Sustainable Land Use Principle as Employed in the Revitalization of a Zinc Spoil Heap Located in Ruda Ślaska, Poland

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Abstract. Part of the project called Implementation of Sustainable Land Use in Integrated Environmental Management of Functional Urban Areas - LUMAT comprised the revitalization of a zinc spoil heap in Ruda Ślaska, Poland. The first step was meeting the local community conducted by the ARCA Studio in order to learn their expectations and propose ideas for the area development. The next step was making a thorough study of the area conditions by the IETU Institute and the HORTUS Studio. The area in question is located in the neighbourhood of a densely populated settlement and could be potentially used as a recreational place. The main problem to solve was the remediation of the spoil heap area due to its high contamination by heavy metals. An additional danger was the steep slopes of the spoil heap. The 2017 design created by the HORTUS Studio provided a broad program for the spoil heap surface remodeling by covering it with protecting clay and soil layers. Besides, the majority of the area is turned into a meadow with plants possessing special protection features for phytostabilization. Part of the area is dedicated to the gradual rebuilding of the plant cover species composition. In order to protect the local biodiversity nearly all the designed plants are native. Some parts of the existing plant cover are left to demonstrate the historical metallophyte plants together with a hump of the original spoil material. The functional program meets the local expectations, having been consulted several times with the local community and their authorities. The recreational program contains a playing field, grill spots, view points, outdoor fitness, a playground, bicycle jumps, field hammocks and educational paths. To support the local identity a playground is designed with the object forms taken from industry; the educational paths provide information about the following issues: history of the local industry, features of the spoil heap deposits, local architecture, natural plant communities and birds living there. The aim of the paper is to show the complexity of re-designing postindustrial brownfields with relation to sustainable land use, biodiversity protection and respect for local identity.

1. Introduction

In Poland, the international LUMAT program, Implementation of Sustainable Land Use in Integrated Environmental Management of Functional Urban Areas, is implemented in Ruda Ślaska, Chorzów and Świętochłowice, which are three boroughs located in the centre of the Upper Silesian urban agglomeration. The aim of the project is to strengthen the green infrastructure in a Functional Urban Area. Basically, the project should provide protection of the existing plants following the principle that sustainable transformation into recreation areas should be achieved with reasonable use of the potential ecosystem services. Author of the paper was a leader of experts who prepared Action Plan for
mentioned above implementation of LUMAT program in 2017, and is leading designer of the LUMAT pilot project described there from the same year also.

The above-mentioned LUMAT program assumptions are implemented in the project of the revitalization of a zinc spoil heap area in Ruda Śląska, Poland. This paper discusses its details as the pilot project of the LUMAT program in Upper Silesia. The pilot project will serve as an example for further investments in other similar sites also selected as Functional Urban Areas. Following the LUMAT program requirements, their local biodiversity should be strengthened and the environmental interrelations improved by enriching the habitats and preserving the plants growing naturally in the degraded area. It is not simple task but possible to acquire in acceptable success. [1] Besides, it is sometimes required to apply remediation of contamination or phytostabilization. In order to maximize the ecosystem services [2], the areas in question ought to be opened up to the public by creating a recreation infrastructure. Its basic elements will include bicycle paths with stopping places, viewpoints and educational paths.

2. Regional context

The above mentioned pilot project conducted in the three Upper Silesian boroughs covers 25 Functional Urban Areas selected for revitalization as being postindustrial, wasteland and urban green areas. Their sizes vary from one hectare to a few dozen, with the exception of the Silesian Park (Park Śląski) of 535 hectares. Securing functionality entails connecting them with bicycle paths, which partially exists, but on the whole the infrastructure is not developed yet in postindustrial areas.

![Figure 1. Wastelands in Orzegów - an element of Functional Urban Area with high level of biological diversity but endangered by alien invasive species](image_url)

The Action Plan related to the LUMAT program is based on the diagnosis of the investment level in the green infrastructure as well as a possibility of its development within the context of the local
urban and natural circumstances [3]. The basic idea of the program is to increase the use of ecosystem services within the boundaries of a Functional Urban Area, which could be implemented by strengthening biodiversity of ecological corridors and core areas. The direct action should limit the spreading of invasive alien species and introduce indigenous species, thus increasing the diversity in their particular plant communities. The actions taken should increase the natural potential of the area and its biological efficiency [4]. Some of areas already have diversity of astonishing high level (figure 1). Especially Silesian brownfields are rich in rare bird species (figure 2).

![Rare species of birds can be often find in Silesian brownfields. Eurasian marsh harrier (Circus aeruginosus) is nesting in Żabie Doly - an area related to Action Plan](image)

Figure 2. Rare species of birds can be often find in Silesian brownfields. Eurasian marsh harrier (Circus aeruginosus) is nesting in Żabie Doly - an area related to Action Plan

In the social context, the project implementation should promote a healthy lifestyle, contribute to addressing phenomena such as social alienation and develop ecological education. The project should foster the sense of value of wild and spontaneously developing nature. Currently, the predominant opinion is that the existence of green areas or well-maintained parks is sufficient. It is not common knowledge that also the quality of green areas is essential. The positive effects depend on the harmony within the habitat, the diversity of habitats, their native character and the cohesion of a town's natural system, promoting natural processes and a variety of species. This ecological awareness can be developed by means of educational paths, sites for conducting outdoor lessons, various forms of recreation at the bosom of nature and also employing IT, as well as social actions like 'Clean the World' [5].

In the economic context, the project's aim is to activate investments related to recreation and public transportation. Thus, the creation of an efficient network of bicycle paths should limit car traffic in the agglomeration (figure 3). The experience in the countries in which ecosystem services are strengthened shows us that in this way it is even possible to increase work performance and decrease the number of doctor's leaves.
Figure 3. Elements of Functional Urban Area in Upper Silesia, Poland

Within the Functional Urban Area there was a well-developed railway system with a number of viaducts and embankments, not used any longer, which could be transformed into an efficient system of safe bicycle paths at a relatively low cost. Another positive aspect of implementing the Action Plan is transport and space. Time is vital, because many elements of the railroads are being dismantled carelessly to serve as a source of aggregate. The Action Plan points out certain priorities, namely preserving the existing infrastructure, strengthening ecosystem services, promoting blue and green infrastructure, decontamination, remediation, preserving nature potential of brownfields and popularizing social participation. The Action Plan includes also indications of how to administer the program implementation process.
3. Actions preceding the construction design of pilot project

3.1. Preliminary workshops with residents of the neighbouring areas

The actual construction design of the revitalization of the zinc spoil heap area in Ruda Śląska was preceded by consultations with the local community. They were conducted in the form of workshops by the ARCA Studio, Gliwice, in 2014. Their coordinator, Michał Stangel, established the local community's expectations concerning the design and, besides, the details of the local transportation network. The workshop participants were to determine what they liked about the area in question, and how the place was actually used. The answers ranged from nice views from the spoil heap top and its green area character, to its closeness of a shopping center. The problems pointed out were neglect and lack of safety. Their expectations involved the construction of sports and recreation facilities. In February 2017, a target development design of the HORTUS Studio was presented to the local community, which won their approval.

3.2 Pre-design studies

The analysis of the spoil heap plants carried out by Prof. Adam Rostański, Faculty of Biology and Environmental Protection of the Silesian University, showed the dominance of plants representing metallophyte species, thus proving the area's heavy contamination. The spoil heap plants could form colorful, even nice-smelling patches: pink ones with broadleaved thyme (*Thymus pulegioides*), white with bladder campion (*Silene vulgaris*), and yellow with mouse-ear hawkweed (*Hieracium pilosella*), or purple ones with thyrse sorrel (*Rumex thyrsiflorus*) against the green background of sheep fescue (*Festuca ovina*). Despite their attractiveness, they, unfortunately, collect toxic amounts of heavy metals in their over-ground shoots. Thus it was important to reduce the plant communities and replace with others able to retain contamination in their roots.

The heap area is overgrown with trees called pioneer plants, being the first to settle in degraded places and wasteland. These native species like common oak (*Quercus robur*), common mountain ash (*Sorbus aucuparia*) and silver birch (*Betula pendula*) are characterized by their ability to stabilize toxic compounds. On the other hand, common pine (*Pinus sylvestris*), also growing there, tends to acidify the soil and release toxic compounds. Thus, pines will be gradually replaced with other species, which will be done after other elements of the project have been realized, so as to keep the aesthetic effect socially acceptable.

The mineralogical and chemical analysis of the area carried out by Prof. Iwona Jonczy, Silesian University of Technology, confirmed a high Cd, Pb and Zn content. Fe2O3 constitutes cca. 25% of the spoil heap mass, and SiO2 ca. 20%. Other compounds in major quantities are magnetite Fe3O4, franklinite Fe2ZnO4, calcite CaCO3, gypsum CaSO4·2H2O and barite BaSO4. Besides, there are smaller quantities of various oxides like calcium CaO, magnesium MgO, aluminum Al2O3, sulphur SO3 and other elements. The amounts of the toxic compounds enforced the decision to cover the heap with insulating layers of clay and earth.

The landscape analysis showed a beautiful view from the spoil heap southwards. Consequently, view attractions will be located on the southern side of the heap and a playground at the bottom, considering its insolation as well as the nearness of apartment houses and shops. On its northern side, steep escarpments and a dangerously sharp slope of slag enforced the decision to make the slopes gentler. The fact that snow tends to remain longer on this side suggested creating a toboggan hill. The eastern side due to its diverse land form is used by BMX fans for off-road rides, which suggested equipping this place with additional elements for cyclists.

4. Development plan

The design introduces shape changes both to the northern slope and the spoil heap top. As the steep fall on the northern side will be levelled, the excess of the ground will be used for the construction of the toboggan hill and the viewing hill. On completing the modelling of the spoil heap surface, its remediation will be conducted. The northern slope is to be covered with clay and a layer of soil. Then
the ground will be fertilized and grassed over with a special mixture helping to keep contamination inside the spoil heap. Its top is to undergo a more advanced phytostabilization. That is, the upper layer of the spoil heap material is to be mixed with brown coal and a fertilizer including calcium, which should prevent toxic compounds of the layer from being released into the environment. Next, the area will be covered with a layer of soil followed by grassing over with a special mixture having phytostabilizing qualities (figure 4).

Figure 4. Pilot project development plan in Ruda Śląska. Different intensity of fills shows different kind of remediation methods.

The southern slope is not to be used for recreation but as a purely natural landscape, so users will only be moving along the paths. The plant content will be gradually replaced by appropriate mowing and occasional sowing of the target species. In order to reduce the raising of dust, the construction works should be carried out in winter. Parts of the existing green with metallophytes are preserved as plant signatures, i.e. witnesses of the past, the idea borrowed from New Zealand and Australia. In areas radically transformed certain places are preserved in order to show what naturally developed plant communities looked like. These areas will be pointed out and described on information boards as natural plants growing spontaneously in the zinc spoil heaps of Upper Silesia. On the northern side, in turn, a sintered boulder will be preserved as part of the original sharp slope with its exposed slag surrounded by metallophyte species. The boulder will be protected with a barrier from free access.

An important element of the design is trees, that is their selection and planting schemes. The changes introduced to the northern slope of the heap have caused the removal of the trees growing there. Following the sustainable development principle of promoting native plants, the trees to be planted are indigenous like common oak (Quercus robur), silver birch (Betula pendula), and common mountain ash (Sorbus aucuparia). Moreover, their natural occurrence there proves their resistance to the chemical content of the heap. They will be planted in regular groups following an orthogonal grid in order to emphasize the anthropogenic origin of the spoil heap landscape and its composition.
elements. Birches will provide a delicate shade in the grill area. Rows of common hornbeam (Carpinus betulus) planted at the bottom of the northern slope will form green walls for children to play games in e.g. tag or hide-and-seek.

In the southern part the native plants will be more decorative like birch and mountain ash as well as silver maple (Acer saccharinum), which, however alien, grows quickly and has an openwork crown. Thus the trees should provide a partial shading of the playground and various devices in its neighbourhood. The decorative bushes planted here will be used twofold, namely, to hide the transformer stations placed nearby and to improve the looks of the playground.

Since the heap top will have a playing field, a protective wall of earth is designed near the northern slope to prevent balls from rolling down. Moreover, the wall will have tunnels for children to play in. In the neighbourhood of the playing field, a viewing hill will be located. On the educational path designed at the edge of the southern slope there will be an outdoor fitness site next to a small beauty spot surrounded by rocks and cinders from the heap. Similar fragments will be exhibited also in other places e.g. a huge dolomite 1m in diameter, demonstrating zinc and lead ore deposits. In yet another place, three vats from an arc furnace will be filled with earth and planted bushes of boxthorn (Lycium barbarum) to imitate the smoke coming out of a vat with melted pig-iron.

![Figure 5. Hammocks designed in pilot project area in Ruda Śląska.](image)

On the western side of the heap, grill spots will be found separated by means of belts of giant miscanthus (Miscanthus x giganteus). The grill sites will consist of sand-pits with gravel, which is to additionally protect users from the plants rooting in the heap material. Concrete boxes with benches reflecting light at night are planned as recreational facilities for landscape watching. Inside they will have information boards about the history of the local industry, also about the local birds and plants. Besides, supporting structures for hammocks are designed in the form of arched elements covered with wooden rungs. The bad quality of the environment, particularly of the air in the Upper Silesian industrial zone, prohibits the use of canvas elements because they would be dirty in a few days due to the dust. For this reason, one's own hammocks will have to be brought. The carrying structure might be used as a bench even without a hammock (figure 5).
On the northern slope there will be a toboggan hill. The site is attractive enough as the altitude difference is about a dozen meters. The toboggan hill will be hidden from the sun and sheltered from winds by the surrounding scarps.

The south-eastern part will contain a downhill route with a springboard for BMX users, since already a large group of young BMX fans make use of a natural steeplechase track formed by a birch coppice growing on this slope. To meet their needs, the design will include a circus with a few jumps and various slopes for BMX riders. Younger children will have an enclosed playground whose structures of turrets and foot-bridges refer to the mining and metallurgical character of this area. The structures resemble a pit-head and blast furnace shells. Although the playing facilities are typical, yet they are modern in character, and in form similar to industrial structures. On the slope near the enclosed playground there will be a multi-slide and on the nearby meadow eight grassy hillocks for outdoor games.

The project introduces a wide range of educational elements. Information boards in this section present historical facts about ore mining in Upper Silesia, which goes back to 1136. At the beginning, it was mainly silver, later lead and iron. In the 19th cent. zinc metallurgy developed. In 1786 Lazarus Henckel von Donnersmarck had a blast coal-fired furnace installed at Haledz, a district of Ruda Śląska, which was in blast till the beginning of the 19th century. In 1805 Baron Donnersmarck had the Antonienhuette ironworks built at Wirek, a district of Ruda Śląska, as well as the Gottessegen coal mine in order to provide the ironworks with coal supplies. In 1812 the Hugo works was opened, followed by the Liebe-Hoffnung, which deposited its spoils on the revitalized heap, and finally the Antonina rolling mill of zinc sheet was built. Near the spoil heap area one can still see a well-preserved workers' housing estate, named Ficinus Colony built in 1860-1867 for the workers from the Gottessegen mine. The houses have a characteristic architectural detail, namely their corners and window framing are made of brick, whereas the remaining part of the wall is sandstone. The 1880s brought a technology facilitating the local production to such a degree that a majority of the arms production in WW1 was based on the zinc made here. In the 1930s a more effective method was employed raising metal purity up to 98.5%. In the 1950s a modern method of zinc production was invented, which is still used. Also the former zinc spoil heaps began to be processed with a lot of zinc retrieved as a result. The information boards in this area mainly deal with ores exploited, features of slag deposited, zinc production technology, and the use of metallurgical vats. Apart from the industrial section, the boards will also describe plants typical of this site which all have the ability of succession in the areas of zinc spoil heaps. Some of them are indicator plants whose presence shows that the area is contaminated by heavy metals e.g. haller cress (Cardaminopsis halleri). Beside the plants mentioned earlier, one will learn about sand rock-cress (Cardaminopsis arenosa), sea thrift (Armeria maritima), broadleaved thyme (Thymus pulegioides), heart's ease (Viola tricolor), ribwort plantain (Plantago lanceolata), broad-leaved clover (Trifolium pratense), and common mullein (Verbascum thapsus). Another board will discuss the phytostabilization process applied. Mixing the upper layer of the ground with brown coal and calcium fertilizers should neutralize heavy metal compounds and prevent plants from absorbing them. Next the area is covered with fertile soil in order to create proper conditions for the growth of grasses having the ability of phytostabilization i.e. creeping red fescue (Festuca rubra) and rye grass (Lolium perenne). Even if the soil contains heavy metal compounds, they are not transported to their overground shoots. Also giant miscanthus (Miscanthus x giganteus), which separates the grill spots, has this ability.

5. Conclusions
Following the slogan of Local Agenda 21 - Think globally, act locally, the revitalization of a zinc spoil heap in Ruda Śląska seems to be an essential element of constructing a system of recreation areas in Upper Silesia in degraded areas and wasteland. So far such areas have been treated as sites for indiscriminate development, regardless of their potential function in the natural system of the Upper Silesian agglomeration. That is why many similar places have been used as building sites, thus causing the loss of many potentially important connections of the green system. Basically, sustainable growth
always aims at people's welfare, even against their vested interests. Both, the Action Plan implementation and strengthening the ecosystem services will allow us to save the natural values of the agglomeration and improve them. The main advantage, however, will be a conscious process of improving the urban structure aiming at a healthy environment, thus creating the best possible living and working conditions for about three million people living in the agglomeration. This project of the revitalization of the zinc spoil heap in Ruda Śląska makes us aware of the complexity of local investment problems, but also of how to use the potential of brownfield effectively for the people and nature.

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