# The Application of the PAN Reclamation Model on the Example of Former Landfills Cracow Soda Works "Solvay"

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*Abstract*

*Krakow Soda Plant "SOLVAY" was founded in 1901 in Krakow. Since the beginning of the liquidation in 1991, the factory was producing various derivatives of sodium carbonate and calcium fertilizer. As a result of the manufacturing process liquid wastes were deposited in the lagoons. The area on which the former landfill, is unique in the Polish and the European Union. The deposited sludge contains large amounts of alkaline cations of a basic nature. This is due to the specificity of production establishments and raw materials used for production. Landfills are very specific sites to conduct any rehabilitation work. The substrate posed by sodium deposits is difficult to reclamation and development due to induction of stress in plants and their decay.*

*Keywords: Krakow Soda Plant, PAN reclamation model*

## Introduction

The landscape is identified with the external appearance of the surface of the Earth in relation to a particular place. It results from the interaction of various natural phenomena and processes, which is dominated by geological and geomorphological processes [Nita 2001]. Natural space, which is located in the sphere of human interaction takes the form of cultural, expressed in terms of the cultural landscape. The landscape can be understood as anthropogenic shaped portion of geographical space, formed by aggregating environmental and cultural impacts, creating a specific structure, as manifested by regional distinctiveness, perceived as peculiar physiognomy [Myga-Piątek 2001].

Biological reclamation should be conducted in two ways. Slopes should sow grass mix by hydroseeding goal as soon as possible sodding and prevent the formation of conical erosion processes. The following year, after turfing enter the belt system of bushes in order to strengthen the embankments by plant roots [Sobczyk et al. 2010; Sobczyk and Pawul 2012].

One of the first quarry reclamation projects in the Foothills (Krakow), which is already implemented in the period 1896–1909 nature park, or park and amphitheater in a quarry in Mount St. Anne (implementation in 1934–1936). Unfortunately, after World War II, post-mining land use forms in multi-directions were rare. An example is the Kadzielnia reserve in Kielce, where land development project launched in 1969–1971. However, most projects never been realized or is managed in a manner that partial – eg. Wietrznia and Józefka quarries. It is encouraging the implementation of a wide variety of development projects postindustrial space for the purpose, among others, sports and recreation such. Dolomites Center "Sports Valley" in Bytom, "Hill" in Sosnowiec whether the project J. Bogdanowski and Z. Myczkowski "Streptococci Hills" in relation to post-mining areas in Bieruń [Stawicki 2003; Sobczyk and Wawrzyniak 2009].

## Facility location

Sediment former Cracow Soda Works "Solvay" are located in the southern part of the city of Krakow, on the border districts of Borek Fałęcki and Kurdwanów. From the north border of the area belonging to the Sanctuary of Divine Mercy in Lagiewniki. From the southern and eastern settling adjacent to the wasteland belonging to the municipality of Krakow. The area west of settlers occupied the factory "Solvay". Today, it houses a shopping center Zakopianka (Fig. 1) [Gliniak 2014].

## Production waste soda industry

In the production process of the Solvay soda method and kaustification per 1 Mg of product and a 0.2 ton of waste. Due to the wide variety

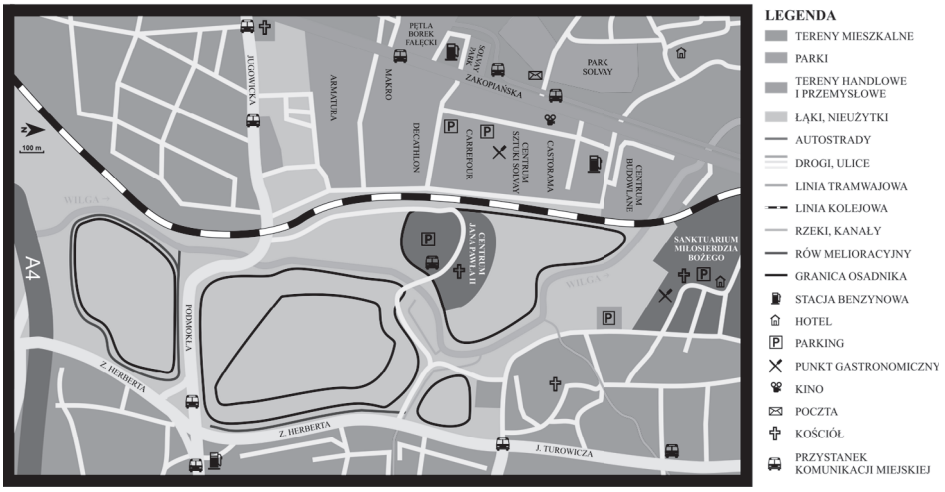


Fig. 1. Location for the sites of the former Cracow Soda Works "SOLVAY" [Gliniak 2014]
Ryc. 1. Lokalizacja terenów składowisk krakowskich Zakładów Sodowych “SOLVAY” [Gliniak 2014]

of raw materials used to produce soda in various establishments sodium, later in this chapter focuses only on waste generated in KZS "Solvay". In the area of the former landfill Cracow Soda Works deposited a total of about 5 million ton of waste. In KZS "Solvay" formed two groups of waste. The first group consisted of solid waste from the combustion of coke and limestone calcination. These wastes were used for the construction and strengthening of embankments settlers. The second group is a semi-solid sludge waste, which was deposited in tailings ponds for later drainage [Leszczynski 1979; Ślęzak 1993].

Sediments deposited in landfills are characterized by a layered structure (Fig. 2), which is the result of sedimentation and hydrostatic pressure upper layers. The layers differ from each other physicochemical properties and thickness. pH deposited sediments in the range from 7.6 (the top layer) to 13.0 (more deeply). The average value of the waste electrolytic conductivity is 1.7 $mS \cdot cm^{-1}$. Wastes have a high content of carbonate (72÷96%), the concentration increases with depth. The sediments are the dominant elements calcium (394 $g \cdot kg^{-1}$), potassium (9 $g \cdot kg^{-1}$), iron (3 $g \cdot kg^{-1}$) and sodium (2 $g \cdot kg^{-1}$). The aqueous extract was determined cations of calcium (266 $mg \cdot 100g^{-1}$), magnesium (7 $mg \cdot 100g^{-1}$), sodium (2 $mg \cdot 100g^{-1}$) and potassium (1 $mg \cdot 100g^{-1}$) and to chloride (26 $mg \cdot 100g^{-1}$) [Ślęzak 1993; Crumbs and Wartalski 1996; Bytnar, 2002; Gliniak 2014; Gliniak et al. 2014a; Gliniak et al. 2014b].

**Examples of soda waste reclamation**

Landfills soda are a difficult subject to reclamation. The main feature of this type is the occurrence of large amounts of easily soluble salts which interact with the surrounding environment, reducing its value. In addition, post-saline waste is stored in large settling tanks (eg. in the USA the surface of individual settlers dating back more than 8 $km^2$), have significantly marked by the landscape [Koś and Miakota 1988; Loska and Tadych 1988; Poda 1999; Matthews and Effler 2003]. In considering the issue of soda waste landfill reclamation, we can distinguish two main lines used today – leaving the area of secondary succession and to carry out some treatments technical and biological reclamation.

In Europe, the spontaneous secondary succession that occurs on soda waste storage areas can be observed in the vicinity of Brenburg (Germany) and Petrovic (Czech Republic). In both cases the natural development of vegetation lasts for more than 70 years. Comparative studies conducted by a team led by Grünewald [2006; 2007] have shown that in non-reclamated areas of the settlers followed fast accumulation of organic carbon compounds and humus. This phenomenon, together with the transformation of the substrate can be considered as initial soil forming process [Golda 2007]. Hanel [2004] and Rusek [2004], based on phytosociological records and analysis of soil fauna in the area Petrovic showed that landfill sites soda strongly differ in composition of flora and fauna in comparison to the neighboring, semi-natural forest communities. These differences result from the toxic effects of salinity on plants, and easy penetration of salts (especially chlorides) microfauna organisms causing their rapid decay. Another factor contributing to reduced biodiversity landfill sites with respect to the surrounding

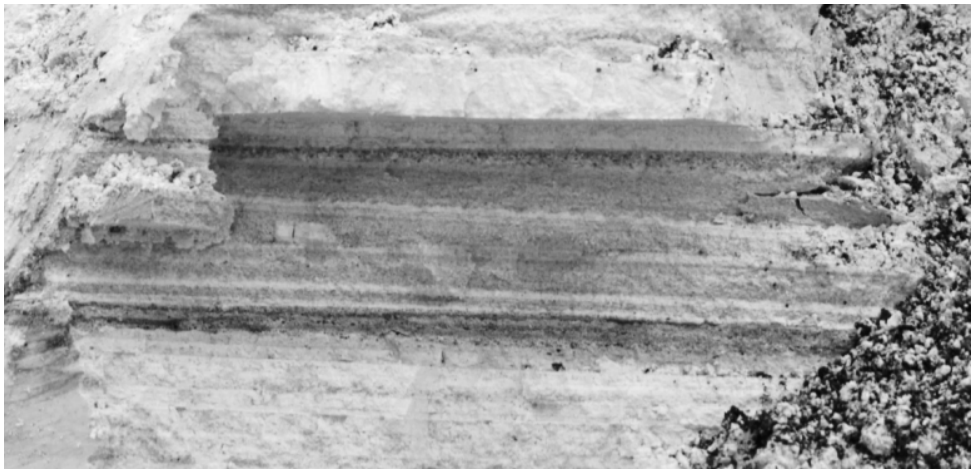

Fig. 2. Sediment layer system in the pond No. 3. The area former landfills KZS "SOLVAY" in Krakow [own photo]
Ryc. 2. Struktura warstwowa osadów zdeponowanych na stawie osadowym nr 3, na terenie byłych składowisk KZS „SOLVAY" w Krakowie [fot. wł.]

forestation was unfavorable microclimate, which caused rapid heating to a high temperature surface layers of accumulated waste and fast drying staying there invertebrate organisms.

The problem reclamation of soda in Poland is still valid, as exemplified by Janikowskie Soda Plant "Janikosoda". Closed landfill plants in Janikowo has been rehabilitated on the basis of a modified reclamation project developed for the former Cracow Soda Works. Said modification phase concerned the use of biological sludge which is mixed with the sludge post-saline and seeded with a mixture of grasses and brachina. Reclamation carried out showed a positive result despite the lack of availability of rainwater during the growing season. The use of sludge conducive to yielding crops and increased availability non-saline water to the root system of plants as a result of a continuous process of evapotranspiration. This allows you to skip the mineral fertilization in the growing season [Siuta, 2005; Siuta et al. 2008].

**Carried out reclamation works**

The existing tailing ponds reclamation consisted in the execution of drainage water discharge, in order to dry embankments, leveling the crown joints, shaping and securing the slopes, land replenishment and sowing it with grass and shrubs. Initially, the surface had a settler pH 10,0–10,6. Isolated appeared halophilous vegetation (Chenopodium glaucum L., Puccinellia distans (L.) Parl. and mosses). Over time, subsurface layers were washed by rainwater and chloride content and pH decreased (after three years of pH decreased to a value of 7.0–7.5 in subsurface layers). Gradually there were green plants, grass and young trees (primarily aspen, birch, willow and poplar), which currently covers 80–98% of the [Trzcińska-Tacik 1993; Malecki 1997]. In addition to the flora on settlers also found several species of fungi (ascomycetes) and 13 taxa of molluscs. The study biometric seven species of snails have shown that they do not differ significantly from those populations occurring in natural environments. So relatively rich fauna in artificial habitats indicates a tendency towards spontaneous rehabilitation of settlers, whose course can be monitored by the analysis of the malacological [Trzcińska-Tacik 1993].

**Proposed development model of forest Academy of Sciences**

In 2010–2013, we studied the physicochemical properties of sedimentary material and landfills. Based on the results of laboratory tests of sedimentary material obtained by Gliniak [2014] and Gliniak et al. [2014a; 2014b] decided to choose the model of forest management Sciences. It assumes direct introduction into the target plants soilless and several years of intensive fertilization. This method of rehabilitation is currently the most effective and economically viable [Bender and Gilewska 2004].

According to the model of Sciences advised to cast trees at the level of 5000 plants per hectare and the planting of shrubs in quantities of 2500 units per hectare. To adapt those sites use small three-year seedlings of a very well-developed root system (due to the very difficult physical and chemical conditions prevailing in the substrate). In order to improve the health of plants and stress limit habitat process can be used micorised seedlings. Through this process the plants receive

additional absorbent surface and have access to substances fold and absorbed by the mushrooms [Bender and Gilewska 2004].

Evaluation of the the usefulness of reclamation established on the basis of the results of laboratory tests occurrence on opposite layers of moist and soft with hard and dry layers. In addition, with increasing depth increases electrolytic conductivity of the material and therefore also the salinity of the material. These factors make it necessary to perform the surgery and then technical reclamation area.

Technical reclamation in the case of the object is associated with reforming slopes and soil material with different thickness in order to improve habitat conditions for plants [Boroń and Szatko 1998]. Growing out of a tree should be cut. Due to the dusty nature of sediment deposited slope slopes settler should be 1:5 (about 20 degrees). Such a drop will minimize the possibility of blurring and crawling reclaimed material during heavy rainfall. In addition, in order to limit this process in the early stages of reclamation can be used wicker hurdles or fascines. Slopes of the respective formation it is recommended to cover 25 cm layer of soil having an average particle size, and the crown layer settlers 50 cm. Thus prepared, the object can be recycled and biological reclamation and begin development targets.

Biological reclamation should be conducted in two ways. A separate discussion will cover slopes and crowns settlers. Slopes should sow grass mix by hydroseeding goal as soon as possible sodding and prevent the formation of conical erosion processes. The following year, after the transverse sloping turfing, a belt arrangement of bushes in order to strengthen the embankments by plant roots. Crowns settlers, as previously mentioned to be filled seedlings of trees and shrubs and grass mix sow area with leguminous plants. After the seeding and train plantings should be fertilized for five years with additions of fertilizers complex micro- and macronutrients. In the first and second year should be used doses of fertilizers meeting the requirements of the food crops increased by 25% of normal. The increase of the standard sowing bind with high basicity of the substrate (immobilization of certain nutrients and the need to reduce pH) and sterility nutrients. Biological reclamation process it is recommended that the following plant species [Gliniak 2014]:

- grasses and legumes – Lolium multiflorum, Dactylis glomerata L., Festuca rubra L., Trifolium pratense L., Trifolium repens L.,
- shrubs – Lonicera xylosteum L., Hippophae rhamnoides L., Syphoricarpos albus Duhamel, Euonymus europaeus L., Frangula alnus Mill., Rosa rugosa Thunb., Viburnum opulus L.,
- trees – Padus avium Mill., Acer campestre L., Prunus avium L., Alnus incana (L.) Moench, Robinia pseudoacacia L., Populus tremula L., Acer platanoides L.

Selected plant species for reclamation of the landfill are most commonly used and most tolerant species. Due to the specific climate habitat and substrate, it is difficult to identify resistant plants or not. By using the above-mentioned recommendations, and partial improvement of ground plants should grow properly. An additional criterion for selection of species of trees and shrubs were their landscapes. The above plants are most common in the assumptions park and avenue in Poland. They have a neat appearance and are widely known among gardeners and landscape architects. An additional feature of this plant selection is their staggered flowering which is an additional advantage of such a composition of species.

**Summary**

Conducted in 2011–2014 observations of vegetation in landfills former Cracow Soda Works helped in identifying the main guidelines for the reclamation of the area. As a basis for the technical reclamation author of the paper substrate received characteristic parameters, shown in laboratory work described in this dissertation (alkaline pH, toxic electrolytic conductivity, the heterogeneity of stored material). Most important way of what you should do when you customize the site for the development plans, is to compensate and increase the thickness of soil material, originally used to cover the tailings ponds. At the same time carry out work to stabilize embankments and slopes, to counteract water erosion of the deposited material. Biological reclamation should be carried out in accordance with the model PAN using intensive fertilization in the first years of cultivation. A very important aspect of this part of the revitalization project is to include green species of plants with shallow root system and high resistance to very high salinity of the ground, which is confirmed by the observations described in papers Boroń et al. 2000; Sroczyński et al. 2007; Hare et al. 2007; Gliniak 2014 Gliniak et al. 2014 and 2014b.

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*Streszczenie*

*Przeprowadzone w latach 2011-2014 obserwacje szaty roślinnej na terenie składowisk byłych Krakowskich Zakładów Sodowych pozwoliły wskazać główne wytyczne dotyczące rekultywacji tego obszaru. Jako podstawę do przeprowadzenia rekultywacji technicznej autor rozprawy przyjął charakterystyczne parametry podłoża, wykazane w pracach laboratoryjnych opisanych w niniejszej dysertacji (m. in. zasadowe pH, toksyczna przewodność elektrolityczna właściwa, niejednorodność składowanego materiału). Najważniejszym zabiegiem, jaki należy wykonać podczas dostosowywania tego terenu na potrzeby planów zagospodarowania, jest wyrównanie i zwiększenie miąższości materiału gruntowego, pierwotnie wykorzystanego do przykrycia stawów osadowych. Jednocześnie należy prowadzić prace mające na celu stabilizację skarp i zboczy, przeciwdziałającą erozji wodnej zdeponowanego materiału. Rekultywacja biologiczna powinna zostać przeprowadzona zgodnie z modelem PAN z zastosowaniem intensywnego nawożenia mineralnego w pierwszych latach uprawy. Bardzo ważnym aspektem tej części rewitalizacji jest uwzględnienie w projektach zieleni gatunków roślin o płytkim systemie korzeniowym i wysokiej odporności na bardzo wysokie zasolenie podłoża, co potwierdzają obserwacje opisywane w pracach m. in. Boronia i in. 2000; Sroczyńskiego i in. 2007; Zająca i in. 2007; Gliniaka 2014, Gliniaka i in. 2014a i 2014b.*

*Słowa kluczowe: Krakowskie Zakłady Sodowe, rekultywacja, tereny zasolone*