities has exacerbated the problem, demands urgent and sustainable solutions to address the mounting sludge problem. Ghazy et al., (2009) stated that, the quality of the produced sludge in most of the WWTPs doesn't fit with the Egyptian or international standards, especially pathogens limits, posing and environmental and health threat.

Understanding the Biological Hazards:

Dry sludge is the residue formed through wastewater treatment plant, is rich in organic matter but laden with potential biological hazards with a wide range of pathogenic microorganisms that pose significant risks to the health and safety of workers involved in its management and disposal (Gantzer et al., 2001). Pathogens are present in sludge as result of human and animal wastes, food processing, biological laboratory and during some treatment of wastewater (Hédi Romdhana et al., 2009)

Workers exposed to dry sludge are often unsung heroes in the sanitation infrastructure, are faced with a myriad of biological hazards, from bacteria and viruses to fungi and parasites. The composition of dry sludge harbors a spectrum of microorganisms that can lead to various health complications upon exposure (Ujang and Henze, 2006). They have the misinformation that dry sludge is usually safe, so they handle it carelessly ignoring any safety measures.

The primary concern for dry sludge workers lies in the large range of pathogens present in this material. Meerburg et al., (2016) revealed structural differences in the bacterial community of domestic and industrial sludge. Bacterial agents like Salmonella, E. coli, and Legionella can thrive within the sludge, posing severe risks of gastrointestinal and respiratory infections.

During the declared pandemic SARS-COV-2 (COVID 19) by World Health Organization (WHO), the possibility of transmission of this virus was investigated through the wastewater treatment plants (WWTPs). It was concluded that the enveloped viruses have been proven to survive for days to months in the municipal wastewater system and it was also believed that this sewage acts like a reservoir due to the enrichment of 30%–50% of pollutants. Meanwhile, pathogens may survive at biosolid disposal sites from where can spread to surface water, groundwater, and soils, posing a potential threat to human health (Yang et al., 2020).

Additionally, viruses such as norovirus and hepatitis A can persist in this environment, causing acute illnesses upon contact. The diversity of pathogens were investigated by Yang et al., (2022) and concluded that it depends on the characteristics of the sludge and method of treatment. Resistance of pathogens to sludge treatment was type-dependent, and pathogenic protozoa and fungi showed greater resistance to anaerobic digestion. Fungal spores are often abundant in sludge and can trigger respiratory system and allergies among workers.

Sabbahi and his colleagues (2022) carried out parasitological assessment of sewage sludge and detected Trichuris spp., Hymenolepis diminuta, and Toxocara spp. eggs, however sample contents were below the WHO (2006) and US EPA (2003) recommendations, and thus, the sludge can potentially be reused in agriculture. Other parasitic organisms like Ascaris lumbricoides and Giardia lamblia may also find a habitat in sludge, leading to parasitic infections upon exposure. Direct contact with contaminated sludge, inhalation of airborne particles, and accidental ingestion due to inadequate personal protective equipment (PPE) can heighten the risk of exposure to these biological agents. It is essential to optimize the treatment and disposal of sludge for pathogenic microorganism

control (Mengtian et al, 2022).

Rui et al., (2020) investigated sludge workers› exposure to airborne bacteria and endotoxin, and the total inflammatory potential (TIP) of their exposure and estimated the potential deposition of bacteria in the airways. They confirmed the high risk of the lower respiratory tract affection in aerosol exposure and identified the microorganisms related to gastrointestinal problems. According to the American Thoracic Society, sewage workers most commonly reported respiratory issues (66%), followed by skin problems (31%) and noise-induced hearing impairment, as the highest occurrences of occupational diseases (Achutan and Nemhauser , 2003).

Apart from health hazards that include exposure to harmful gases such as methane and hydrogen sulfide, cardiovascular degeneration, musculoskeletal disorders like osteoarthritic changes and intervertebral disc herniation, skin problems, respiratory system problems and altered pulmonary function parameters, infections like hepatitis, leptospirosis , helicobacter and others can also be detected (Tiwari et al., 2008).

Furthermore, improper handling procedures and insufficient sanitation practices can exacerbate the danger, amplifying the likelihood of infections and health complications.

Mitigation Strategies and Safety Measures:

To safeguard the well-being of workers engaged in handling dry sludge, stringent safety protocols and mitigation strategies are imperative. Proper sludge disinfection is ensured to minimize the risk of pathogenic contamination and ensure the safety to workers and public health. While prioritizing the shift of workers from manual to mechanical de-sludging methods, it's crucial to note potential safety concerns within a mechanized context where de-sludging trucks are employed for these services. However, the mechanical treatment process carries a greater risk of exposure to airborne bacteria (Gautam et al., 2021).

Several measures can provide disinfection of sludge, as chlorine oxidation, lime stabilization, heat treatment and thermophilic aerobic digestion (TAD). Anaerobic and aerobic digestion but it acts by greatly reducing the number of pathogenic organisms. Long-term storage and composting are probably the most effective means

of disinfecting dewatered aerobic and anaerobic digested sludge (Goel et al., 2002).

Various nations have crafted regulations aimed at managing health risks associated with pathogens when reusing sewage sludge in agriculture. These regulations primarily focus on monitoring microbial parameters, particularly helminth eggs. However, protozoan parasites are typically omitted from the legislation of most countries (Jiménez-Cisneros , 2006).

Adequate training programs should be implemented to educate workers about the potential risks associated with sludge exposure and emphasize the importance of adhering to safety guidelines. Regular health screenings and medical check-ups yearly for workers exposed to dry sludge can aid in early detection of any potential infections or health concerns, enabling timely intervention and treatment (Tiwari , 2008).

After medical records of infections, great concern should be taken for return to exposure after ensuring mitigating the risk of such infection. Workers with chronic diseases should be prevented from such exposure because of their immune-compromised state. Also workers with chronic skin diseases may lack the protective functions of the skin against infectious pathogens (Guidelines for Occupational Medical Examinations (ufpr.br) (2007).

Utilization of personal protective equipment, including gloves, masks, goggles, and overalls, becomes crucial to minimize direct contact and inhalation of hazardous particles. Rigorous hygiene practices, such as frequent hand-washing and decontamination measures, should be strictly enforced to mitigate the spread of pathogens. By fostering awareness, implementing robust safety measures and prioritizing worker education and protection with range of behavior change campaigns, the risks associated with biological hazards among dry sludge workers can be significantly mitigated, ensuring a safer working environment for those dedicated to manage this essential yet challenging aspect of waste disposal (Gautam et al., 2021).

Sustainable strategic management:

Different issues needed to achieve a sustainable sludge management in developing nations as Egypt. Effective sludge management significantly contributes to sanitation programs, mitigat-

ing health issues and their related risks. The primary hurdle for sludge reuse lies in the diverse array of microorganisms, demanding science-based decisions for the treatment process, while heavy metal content tends to be relatively low. Comprehensive sludge management necessitates commitment from various sectors to formulate and enforce regulations (Jemenez et al., 2004).

1- Investing in advanced treatment technologies and upgrading existing facilities is imperative. Implementing innovative methods such as anaerobic digestion, thermal treatment, and composting can effectively reduce sludge volume and mitigate its environmental impact (Goel et al.,2002).

2- The idea of shifting the perspective on sludge from waste to resource is crucial. It is important to focus on the recovery of potential valuable products from sludge and the development of markets for these products. One of these ideas is utilizing treated sludge as a source of renewable energy through biogas production (Skrypsi-Mantele et al., (2000), or converting it into fertilizer for agricultural purposes can not only alleviate the burden of disposal but also offer economic and environmental benefits, or the integration of treated dry sludge in other industrial activities (Odegaard et al., 2002).

3- Enforcing comprehensive regulations and standards for sludge management is essential. Clear guidelines for treatment, disposal, and utilization of sludge will streamline the process and ensure uniformity in practices across different regions.

4- Educating the public about the importance of proper sludge management and its potential benefits can foster community involvement. Encouraging citizen participation in waste reduction and recycling initiatives can significantly contribute to the overall solution (Englande and Reimers ,2001).

5-Collaborating with international entities for exchange programs, might aid in adopting best practices from around the globe. Learning from successful models implemented in other countries can provide valuable insights for effective sludge management in Egypt.

Conclusion and Recommendations: The realm of dry sludge management presents a crucial but hazardous domain within the waste management sector. The accumulation of dry sludge in

Egypt demands a holistic approach that combines technological advancements, policy reforms, public engagement, and international collaboration. By transforming the perception of sludge from a waste burden to a valuable resource, Egypt can forge a path towards national sustainable waste management practices, mitigating environmental hazards and fostering a cleaner, healthier future for the nation. Egypt can incorporate dry sludge in circular economy where it is considered a raw material, for use as a higher priority source as energy production or use in construction field. Legislations should be more adapted to the Egyptian nature as well as improvement of the institutional capacity to guarantee the enforcement of their application. The diverse array of biological hazards within dry sludge necessitates proactive measures and strict adherence to safety protocols to safeguard the health and well-being of workers.

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