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Review

A review on alum sludge reuse with special reference to agricultural applications and future challenges

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ABSTRACT

Alum salts are commonly used in the water industry to promote coagulation in the production of clean drinking water, which results in the generation and accumulation of 'waste' by-product 'alum sludge' in large volumes. Effective and efficient management of alum sludge in an economically and environmentally sustainable manner remains a significant social and environmental concern with ever increasing demand for potable water as a result of rapidly escalating world population and urban expansion. Various intensive practices have been employed to reuse the alum sludge in an attempt to figure out how to fill the gap between successful drinking water treatment process and environmentally friendly alum sludge management for over the years. This paper primarily aimed at comprehensive review of the existing literature on alum sludge characteristics, its environmental concerns and their potential utilization, especially in agricultural and horticultural sectors leading to update our recent state of knowledge and formulate a compendium of present and past developments. Different types of alum sludge utilizations in various fields were recognized and examined. The strengths, weaknesses, opportunities and potential risks of alum sludge reuse options with particular reference to agriculture were highlighted and knowledge gaps were identified. Research priorities and future challenges that will support in the development of effective alum sludge management practices in agriculture with multi-prong strategies were discussed.

Contents

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1. Introduction

Coagulation and flocculation are the essential pre-treatment practices employed by water industries around the world for water purification and conventionally aluminium and iron salts have been used for this purpose for many years. Alum sludge is the by-product resulted from drinking water purification plants when aluminium (Al) salts are used as the primary coagulating–flocculating agents (Zhao et al., 2011; Zhao, 2002; Yang et al., 2006a). Al-salts are the most commonly used primary coagulating agents by water industries across the world for water treatment processes due to their effectiveness and low costs (Gebbie, 2001; Zhao et al., 2009, 2011). Therefore, alum sludge is the most extensive by-product generated by the water industries globally.

Global demand for drinking water has been increasing exponentially because clean water is indispensable commodity for life and human growth. The world's population is growing by roughly 80 million people each year and changes in lifestyles and eating habits in recent years are requiring more water consumption per capita. Therefore, demand for freshwater is increasing by 64 billion cubic meters a year (Gerbens-Leenes et al., 2009). Further, quality parameters are the main indices for deciding the appropriateness of water for its designated purposes. In the present context, various drinking water treatment processes generate large volumes of alum sludge around the world where the immediate attention must be directed for economically sustainable and environment friendly management of alum sludge. Sludge production from drinking water treatment process generally estimated to be 1–3% by volume of the raw water use through the treatment process (Blakemore et al., 1998). In addition, the solids content of thickened sludge is typically 2–4%, and mechanically dewatered sludge (via centrifuge) varied between 17% and 23% solids (Maiden et al., 2015).

Surprisingly, there is little information on global or national level alum sludge production and disposal data. Sludge production statistics, costs and other associated information are generally limited even in recent literature. According to the Czech statistics office, the Czech Republic produced 34,494 tons of water treatment sludge in 2006 (the quantity is expressed in dry mass). The estimated amount of alum sludge production in Portugal is 66,000 ton yr^{-1} (Boaventura et al., 2000) while sludge disposal cost in Netherlands stand at a huge sum of £30–£40 million per year (Evuti and Lawal, 2011). It was estimated that the alum sludge disposal cost in Ireland will be doubled by the end of the next decade from the present assessment of 15,000–18,000 ton yr^{-1} of the dried solids (Evuti and Lawal, 2011).

The key perennial issue associated with alum sludge is its cost effective and efficient disposal due to the large sludge volumes and environmental drawbacks which eventually affects metropolitan and regional water utilities around the world. The amount of sludge generated by various Australian water authorities varied from 150 to 43,500 tons per annum depending on the number of treatment plants that owned by respective organization (Maiden et al., 2015). Based on the estimate of alum used in the Victorian water industry (Australia) the typical cost for alum sludge disposal is $130 per ton which amounts a total cost of over $6.2 million per annum (Maiden et al., 2015). In Australia, much of this sludge is regarded as a waste product and is disposed to sewer or to landfill, with associated financial and environmental costs. Hence, there is an identified need to examine potential options for recycling and reuse of alum sludge and to quantify the potential cost savings and benefits of alternatives. Stockpiling, disposal into sewers and landfill have been the most widely adopted conventional practices (Ippolito et al., 2011; Elliott and Dempsey, 1991) in many countries for decades, however financial and environmental costs of these practices are escalating and forcing the industry to develop alternative management strategies such as recycling, reuse and resource recovery. In the meantime, practicability, long term viability and sustainability of some of those options have been questioned (Kolarik and Priestley, 1995; Ippolito et al., 2011); therefore, there is a clear need for investigating and evaluation of commercially viable better management options for alum sludge reuse particularly where this material can effectively be utilized in substantial quantities easing the pressure on water treatment industry.

There are numerous research studies can be found on sewage sludge utilization (Fytili and Zabaniotou, 2008; Smith et al., 2009; Teixeira et al., 2007; Krogstad et al., 2005; Kelessidis and Stasinakis, 2012) but review articles on alum sludge utilization are limited (Babatunde and Zhao, 2007). Although there are some investigations on potential industrial reuse and recycle of alum sludge, studies on its agricultural utilizations are limited. Therefore, this review will mainly focus on following aspects; (1) various uses of alum sludge with special reference to agricultural applications, (2) strengths, weaknesses, opportunities and threats analysis (SWOT) on alum sludge utilization in agriculture (3) implications, future opportunities, challenges, research needs and priorities of alum sludge utilization in agricultural systems.