

AGRICULTURAL USE OF WASTE AS A LINK OF THE CIRCULAR ECONOMY VALUE CHAIN

Fertilisers derived from waste and by-products as a source of nutrients for plants and a factor for improving soil fertility

Abstract

Waste is often seen as an attribute of modern civilisation. It is estimated that in highly developed countries, with a population growth of 1-2%, industrial production increases by 4-6% and the amount of waste generated per year increases at a similar rate. In the 21st century, under the pressure of increasing environmental, climate and demographic problems, it has been realised that the current model of the world economy, the so-called "*linear model*", is becoming an increasing civilisational threat. An economy based on this model builds its continuous economic growth on increasing consumption of raw materials and increasing volume of waste. It is simply based on the "*take - produce - use - throw away*" principle. One of long-term effects of such a management model that dominated the world economies of the 20th century was, among others, a side effect expressed by low attention paid to efficient use of raw materials, both in material and energy terms, as the main economic goals were focused on primary production and profit. It has become one of the significant global factors of environmental hazards indicated by excessive accumulation of waste in all elements of the global ecosystem of the world - the lithosphere and the hydrosphere, becoming also an important factor of air pollution. In addition, there was a real threat of depletion of non-renewable resources and an increase in their prices, which would pose a significant risk to stable economic development of many countries. As a result of these global threats, at the beginning of the 21st century, a new view on broadly understood management developed which consists in gradual departure from the traditional "*linear model*" to the so-called "*loop model*", in which waste, if formed, becomes a raw material. This new management and development strategy referred to as the "*circular economy*" is a kind of regenerative management system that minimises the consumption of raw materials and the amount

of waste, as well as reduces emissions and energy losses by creating closed loops of manufacturing processes in which waste from one process is used as raw material for other processes. The so understood new management strategy allows to maintain economic growth while optimising the consumption of increasingly limited natural resources. However, its implementation is associated with a fundamental transformation of production and consumption chains and requires a new supply chain management in which the concept of product end-of-life is eliminated or substantially limited. The transformation towards a circular economy requires coordinated action at all stages of the *product life cycle* - from raw material acquisition, through design, production, consumption, waste collection to waste management. Thus, waste management is an integral part of the life cycle in the circular economy model, which fundamentally distinguishes this model from the linear economy. The circular economy also introduces a new approach expressed by the extended producer's responsibility (EPR) which obliges them to collect and manage waste generated by-products they manufacture and market. This encourages the manufacturer to analyse the entire product life cycle in terms of reducing waste or its economic use. This implements the universally recognised '*polluter pays*' principle. It should be emphasised that there is no universal model of transformation towards a circular economy for all countries. The transformation towards a circular economy must be based on individual national programmes, taking into account the specificities of national economies and their current level of economic development. However, a programme implementing the concept of the circular economy at the national level, to be comprehensive and internally coherent, should be implemented at all levels of national structures: at the level of regions, provinces and municipalities.

Waste-derived fertilisers as a link of the circular economy

The world economy of the 21st century is increasingly focusing on production based on the sustainable use of raw materials, in which an increasingly important role is played by technologies that enable broadly understood waste and by-products to be re-included in the production cycle. New technologies are being extensively developed in which the management of the generated wastes is becoming an important link consisting in re-integrating these wastes into the production cycle. Among many ways of processing waste into useful products, fertilising use plays a particularly important role. A number of wastes generated in the agri-food processing, animal farms, municipal economy, as well as in many industries based on mineral resources, have significant fertilising potential. Their wider use for the production of fertilisers would significantly improve the balance of nutrients and organic matter in many countries. However, for waste to be used for fertilisation, both as raw or processed material, it must comply with legal requirements at national and European level. Legal requirements allowing the natural use of waste-based fertilisers vary significantly across the EU countries. Therefore, in order to amend the situation, in June 2019 the European Parliament adopted new legal regulations (Regulation EU 2019/1009 of the European Parliament and of the Council of 5 June 2019) which open the European market for all types of fertilisers, both mineral and organic and organic-mineral ones as well as new waste-derived fertilising products with the status of soil improvers, growing media, etc.

Overview of the content of the book

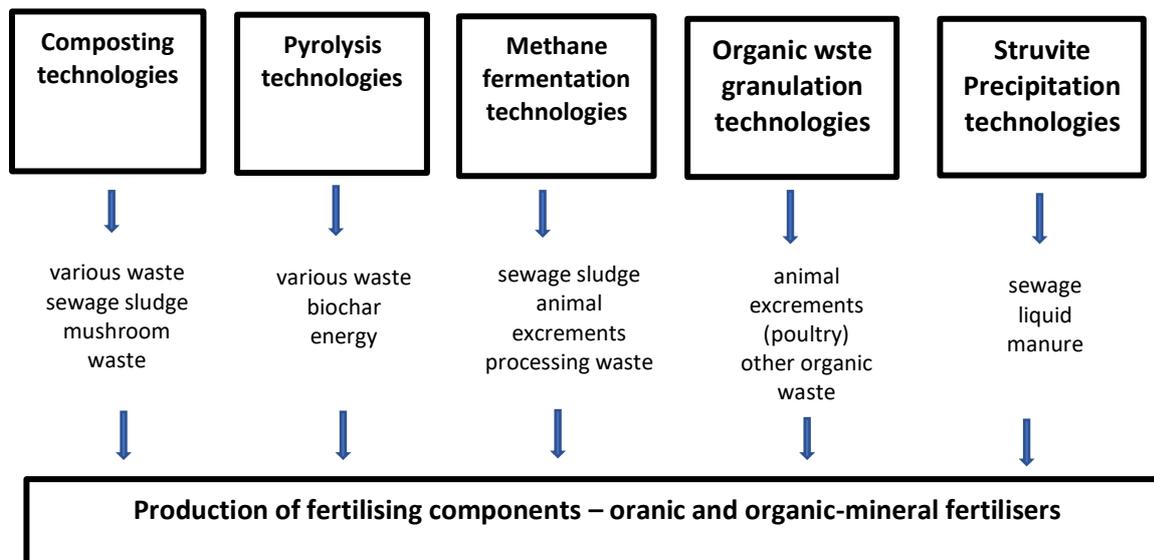
The present handbook is consistent with the European Union's action plan for the circular economy, which encourages the Member States to produce fertilisers derived from organic or secondary raw materials and creates new opportunities for their production and marketing on a large scale. This book is a material for education on circular economy focused on broadly understood sustainable management of plant nutrients in agriculture. In addition to basic information on the essence of the circular economy and fertilising potential of the broadly understood waste, it presents innovative technologies for processing various wastes into fertilisers of agro-ecological utility. It also contains a basic compendium of knowledge in the field of legal aspects related to the use of fertilisers.

The introductory part presents the concept of a circular economy focused on the natural recycling of waste mineral components, extending the concept of nature resources as an object of management, as well as presenting the EU strategy for the bioeconomy, in particular in relation to fertilising use of waste.

The second chapter extensively discusses the fertilising potential of the main waste, both organic and mineral, providing a wide range of figures on the content and amount of fertilising components, both macro - and microelements, in the waste produced by numerous industries. In relation to organic waste, the fertilising potential of animal excrements, post-production mushroom base, agro-food industry waste, biodegradable fraction of municipal waste, including sewage sludge is discussed. In relation to inorganic waste, the fertilising potential of the following is presented: post-production mineral wool from soilless culture of horticultural crops and by-products of combustion generated in electricity and heat production processes, which are mainly fly ash from lignite and waste biomass combustion, as well as gypsum from desulphurization of exhaust gases. Phosphogypsum is another important waste the potential of which is widely discussed, not only as to fertilising but also in other fields. Among other inorganic waste, the fertilising potential of lignite waste and waste materials that could be used for soil deacidification is also highlighted.

The next part focuses on the directions of processing or treating various wastes into fertilising products, with particular emphasis on new innovative technologies. These technologies differ fundamentally regarding organic and inorganic waste.

Directions and technologies of organic waste processing to fertilisers



The handbook presents a wide range of technologies for converting organic waste to compost. Various composting methods are discussed, both in static and dynamic bioreactors intended for processing organic waste into compost at various scales (cities, industrial plants and farms of various sizes). It also elaborates on some unconventional composting technologies, such as composting in the form of specially formed briquettes (Brikollare system) or composting using earthworms (vermicomposting). The possibilities of using sewage sludge in agriculture are also widely discussed, taking into account the existing environmental restrictions.

An important direction of organic waste processing is the production of biochar with the use of thermal treatment of waste biomass called pyrolysis. The paper indicates the purposefulness of this method and the possibilities of its application, pointing to the values of biochar which is a heterogeneous material rich in aromatic carbon and mineral compounds. Technologies of its production from various wastes are discussed, as well as agricultural benefits for soil fertility without negative environmental effects.

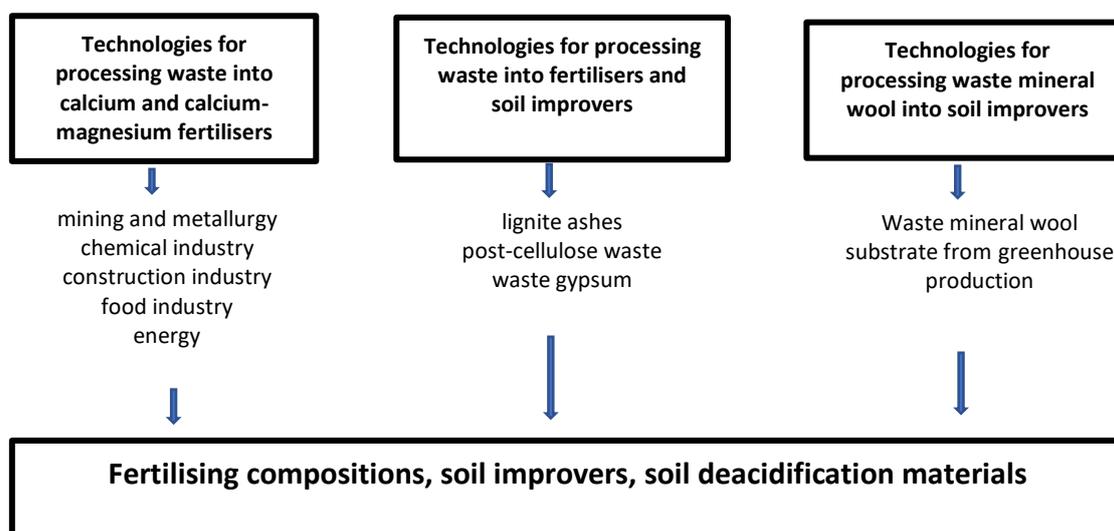
The work extensively discusses methane fermentation as an alternative to biochemical composting by managing and processing organic waste, carried out in agricultural biogas plants. The handbook discusses the fertilising properties of the digestate and the possibilities of processing it into fertilising granules.

An interesting topic discussed in the work is a new forward-looking concept of constructing biorefineries based on agricultural biogas plants and focusing on the recovery of mineral components. On the example of an experimental biorefinery installation at the De Marke farm (Netherlands), ways of separating the digestate obtained from liquid manure into solid and liquid fractions are discussed. Fertilising usage of the solid fraction is indicated and the process of liquid fraction treatment aimed at the recovery of biogenic elements is also discussed. The handbook also illustrates a technology of obtaining two mineral fertilisers from the liquid fraction of the fermentation product, namely struvite being a slow-acting phosphorus-nitrogen fertiliser and ammonium sulfate.

A significant part of the handbook is devoted to a presentation of various technologies for processing inorganic waste into fertilising products.

One of the basic problems of agriculture in the countries of Central and Eastern Europe is excessive soil acidification. The handbook extensively discusses these issues in relation to Polish conditions since Poland with its share of very acidic and acidic soils amounting at 60% occupies one of the first places in Europe as regards to soil acidification. It is known that calcium fertilisers are used for deacidification of soils, whether in carbonate or oxide form. However, calcium fertilisers and liming agents, being by-products of many industries, are increasingly appearing on the market.

Directions and technologies of processing industry waste (inorganic) to fertilisers



Some of them are produced in very large quantities and can be successfully used to regulate soil pH. The paper discusses the most significant fertilising products for deacidification derived from waste as well as agricultural technologies for their use on agricultural land. Relevant legal regulations are also presented.

The use of combustion by-products is also elaborated on in the work. Opportunities and threats related to their processing into fertilisers are discussed, as well as the scale of the problem related to their production and storage. Reference is made in detail to the use of fly ash resulting from the combustion of lignite and waste biomass, including wood biomass. It has been indicated that gypsum formed during the coal desulphurization process is the most widely used. The authors have also referred to the use of phosphogypsum formed in large quantities during the production of phosphate fertilisers (phosphoric acid) in chemical plants.

An important part of this handbook is the section on the principles of using waste-derived fertilisers. It provides basic information on the specific conditions of waste use in agriculture, discusses the issue of nutrient balance in fertilisation, and presents methods and technologies for applying waste-derived fertilisers into the soil in terms of their impact on the physical and chemical properties of the soil environment.

The handbook pays special attention to discussing legal aspects related to the use of waste and waste-derived fertilisers in agriculture. Current legal provisions, both European and national, regulating the use of waste as fertilisers are also presented. It has been emphasised that many organic and mineral wastes due to their physical properties and chemical composition (e.g. high content of organic matter, nutrients, silt and dust fractions) have a beneficial effect on soil properties as well as on plant growth and yielding. However, their natural use is subject to many legal restrictions, compliance with which is the basic condition for allowing waste-derived fertilisers to be used.

In addition, the handbook presents a modern approach in assessing the economic use of waste for fertilisation, adapting the concept of "Life Cycle Assessment". The whole handbook consists of 13 chapters, completed by a rich list of current world literature on the natural use of waste, as well as a related list of current European and national legal acts.

In conclusion, we would like to emphasise that although this handbook refers primarily to Polish conditions, especially when it comes to figures, much information on the technology of processing waste into fertilising products and on their use in agricultural ecosystems is universal and can be applied in European natural space.

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