A PROJECT ON REDUCING RISKS ASSOCIATED WITH MSW OPEN DUMPS

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ABSTRACT:

In many countries around the world, the most commonly used method for the disposal of municipal solid waste (MSW) is the landfill method. Before the sanitary landfills, solid waste was disposed randomly to any area outside the city by open dumping. In many countries, open dumps still represent environmental problems. Even in the countries which switched to the utilization of the sanitary landfill method, abandoned open dump sites continue to danger the environment and human health. Methane gases, leachate, and structural stability are three significant problems which pose various type of risks in the open dumps. An European project with the acronym of SMARTEnvi is underway to tackle issues related to risks associated with MSW open dumps. SMARTEnvi project, the topic of this paper, seeks to develop, pilot and test innovative digital tools, training methods, and materials for reducing hazards to the environment and water resources by rehabilitating open dumps. The intellectual outputs of the project, namely smart decision tool for rehabilitation of open dumps, competence tool, multilingual e-learning-platform, learning modules, and smart guidance manual, will help develop competences in various sustainability-relevant sectors so that target groups will be able to deal effectively with rehabilitation of open dumps. This paper presents the SMARTEnvi project and discuss the risk posed by open dumps.

KEYWORDS: Smart Decision Tools, Landfill, Municipal Solid Waste, Open Dumps, Risk, Static and Seismic Stability

1. INTRODUCTION

Sustainability of the environment is a major issue with increasing level of consumption of all resources particularly in the last few decades. This high level of consumption naturally increased the waste amount produced in the towns and cities. Unfortunately, in order to find a fast and economical solution, these wastes were dumped in open fields without any engineering or environmental considerations and consequently these processes created tens of thousands of open dumps in Europe and around the world. Many developed countries foreseen the environmental impacts of open dumps and left these practices and enforced engineered landfills. Most other nations followed this more environmentally friendly practice either by voluntarily and/or adapting to, for example, EU legislation. However, even though those countries constructed and started using engineering landfills the previous open dumps still existed without any use. The topic of the project described herein focuses on smart decision tools for reducing hazards to the environment and water resources by rehabilitating open dump sites that cause serious environmental problems. This project aims at the development and testing of innovative practices in a digital era to prepare the beneficiaries to become true factors of change as a horizontal priority. In addition, competences will be developed in various sustainability-relevant sectors so that they will be able to deal with rehabilitation of open dumps as part of environmental and climate goals.

Reducing the environmental impacts of solid waste generation continues to be a priority of national and European Union (EU) environmental policies. Consecutive directives on solid waste management have strengthened standards and policy guidelines for implementation by EU members, and the EU boosts the sector development to the required standards with grant funding to member states and candidate countries. Yet, despite the significant amounts of financial resources allocated to the sector, many countries face the challenge of being behind the ambitious targets. Still, the most used method for the disposal of solid waste is the landfill method. To decrease the need for the landfills, various efforts such as reducing the waste amounts by separate waste collection and recycling, and composting have been underway for some time and appear to be one of the prominent issues for many decades to come.

The partnership in this project consists of universities, private organizations, and municipalities with high reputations in their respective fields which got together according to requirements of the project and experience of the partners (SMARTEnvi, 2021). Figure 1 shows the partners involved in the project with the acronym of SMARTEnvi. The coordinator of the project is Gebze Technical University, Turkey. The important activities and intellectual outputs involving the project are (Toprak, et al, 2021): i) Smart Decision Tool for Rehabilitation of Open Dumps which guides users interactively through the open dump evaluation process and helps them for risk based optimum decisions. As the tool will be functioning in web platforms and smart devices, it will be accessible worldwide so that many people can benefit, ii) Multilingual e-learning-platformò which is based on modern learning outcomes which satisfy up to date and most recent requirements of the environmental regulations, rules, EQF and ECVET. The output will be influential in the way the learning content is produced, iii) Competence Tool involves the presentation of the learning material according to Learning Outcomes and Training Units forming personalized training paths for specific professional competence and reference level, iv) Learning Modules provide specialized training curriculum, focuses on key issues regarding rehabilitation of open dumps for environmental health and ecology. This intellectual output produces training modules covering basics, fundamental and the new developments and technologies. The users will be able to learn and apply this up-to-date information by using the training modules produced in this project.

Demographic characteristics, legislation as well as lifestyle cause the municipal solid waste (MSW) composition to differ according to the region (Reddy et al., 2009). The disposal of municipal solid wastes can be by recycling, composting, incineration and landfilling. Figure 2 shows global treatment and disposal of MSW in OECD and European countries including partner countries of this project according to 2018 statistics. The graph shows that there are significant differences between how European countries handle their MSW. In about half of the countries included in the graph, the most commonly used method for the disposal of solid waste is the landfill method.

Figure 1. Partners of SMARTEnvi international project

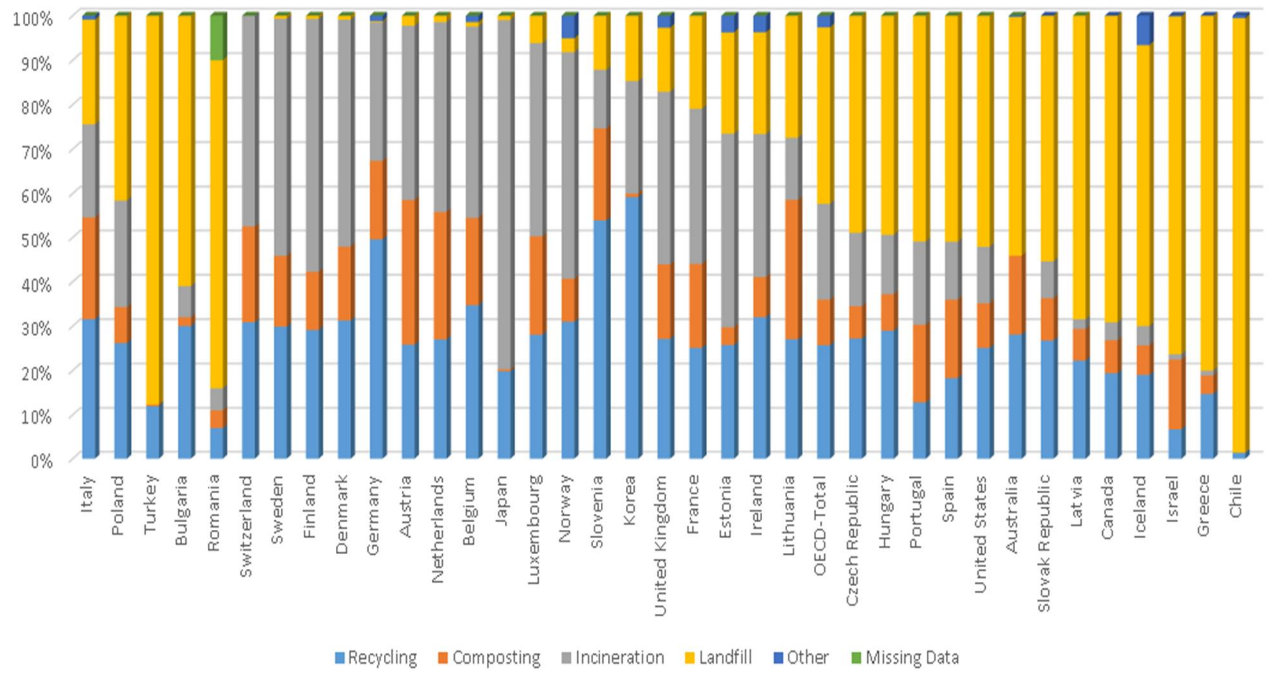

Figure 2. Municipal solid waste disposal in OECD and European countries in 2018 (OECD,2021; CEWEP,2020)

2. POTENTIAL RISKS IN OPEN DUMPS

Water, soil and air pollution occur due to the improper municipal solid waste disposal. Some of the general properties of open dumps are described by (UNEP, 2005) as follows. The locations of open dumps are unplanned according to environmental standards and for this reason the places chosen are not suitable in general. The capacities are unknown, and they have haphazardly dumped waste. Not only gas but also leachate management do not exist in these dumps. Soil cover is not or occasionally applied. There is no waste compaction and fence. Composition or/and amount of waste inputs are not controlled. Also, record keeping is not applied. The scavengers can pick up the waste in open dumps. While its cost is low initially, it is high for the long term. There is a considerable risk of fire and negative effects on health and environmental issues. Furthermore, they can be dangerous for groundwater. Because waste dumping is done indiscriminately, not only surface water but also ground water supplies get polluted (Srigirisetty et al., 2017). Standing water on or nearby open dumps allows insects to breed and creates minor floods in rainy seasons.

Open dump areas can also change not only chemical but also engineering soil properties. Ukpong and Agunwamba (2011) presented investigation of three open dump areas in Nigeria in order to determine the impact of the open dumps on soil characteristics. For this purpose, properties of soil approximately 40 m distance from the open dumps were also investigated as the control, and the soil layers for the control were similar to the soil layers in open dump areas. The comparisons showed that the optimum moisture content as well as the liquid limit values for the soil at dump sites were lower than the soil of the control while the amount of lead, iron and zinc, plasticity index, permeability, specific gravity as well as maximum density for the soil under the dumps were higher than the soil under the control.

Uncontrolled dumps tend to contaminate groundwater due to leachate generation (Srigirisetty et al., 2017). Degradation level and waste types located in the disposal area identify the leachate composition (Joseph et al., 2008). The contamination of surface and drinking water because of the leachate can be treated but this treatment may be lengthy, costly and thorny. Abandoning groundwater wells that have been affected is often the only thing that is done in this situation. Contamination of groundwater as well as surface water due to polluted water from a facility used for waste disposal is shown in Figure 3 (UNEP, 2005).

Kanmani and Gandhimathi (2013) investigated the contamination of heavy metal caused by leachate problem in Ariyamangalam open dump located in India which stores urban solid waste by collecting soil specimens around this open dumpsite. As a result, some heavy metals like Mn, Pb and Cu were observed in these soil specimens. This shows that migration of leachate from this open dump caused noticeable soil contamination.

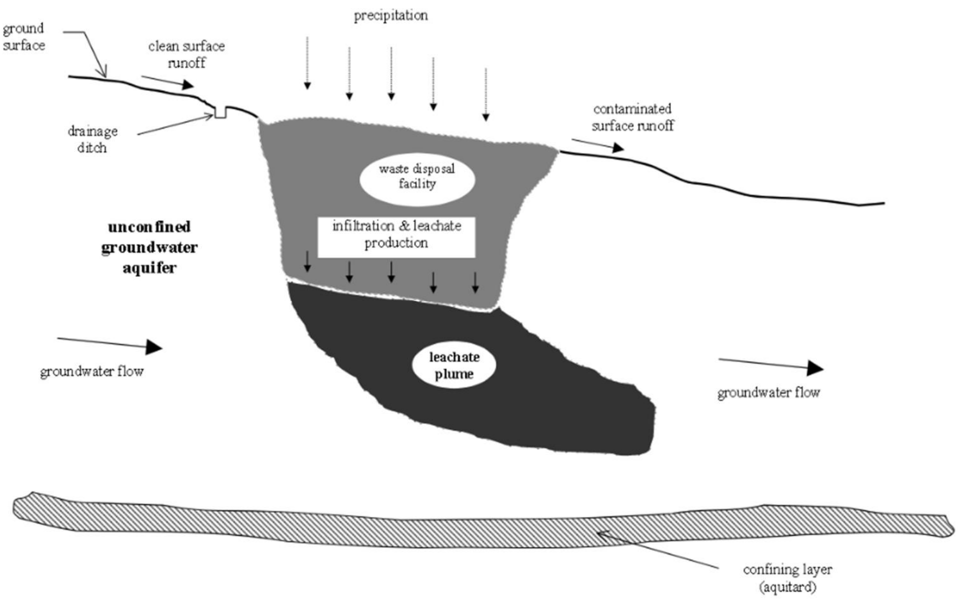

Figure 3. Contamination of groundwater as well as surface water due to polluted water from a facility used for waste disposal (UNEP, 2005)

Mostly carbon dioxide as well as methane gases are produced due to the waste decomposition. When the methane is created, pressure is built up by methane and after that, it starts to move in the soil by using the way of minimum resistance. Methane is quite combustible and it weighs less than air. If the concentration of methane gas in the air of a closed structure like buildings rises to approximately 5% to 15%, a flame or spark will probably bring about a major explosion and fatal accident. In addition to this, methane gas released into the atmosphere is much more effective on global warming than carbon dioxide. According to estimates, landfill of wastes as well as waste dumping cover approximately 5 to 15% of methane gas released into the atmosphere (Joseph et al., 2008). Apart from the leachate and methane gas problems, potential infectious disease carriers such as flies as well as vermin may breed in open dumps. In addition, open dumps where no daily cover is applied may be dust and odor source (UNEP, 2005).

3. STABILITY ISSUES

In general, landfills including open dumps are enormous structures that cover a big area, ranging in height from tens of meters (Choudhury and Savoikar, 2009) to more than a hundred meters. Foundation soil of landfills can be different such as rock and soil of different compositions (e.g., clay, silt, sand). Leachate problem increased the environmental concern related to the water bodies as well as soil contamination. Another concern related to these sites is possible stability problems including slope failures. In general, stability problems in landfills may result from soil and waste themselves, and their interactions with liners. In essence, foundation soil, liner system, and cover system should all be considered. In open dump sites, however, the liners are not available, hence the soil and waste and soil-waste interface may be critical. Jayaweera et al. (2019) presented a slope failure which took place in an open dump located in Sri Lanka as shown in Figure 4. Just before the collapse in this open dump, its height ranged from 20-49 m while slope angles ranged from 20° to 85°.

There were also many failure examples in open dump sites. For example, at Saravejo, a flow slide occurred in an urban solid waste uncontrolled dump in 1977. The volume of waste moved in this flow was 200,000 m^3 and the flow distance was 1 km. Consequently, 5 houses as well as 2 bridges had damage because of this flow slide (Blight, 2008). Also, a gas explosion occurred in a landfill located in Denmark in 1991 (Kjeldsen and Fischer, 1995). In 1993, there was an explosion in an open dump located in Istanbul and then solid waste displacement occurred in there. As a result of this accident, 11 houses were damaged and 39 people died. The volume of the waste moved in this flow was 1,200,000 m^3 (Kocasoy and Curi, 1995). Another slope failure was observed in Payatas landfill located in Philippines after several days of exceedingly torrential rain in 2000. The volume of waste moved in this flow was about 13,000-16,000 m^3. Hundreds of people died because of this failure (Merry et al., 2005). In Leuwigajah dumpsite located in Indonesia, another landslide happened with the volume of 2,700,000 m^3 wastes in 2005. Consequently, there were 147 dead (Koelsch et al. 2005).

Figure 4. Damage to dwelling units because of the slope failure in Meethotamulla open dump (Jayaweera et al., 2019)

Seismic activities affect many structures adversely (e.g., Jinguuji and Toprak, 2017; Toprak et al., 2008; Holzer et al., 2000) and should be considered in risk evaluations. Landfills, including open dumps, are no exception to this. For example, in the 1994 Northridge earthquake, some tears were observed in a geomembrane liner of a landfill (Augello et al., 1995). In the 1989 Loma Prieta earthquake with a magnitude of 7.1, small cracks and little settlement were observed in some landfills (Johnson et al., 1991). After the 1995 Hyogoken-Nanbu earthquake, some waste fills had ground cracks (Akai et al., 1995). Seismic response analyses of the landfills where urban solid wastes are stored are crucial in terms of its serviceability as well as safety evaluations after the earthquakes. Vibration properties of landfills, strong motion as well as foundations, foundation types and landfill stiffness are important parameters in order to assess the landfill seismic response (Choudhury and Savoikar, 2009).

Thusyanthan et al. (2004) investigated the amplification characteristics of a MSW landfill via experimental results from dynamic centrifuge testing of a MSW landfill model and comparison of the experimental results with one-dimensional numerical predictions. They produced a simplified acceleration response chart for MSW which relates the maximum base acceleration to the maximum top surface acceleration of MSW landfill for various fundamental frequencies. According to their analyses results, 1D frequency-domain numerical analysis can predict the acceleration response of a MSW landfill well provided that correct and validated shear modulus reduction and damping curves are used in the analysis.

4. ASSESSMENT OF RISKS AND SMART DECISION TOOL

The legal, technical, technological, environmental, and economical dimensions should be taken into account in deciding the best way for the rehabilitation of open dumps. These multi dimension considerations and complexity of the problem makes it a requirement to apply smart digital systems in the solution. Therefore, this study develops a smart decision tool for rehabilitation of open dumps which will be beneficial for decision makers, engineers, technicians, and vocational trainers. This smart tool guides them interactively through the open dump rehabilitation assessment process and help them for risk based optimum decisions. As the tool will be functioning in web platforms and smart devices, it will be accessible worldwide so that a large number of people can benefit. The smart decision tool incorporates several elements of the following methods: life cycle assessment (LCA); life cycle impact assessment (LCIP)-ReCiPe; life cycle costing (LCC); cost benefit analyses; eco invent database plus dedicated inventory; multicriteria analyses (MCA); risk assessment and expected values (e.g., Pikon et al., 2021; Bogacka and Pikon, 2014). The process considers assessment of current environmental footprint, assessment of environmental impact of defined options of rehabilitations, and different types of impact resulting from emission to air, emission to waters (leachates), structural stability including slope failures, waste, use of resources, land occupation, relevance to circular economy concept. Some airborne technologies, such as LiDAR can be integrated for monitoring and assessment purposes (e.g., Toprak, et al., 2018). Some soil improvement techniques are available to enhance the stability conditions at sites against multiple hazards (Manav, et al., 2019). Figure 5 shows only the environmental evaluation aspect of the smart decision tool.

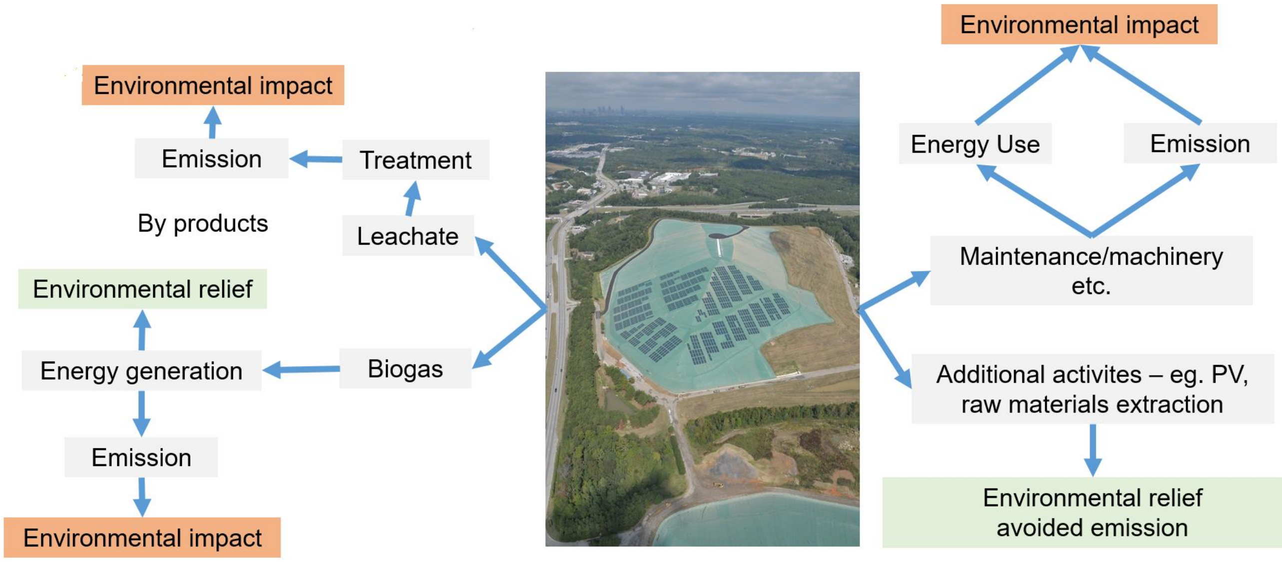

Figure 5. Environmental evaluation aspect of the smart decision tool

The important result of the assessment of risks to the open dumps in a systematic way is to be able to take appropriate precautions before it is too late. To take actions only after the damages occur can be significantly costly by all means. The adverse consequences cannot be tolerated socially and financially. As an example, Figure 4 shows the slope failure in Meethotamulla open dump and its dramatic consequences. Some of the stabilization efforts following the failure are provided in Figure 6. After the collapse, a buttress for the toe part was constructed to provide the stabilization in the open dump in Sri Lanka (Jayaweera et al., 2019). Unfortunately, these efforts cannot eliminate the existing damage.

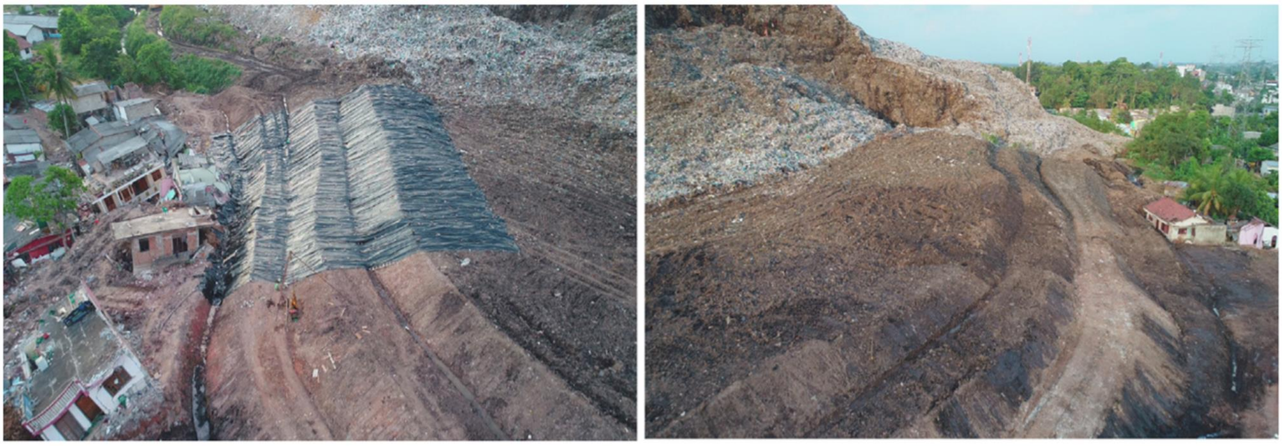

Figure 6. Stabilization of an open dump by constructing toe buttress after its collapse (Jayaweera et al., 2019)

Considerable efforts are underway for the rehabilitation of open dumps in many countries. For example, according to the domestic waste action plan of the Ministry of Environment and Urbanization in Turkey, there are more than 800 open dumps in Turkey as of 2016 and 8 million tons of MSW disposed of by open dump. Over the years, the number of existing open dumps has been decreasing in Turkey as some of them were rehabilitated. For instance, the rehabilitation of an open dump area located in Denizli can be seen in Figure 7. There exists considerable progress in the other partner countries of SMARTEnvi project, such as Italy. The European Court of Justice, with the judgment n. C-196/13 (2014) condemned Italy, with heavy financial penalties, for its failure to adopt the previous judgment of 2007; the judgment obliged Italy to adopt specific measures, including research and studies (concerning the landfill and its mechanism) and rehabilitation of 218 open-dumps not complying with the EU legislation; among these, 16 contained hazardous waste. In 2017, in order to overcome management problems of 81 sites, considered the most complicated realities, the Government appointed an extraordinary administrator with special powers (in the field of authorization procedures, financial capacity, open dumps rehabilitation or safeguarding, territorial coordination of local authorities etc..) who was mandated to act in the maximum transparency to ensure effective competition between economic operators involved also through reporting activities of all the interventions undertaken with semi-annual frequency. With the persistent follow ups, the national situation was improved: as of December 30th, 2020, 51 sites were rehabilitated in accordance with community regulation (SMARTEnvi Italy National Report, 2021).

Figure 7. Tavas, Denizli, Turkey open dump area before and after rehabilitation

5. CONCLUSIONS

Increasing urbanization and consumption resulted in more municipal waste to be disposed of. The most commonly used method for the disposal of municipal solid waste in many countries around the world is the landfill method, and open dumps still represent environmental problems. Open dumping which is practiced by about three-fourths of the countries in the world, is basically the worst case of disposing activity due to lack of appropriate facility such as drainage system, methane gas collection, and leachate management. Even in the countries which switched to the utilization of the sanitary landfill method, abandoned open dump sites continue to danger the environment and human health. Hence, it is crucial to evaluate the risks associated with existing and abandoned landfills including open dumps. As part of the current EU project, SMARTEnvi, the researchers of 9 institutions from 5 different countries come together to produce the intellectual outputs to reduce hazards to the environment and water resources by rehabilitating open dumps. The project will have a contribution on implementation of Europe 2020 Standards for environment and climate goals through developing partnerships aimed at promoting work-based learning in rehabilitation of open dumps. One major purpose herein is to produce a prolong impact at national level by enabling the good practices on rehabilitation of dumpsites. As solid waste management procedures are still lacking in most countries, most landfills are operated by open dumping method. This project is expected to have an impact not only local, regional but also national and international levels by stimulating improvement in legislations and/or developing new strategies about environmental aspect.

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