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Irrigation in the Reclamation of Municipal Waste Landfills

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1. Introduction

Storage in landfills is the oldest and still the most popular method of waste disposal. Deposited waste as a result of biochemical transformation processes undergo decomposition and mineralisation, transforming into anthropogenic material harmless to humans. Landfills must comply with the recently tightened provisions of Polish law, primarily resulting from the necessity of their adaptation to the requirements of the European Union (Regulation of the Minister for the Environment of March 24, 2003 with detailed information concerning the siting, construction, operation and closure to be fulfilled by certain types of landfills (Journal of Laws No. 61 item 549, as amended). In the field of waste management, the European Union has issued as many as nine directives. They have imposed numerous obligations for Poland, of which the most important are: achieving min. 60% of recovery and 55% of recycling for packaging waste in 2014, and at least 25% of recovery for biodegradable waste by 2010 so as not to deposit it in landfills (Rosik-Dulewska 2011).

In practice, the majority of organised municipal landfills in use in Poland do not have any technological solutions for managing leachate, which arises during their operation. Approximately 35% of landfills recirculate leachate to the landfill surface in order to reduce the disposal cost. (Żakowicz, Hewelke 2012). At the same time, for economic reasons, the distribution of leachate on the landfill surface is very rarely carried out with the use of irrigation systems. Not only should these systems support the development and proper maintenance of landfill vegetation by continuous ensuring adequate moisture in the plant root layer, but also favour microbiological processes and consolidate the cover layer of the

landfill. It is therefore appropriate to apply an adequate irrigation technology by administering optimal irrigation doses at the appropriate frequency, similar to evapotranspiration. It should cover the water demand of vegetation growing in landfills, inhabited primarily by perennials, including grasses and annual plants (Dyguś et al. 2012, Łuniewski, Łuniewski 2011, Rosik-Dulewska 2011, Skibniewska 2011). Reclamation of landfills as the final process of its operation is divided into two stages: technical reclamation i.e. preparation of conditions for biological reclamation and biological reclamation i.e. introduction of specific plant species to the reclaimed area. The concepts of biological development of the above-ground municipal waste landfills have been the subject of numerous research. The studies also included the technology and size of irrigation doses. The properly developing vegetation layer in the landfill canopy enriches the landscape and creates a friendly microclimate. Especially given the fact that the cover layer of the landfill is not soil, is exposed to water and wind erosion, and characterises with unfavourable physic-water properties. Maintenance of grassy vegetation, trees and shrubs, which in the initial phase of landfill reclamation is not sufficiently developed, depends on the supply of additional water by irrigation. The treatment must be accurate, since the use of too high irrigation dose drains water from the sealed surface of the landfill and accumulates it locally, adversely affecting the structure of the landfill canopy (Żakowicz, Hewelke 2005). In order to maintain the best moisture conditions of the top layer, the most suitable irrigation technology is to provide small doses of water with high frequency, corresponding to evapotranspiration. Application of irrigation should be an indispensable procedure used for efficient and quick landfill reclamation. Specifically that approx. 35% of landfills use the recirculation of leachate to the canopy surface to reduce the cost of its disposal. The distribution of collected leachate to the landfill surface should be carried out with the use of irrigation systems. Well-growing vegetation on the canopy surface protects it, creates a good microclimate and allows it to blend in with the landscape by blurring landscape differences.

2. Material and methods

The aim of the study was to present an irrigation solution (sprinkler and slope) as a necessary element in the biological reclamation and management of the municipal waste landfill in Boduszewo, the commune of Murowana Goślina in the Wielkopolska province (Fig. 1). The scope of work included the presentation of landfill irrigation technologies, selection of irrigation doses, determination of water consumption by vegetation on scarps with different exhibition, selection of the amount of water needed for irrigation along with the applied irrigation doses (net). Determination of the average daily water demand (gross) for irrigation and evapotranspiration.

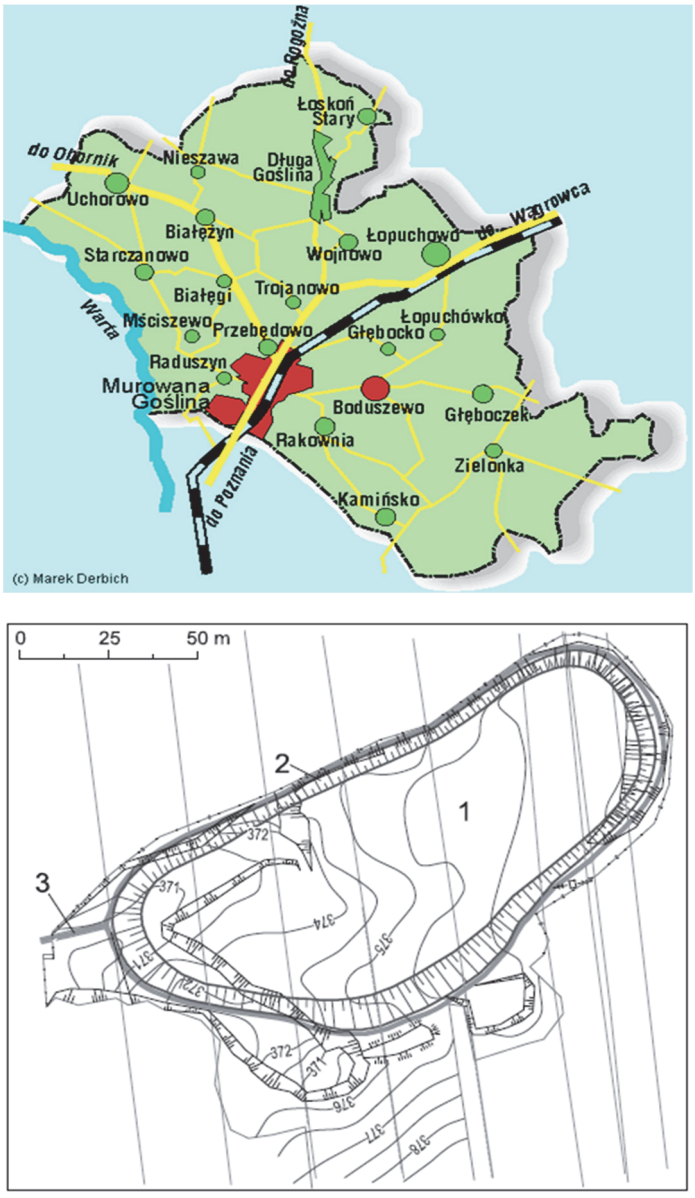

Fig. 1. Location of the village of Boduszewo in the background of the commune of Murowana Goślina and the area of the reclamated waste landfill; 1 – water reservoir, 2 – ditch, 3 – receiver, (source: http://www.murowana.pl/ogminie/img/mapy/gmina.gif)

Water easily accessible to plants was maintained within the range from the value of field water capacity to the beginning of plant growth inhibition (pF 2,0-2,7). Plants for planting were selected according to the recommendations for similar facilities in Poland. In the first stage (up to 3 years from the start from 2012 to 2014) the reclamation included island planting, trees and shrubs (black locust, Norway maple, bird cherry, black lilac). In the second stage of reclamation from 2015, the islands were enlarged with grassy vegetation and merged into green corridors as biological barriers performing anti-erosion and windbreak functions. Sprinkler irrigation solutions were implemented in the vegetative period of 2015, and the system was supplemented with a slope irrigation technology (in 2016). The value of water consumption in the balance method, from the soil layer with controlled moisture, was calculated for individual months of the vegetative period (IV-IX), depending on the average air temperature. The values of water consumption by vegetation was differentiated between: I reclamation phase (2012-2014) and II reclamation phase (from 2015), taking into account the type of exhibition of the irrigated surface, i.e.: the canopy, southwest, north and east scarps. The precipitation level and average air temperature were obtained from the nearest meteorological station in Zielonka. For calculations the value of real precipitation (up to 3 years after planting trees and shrubs) was decreased due to interception (by 1 mm with precipitation less than 3 mm, by 2 mm with precipitation more than 5 mm). In the period of more intensive growth of trees and shrubs (more than 3 years after planting), the study did not take into account the precipitation level lower than 3 $mm \cdot d^{-1}$.

3. Results and discussion

The village of Boduszewo is located entirely in the buffer zone of the "Puszcza Zielonka" Landscape Park, approx. 3km from Murowana Goślina. From the east and south Boduszewo is surrounded by forests of the Zielonka Forest. These are very valuable natural areas, containing objects of nature conservation. The municipal waste landfill in Boduszewo was built as an above-ground landfill, surrounded by a protective wall formed from local soil. The landfill is shaped similarly to a rectangle with an area of 5,58 ha and the volume of accumulated waste is 837500 m^3. Taking into account the characteristics of the reclaimed landfill in Boduszewo, a sprinkler system equipped with a reel-operated sprinkler RV5 manufactured by Aqua-Rol was applied on island plantings (Tab. 1).

During the first three vegetative periods of field tests and observations (from 2012 to 2014) additional irrigation was not necessary due to the favourable distribution and rate of precipitation. It was also the result of optimal moisture of the top layer of the landfill caused by higher than average long-term atmospheric precipitation values in the winter half-years and longer persistent melt-water

occurring in years preceding the research period. During the vegetative period of 2015, with the total precipitation of 242 mm (lower by 78 mm than the multi-year average for this season), precipitation shortages appeared (from 17 mm in May to 77 mm in August) (Fig. 2). Deficiencies were supplemented by sprinkling with irrigation doses net ranging from 18 mm to 25 mm. The irrigation doses were calculated for the grass root layer, (volume 0-15 cm), with the planned maintenance of moisture for water easily accessible to plants (pF 2,0-2,7).

Table 1. Technical and operational characteristics of Aqua-Rol RV5 sprinkler (source: Aqua-Rol Sp. z o.o.)

Model / hose diameter (mm) / length (m)	Sprinkler	Nozzle size (Ø mm)	Flow ($m^3 \cdot h^{-1}$)	Pressure (bar)	Maximal / optimal irrigation area (m)	Efficiency (in ha) in a work cycle	Winding speed For 10 mm dose ($m \cdot h^{-1}$)
RV5 / / 100 / / 500	RANGE R	22/24/ /26/28	31.3 - - 62.4	5.0 - - 11.2	100 / / 59-80	4.51	53-78

In addition, the top of the landfill was sown with a mixture of grasses, recommended for dry habitats, which consisted of more than 50% of red fescue (*Festuca rubra L.*) and its varieties with an admixture of white clover (*Trifolium repens L.*). As a result of the calculation with the use of the balance method, recommended by Zakowicz and Hewelke (2005), the water consumption by grasses was determined depending on the average daily air temperature. It was varied and depended on the location of the layer, with controlled moisture, in the landfill. The water consumption on the southwest scarp ranged from 78 mm (IV) to 160 mm (VII). The average water consumption in the vegetative period of 2015 (IV-IX) was 124 mm. During the same period, the water consumption on the northeast scarp was lower (by 46%) and fluctuated from 48 mm (in April) to 123 mm (in July). During the vegetative period of 2016, there was necessary to irrigate shrubs and trees with the use of a slope solution (common oak *Quercus robur L.,* field maple *Acer campestre L.*, bird cherry *Prunus padus L.*, dog rose *Rosa canina L.*). It resulted from the unfavourable distribution of precipitation and, above all, its rate (255 mm), lower than the average by 65 mm as well as air temperature, higher than the average (by 1.0°C).

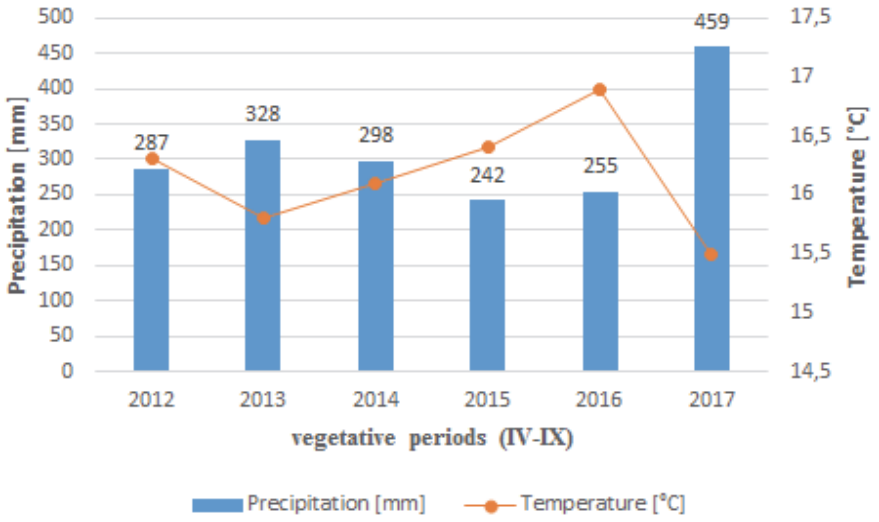

Fig. 2. Total precipitation and average air temperature in vegetative periods 2012-2017

Sprinkler irrigation combined with slope irrigation was carried out in the root layer (0-35 cm) with irrigation doses ranging from 25 mm (in April) to 35 mm in the remaining months of the growing season. During the vegetative period of 2017 irrigation was not conducted due to the total precipitation (459 mm) higher than the multi-year average (139 mm), which retained optimal moisture in the root layer of grasses, trees and shrubs in the landfill (Fig. 3).

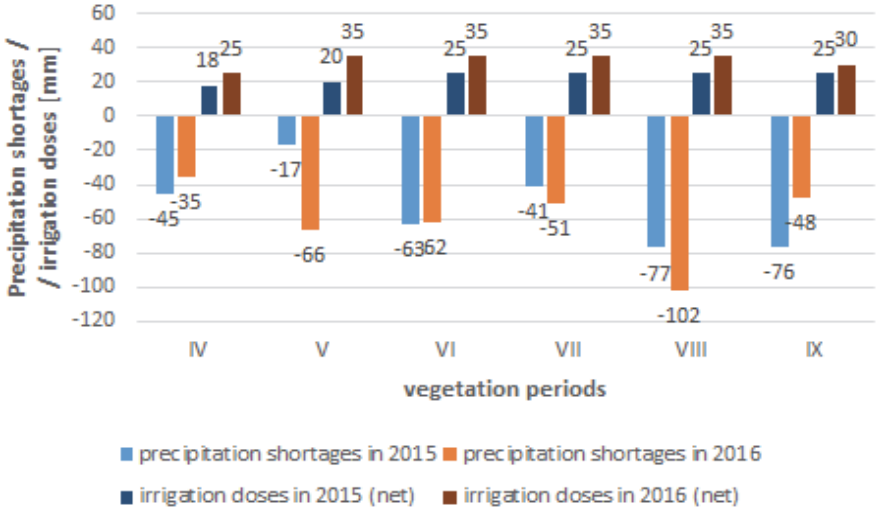

Fig. 3. Precipitation shortages and irrigation doses used in irrigation of the landfill in vegetation periods in 2015 and 2016

4. Conclusion

In the biological reclamation of above ground landfills, adequate maintenance of grass, trees and bushes on their surfaces, particularly in the initial phase, is an important factor conditioning the proper course of the process. The study described irrigation (sprinkler and slope) as a necessary component in the biological reclamation and management of the municipal waste landfill in Boduszewo, the commune of Murowana Goślina in the Wielkopolska province. Irrigation was carried out in the vegetative periods during which, due to the rate and distribution of precipitation (2015 and 2016), it considered necessary. There were determined adequate irrigation doses corresponding to the water consumption by plants covering the landfill. It was indicated that precise irrigation with the use of two complementary systems: sprinkler and slope, allows for accurate and controlled retaining of the moisture in the root layer of vegetation in the landfill. After applying irrigation solutions, significant growth and development of trees and shrubs was observed in the periods with high precipitation deficiencies. Field observations confirmed faster and much wider development of root systems in irrigated plants (in the canopy and on the southwest scarp) compared to plants on the north scarp that was devoid of irrigation. The affected by sprinkling plants on this landfill bloomed (i.e. black lilac and bird cherry), and there was observed a significant height gain comparing to plants planted at the same time but not irrigated. Poplars and maples also developed faster, and their growth was 30-40% higher after applying irrigation. The conducted research and field observations demonstrated that the use of plant irrigation in municipal waste landfills is an indispensable procedure contributing to its effective and fast reclamation.

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Abstract

The study identifies irrigation (sprinkler and slope) as a critical component in the biological reclamation and management of the municipal waste landfill in Boduszewo, the commune of Murowana Goślina in the Wielkopolska province. Irrigation was carried out in the vegetative periods during which, due to the rate and distribution of precipitation (2015 and 2016), it was considered necessary. The irrigation doses were determined corresponding to the water consumption by the vegetation covering the landfill. Results show that precise irrigation with the use of two complementary systems: sprinkler and slope, allows for the prevention and accurate control of the drought, resulting in continuous and uninterrupted growth and development of vegetation in the landfill.

During the vegetative period of 2015, when the total precipitation (242 mm) was lower by 78 mm than the multi-year average for this season, rainfall deficiencies were supplemented by means of irrigation with doses from 18 mm to 25 mm. These were varied depending on the vegetation water consumption. On the southwest scarp of the landfill, the water consumption was 124 mm on average, whereas in the same period on the northeast scarp it was 46% lower. During the vegetative period of 2016, there was identified an additional need for irrigation of shrubs and trees. Sprinkler irrigation combined with slope irrigation was carried out with doses ranging from 25 mm to 35 mm, depending upon the water consumption by plants. During the vegetative period of 2017, there was no additional irrigation due to the favourable distribution of precipitation and its high rate (459 mm), higher than the multi-year average (by 139 mm), which retained optimal moisture in the root layer of grasses, trees and shrubs in the landfill. The use of irrigation of plants in the municipal waste landfill proved to be an indispensable process contributing to its effective and fast biological reclamation.

Keywords:
irrigation in waste landfills, irrigation doses, biological reclamation

Nawadnianie w rekultywacji składowisk odpadów komunalnych

Streszczenie

W pracy przedstawiono nawodnienie (deszczowniane i stokowe), jako jeden z elementów niezbędnych w przeprowadzeniu rekultywacji biologicznej, składowiska odpadów komunalnych we wsi Boduszewo, gmina Murowana Goślina w województwie Wielkopolskim. Nawodnienia prowadzono w okresach wegetacyjnych: 2015 i 2016 roku, w których ze względu na wysokość a przede wszystkim rozkład opadów występowała potrzeba nawadniania. Określono dawki polewowe, odpowiadające zużyciu wody przez rośliny pokrywające składowisko. Wykazano, że precyzyjne nawadnianie, przy pomocy dwóch uzupełniających się systemów: deszczownianego i stokowego, pozwala uniknąć i zapobiegać okresom suszy, wpływając tym samym na niezakłócony wzrost i rozwój roślinności na składowisku.

W okresie wegetacyjnym 2015 roku, w którym suma opadów (242 mm), była niższą o 78 mm od średniej z wielolecia, występujące niedobory opadów uzupełniono

nawadnianiem dawkami w ilości od 18 mm do 25 mm. Były one zróżnicowane w zależności od zużycia wody przez rośliny. Na skarpie południowo-zachodniej składowiska, zużycie wody wynosiło średnio 124 mm, podczas gdy w tym samym okresie na skarpie północno-wschodniej było o 46% niższe. W okresie wegetacyjnym 2016 roku, wystąpiła dodatkowo potrzeba nawadniania krzewów i drzew. Nawodnienie deszczowniane połączone ze stokowym przeprowadzono dawkami w ilości od 25 mm do 35 mm, uzależnionymi od zużycia wody przez rośliny. W okresie wegetacyjnym 2017 roku, nawodnień nie prowadzono, z powodu wystąpienia opadów o dużej wysokości (459 mm), wyższych od średniej z wielolecia (o 139 mm), a przede wszystkim korzystnego ich rozkładu. Spowodowały one optymalne uwilgotnienie w warstwie korzeniowej roślin trawiastych oraz drzew i krzewów na składowisku. Zastosowanie nawodnienia roślin na składowisku odpadów komunalnych, okazało się niezbędnym zabiegiem, przyczyniającym się do efektywnej i szybkiej jego rekultywacji biologicznej.

Słowa kluczowe:
nawadnianie na składowisku odpadów, dawki polewowe, rekultywacja biologiczna