Recycling Fire Extinguishing Powder: A New Source of Phosphorus for Agriculture

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ABSTRACT

Phosphorus (P) is a crucial macronutrient to plant development and agricultural production. However, rock phosphate reserves are finite and estimated to be depleted in coming years. Recycling phosphorus through high phosphorus-containing waste may be a possible substitute to food production enabling phosphorus use. Exhausted fire extinguisher powder (EEP) is primarily composed of monoammonium phosphate and may be a secondary phosphorus source. This article highlights the potential for EEP to be used in agriculture considering chemical composition, any safety concerns and the practical management of EEP waste. The heavy metals are below concentration thresholds, indicating the EEP is safe to apply onto land. However, the rapid volatility, dust emissions and low solubility of EEP are all challenges to applying EEP waste to agricultural fields without some form of pretreatment. Applying EEP with composting or densification is one way to mitigate the issues associated with using EEP waste while reclaiming nutrients, as well as, addressing soil and environmental health. Therefore, utilizing EEP as a fertilizer may be considered a sustainable practice to conserve phosphorus and to reinforce closed loop nutrient economy in agriculture.

INTRODUCTION

Phosphorus is one among the crucial macronutrient required for plant growth and development. Sufficient availability of phosphorus in farming enhances the quality and quantity of crop production. Fertilizers are often applied to raise the level of phosphorus in soils as it often exists in forms that cannot be readily taken by plants. Proper management of phosphorus reduces environmental impacts such as runoff, which can pollute water and optimizes nutrient uptake. Phosphorus is thus crucial for maintaining long-term agricultural productivity as well as for plant growth. Based on the increased demand pattern of phosphate rock extraction, phosphate rock deposits, which would become extinct as early as the coming 64–130 years. Thus, recycling P-rich waste materials has become a matter of pressing necessity in the food and industrial production line (Nenov *et al*., 2020).

Most frequently used extinguishing agents are dry fire-extinguishing powders (FEP), which consist of 40–50% mono-ammonium phosphate (MAP), ammonium sulfate, fluxing agents and coloring additives. This substance can be applied in agriculture as fertilizer, *e.g*., after it has been discharged from chemicals necessary for maintaining flowability and water-repellent properties (Pratico *et al*., 2010). When its entire service life has passed (36 months, according to existing legislation), the issue is raised of how to deal with exhausted extinguishing powders (EEP) so that a high-value, non-renewable phosphate material could be recovered in near-pure form.

After its expiration date, a national fire extinguisher dealer kindly supplied the fire-extinguishing powder (ABCE class fire, ProPHOS Chemicals S.r.l.) as a mixture of fine particles. The main components of the powder are coating additives: $NH_4H_2PO_4$ (40 ± 2 %), $(NH_4)_2SO_4$ (52 ± 2 %) and coating additives (~5 %). Heavy metal content: As <0.5 ppm, Cd < 0.2 ppm, total Cr 7.1 ppm, Hg < 0.2 ppm, Ni 2.38 ppm, Pb < 0.5 ppm, Cu 12.6 ppm, Se < 0.5 ppm (Gelsomino *et al*., 2024). The amounts of heavy metals (Pb, Cd, Cr, Hg, Cu, Ni, As, Zn), organic phosphorus and oil in the fire extinguisher powder that was dumped were found to be below the limits specified by the Wastes Control Act (WCA), the Fertilizer Control Act (FCO), and the Soil Environment Conservation Act (SECA) was reported by Jeong *et al*. (2015).

Exhausted fire-extinguishing powder had extreme volatility, which prevents proper distribution in the field and occasionally causes issues with pollution management, is among the most problematic aspects of using this depleted EP [Dotelli *et al*., 2020]. In order to address the issue of water surface flotation and provide hydrophilicity, research has suggested both chemical and non-chemical ways to make the waste more soluble. End-of-life extinguisher powder residue was dissolved in aprotic solvents (methyl alkyl ketone, acetone, hexane, pentane, benzene, cyclohexane, toluene, or their blends). High-pressure filtration was then performed to produce solutions with a high N and P content and used straight as fertilizer by pulverizing a finely ground extinguisher powder with an average particle size of 30 to 60 µm. These waste processing methods may be costly, energy-intensive, and involve environmentally hazardous solvents. Other farms employ the use of a manure spreader to distribute the extinguishing powders onto the field (Dotelli *et al*., 2020), but this method is not always successful and may have harmful environmental impacts since the dust emissions due to the microscopic particles, which vary in size from 0.250 to 0.040 mm,

may raise the possibility of respiratory problems (Chongyang *et al.,* 2018).

As per most research works (Chia *et al*., 2015), EEP is very unstable, which frequently makes storage and transportation operations more difficult. For making management much easier, it may be required to compact or agglomerate the EEP with other matrices to create single, solid, and resistant agglomerate. Mixing compost with other organic biomasses and agricultural wastes is one potential remedy. Composting is a good way to get rid of organic waste, especially when it comes to managing waste in cities. This aerobic process helps to lower the volume of waste, destroys any pathogens present in the waste and above all reduce the amount of leachate that is generated during the decomposition process.

Densifying compost would help lower the necessary storage capacity because it typically has a low density and can occupy a large amount of storage volume. Furthermore, handling compost poses a risk due to the spread of dust, which may contain pathogens and hazardous organic materials that if inhaled, could result in respiratory issues. The fresh and dry weight of lettuce shoot and roots markedly increased with application of EFP-enriched compost, becoming more evident at the highest rate in the shoot than in the root fraction (Gelsomino *et al*., 2024).

CONCLUSION

In conclusion, phosphorus is an indispensable element in plant growth, agricultural productivity and ecosystem health. The finite nature of phosphate rock reserves and increasing global demand, recycling of phosphorus from secondary sources like exhausted fire-extinguishing powders (EEP) offers encouraging alternative to conserve this vital nutrient. While EEP contains valuable phosphorus and nitrogen compounds suitable for fertilizer use, challenges related to its volatility, heavy metal content, and environmental safety must be carefully addressed through appropriate pretreatment and regulation compliance. Integrating EEP recycling with composting and densification techniques, nutrient recovery can be improved, waste volume minimized and risks to health from dust emissions lowered. Overall, advancing innovative recycling strategies will be crucial for ensuring a sustainable phosphorus supply and promoting circular nutrient economies in agriculture.

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