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A Path to Sustainable Municipal Waste Management: From Engineering Practices to Education and Training

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Abstract

With population growth and increasing municipal solid waste generation, efficient and sustainable waste management strategies become important to protect both human health and the environment. Although the transition from the prevailing waste management systems, such as landfilling, to modern waste management systems based on the 3R principle (reduce, reuse and recycle) is imperative, it is still very difficult to achieve in many countries. The waste management systems applied are in line with the country's income level, and the sustainable cutting-edge technologies are almost exclusively applied in high- and upper-middle-income countries. Thus, the modernization of the waste management system is achieved mostly through the growth of the gross domestic product. Moreover, the efficiency of modern sustainable waste management systems depends not only on the implementation of appropriate technical and economic strategies, but also needs to be supported by the education of citizens and the training of waste management professionals. The paper gives an overview of the educational-professional project "EDUcation for CLImate Change mitigation in the municipal solid waste sector", which is part of the European Climate Change Initiative (EUKI).

Keywords: *municipal waste management, sustainability, landfills, training in waste management, greenhouse gas mitigation, EUKI*

1. Introduction

The protection of human health and the environment and the conservation of resources have been recognized as the main objectives of waste management. Nowadays, it is not enough to achieve these goals through proper waste management, but it is also necessary for waste management to be sustainable. Sustainable waste management not only takes into account the present generations but also extends these goals to future generations [1]. The increasing transformation of materials has a major impact on waste management. The transformation of materials was up to 5-6 tons per year in prehistoric population, while in modern population it is up to 80-90 tons per year today [2]. This level of material use has resulted in the global generation of approximately 2.01 billion tonnes of municipal solid waste annually, of which probably more than 33% is not managed in an environmentally sound manner (in a conservative sense) [3]. The waste hierarchy (Figure 1) is the most popular graphic in any presentation on waste management.

However, the question arises whether the hierarchy can be implemented equally in all countries, regardless of their level of development.

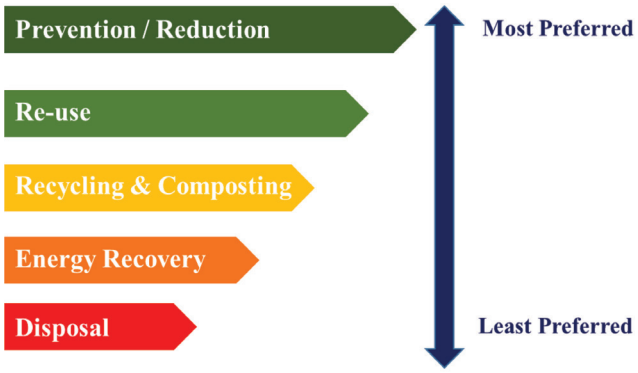

Fig. 1. Schematic presentation of the waste hierarchy

For a long time, the prevailing view was that landfilling and incineration of waste were the accepted options for municipal waste management. However, the development of modern waste management technologies has been driven by the fact that natural material and energy resources are not unlimited, and by the decline in landfill capacity in the 1980s [4]. In addition to prevention/reduction of waste generation, modern waste management systems include recycling and composting, as well as reuse of transformed materials wherever possible (Fig. 1). Many incentives

encourage the transition to the aforementioned modern waste management systems (implementing the "3R" principle: reduce, reuse and recycle), as the far-reaching effects of these incentives are energy conservation and greenhouse gas emission reductions. The landfilling, either in sanitary landfills with gas collection systems or in unsanitary landfills or dumps, is still the most widespread municipal waste disposal system, responsible for 11% of all global methane emissions (making it the third-largest anthropogenic source of methane) [5]. The landfilled organic fraction of municipal solid waste initially degrades aerobically, producing only very small amounts of methane. However, once anaerobic conditions are established and methanogenic bacteria become active, the landfill begins to emit significant amounts of methane, which can continue for years (even for landfills that have completed their life cycle) [5]. Thus, the transition to more sustainable waste management systems is imperative. Even more in the EU, where a bold package of measures called the European Green Deal has been adopted in 2020, aimed at overcoming climate change and environmental degradation as the greatest existential threats to both Europe and the world. The plan to reduce greenhouse gases by at least -55% by 2030, compared to the levels in 1990 (set by the legally binding European Climate Law) aims to make EU climate-neutral by 2050. In addition to climate action, the European Green Deal also seeks to transform the EU into a "modern, resource-efficient and competitive economy by ensuring that economic growth is decoupled from resources and that no person or place is left behind" [6].

2. Waste management systems and country's income level

To what extent do the applied waste management systems correspond to the country's income level? In general, high-income countries generate approximately 34% of the global waste, even though they make up only 16% of the global population. However, the projected increase in waste generation for high-income countries by 2050 is much smaller (19%) than the increase projected for low- and middle-income countries (40%). This is likely due to the fact that an incremental increase in income leads to an increase in demand and consumption, which in turn leads to an increase in waste generation [3].

A crucial step in waste management is the collection. In high- and upper-middle-income countries, the collection rate is almost complete, while in low-income countries in urban and rural areas, only about 48% and 26% of the total amount of waste is collected, respectively [3].

As mentioned earlier, landfilling and open dumping are still the predominant methods of municipal solid waste disposal, accounting for 37% and 31% of the total amount of waste, respectively. Of this, 8% are landfills with gas collection systems. Recycling and composting account for 19%, and incineration for final disposal 11% of the total waste volume [3]. Modern sustainable waste management technologies that include different waste transformation processes, such as recycling, composting, energy recovery, biogas and other alternative fuels production are used almost exclusively in high- and upper-middle-income countries [3]. Even though low-income countries mostly rely on open dumping (93%), the chances of a successful transition from open dumping (or other rudimentary waste management technologies) to more advanced and sustainable waste management methods are high if locally appropriate solutions are implemented [3].

The Environmental Kuznets curve (EKC) attempts to explain the economic correlation between a society's standard of living and the degradation of the environment [7].

The hypothesis underlying the EKC was first formulated in the early 1990s by researchers Grossman and Krueger, who asserted a negative scale effect of economic growth on the environment-pollution increases as economic activity intensifies. However, technological progress and changes in the structure of production leading to a transition from capital-intensive industrial activities to a service economy can reverse this negative effect and reduce pollution [7].

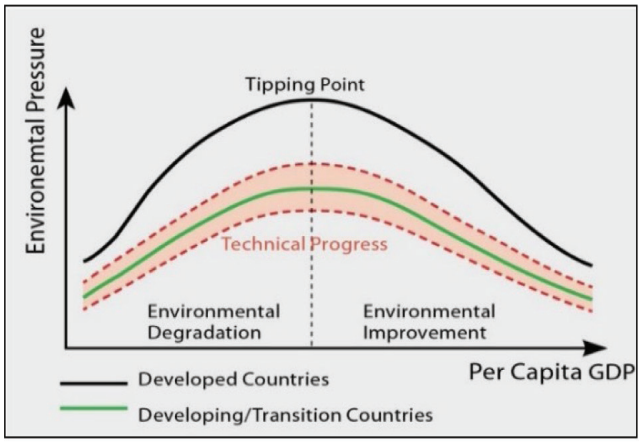

Fig. 2. The Environmental Kuznets curve

The same hypothesis can be applied to waste management. The EKC confirms that it is impossible to skip certain steps in the development of the waste management system in underdeveloped countries, which means that transition countries must find a less costly solution to waste management problems [8].

In order to achieve some technical progress in waste management and a reduction in the negative impact on the environment, a simultaneous growth in the gross domestic product (GDP) is required. Above a certain threshold, as income increases, so does environmental awareness and demand for improving environmental quality, as well as the willingness to fund the steps that lead to that quality improvement [7]. In other words: only through the growth of GDP, and thus the living standards of the population can the modernization of the waste management system with advanced technologies be achieved.

3. The importance of education and training in the field of municipal solid waste management

The efficiency of modern sustainable waste management systems does not depend solely on the implementation of appropriate technical and economic strategies. Environmental education, and particularly waste management education, is one of the pillars of successful waste management because it changes attitudes and provides learners with knowledge, values, and skills that enable a change in the way communities manage waste. i.e. it raises public awareness and enables "effective participation in the implementation of the waste management system" [9].

The case study of the city of Toyama in Japan shows that education is the key to sustainable waste management, because the most advanced waste management technologies and practices will not be sustainable if they lack citizen participation. Moreover, without citizen education, they will not be sustainable in the long run. Waste management in Toyama is based on the "3R" principle and aims to become a recycling-based society by integrating comprehensive education and waste management. This is also implemented in key municipal documents (Toyama City Basic Environmental Plan and City Basic Plan for General Waste Disposal). One of the most important examples within the Toyama city model is Eco-Town, an educational centre for waste recycling, which aims to raise citizens' awareness of the methods and importance of recycling and to promote cooperation among all stakeholders in waste management: citizens, businesses and the government [10].

In addition to waste management that targets citizens of all ages and backgrounds, training waste management professionals is a vital aspect of a sustainable waste management system. The common duties of waste management professionals among others include the development of contaminated or/and hazardous waste disposal procedures, development of storage protocols and recycling programs, management of waste facilities, providing outreach and marketing, working with accounting and budgetary milestones, selling waste materials to third parties, assist with the development of information and promotional materials, aim to meet waste reduction and recycling targets [11]. The list of duties and responsibilities of a higher-level waste management officer is even more complex, as they must be in line with all technological, organizational and legal developments and practices in the field of waste management. This also requires appropriate qualifications, e.g. a degree in waste management or similar (biological or biochemical sciences, chemical and physical sciences, civil engineering, structural or mechanical engineering, earth sciences, environmental sciences, etc.).

Considering all this, and the aforementioned fact that the best waste management technologies cannot work and be considered sustainable without human contribution (in this case a skilled waste management professional), the establishment of training centres for waste management professionals is extremely important.

4. EDU-CLIC: EDUcation for CLImate Change mitigation in the municipal solid waste sector

The educational-professional project "EDUcation for CLImate Change mitigation in the municipal solid waste sector" is a part of the European Climate Initiative (EUKI) [12]. EUKI is a project financing instrument by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The EUKI call for project ideas is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.

The project is carried out by 5 members of the project team from the Faculty of Food Technology Osijek (PTFOS), reinforced with an external expert in municipal waste treatment from the company CROTEH Ltd.. In addition to the PTFOS project team, there are also 5 team members from the Faculty of Technical Sciences, University of Novi Sad, Serbia and 4 members from the Regional Development Agency Srem, Serbia.

The activities planned under this project aim to establish the infrastructure for a training center for landfill operators and to develop a plan to upgrade the

Sremska Mitrovica regional landfill as a pilot landfill to achieve a long-term goal - to reduce greenhouse gas emissions in municipal waste management in Serbia.

Waste management in Serbia is mainly based on landfilling, which contributes significantly to the national carbon footprint. In fact, there are over 3,600 landfills in Serbia, most of which are unsanitary and illegal dumps. Annual methane emissions from these landfills amount to 60,000 tons [13]. The Serbian National Waste Management Strategy from 2010 to 2019 (Official Gazette of RS - 29/2010) [14] provides for the closure and remediation of all current unsanitary municipal solid waste landfills and the construction of 29 regional sanitary landfills, as well as recycling yards and transfer stations. According to the Strategy and the Law on Waste Management, the optimal solution for waste management in Serbia is proposed to be the establishment of regional centers based on the construction of sanitary landfills with additional treatment technologies and covering at least 250,000 inhabitants. So far, only 11 sanitary landfills have been built since 2002, and most of them do not comply with the operating procedures for modern landfills. In Serbia, there are no composting plants or other facilities for organic waste treatment, except for some pilot projects for green waste composting. However, the strategic documents envisage the construction of several mechanical biological treatment, anaerobic digestion and composting facilities.

A major problem in Serbia is the implementation of the system of source separation [15]. The lack of a systematic solution, regulations and public awareness of the need for source separation of waste as the first and crucial step towards the implementation of a functioning waste management system is a problem that needs to be solved as soon as possible at the national level. The implementation of a proper waste management system (separate collection, waste treatment, disposal on sanitary landfills) involves costs, and this additional financial burden should be borne by all citizens, which will be another major problem in the future.

This shows that there is a need to improve waste management infrastructure and practical education (training) of personnel involved in municipal waste management, especially landfill operators. As there are currently no formal or informal forms of such training in Serbia, the EDU-CLIC project seeks to meet this need while mitigating the negative environmental impacts of landfills and reducing methane emissions from landfills in the long term. A plan for upgrading the Sremska Mitrovica Regional Landfill will be developed within the project in order to obtain a modern waste management center. The developed plan for upgrading the landfill will serve as a blueprint for other regional landfills in Serbia. In addition, the project envisions the establishment of infrastructure

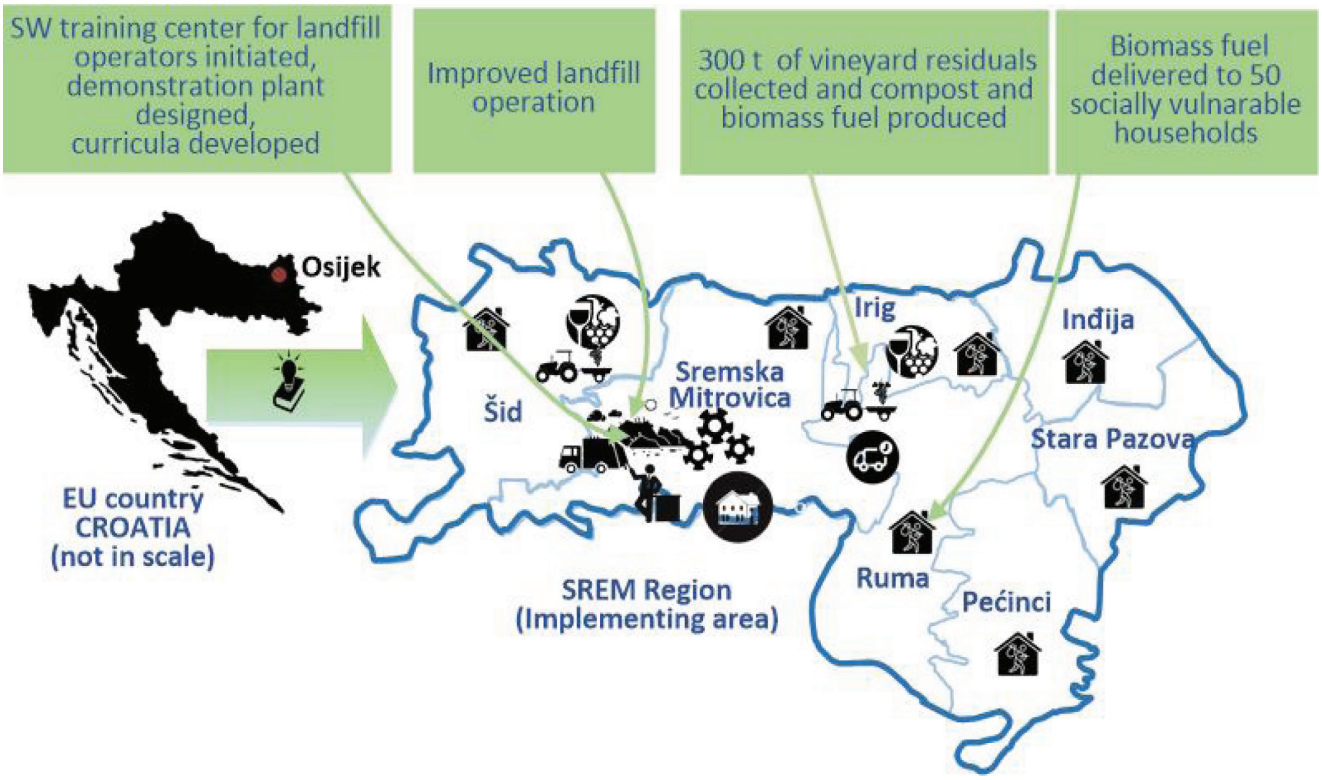

Fig. 3. Schematic representation of the project results

for a training center at the Sremska Mitrovica Regional Landfill and the development of a curriculum for training employees and operators in the field of municipal waste management. In order to make the management of municipal waste at the Sremska Mitrovica Regional Landfill more sustainable, activities/strategies are also planned to reduce methane emissions by 16.65 tons per year. The agricultural waste (biomass) generated after vine pruning will be collected from vineyards in the region and used for the production of compost and firewood briquettes. Thus, two practical strategies for methane reduction are envisaged: (1) the use of compost as a daily landfill cover and (2) the conversion of green waste and agricultural residues into biomass fuel.

The unique feature of the project is that it aims to offer the renewable energy source as fuel for vulnerable groups, thus realizing the principles of the circular economy and the three pillars of sustainability: economic viability, social justice and environmental protection.

The entire municipal waste management sector in the region is expected to benefit from the EDU-CLIC project, as all stakeholders involved in municipal waste collection and disposal will gain insight into ways to reduce greenhouse gas emissions and improve overall quality of environment through effective landfill modernization and a developed training program.

5. Conclusions

The importance of adopting sustainable waste management systems and the transition from the less sustainable but still prevalent waste management strategies in low-income countries was outlined. In addition, the importance of education and training in waste management was also discussed. The EUKI project EDU-CLIC implemented in Serbia was presented, which aims to reduce greenhouse gas emissions and improve the overall quality of environment through the effective modernization of the selected landfill and a developed training program for waste management professionals.

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