BIODEGRADABLE WASTE TREATMENT AS OPPORTUNITY FOR PHOSPHOROUS RECOVERY IN SERBIA

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Abstract
Phosphorus is a non-renewable and an essential resource for which there is no substitute. Currently the most economical way of getting phosphorus is extraction from phosphate rock. Up to 80% of the total amount of phosphate in the world is used as fertilizer. Phosphorus also can be found in significant amounts in the biomass. In this paper, amount of phosphorus which can be obtained from collected and unused biodegradable waste are calculated based on quantity of waste and the percentage of phosphorus. The total potential for phosphorus recovery from these waste streams is 5,630 tons per year, of which from municipal biodegradable waste 2,400 tons, from agriculture waste 2,500 tons, sludge from waste water treatment 200 tons, forest waste 30 tons and industrial biodegradable waste 500 tons. Numerous techniques for phosphorus recovery are available and it is necessary to choose the appropriate depending on the type of waste. This paper analyzes the management of biodegradable waste in Serbia in order to evaluate potential of phosphorus in collected but unused waste streams in terms of re-use as a resource.

Keywords
Keywords: phosphorous, biodegradable waste, waste management

1. Introduction

Phosphorus is so far usually managed as pollutants, while in the 21st century it is prevailed thinking of phosphorus as a globally limited resource. Concern about the limited resources of phosphorus and future scarcity is indicated even since 1798 by Thomas Malthus. Later, in 1972, Donella Meadows [1] in the book "Limits to Growth" suggest that phosphorus represents one of limited elements of planet Earth, and that one day they can be depleted. Well-known stocks are estimated to be exhausted in about 70 years and additional reserves might last another 200 years [13].

Phosphorus is one of the most important nutrients for plants and therefore it can be found in significant amounts in the biomass. Most plants contain phosphorus in concentrations varying between 0.1% and 0.4%, and it an energy store and source in the form of adenosine diphosphate (ADP) and adenosine triphosphate (ATP) and can be found in proteins, enzymes and phospholipids [7]. Various biodegradable waste utilizations are resulting also in different transformations of phosphorus flows. If information about phosphorus flows in biodegradable waste is unknown or incomplete, suboptimal solutions for the management of those wastes might be developed.

Management of phosphorus in waste management is currently focused on the emissions control of phosphorus in surface and underground water [6]. Currently, there is no approach for decision making in biodegradable waste management which takes into account the flows of phosphorus. Such integrated waste management approach will be involved expanding phosphorus management framework on all phosphorus transformation which enables finding a solution for sustainable management. For this reason, the task of paper was primarily collection of all data to quantify the whole system to assess the potential for recovery. An assessment of the system can propose alternative strategies that would have the potential for long-term solutions to problems.

2. Materials and method

In order to assess the potential for the phosphorus the following are conducted:

1. Analyzing of current management practices of biodegradable waste streams.
2. Determination of generated biodegradable waste amount in Serbia.
3. Analyzing of potential phosphorus in biodegradable waste.

2.1. Current status of biodegradable waste management in Serbia

Biodegradable waste management involves management of the following waste categories:

- Municipal biodegradable waste,
- Agricultural waste
- Forest waste,
- Sludge after wastewater treatment,
- Biodegradable industrial waste (wood processing, food industry, packaging waste).

Unlike developed European counties, in Serbia there is no capacity for biodegradable waste treatment. Such practice has the effect that generated and collected municipal biodegradable waste usually ends up mixed with other waste fractions in landfills which are not constructed according to the EU regulations.

Agriculture biomass, especially solid manure is usually used as fertilizer but only small portion of liquid manure is used [18]. Some amount corps residue is used as animals bedding, and rest is left unused. Waste from orchards and vineyards is somewhat used for obtaining energy. In Serbia, forests cover about two million hectares, or more than one-quarter of the total surface area of Serbia. The total amount of wood residue in the forests after felling is estimated at 1.1 million m^3. However, one part of the forest waste are already being used for different purposes, so unused forest waste is about 0.6 million m^3 [10]. Sludge from wastewater is classified as biodegradable waste. Currently in Serbia there is no sufficient number of these plants and the amount of this type of waste is small, but in the future we expect an increase in their number so this waste stream must be taken into account.

2.2. Amount of generated biodegradable waste

According to recent study performed by IMG [9], total amount of generated municipal solid waste in Serbia is 2.4 million tons. More than 50% of municipal waste is biodegradable waste: kitchen, garden waste, paper and cardboard (paper and cardboard are recyclable raw materials, however, if they are not diverted from the waste behave like other biodegradable waste). The annual generated quantity in Serbia includes about 1.5 million tons of this waste and comprises waste types shown in the table 1.

Table 1: Biodegradable municipal waste [9]

Type of waste	**Tons per year**
Green waste	450,000
Kitchen waste	770,000
Paper and cardboard	260,000
Total	1,480,000

Serbia is an agricultural country and it is estimated that each year in organized waste management system went about 350,000 t generated agricultural waste which is common to organic and mostly biodegradable. However, the total amount of agricultural biomass is estimated at about 13 million tons per year (agricultural residues and field crops and liquid manure) [5].

In Serbia, only 5-10% of waste water is treated [11], which results with 50,000 tons of sewage sludge usually disposed on landfills. Amount of forest waste can be estimated based on average density of this waste flow. In this way, annually quantity of generated forest waste in Serbia is estimated at around 270,000 tons. Biodegradable industrial waste mainly includes waste that is generated in the food industry and wood processing industry. According to the national statistics of waste, total generated amount of industrial waste from plant and animal origin is more than 300,000 tons, and waste generated from wood processing is 37,000 tons [3, 4].

2.3. Potential of phosphorus in biodegradable waste

Phosphorus can be recovered from mixed waste streams, and separate organic waste fractions. The total amount of available phosphorus in each source will vary from country to country. Various biodegradable waste streams have different parts of the phosphorus. In table 2, the percentages of phosphorus are shown.

Table 2: Phosphorus content in different biodegradable waste type [8, 12]

Biodegradable waste	P (% P by weight)
Food waste	0.35
Green waste	0.15
Paper and cardboard	0.017
Crop residues	0.04–0.33
Poultry manure	1.27
Sewage sludge	1.4
Wood waste	0.01
Animal waste from food preparation	0.42
Vegetable waste from food preparation	0.23

3. Results and discussion

For the purposes of agriculture, land development, horticulture, nutrients are necessary. As well as other nutrients, phosphorus is usually provided from mineral fertilizers. The question is how much phosphorus as a nutrient may be recovery from biodegradable waste. In table 3, the potential of phosphorus recovery from biodegradable waste is shown. This biodegradable waste is collected but remained untreated or unused.

Table 3: Potential of phosphorus recovery in unused biodegradable waste in Serbia

Category of biodegradable material	Generated (t/year)	Collected (t/year)	Unused (t/year)	Potential of phosphorus recovery (t/year)
Municipal biodegradable waste	1,500,000	1,000,000	985,000	2,400
Agriculture waste	13,000,000	-	350,000	2,500
Sludge from waste water treatment	50,000	50,000	50,000	200
Forest waste	270,000	-	270,000	30
Industrial biodegradable waste	300,000	300,000	160,000	500

For phosphorus recovery there is no single solution. Available technics for recovering and reusing phosphorus can range from low-tech, small-scale solutions like direct reuse, through to large scale, high-tech solutions such as recovery from wastewater treatment plants [8].

Phosphorus from biodegradable municipal waste can be recovered in several ways. One of solutions is biological treatment either aerobic or anaerobic [18]. As final result of treatment, compost can be used as fertilizer depending on produced compost quality [15]. Also if the waste is treated by incineration, phosphorus can be recovered from the ashes [16].

The forest waste and part of agriculture crop waste can primary be used as alternative fuel for energy consumption. After combustion main part of phosphorus retain in the ash. Phosphorus can be recovered from the biomass ash as represented by Tan and Lagerkvist [17].

Manure is traditionally applied to agricultural fields to close the cycle of nutrients. Anaerobic digestion is an alternative to traditional manure management, alleviating environmental concerns and yielding profitable biogas. From wastewater it can be recovered 95% of the phosphorus and concentrated into the sewage sludge that, after the appropriate treatment, can be applied to land as nutrient. The phosphorus recovery from waste streams can be used as a fertilizer or as a raw material for the fertilizer industry.

4. Conclusions

Decision-making in the research field of waste management is a complex task. The content of valuable nutrients (such as Phosphorus) in biodegradable waste may strongly influence the optimal management of those wastes. Only holistic view will allow developing nutrient-recovering management solution for biodegradable wastes management.

Whereas in developed country utilization of biodegradable wastes with respect to nutrients (e.g. Phosphorus) recovery is increasingly practiced and largely based on national inventory studies, for Serbia alike information is largely missing.

According to the paper results it can be concluded that the management of biodegradable waste in Serbia has potential of phosphorus reuse as a resource. Special attention should be on phosphorus flows in biodegradable municipal solid wastes. Significant phosphorus amount in this stream is indicated as an important source along with agriculture waste which has traditions of usage. The results can be the base for the implementation of appropriate technologies for the management and treatment of biodegradable waste from the aspect of resource-oriented management phosphorus.

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