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PERSPECTIVE ARTICLE

Granular Activated Carbon: Concerns of Occupational Health and Food Safety Specialists

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ABSTRACT

Granular Activated Carbon (GAC) is a versatile material used across various industries, including water treatment and environmental remediation. Its micro/nano-pore structure enables the adsorption of diverse impurities, such as organic compounds and heavy metals. Producing high-quality GAC is crucial; however, its production, handling, and application raise significant occupational health, safety, and environmental concerns. The main occupational hazards include: (1) exposure to fine carbon dust, which may lead to respiratory risks such as lung irritation and pneumoconiosis; (2) chemical exposure during the activation process, with associated risks of burns, skin irritation, and inhalation of toxic fumes; (3) fire and explosion hazards from combustible carbon dust; and (4) ergonomic risks associated with manual handling of heavy GAC bags or containers. General safety measures include dust control systems, PPE, proper chemical handling, and ergonomic interventions.

GAC is widely used in the food and beverage industries for decolorization, deodorization, and purification of food items. The product can easily become contaminated due to poor manufacturing practices, storage, or handling, while its excessive use may adsorb essential nutrients and thereby deteriorate product quality. These risks can be mitigated by adhering to regulatory standards and Good Manufacturing Practices. Granular activated carbon is essential in various industries—especially food and beverage processing—for producing non-harmful, high-quality products. Nevertheless, robust management of safety, toxicity, and occupational health risks associated with GAC use remains imperative. Ensuring compliance with regulations, implementation of safety protocols, and optimization of usage will help protect both consumers and workers while sustaining industrial benefits.

KEYWORDS: *Occupational Health, Activated Carbon, Food Industry, Safety*

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INTRODUCTION

Granular Activated Carbon (GAC) is a highly porous form of carbon that has been treated to produce small, low-volume pores, thereby increasing its surface area for chemical reactions or adsorption. It is manufactured from raw materials such as coconut shells, wood, coal, or peat, which are treated at high temperatures and with chemicals to develop a micro/nano-pore structure. This unique structure enables GAC to adsorb a wide range of impurities, including organic compounds, chlorine, volatile organic compounds (VOCs), and heavy metals, making it an extremely versatile material used across many industries [1].

GAC is used extensively in water purification plants to filter out impurities, including pesticides, industrial pollutants, and disinfection byproducts. It is a standard component in municipal water treatment facilities, home water treatment systems, and industrial wastewater treatment plants. By adsorbing toxic substances, GAC plays a crucial role in providing clean and safe drinking water [2]. In air purification systems, GAC is employed to remove airborne impurities, odors, and harmful gases. It is widely utilized in industrial processes, heating, ventilation, and air conditioning (HVAC) systems, and even domestic air purifiers to maximize indoor air quality and safeguard human health [3].

In the pharmaceutical industry, GAC is used to purify raw materials and remove impurities from drug products. It is also employed in emergency poison control to adsorb toxins from the stomach [4]. In environmental cleanup, GAC is utilized to adsorb contaminants from water and soil, proving especially effective in mitigating the effects of oil spills, chemical spills, and industrial effluent [5].

The effectiveness and versatility of GAC make it a cornerstone of contemporary industrial and environmental technologies. However, its manufacture, storage, and use are not without challenges [6]. Occupational health and food safety professionals are increasingly concerned about potential hazards associated with GAC, including worker exposure to toxic dust and chemicals, contamination risks in food processing, and environmental harm due to improper disposal. Addressing these concerns is essential for ensuring the safe and sustainable use of this valuable material.

OCCUPATIONAL HEALTH ISSUES

GAC has widespread industrial applications, ranging from water purification and air filtration to chemical separations. Although GAC significantly enhances the profitability of most industrial operations, its production and handling present several occupational health and safety hazards. These hazards pose substantial health risks to employees and operational threats to facilities if not properly controlled [7]. Some of the major occupational health concerns are outlined below, along with key measures required for their mitigation.

Exposure to Dust and Particulate Matter

The manufacturing and handling of GAC generate fine carbon dust, which poses serious respiratory hazards to workers. Chronic exposure to carbon particles can lead to lung irritation, persistent respiratory issues, and even pneumoconiosis. Effective dust control measures—such as proper ventilation systems—are essential. Workers should be equipped with appropriate personal protective equipment (PPE), including respirators and masks, and undergo regular health monitoring to prevent respiratory problems and detect potential health issues at an early stage [8].

Chemical Exposure

Carbon activation requires high temperatures and the use of chemicals such as phosphoric acid or zinc chloride. Workers involved in the activation process are at risk of chemical burns, skin irritation, and toxic inhalation. These risks can only be mitigated if industries ensure that workers are thoroughly trained in the proper handling of these chemicals and in responding to chemical emergencies. The provision of appropriate personal protective equipment (PPE), well-ventilated workspaces, and the enforcement of stringent operational safety protocols are essential measures to minimize chemical exposure [9].

Fire and Explosion Hazards

GAC, particularly in powder form, is highly combustible. Powder clouds generated during processing or handling can be ignited, leading to fires or explosions with potentially catastrophic consequences for workers and facilities. To eliminate such risks, facilities must implement explosion-proof equipment, dust control and suppression systems, and rigorous housekeeping practices. Regular safety inspections and strict adherence to fire prevention codes are also essential [10].

Ergonomic Risks

Manual lifting of large GAC bags or containers can result in musculoskeletal disorders, such as repetitive strain injuries or back strain. Physical stress can be mitigated through the use of mechanical lifting devices, including forklifts or conveyor belts. Workers should also receive training in proper lifting techniques, and ergonomic evaluations of the workplace must be conducted to prevent injury and promote overall workplace safety [11, 12].

GRANULAR ACTIVATED CARBON IN THE FOOD AND BEVERAGE INDUSTRY

Applications

The numerous benefits of GAC across various industries in the present century are well recognized. In the food and beverage sector, GAC is used to enhance product quality and eliminate a range of pollutants, including dyes, pharmaceuticals, pesticides, and preservative residues resulting from storage processes [13, 14]. Owing to its high adsorption capacity, GAC effectively removes undesirable flavors, dyes, and contaminants, thus ensuring the product meets required quality and safety standards [15].

Decolorization

As mentioned above, GAC is widely used to remove dyes and pigments from food products. Although these colorants are edible and generally safe in approved quantities, their levels may occasionally exceed the limits set by the Food and Drug Administration (FDA) [16]. In such cases, GAC serves as an effective means of removing excess amounts. In the sugar industry, it is used to eliminate dark-colored impurities and produce white, transparent sugar [17]. In the refining of edible oils, GAC is employed to obtain lighter-colored products that are more visually appealing.

Deodorization

The food industry uses GAC to adsorb odor-active compounds, such as sulfur-containing molecules, in products like fruit juices, alcoholic beverages, and edible oils [18]. This process enhances the sensory quality of the final product, potentially increasing consumer satisfaction, boosting product sales, and improving industry profitability [19, 20].

Purification

GAC is widely applicable for the separation and removal of contaminants such as pesticides, heavy metals, and organic pollutants from foodstuffs [21]. For example, in the purification of alcoholic beverages, it is used to eliminate impurities that may compromise taste and safety. Additionally, GAC is employed in water purification systems to ensure the quality of water used in food processing [22].

Flavor Enhancement

GAC improves the taste profile of food and beverages by adsorbing unwanted flavors. This is particularly important in the manufacture of beverages such as wine, beer, and fruit juices, where the presence of off-flavors can significantly compromise consumer acceptability [23].

Concerns

Despite the widespread use of GAC in the food and beverage sector due to its numerous advantages, its application is not without hazards. Persistent concerns over safety and toxicity highlight the need for strict adherence to regulatory standards and continuous examination of research findings related to its use [21, 23].

Potential Contamination

If GAC is not properly manufactured, stored, or handled, it can become a source of contamination. For instance, harmful substances may enter food products if microbes proliferate on inadequately cleaned GAC, or if residual chemicals from the activation process remain present. Strict adherence to Good Manufacturing Practices (GMP) and routine quality control checks are essential to mitigating this risk [23].

Adsorption of Nutrients

While GAC is effective at removing contaminants, it may also adsorb essential nutrients and beneficial compounds in food products [24]. For instance, it can remove vitamins, minerals, or flavor-enhancing molecules, potentially diminishing the nutritional value and sensory qualities of the final product [25]. Therefore, optimizing GAC usage and drawing on prior research are essential to minimizing these unintended effects.

Regulatory Compliance

The use of GAC in food processing must comply with strict regulatory standards established by organizations such as the U.S. Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) [26]. These regulations ensure that GAC is food-grade and free from harmful impurities, including heavy metals and polycyclic aromatic hydrocarbons (PAHs). Failure to comply can result in serious legal consequences and reputational damage for food manufacturers [27].

Worker Safety

In industrial settings, workers handling GAC may be exposed to carbon dust, which poses significant respiratory hazards. Prolonged exposure to fine particulate matter can lead to lung irritation and chronic respiratory conditions. To protect workers' health, it is essential to implement effective ventilation systems, provide appropriate personal protective equipment (PPE), and conduct regular health monitoring.

CONCLUSION

Granular Activated Carbon is an invaluable tool across many industries, including the food and beverage sector, where it contributes to the production of safe, high-quality products. However, its application must be carefully managed to address potential safety and toxicity concerns. Through strict adherence to regulatory standards, the implementation of comprehensive safety protocols, and optimization of GAC usage, industries can continue to benefit from this versatile material while protecting both consumer and worker health. Proactively addressing occupational health risks with robust safety measures and ongoing monitoring also fosters a safer working environment and ensures compliance with health and safety regulations.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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