International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:13, No:4, 2019

Managing the Baltic Sea Region Resilience: Prevention, Treatment Actions and Circular Economy

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***Abstract*—**The worldwide future sustainable economies are oriented towards the sea: the maritime economy is becoming one of the strongest driving forces in many regions as population growth is the highest in coastal areas. For hundreds of years sea resources were depleted unsustainably by fishing, mining, transportation, tourism, and waste. European Sustainable Development Strategy is identifying and developing actions to enable the EU to achieve a continuous, long-term improvement of the quality of life through the creation of sustainable communities. The aim of this paper is to provide insight in Baltic Sea Region case studies on implemented actions on tourism industry waste and beach wrack management in coastal areas, hazardous contaminants and plastic flow treatment from waste, wastewaters and stormwaters. These projects mentioned in study promote successful prevention of contaminant flows to the sea environments and provide perspectives for creation of valuable new products from residuals for future circular economy are the step forward to green innovation winning streak.

***Keywords*—**Resilience, hazardous waste, phytoremediation, water management, circular economy.

I. Introduction

The Baltic Sea environment is exposed to pollution already from late 19th century; pollutants emitted or discharged by households, traffic, industries and agriculture. Many of these substances, like oil products, heavy metals and other contaminants, known to be very dangerous are forbidden and create concerns in coastal areas, soil, sediments, waste and surrounding groundwater sources. Hazardous substances are transported to the sea via water courses and the air making the Baltic one of the most polluted seas in the whole world and affecting the life of about 85 million people living in the Baltic Sea catchment area [1].

Nutrients are posing large problems for eutrophication and this is highly the concern for EU [1]. The risk of eutrophication and oxygen deficiency during the summertime in EU costal waters is the problem starting from Baltic Sea Region, across the Blacks Sea and its smaller appendices as well as Caspian region [2], [3], the problematic eutrophicants are coming in from watersheds from densely populated areas, agricultural lands as well as wastewater treatment places. Baltic Sea sediments are phosphorus internal leaching 100 000 t a year however from agricultural lands just 30 000 [1]. Furthermore, the world's production of chemicals has increased from 7 million tons in the 1950ths to 400 million tons in 2000. These chemicals can lead to a great environmental problem in the future. The problems connected with dangerous hazardous substances are worldwide [4]. Our Baltic Sea Region is one of most contaminated in the world [5], [6]. Water residence in Baltic Sea is 30 years per cycle, intensive economy and 85 million people do the problem topical. All cocktail of hazardous and toxical trace elements are sinking in sediments in time and space [7], [8]. The sediments are mixing up when the ships and streams mix the waters and toxicants go around in the food chain.

The EU Waste Framework Directive (2006/12/EC), the EU Water Framework Directive (2000/60/EC) and the EU Groundwater Directive (2002/118/EC) are important legislative tools for environmental protection. Other NGO resources exist in Europe to support work on remediation, e.g., The European Commission's Joint Research Centre (JRC) Land Management and Natural Hazards Unit. The EU adopted the Environmental Technology Action Plan in 2004 to encourage the development and broader use of environmental technologies, including environmental remediation technologies. The Network for Industrially Contaminated Lands in Europe (NICOLE), The European Coordination Action for Demonstration of Efficient Soil and Groundwater Remediation (EURODEMO) decade ago promoted sustainable, cost-effective soil and groundwater remediation technologies, elaborated protocols for efficient and sustainable actions.

The aim of this paper is to provide recommendations through describing environmental management case studies at coastal areas, management and treatment of hazardous contaminants.

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II. Case Studies

A. Sediment Pollution at Bays

Kalmar and surroundings has a bit more than 160 000 inhabitants, business, culture and environmentally sustainable innovations and well-considered focus on marine ecology and landfill/harbor contamination. "Kalmar Strait Commission" coordinates costal municipalities along the east coast of

Sweden. The cooperation has resulted in a wide set of marine projects such as: "Aqua best" (Interreg) for mussel farming and other. The focus has been on recycling of phosphorous by introducing large scale commercial mussel farming within the Baltic Sea ("Blue growth" - A seed money project financed by the secretariat for the Baltic Sea Strategy). Based on Malmbay dredging project experience Kalmar wishes to develop methods based on the removal phase and recycling of - to clean sediments and improve water quality. The SURE-project (LIFE) as continuation of started work demonstrates a disruptive, cost effective bottom sediments treatment [1]. Today, in EU more than 200 million cubic meters of sediments are annualy dredged in EU borders: 1) to dredge with a minimum of disturbance and release of toxic and nutrient rich sediments; and 2) to manage and recycle the sediments cost-effectively for beneficial use. LIFE SURE project will: 1) Treat and recycle up to 70% of dredged sediments. Focus is put on both toxic substances and nutrients. 2) To demonstrate a mobile dredging technology which will be 20% cheaper compared to state of the art. Today the cleanest dredging methodologies are expensive and technically advanced. 3) Optimizing technical solutions. 4) Presenting and popularizing results to other stakeholders. The triple helix character is in line with a number of EU policies and interregional agreements. During the SURE-project 40 000 m^3 of sediments will be removed from Malmfjärden in Kalmar city [1]. The project is related also to fulfill obligations to EU legislative documents.

B. Coastline Dumping

Landfills represent one of the main sources of heavy metals to the Baltic Sea environment. Industry, commerce and residential areas create waste and still even the best recycling does not solve problems with landfilled masses. The special attitute may be paid to historical closed landfills (dumps). Landfills can provide new inexpensive resources of metals and construction soil that can be used further in different industries like cement, foam glass, flooring and other construction industries and be part of the circular economy [9]. Different chemical, physical and biological remediation techniques have been used for the remediation and the rehabilitation of contaminated soils with heavy metals but all these methods are in general expensive, labour intensive and result in extensive changes to the chemical, physical and the biological properties of the treated soil [10]. The physical and the chemical methods are in general applicable for small areas and not for large areas like the situation of the glassworks landfills in Småland. Phytoremediation is a relatively cheap technology; uptake of metals by plants happens through roots and shoots thus diminish the pollution in soil [11]. The Triple helix collaboration is always important to get succesful stakeholders involvement, move step by step and implementing phytoremediation as succesful gentle technology elaborate public environmental awareness [12]. In Estonia, during the landfill mining project of the Kudjape landfill in Saaremaa (sponsored by the Swedish Institute), the phytoremediation technique was used as a rehabilitation step after the excavation of the landfill in a form of a recreation park. The same idea can be used to remediate and recover the glassworks sites in Småland after excavation by combining the knowledge gathered from the Estonian project and the talents of the glass artists in Sweden to build a phytoremediation tourist glass park in a selected old landfill site in Småland like the Boda glasswork in Emmaboda.

Fig. 1 Orrefors Park in October 2017. Photo: Jovita Pilecka

Phytoremedial actions as a tool may help the region to meet the goals of sustainable development and restored ecological status established by the HELCOM to be reached by 2021. The main goal of the policies EUSBSR2013 PA Hazards and the BSAP2007 A is to reduce the use and the impact of hazardous substances in the Baltic Sea region and these mentioned projects were exactly driven to reach the targets.

C. Water Treatment Sludge at Catchment Areas

Other novel studies were performed in Southern Sweden about water supply sludge stochastic storage site. Ringsjöverket in Stehag, Eslövs municipality, managed by Sydvatten AB, has been in operation since 1963. At present, the waterworks supply approximately 900,000 inhabitants with drinking water from Bolmenjön and the annual distribution for 2015 is 45 mm^3. Since the mid-60s, water production has shown a steady positive trend, and from 2010 to 2015, water distribution increased by 29%. Before the 80-kilometer Bolment tunnel was commissioned in 1987 to lead Bolmensjövatten to Ringsjöverket, a measure taken to cover the prevailing water consumption needs in the Skåne region, Ringsjön was used as a raw water source. The preparation for interconnection of the tunnel to Ringsjöverket was initiated in the 1970s by upgrading the work with four parallel flocking systems with subsequent lamellar sedimentation and fast sand filtration as a reinforced treatment step for Bolsjö's humus-rich water [13]. Rönneholms Mosse is located on exploited peat moss, at which activity for peat is driven. Generally, there are water bodies lined with aluminum deposited in the deepest and central parts of the ponds while in the outer areas, iron sludge has been laid on top of the aluminum sludge. The ponds are overgrown with local vegetation such as marsh, cavalry and various grass species.

Fig. 2 Location of Rönneholms Mosse in Southern Sweden where the sludge samples were derived (authors' workout using GeoHack Globala Karttjänster and Google Maps)

The quantity and character of the deposited waterlogging in Rønneholm's area has fluctuated over the years, due to parameters such as the composition and degree of pollution of the raw water (Ringsjön and Bolmen), the amount of chemicals and the use of precipitates (iron chloride or aluminium sulphate) and the function and condition of the water treatment technology for sludge thickening and dewatering. The long term analysis was scheduled to discuss opportunities of using the sludge potential for possible aluminium, iron or even possibly rare earth elements extraction from the sludge to industry needs [13]. However, results showed that these can be estimated as very hypothetic reserves of metals as concentrations even if high still lack processing options in sustainable way [14], [15].

D. Nutrient Retention from Agricultural Areas

As agricultural diffuse pollution is one of the significant nutrient sources in the Baltic Sea as defined in EU Nitrates directive [16], a holistic approach on nutrient retention from agricultural lands was studied. The study site is located in Zemgale region with intensive agricultural activities. Two separate constructed wetlands were implemented to control surface and drainage runoff from agricultural area and to improve water quality retaining nitrogen and phosphorous compounds as well as suspended solids. Water samples were collected at the inlet and outlet of the each constructed wetland, since June, 2014 using a grab sampling approach once or twice per month depending on water discharge. A horizontal subsurface flow constructed wetland (Fig. 3) was built with a purpose of treating nutrient-rich storm water from a farmyard area. A treatment method with open sedimentation pond as a pretreatment stage was chosen to possibly enrich water with oxygen and thus activate aerobic bacteria through nitrification process that would decrease ammonium-nitrogen concentration. Then water was periodically pumped to the filter part of horizontal subsurface constructed wetland. The surface area of the wetland filter was 1.2% of the catchment area. The subsurface flow constructed wetland showed a steady decrease of ammonium-nitrogen and total nitrogen throughout the year by 68% and 53%, respectively, when concentrations at the inlet and outlet were compared.

Fig. 3 Subsurface constructed wetland in the farm Mezaciruli, Latvia. Photo: Linda Grinberga

The potential to retain nitrate-nitrogen more efficiently during the vegetation period was detected as a result of plant uptake. Wetland showed a total phosphorous reduction by 89% in a study period without an efficiency impact of seasonality. The in-stream surface flow constructed wetland was built on the open drainage ditch to collect surface and drainage runoff from an agricultural catchment. Surface area and catchment area ratio was 0.5% for the wetland. The surface flow constructed wetland showed the reduction of the concentrations of total nitrogen on average by 19%. The slight increase of ammonium-nitrogen was detected during the low or no discharge conditions, but throughout the study period ammonium-nitrogen concentrations were reduced by 36%. Total phosphorous concentrations were reduced by 50% after the wetland treatment in a study period.

E. Phytoremediation of Brownfield

Latvia-Lithuania project's aim is to revitalize within the project three brownfields:

First territory is former linen factory in **Ludza**, Latvia with total area 8.97 ha, where air quality in the former linen factory area should be described as good, as there are no volatile petroleum products in the area and no economic activity. While heavy metals are naturally in the soil, anthropogenic activities increase their concentration, and heavy metals become harmful to both plants and animals [17]. In the former area of the linen factory, the soil is potentially contaminated with a variety of chemical elements left in linen tannery ponds. Bioremediation, which includes phytoremediation, is an environmentally friendly method as soil remediation using pants is natural processes [17]. Phytoremediation is also an economically viable method, since soil is not moved anywhere and purification takes place on site in the contaminated area. Heavy metals do not disappear during bioremediation; these become in chemically different form - less toxic, slightly vaporized, more soluble in water. Therefore in this way heavy metals can be removed through precipitation from the environment [17]. Phytoremediation is best used technology when large areas in low concentration are contaminated with heavy metals and have to be cleaned [17]. In the site, the level of groundwater fluctuates seasonally with the first peak in spring following the melting of the snow and with a minimum during the summer. The site is surrounded by a network of ditches and a pond where it is likely that contamination from the ponds of the former linen mills can leach.

Second area of former Ignalina district, Lithuania with total area of 385 m^2, where abandoned heating plant with heavy fuel pollution is both inside the building and at surroundings: Soil poses an increased risk to air pollution by volatile organic compounds, particularly during the summer period, when the rise in air temperatures results in volatile organic compounds released from the mass of heavy fuel. The soil is contaminated with heavy fuel oil moreover mechanical properties of the soil have been changed as pores are filled with the mass of heavy fuel, thereby increasing the plasticity of the soil. Infiltration in such soil is difficult, resulting in long-standing pools of water in which water is contaminated with soluble petroleum products. The aeration of the soil is reduced and there are no oxygen-free zones where anaerobic processes are taking place and any biochemical processes are stopped. Lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni) are common in contaminated soils [18]. In the samples taken, As was found in all samples (Kuiskis 2,1 mkg/g, Ludza 2.4 mg/g and Ignalina 1.5 mg/g). In the site, the level of groundwater fluctuates seasonally with the first peak in spring following the melting of the snow and with a minimum during the summer low water period. The area is on the mound and a major surface runoff is possible during the rain, which can carry pollution to the nearest surface water source.

Territory of former oil products station in Kupiškis district, Lithuania with total area of 313 m^2, there is no air pollution in the former oil storage facility. However, it should be taken into account that any in-depth excavation or alignment work may present a risk of contaminating the air with volatile organic compounds. They may be released during excavation, particularly during the summer period, when an increase in air temperature results in volatile organic compounds being released from petroleum products which may be present in the soil. Soils may become contaminated by heavy metals and metalloids due to emissions from fast-growing industrial zones, mine waste, major metal waste disposal, lead petrol, paints and fertilizer use, animal manure, sewage sludge, pesticides, coal incineration, petroleum chemical products and atmospheric deposition [19]. Soils are the main site of accumulation of heavy metals released into the environment with the abovementioned anthropogenic activities and, unlike organic pollutants which oxidize microbiologically to carbon (IV) oxide, most metals are not subject to microbial or chemical degradation [20]. In the vicinity of the site, the level of groundwater fluctuates seasonally with the first peak in spring following the melting of the snow and with a minimum during the summer low water period.

In closure of the project the outcome will be full revitalization of Ludza, Ignalina and Kupiskis brownfields. Monitoring and publishing of success stories will provide new platform for further brownfield treatmenyt in EU and beyond.

III. Discussion

It is axiomatically known that performance and management of projects is highly dependent of choosing the partners and locations for the pilot projects. Partners were selected based on their expertise and team capacities; thus it is easy to take full responsibility for the dissemination of the project results once the project has ended as well. It is important that pilot studies and actions are promoted further as an example or even best available technologies in solutions of definitive problems. E.g., institute/ cluster as they will be co-founding members of this initiative and want to promote their regions and the solutions being implemented there. One of the reasons for the creation of the institute/cluster is also to be able to transfer the knowledge about the installed solutions between the South Baltic Regions and at the same time induce new initiatives and cooperation. According to beneficiaries, not only the project results will be sustained, but they will also lead to additional installations in the region through the triple-helix approach in the institute/ cluster. We see this initiative as a great opportunity to use the prior experiences from the South Baltic Programme, LIFE or Swedish Institute supported projects to achieve a high degree of environmental impact and at the same time involve SME´s, Universities and public organizations for the benefit of the entire region.

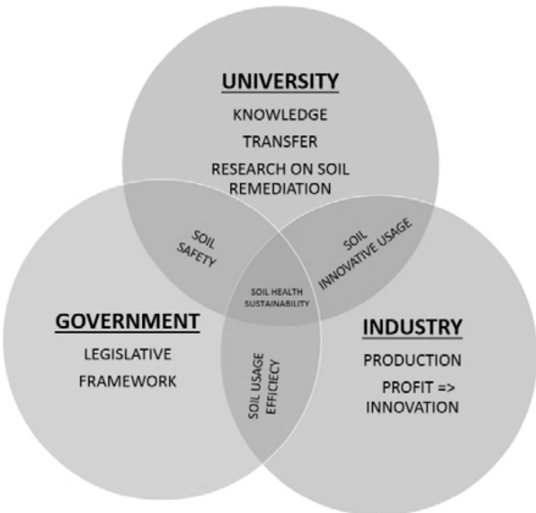

Fig. 4 The conceptual framework of Triple helix in soil remediation field. Source: author's construction

IV. Conclusions

Projects promote collaboration between different organizations in the Baltic Sea countries in research related to the ecological sustainability in the region by implementing workshops, online meetings and other joint planning activities so that the engaged organizations and countries will learn, develop and contribute their own perspectives to face the challenges of environmental and sustainability planning in Baltic Sea Region. It may be for instance, phytoremediation tourist glass park in Boda glasswork in Sweden where gathered knowledge of making a tourist park in an old landfill area is used as a marketing tool. Also Estonian Kudjape landfill becoming the park has enlarged the wide public interest to sustainable solutions – as we see these solutions in life not in academic shelves or municipality plans in distant future. The main goals of all mentioned project in the paper is fulfilling plans established by the Helsinki Commission (HELCOM), EU Strategy for the Baltic Sea Region (EUSBSR) - creation of cross-sector partnerships within different countries in the Baltic Sea catchment area in different levels of the society is the promising strategy. The role of partnership between different organizations will be to support and stimulate cooperation in Baltic Sea region for sustainable relationship among partners.

Acknowledgment

The research was supported by Interreg Interactive Water Management (IWAMA) and Baltic Beach Wrack - Conversion of a Nuisance To a Resource and Asset (CONTRA) as well as RBR (Reviving Baltic Resilience) Interreg-V-A project, grant No. STHB 02.02.00-22-0092/16 of EU South Baltic Programme 2014-2020. Great thanks to Swedish Institute about the PECEC and LASUWAMA projects and Geo IT Ltd. from Republic of Latvia. Additionally it was supported by the European Union, the European Regional Development Fund, and the Central Baltic Programme project CB295 "Practical actions for holistic drainage management for reduced nutrient inflow to Baltic Sea (NUTRINFLOW)". Finally it was supported by the European Union, the European Regional Development Fund, and the Interreg V-A Latvia – Lithuania Programme 2014-2020 project LLI-325 "Innovative brownfield regeneration for sustainable development of cross-border regions (BrownReg)

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