



## Organo-mineral Fertilizer: Waste to Wealth Economy

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**Abstract:** The document discusses the urgent need for sustainable agricultural practices to ensure global food security amid rising population and rising fertilizer costs. It highlights the environmental and economic challenges posed by conventional mineral fertilizers, emphasizing the potential of organo-mineral fertilizers (OMFs) as eco-friendly alternatives. OMFs combine organic waste materials with mineral nutrients to improve soil health, enhance nutrient use efficiency, and reduce greenhouse gas emissions. The paper explores various organic feedstocks and processing techniques for OMF production, noting their benefits in waste valorization and circular economy models. It underscores the importance of technological advancements, regulatory frameworks, and scientific validation for widespread adoption of OMFs. The authors advocate for further research into OMF effectiveness across diverse soil types and conditions to promote sustainable, balanced nutrient management in agriculture.

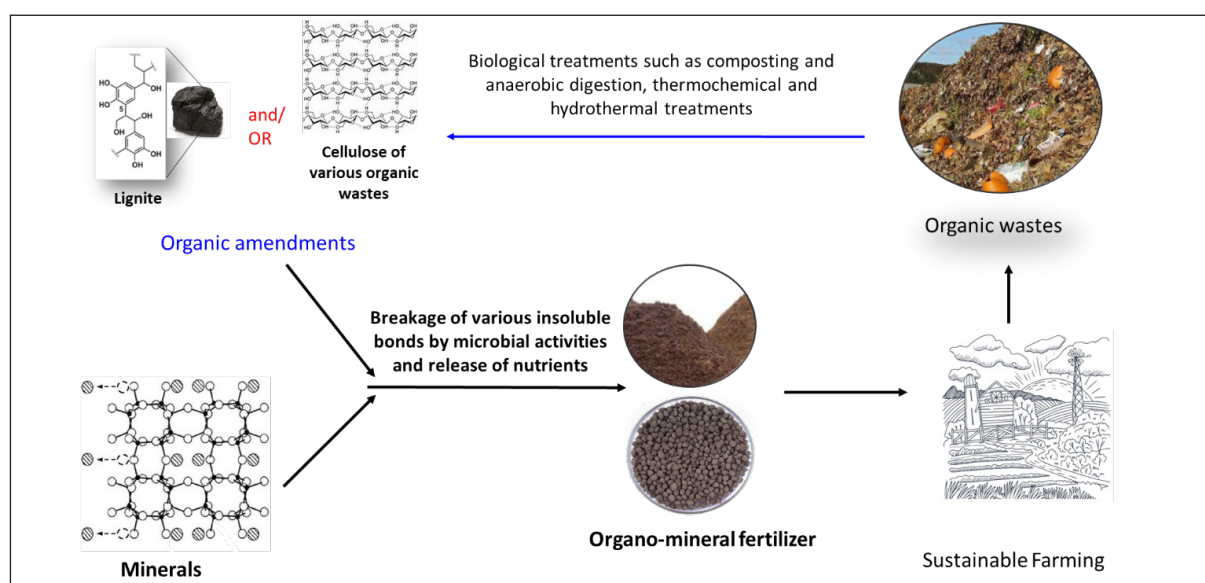
**Key words:** Organo-mineral fertilizers, agriculture, economy.

The agricultural sector must continue to change in order to provide sufficient, safe, nutritious food to feed the world's expanding population, which is predicted to reach 10 billion people by 2050 (United Nations, 2019). Food security for increasing global population is a growing challenge. The agricultural sector is key for a secure supply of food but relies up to 50% on mineral fertilizers to meet crop nutrient demands. The mineral fertilizer industry is presently undergoing an unprecedented crisis due to the rapidly increasing cost of energy and raw materials. In 2024, global nitrogen fertilizer prices remained significantly elevated compared to pre-pandemic levels, with average nitrogen-phosphorus-potassium fertilizer costs reaching approximately USD 327 per tonne in May—more than three times higher than the 2019 average of around USD 100 per tonne (FAO, 2024). Recent West Asian and Russia-Ukraine conflicts again lead to increased cost of raw as well as other associated cost. As a result, energy prices kept driving up the cost of producing fertiliser. The economic sustainability of conventional fertilisation is being called into question by this price volatility and growing worries about food security, which is speeding up the hunt for more sustainable alternatives. Concerns over the usage of mineral fertilisers' effects on the

environment are growing at the same time. In order to boost or rather maintain agricultural productivity in both developed and developing nations, this calls for highly efficient utilization of the available mineral reserves. With the price of mineral fertilisers growing and the state of soil health diminishing, solutions are needed to meet crop nutrient demands while ensuring that sufficient organic matter is maintained in the soil. The current trend is aimed at studying the idea of supplementing minerals with organic fertilizers and/or organic matrices that are eco-friendly and cost-effective.

Using more organic feedstocks is one possibility, but in order to make up for any shortfall, mineral fertilisers must be added. A novel solution can be in the form of organo-mineral fertiliser (OMF). This idea is based on innovative fertiliser formulations that combine elements of organic and mineral resources, potentially simultaneously addressing problems with soil fertility and health. OMFs are produced using a variety of techniques that centre on the co-processing of organic and mineral matrices. OMFs are an innovative idea that uses organic feedstocks, such as materials produced by municipal, agricultural, agro-industrial, and biomass-based processes, which have shown promise as nutrient sources. These include different amounts of nitrogen, phosphorous, potassium, and organic carbon found in livestock manure, compost, sewage sludge, digestates, vinasse, ashes, and biochar.

Lignite and/or Leonardite coal, which have a low energy value, can nonetheless be a good source of organic material. These materials can partially or completely replace synthetic fertilisers, depending on where they come from and how they are processed. This helps achieve waste management goals while lowering dependency on non-renewable resources. However, there are a number of environmental risks associated with applying untreated organic leftovers directly to land. Current approaches include chemical processes, thermochemical techniques like pyrolysis and hydrothermal carbonisation (HTC), and biological therapies like composting and anaerobic digestion. Microbial nutrient solubilisation, which depends on soil and plant properties, feedstock, and mineral matrices, could be greatly enhanced by OMF supplemented with native mineral solubilising microorganisms (MSM). Organo-mineral fertilisers increase output and nutrient use efficiency by releasing nutrients gradually and uniformly throughout the growing season (Saritha *et al.*, 2021). OMFs add organic matter and humified compounds to the soil. In addition to lowering soil bulk density and improving a number of soil physical characteristics, organic matter also contributes to the stability of soil aggregates, which in turn enhances soil chemical and biological activities. This leads to increased nutrient use efficiency, improved soil health and sustainable yield. Application of OMFs can substantially reduce the GHG emission form agricultural soil. The lowering of GHG



Schematic diagram of organo-mineral Fertilizer circular economy

from OMF is mainly due to the adsorption of released nutrients to the acidic functional group of organic matter.

However, as OMF is a novel method to agriculture that permits the circular economy, it might not necessarily fetch a reduced price because it will require new technology to process, dry, and pelletise the feedstock. Nevertheless, pricing may become more competitive with further advancements in these technologies and improved feedstock logistics. To increase the value of organic feedstock and make OMF more widely used in agriculture, new and improved methods are desperately needed.

The nutrient content of organic feedstock is generally uneven, where application based on one nutrient will cause under application of the other. The mineral OMF can handle nutrient imbalance, making it a balanced fertiliser product. Depending on the type of soil, crop, land management, and climate, the carbon sources of OMF feedstock may also contribute to carbon sequestration. It has been suggested that carbon-sequestering activities promote soil fertility, biodiversity, and water retention.

The mineral fertilisers are made from materials extracted from naturally occurring nutrient deposits or by fixing atmospheric nitrogen into forms that plants can utilise. Mineral fertilisers frequently contain large amounts of one, two, or three plant nutrients. Essential plant nutrients like N, P, and K are included in the mineral component of organo-mineral fertilisers. These nutrients are frequently obtained from mineral sources including low-grade rock phosphate, K-feldspar, gypsum, glauconite, mica, etc. A balanced nutritional profile helps plants grow and produce at their best.

In order to apply OMF in agriculture, national and international legislation are essential. However, strong scientific proof is needed to confirm that OMF is a product and not a waste. In order to collect the evidence required for it to achieve End-of-Waste status, there must be a precise definition and rules regarding what constitutes an appropriate comparison to current OMFs. For feedstock to be valued and used to create OMFs, the technologies that are currently available must be affordable. Innovations connected with technologies suffer from funding issues especially in mid-range Technology Readiness Level (TRL).

OMF is unique in that it uses systematic waste valorisation techniques to produce affordable, environmentally beneficial products that are in line with the bio-circular economy. It is understandable that OMF must be taken into account as part of the strategy to lessen the need for mineral fertilizers to meet crop demands. Use of OMFs in agriculture helps to obtain a net zero and sustainable approach while balancing between conserving the wider ecosystem and meeting food security. The effectiveness of OMF on the physical and chemical properties of soil, as well as its long-term effects on those properties, should be thoroughly investigated in the field. There is still a knowledge vacuum about the effectiveness of OMF in several problematic soils, such as acid sulphate soil, saline soil, red soil, and arid soils (poor organic matter). In this context, exploiting potential combinations of indigenous minerals and agricultural wastes is a sustainable solution for satisfying the nutritional demand. In addition to providing a variety of macro- and micronutrients in addition to organic matter, these combinations of organo-mineral fertilizers can significantly improve the soil conditions of degraded agricultural soils and preserve soil production.

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## Declarations

The authors have no competing interests.

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