(PP9) PILOT ACTION REPORT

Version 1

Deliverable D.T3.5.6

July 2019

Prepared by: Hanna Lewandowska

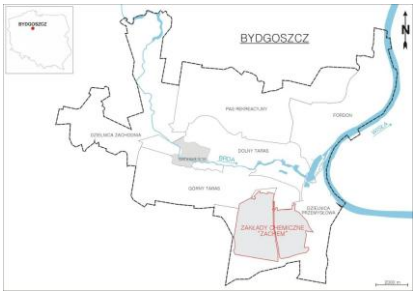
Contents

1. Pilot Action title

Ground and groundwater monitoring on the inhabited area near brownfield site.

2. Place/area of PA implementation

One of the oldest and at the same time the largest in Poland, "Zachem" Chemical Plant JSC administratively is located in the Kuyavian-Pomeranian voivodeship, Bydgoszcz poviat, within the borders of the Bydgoszcz town. It is situated in the south-eastern part of the town at a distance of about 7 km from the centre, From the hydrographic point of view, the characterised area belongs to the water catchment area of the Vistula river. The main surface watercourses are: The Vistula River and its left-bank tributary - the Brda River.



The area of the former "Zachem" Chemical Plant in Bydgoszcz covers about 2000 ha. Currently, in the area occupied before 1992 by the Plant, a number of independent business entities have their headquarters. The area of the "Zachem" Chemical Plant – is therefore historical and contractual, and refers to the area occupied by the Chemical Plant in Bydgoszcz before 1992. This entire area was subjected to preliminary research due to the high potential of threat to the soil and water environment. The area borders with inhabited settlements Łęgnowo and Łęgnowo –Wieś.

3. Duration of PA implementation

The activities started in July 2017 and will end in July 2019.

4. Costs related to PA

The following costs were incurred for the implementation of PA (the conversion rate to EUR 4,3 PLN):

- Inventory of existing wells and drilling 15 new piezometers, ground water analysis – 316 761,35 PLN, 73 665,43 EUR
- Hydrogeological model of ground water and contamination flow – 84 870 PLN, 19 737,21 EUR.
- Guidelines for monitoring – 29 450 PLN, 6 848,84 EUR
- Risk analysis – project of ground analysis and risk analysis report – 84 879 PLN (soil tests) + 55 000 PLN (risk analysis report), 139 879 PLN, 32 527, 91 EUR.

5. Background and challenges faced

5.1 Background

Until 2013 the Chemical Plant "Zachem" in Bydgoszcz was among the largest producers of organic chemistry on the Polish market. The study of the archival topographic maps shows that the Chemical Plant was established at the exact place of the former German explosives factory built during the Second World War (Schiegel, 1878; Sckerl, 1878). *Dynamit-Aktien Gesellschaft (DAG) Fabric Bromberg* was a huge armaments factory, designed for military tasks of the Third Reich. It was established nearby Bydgoszcz in 1939 – 1945. The most rapid development of the plant for the secret production of gunpowder and ammunition filling, due to the hard work of forced laborers, falls in the period of the Nazi regime. The main products of the DAG in the Bauleitung I (Kaltwasser) zone was nitrocellulose ($C_6H_7O_{11}N_3$), smokeless gunpowder and nitroglycerin ($C_3H_5N_3O_9$).

February 1954 is considered as the symbolic beginning of the "Zachem" Chemical Plant in Bydgoszcz, while the production was resumed in 1948 when blasting materials for mining were initially produced.

Then the production was adapted for both military and civilian needs, when TNT, pentaerythritol tetranitrate and tetryl were produced. After five years dyes, dyeing intermediates, pigments and phenol started to be produced. Dinitrotoluene (DNT), nitrobenzene, aniline and products made from recycled PVC were also manufactured. Moreover, acid denitration and nitration acid management was conducted. In the beginning of the 60s of the previous century experimental installations for the production of isocyanates, diene and polycarbonate were tested in the Chemical Plant. Studies for the construction of polyurethane complex were conducted and in the next decade the Plant invested in the production of flexible polyurethane foams, installations for electrolysis of brine, phosgene, DNT, toluene diamine (TDA), toluene diisocyanate (TDI) and epichlorohydrin (EPI) as well as rigid foams and fittings from polyurethane foams for the automotive industry. The production profile of the Chemical Plant evolved over the decades, having regard to the needs of the market and the political and economic situation of the country. It was also affected by the investment stagnation, which in the previous century resulted from economic difficulties of Poland. Basic and most important products manufactured in the Chemical Plant in the last period of its operation included toluene diisocyanate TDI, allyl chloride, epichlorohydrin EPI, hydrochloric acid, sodium hydroxide and sodium hypochlorite. Polyurethane foams were among the products manufactured on a large scale. These compounds (polyurethanes PUR or PU) are polymers that are produced by addition polymerization of polyfunctional isocyanates and amines and alcohols.

On March 14th 2014 the company went bankrupt and its assets are managed by the trustee.

The area of activity of the former chemical plant "Zachem" should be treated in its entirety as a potential source of groundwater pollution, especially the Quaternary aquifers (water-bearing levels) and the Neogene level being locally in hydraulic contact. In 2016 The Regional Directorate for Environmental Protection in Bydgoszcz carried out, as part of its own work, theanalysis of the condition of the environment in the areas belonging to the liquidated chemical plants, as a result of which 19 pollution outbreaks were separated in the area of the former
Chemical plant - "Zachem".

5.2 Challenges faced

The whole process of revitalisation of this mega site will be a long process that requires specific knowledge and huge financial contribution, many engaged parties. Also the ownership of responsibility is not clear at this stage. Few cases are being processed in the court. Another aspect is the close vicinity of residential area and the agriculture production that is taking place and Natura 2000. The challenges faced during the realisation of pilot activities which are only a starting point might be the red light for those for all players who deal with this brownfield areas.

Main challenges identified during pilot action:

- Cooperation of many local stakeholders;
- Lack of plan for the area, each of the owners is dealing the part of the area by itself;
- Financial sources that are needed for remediation and couldn't be coped by small businesses or even a local institutions;
- Gaining data from different data owners, need for one platform;
- Knowledge about specific organic contaminants;
- Availability and costs of laboratory tests – some organic substances are tested by no laboratory in Poland, all probes shall go abroad – this makes them costly and the time is longer;
- Social communication, inhabitants are afraid about impact of contaminants and expecting more actions from public and institutions.

6. PA objectives

The overall objective of the pilot action was to recognize the environmental condition of inhabited area Łęgnowo Wieś, assessing the risk for human health and propose future monitoring activities. Several specific sub-objectives were identified:

- Checking the number and conditions of wells,
- Build a monitoring barrier in Łęgnowo Wieś,
- Check the groundwater quality in the area,
- Modelling migration of ground water and contaminants in up to 25 years in the future,
- Assessing the risk for inhabitants,,
- Defining future monitoring activities
- Deliver the knowledge about impact of contaminants in the groundwater.

7. Activities carried out

The activities carried out within the pilot consisted of recognition of the environmental condition on the inhabited area Łęgnowo Wieś, assessing the risk for human health and propose future monitoring activities. A wild representation of local institution was engaged in the pilot activities which were realised at the time of high interest of inhabitants and media. At that time local and national TV produced the documents and spread the knowledge about danger of the contaminants from former chemical plant. For this reason the pilot activity was on political agenda and every step was commented. This situation made work more difficult. In detail, Bydgoszcz carried out the following actions:

1. Inventory of existing piezometers and wells in order to check their functionality and number for future monitoring purposes. Taking and analysing 18 probes.

As part of this project, the following were performed:

- inventory of 51 individual wells and 20 piezometers within the Łęgnowo Wieś estate and its neighborhood, including the determination of location coordinates, measurements of technical parameters of piezometers, groundwater field measurements and conducting surveys in the field of usability of wells,
- collection and laboratory analysis of groundwater from 8 selected, in agreement with the Ordering Party, individual wells located within the limits of the Łęgnowo Wieś estate,
- inventory of 44 monitoring wells in the field (piezometers and inactive wells) located in the area covered by the activities of the former Chemical Production Facility "Zachem", including the determination of location coordinates, measurements of technical parameters of piezometers and ground field measurements of groundwater,
- collection and laboratory analysis of groundwater from 10 selected in agreement with the Ordering Party monitoring wells of the former Chemical Production Facility "Zachem".

Due to the lack of consent of the owners of the area or the inability to obtain such permission effectively despite attempts made in this area probably 30 piezometers being part of the former monitoring subsystem of the "Zielona" landfill site and piezometers located on the premises of Nitrochem S.A. have not been included in the inventory allowing to verify their exact number or to assess their actual location.
The Assessment of groundwater contamination rate covered by individual wells in selected properties of the Łęgnowo Wieś estate and in piezometers belonging to the monitoring network of the former Chemical Production Facility "Zachem" and determining whether the analyzed areas contain chemical substances in quantities exceeding the established quality standards was carried out on the basis of physicochemical analyzes in relation to the applicable ordinances of the Ministry of the Environment and the Ministry of Health and based on standards / recommendations used in other countries.
The scope of performed physicochemical analyses included:

inorganic ingredients: Ca, Mg, Na, K, Cl, SO4, HCO3, SiO2, NO3, NO2, NH4 and As, Al, B, Ba, Cr, Co, Cu, Fe, Li, Mn, Ni, PO4, Sb, Sr,

organic ingredients: Total Organic Carbon (TOC), Phenol, Aniline, components BTEX (Benzene, Toluene, Ethylobenzene, Xylene), Diphenylsulphone, Chloroaniline, Epichlorohydrin, Hydroxybiphenyls, Nitrobenzene or total of nitro compounds, Octylophenole, Toluenodiamine, Toluidine, total PAH, total AOX and PCE i TCE,

physico-chemical parameters: temperature, water reaction (pH), Electrical conductivity and Redox Potential).

The results of laboratory analyses showed that none of the water samples collected met the chemical requirements set out in the Ordnance of the Ministry of Health on the quality of water intended for human consumption (Journal of Laws 2017 item 2294). With reference to the Ordnance of the Ministry of the Environment (Journal of Laws 2016 item 85) on the criteria and method of assessing the status of bodies of groundwater.

None of tested water samples meet the standards for class I-III, and only at one measurement point the quality of water corresponds to the requirements of class IV. The remaining water samples were classified as V class of the quality. Analyzing received results with reference to the Ordnance of the Ministry of Environment on conditions to be met for sewers discharged to waters or to the ground, and on substances particularly harmful to the environment water (Journal of Laws 2014 item 1800) in a few samples the quality of the tested waters exceeds the standards for sewers to waters or to the ground.

Analyses of almost all water samples showed iron and manganese concentrations exceeding the maximum allowable concentration. In addition, in many samples of water, there are over-normative concentration of Sulphates, Chlorides, Phosphates, nitrogen compounds, bicarbonates and organic compounds, expressed in the form of total organic carbon (TOC).

Amongst specific contaminations associated with the production profile of the former Chemical Production Facility "Zachem", in the two samples of water tested, excessive concentration of polycyclic aromatic hydrocarbons (PAH) and benzene were found. In single water samples, high concentrations of semi-volatile organic compounds specific for production profile were found, such as Aniline, Nitrobenzene, Phenol and organic compounds such as Diphenylsulphone, Toluendiamine, Hydroxybiphenyl and Toluidine. In addition to specific contaminations in significantly elevated concentration and exceeding the quality standards in all water samples tested, adsorbed organochlorine compounds (AOX) were determined.

In the light of the obtained results, it can be pointed out that a significant area in the borders of the Łęgnowo Wieś estate is contaminated by toxic organic and inorganic substances that have penetrated the groundwater stream from the former Chemical Production Facility „Zachem" in Bydgoszcz. However, it should be considered that this is a point-based assessment and it is not possible to determine spatial environmental conditions on this basis. The current monitoring network is insufficient to fully interpret the process of migration of contaminants from the area of former Chemical Production Facility "Zachem" towards the Łęgnowo Wieś estate. Until now, piezometers have been designed individually, creating local monitoring networks around identified contamination sources, and therefore their location and depth is not adapted to the hydrogeological conditions found in the investigated area. Boreholes are often too shallow and not properly localized and therefore they do not provide a possibility of interpretation of environmental conditions in a wide area. 4

2. Installation of the barrier - 15 new piezometers on the inhabited area of Łęgnowo Wieś in order to check the flow of contamination from former chemical plant. Analysing groundwater from the new piezometers.

The monitoring network of 15 piezometers to track the migration of the groundwater contamination front in line –transverse to the flow direction of the contamination front from the Chemical Plant "Zachem" towards Łęgnowo-Wieś estate. The geological project for this 15 piezometers was approved by Marshal office of the Kuyavian-Pomeranian Voivodship. The boreholes were installed o the depth of 7.5 – 8.00 m

bgl. The results are available in geological documentation which contains detailed summary of all work carried out, including:

- Documentation logs for 15 geological boreholes and piezometers
- Description of geological structure and hydrogeological conditions,
- Results maps with location of piezometers
- Geological cross-sections
- Graphs of graining of soil
- Results of laboratory analysis of collected soil and water samples

In order to determine the quality status of groundwater of the first aquifer in the piezometers made, a series of sampling was carried out (15 groundwater samples). In addition, to determine the physiochemical state of the soil from two boreholes, 6 samples were collected from the striate above the groundwater level. Sampling and analysis were carried out by entity with appropriate accreditation and implemented quality control system i.e. I2 Analitycal Limited Sp. Z o.o. in Ruda Śląska. The following physical and chemical analysis were carried out for collected samples:

Inorganic ingradients: Ca, Mg, Na, K, Cl, So4, HCO3, SiO2, NO3, NO2, NH4 and As, Al, B, Ba, Cr, Co, Cu, Fe, Li, Mn, Ni, PO4, Sb, Sr,

Organic ingredients: Total Organic Carbon (TOC), Phenol, Aniline, components BTEX (Benzene, Toluene, Ethylobenzene, Xylene), Diphenylosulphone, Chloroaniline, Epichlorohydrin, Hydroxybiphenyls, Nitrobenzene or total of nitro compounds, Octylophenol, Toluenodiamine, Toluidyne, total PAH, total AOX, PCE and TCE.

Physio-chemical parameters: temperature, pH, Electrical conductivity and Redox Potential).

The obtained results of analyses of groundwater samples show that in each of the installed piezometers water of the first aquifer is contaminated by toxic organic and inorganic compounds, which in the area of documented works have penetrated from the former Chemical Production Facility “Zachem”.

The results of analysis of 6 soil samples collected from two boreholes from the depth horizon of 1.0 – 2.5 m bgl, above the groundwater level, showed no contamination. Nevertheless, the soil environment in the saturation zone is secondary contaminated as a result of migration of pollutants in groundwater.

Due to the contamination of groundwater in piezometers and the location of piezometers in the barrier line on the flow path towards the Łęgnowo-Wieś estate, it is recommended at least five years of permanent monitoring of the quality of groundwater in order to assess the current migration rate of the pollution front from the former ”Zachem” area.

3. Modelling the water and contamination flow on the brownfield site area.

Hydrogeological model of the flow of groundwater and pollutants from the area of the former Chemical Plant "Zachem" residential estate was created on the basis of archival materials, it should be stated that every pollution outbreak located in the area of the former chemical plant "Zachem" in Bydgoszcz is accompanied by clouds of polluted groundwater. These pollutants (mainly phenol, aniline and toluidine) dissolve together with groundwater in the direction of the Vistula and Brda rivers, which poses an ecological threat to the areas also located within the boundaries of the Łęgnowo Wieś housing estate. The main objective of hydrogeological model is to make forecasts of further movement of groundwater pollution towards inhabited areas. The basic input data to the model will include inventoried and documented groundwater pollution zones (so-called "pollution clouds"). The analysis and selection of the most burdensome and characteristic parameters and indicators of groundwater pollution for the examined region was based exclusively on archival materials. On the basis of the selected parameters, maps of groundwater pollution zones in the form of pollution cloud ranges spreading from the source (identified pollution outbreaks) to

the area of the Łęgowo rural district, including the village of Łęgowo, were made. In total, for the purposes of this study, physicochemical analyses from 128 hydrogeological boreholes were inventoried, obtained and used, including: 83 piezometers, 33 deep wells and 12 dug (farm) wells. The indicators of pollution, include following inorganic compounds: sulphates and chlorides and organic compounds: phenol, aniline, toluidine, toluenodiamine, chloroaniline and nitrobenzene. These compounds, organic and inorganic derivatives are closely related to the following materials and waste stored in numerous industrial waste disposal sites located in the area of industrial research.

Model tests on migration of pollutants were carried out on a model with a total area of 73, 78 km.
In the three-dimensional space the numerical model was worked out in 3 layers.
The model was made on the basis of the analysis of over 246 hydrogeological boreholes, 62 monitoring boreholes and archival cartographic studies.
Computer analyses of the direction and time of groundwater flow in the aquifer and migration (movement) of pollutants in the three-dimensional space in the form of a cloud of pollutants were carried out on the model. As a result of the simulation, the time of groundwater flow was calculated from identified 19 pollution outbreaks to Łęgnowo to the border of Toruńska Street.
The calculated groundwater flow times are as follows:
I - The area of the Colouring Plant - flow time 6-8 years.
II - Dye waste pit- flow time 5-6 years.
III – Pressure Gauge Complex Installation Area - flow time 8-9 years.
IV - "Zimna" Headquarters - flow time 6 years.
V - PURINOVA district (former T-7300), according to calculations in the case of PURINOVA District, groundwater flows towards the Brda River with a flow time of about 15 years.
VI - TDI tar extinguishing site - former graveyard (post-galvanic waste) - flow time 9-10 Years.
VII - Brine electrolysis area, brine reservoirs - flow time 11 years, groundwater may also move to the Brda valley with an inflow time of approx. 18-20 years.
VIII - Propylene warehouse - flow time 9-10 years.
IX - EC ash and slag landfill - flow time 6-7 years.
X - contaminated site (TDI/TDA) - contaminated site with toluenodiamine and toluene diisocyanate - flow time 8-10 years.
XI - EPI (epichloridine) installation area - flow time 7-8 years.
XII - SOE - epichloridine sedimentary pond - flow time 8-9 years.
XIII - storage area in Lisia Street - flow time 8-15 years.
XIV - CSN (Central Neutralisation Station) area - flow time 6-7 years.
XV - Area of three aniline sludge storages (pits) - flow time 8-10 years.
XVI - Area of Dinitrotoluene DNT installation - flow time 8-10 years.
XVII - Area of the "old boiler house" - flow time 6-8 years.
XVIII – Landfill complex in Zielona/Elektryczna Street - flow time 5-17 years.
XIX - Brine pipeline route - time of flow from 6 years in the northern part to over 20 years in the southern part.

Calculations of pollution migration were carried out for selected chemical compounds: chlorides, phenol sulphates, aniline, nitrobenzene, toluidine, toluenodiamine and chloroaniline. The migration of pollutants in groundwater from identified pollution outbreaks and contaminated areas in the area of the former Zakłady Chemiczne "Zachem" was forecast.
For the three best documented substances, i.e. chlorides, sulphates and phenols, two numerical scenarios (prognostic simulations) were carried out for each. The aim of these scenarios was to present a differentiated character of the spread of pollution in relation to the initial conditions. In the first, simplified scenario, only the diffusion of the interpreted baseline concentration was considered. This scenario assumes that there is no constant supply of chemical compounds from pollution

sources. This means that only the spreading of the currently observed spatial distribution of pollutant concentrations was simulated. This approximately corresponds to the situation in which pollution outbreaks were eliminated or technical solutions were applied that prevent further inflow of pollutants. The second scenario, apart from the initial concentration, takes into account the additional inflow of pollutants from the best documented pollutant object and the most dangerous at the same time: "Storage complex in Zielona/Energetyczna Street". For other organic compounds: aniline, chloroaniline, nitrobenzene, toluidine, toluidine, toluenodiamine only the first numerical scenario was realized due to poor reconnaissance. It should be emphasized that the first numerical scenario is simplified and presents the direction and time of pollution clouds spreading, however, in case of a constant inflow of pollution it lowers the values of the calculated concentrations. A forecast of the pollution spread for chlorides and sulphates was carried out in the period T+25 years (25 years forward) at intervals of every five years, the so-called time steps. The flow of organic compounds (phenols, aniline, nitrobenzene, toluidine, toluenodiamine and chloroaniline) moving with groundwater was carried out during T+50 years (50 years forward) in time steps every 10 years.

The analysis of pollution migration shows that the area of contaminated groundwater, in particular with organic compounds from the former chemical plant "Zachem", will gradually expand towards the built-up areas of Łęgnowo, causing the progressive degradation of groundwater.

4. Assessing the risk on human health.

Soil sampling plan was developed for the Łęgnowo-Wieś area in order to collect output data for the assessment of health risk to the inhabitants.
The sampling plan was divided into two parts depending on a land use pattern in the Łęgnowo-Wieś settlement:

1) soil sampling plan for residential area

2) soil sampling plan for agricultural land.

Both sampling plans were developed in compliance with national regulations, based on the findings of the previous investigations conducted in the pilot area by AGH University of Technology (2016, 2018) and ARCADIS (2018). Apart from that, numerical cartographic data in the form of a land and building registry map, soil-agricultural map and a map of the Łęgnowo-Wieś settlement borders were used for this purpose. The number of sampling sections was established according to the land function and its area. Soil sampling plan for residential area. The residential area (31.1 ha) was divided into 20 sampling sections taking into account the location of groundwater pollution clouds and a topographic relief. The plots on which bore-holes should be made were chosen considering their central location in relation to the group of residential plots and their location within a given pollution cloud. The location of 9 bore-holes whose coordinates represent the central points of the selected plots was determined. Substances for health risk analysis were selected by assigning appropriate sources and types of pollution to each cloud. At the same time, it was indicated which substances should be determined in soil samples taken from the surface layer of individual sampling sections, and which from deeper layers.
In the majority of sections in the soil layer, the permissible content of substances causing a risk for polycyclic aromatic hydrocarbons is noticed. The highest values for PAHs are recorded in 3 sections (32, 34 and 35). In addition, trace amounts of metals in the soil are noticed, however, their content in the investigated soil does not exceed the values for group I allowed by the regulation (Journal of Laws of 2016 item 1395). Not established presence of other substances tested in the soil - the obtained results for other substances show values below the method's determination.

In the case of soil trials taken below a depth of 0.25 m, p.p.t. only in the hole no. 51 and in the hole no. 25 at the depth of 0.9 m.p.t. the slight presence of pyrene was noted, and for the hole no. 51 - also benzo (a) of anthracene.
For selected six farms in the ground layer up to 0.25 m, p.p.t. notes that exceedances are only for PAHs. Metals are also present in the soil, but they do not pose any risk. The other analyzed substances present values below a given level of quantification.
A health risk analysis was elaborated for residents of the Łęgnowo- housing estate, the scope of work included:

- Performing a basic health risk assessment, consisting of developing a data set input, exposure and toxicity assessments, and risk characterization health, consisting in the integration of the results of toxicity and exposure assessment.
- Determination of local, safe for health content of pollutants, i.e. local remediation criteria if the risk level is exceeded.
- Assessment of soil pollution with chemical substances on the basis of their allowable soil content, as defined in the national regulation.

Health risk analysis for residents of the Łęgnowo-Wieś housing estate exposed to specific ones for the production activity of Zakłady Chemiczne ZACHEM, substances contained in soil have been shown
That total non-carcinogenic risk (hazard index - HI) in all research sections and selected households is significantly lower than the allowable level HI = 1; acceptable level of carcinogenic risk for a single substance (1 * 10-5) is slightly exceeded in the case of benzo (a) pyrene and concerns three research sections (32, 34, 35) and one farm (K30); total carcinogenic risk (CR) in all sections examined and selected households is lower than the CR level = 1 * 10-4, above which usually corrective action is justified.

5. Creating the guidelines for future monitoring based on the performed research.

The guidelines relate to soil and water environment monitoring and contain:

• assessment of the existing monitoring of groundwater in the inhabited areas of the Łęgnowa Wieś estate and proposals for the designation of areas in the inhabited areas of the Łęgnowa Wieś estate, which due to the current state of knowledge should be covered by groundwater monitoring

• specification of the type and quantity of samples that are proposed to be adopted as part of monitoring

• sampling methodology

• the proposed scope of analytical tests for soil and water environment monitoring

• frequency of sampling for tests,

• presentation of monitoring results, including information on the possibility of monitoring data integration in the geoinformation tool

• estimated cost of planned monitoring tests

The purpose of the planned monitoring will be the ongoing observation of the inflow of groundwater pollution migrating from the area of former "Zachem" towards the Łęgnowo - Wieś estate, in the context of the impact assessment on the residents of the housing estate as and deterioration of the quality of the soil and water environment. As part of the assessment, it was found that the old and the new monitoring network (taking into account all archived piezometers inventoried in 2018) is insufficient to fully assess and control the state of groundwater quality in the area of the Łęgnowo Wieś estate and it is required to identify at least 7 additional areas in which the development of the monitoring network should be planned, consistently to the adopted concept of pollution distribution and possible migration directions.
As part of the guidelines, the need to expand the monitoring system was assumed by 7 new observation points (7 double piezometers of different depths - a total of 14 openings) located in zones selected for

additional recognition). Monitoring should also be carried out in the existing observation holes network (8 points were initially accepted) and arch holes / wells (6 points were initially accepted). In total, the planned research network of groundwater monitoring will include 28 observation points. In addition, for monitoring purposes, it is recommended to monitor the quality of water in farm wells (pre-set 9 points) and in surface waters (4 points). In addition, attention was paid to the need to carry out control tests of contamination in ground air, especially in the area of buildings with basements. In connection with the need to build a platform for cooperation and exchange of information between individual entities responsible for monitoring should check at least the propose substances. In order to apply the best available tools and methods for the purposes of interpretation, analysis and visualizing the monitoring results it is important to use the current Web-GIS tool, which will serve to create a database of pollution identified in the Łęgnowo - Wieś housing estate by means of which the residents and other interested parties will have access to current information on the results of monitoring work through the web browser. The guidelines also gives a time plan and estimated costs for yearly monitoring which is c.a. 700 000 PLN.

6. Integrating the achieved results into the GIS tool of the project.

Information like pollutants, number and location of piezometers, soil and water samples results and ownership will be also presented in an online database (GIS). The web GIS tool developed in WP1 was installed on the server of the Regional Directorate of Environmental Protection responsible for taking remediation decisions and all related contamination issues at regional level. Data about brownfields is scattered and not sufficient. As in Poland does not exist official catalogue of contaminated areas, including brownfield, such database will help institutions, as well as private investors and actors to obtain information about the area of interest. The geo-information system was developed in order to support brownfield regeneration by helping institutions to better use available data and manage environmental problems in a more effective way. The tool's database will be constantly updated in order to provide up to date information about the brownfield.

8. Technical specifications and solutions tested

1) The inventory of the monitoring wells (according to inventory card).
2) The ground and groundwater analysis (specific organic compounds).
3) 15 piezometers (7.5 – 18 m bgl).
4) Hydrogeological model – three dimentional space numerical model, from 19 pollution outbreaks, 2 scenarios, forecast +25 and +50 years, in ModPATH Version 5, for spatial analysis MT3D DMS was used.
5) Risk analysis according to EPA standards, using HRA system of managing health risk.
6) Guidelines for monitoring involve using current wells and also drilling new piezometers.

9. Impact/results/experience (how many target groups/stakeholders were reached, pilot events)

Thanks to the GreenerSites project the City of Bydgoszcz was able to check the impact of the contamination of former Chemical Plant "Zachem" on the inhabited area of Łęgnowo-Wieś and provides the monitoring results to induce the activities that improve the quality of life of the city inhabitants. The implemented measures allow preliminary assessment of the environment condition of the site, which is strongly contaminated by organic and inorganic compounds. The results shows that ground water migrating from former chemical plant is strongly contaminated and this contamination reach the inhabited area. No specific compounds was found in soil however the Polycentric Aromatic Hydrocarbons were detected. Implemented pilot action positively contributed to the improvement of the environment and general conditions of the FUA.

Among many other problems caused by closing down chemical Plant "Zachem", the environmental issues were raised recently, the land were sold out by Treasury in Bankruptcy and responsibility for environment became an issue. In this time GreenerSites project has started and joint the common effort to solve this huge local problem. Local stakeholders meeting were organized, 3 meetings with inhabitants (on one of

them the GreenerSites were presented), GreenerSites was presented also during City Council meetings. Additionally the informal contact with inhabitants was made during the collection of soil samples from Łęgnowo-Wieś. Big number of stakeholders participated in transnational and local training. The final results of all documents produced within pilot action in Bydgoszcz was disseminated to selected stakeholders.

The most active cooperation was made with associated institution: Regional Directorate of Environmental Protection, the institution the most competent for contamination of ground and remediation activities. This institution lead the stakeholders group, initiated the meetings on inhabited area and cooperated with AGH University regarding the assessment of environmental conditions.

Also many other local institutions were involved in the pilot site activities. Pilot activities were presented at every stakeholder meeting and consulted with local institutions.
Key stakeholders: Provincial Inspector of Environmental Protection in Bydgoszcz, State Sanitary Inspectorate in Bydgoszcz, the Marshal's Office, Mining Academy in Krakow, Technical University in Bydgoszcz, Municpal Water Works in Bydgoszcz, Bydgoski Wyszogród Association, main Geologist at Municipal Waterworks, Director of Regional Inspectorate of Environment Protection, National Director of Health Inspection, National Epidemic and Health Station, Marshall Office, Voivodship Office, Bydgoszcz Industrail and Technological Park.

No of stakeholders reached: 40 (institutions participating in experts group and pilot event, consulted during realization of pilot action)
No of target groups reached: 52 (inhabitants of Łęgnowo who participated in meetings)

Local expert group meetings (later converted into regional expert group)
19.01.2017
09.05.2017
03.10.2017

Regional expert group meetings
16.03.2018
04.04.2018
25.05.2018
20.06.2018 – study visit
19.10.2018

Presentation of pilot site on the Brownfield Expert Group set up by Minister of Environment
24 April 2019

Presentation of GreenerSites on the City Council sessions:
29 May 2019
24 April 2019
28 March 2019
26 February 2019
30 January 2019
19 October 2018 (MWIK)
17 October 2018
28 March 2018

Meetings with inhabitants of Łęgnowo
18.09.2017
01.12.2017 (presentation of GreenerSites project)
04.04.2018

Achieved results:

- Number and condition of existing monitoring system (inventory)
- Information about ground and ground water contamination (15 piezometers and soil tests)
- Forecast of migration of contaminants in the groundwater (hydrogeological modelling)
- Risk analysis for human health
- Guidelines for future monitoring

10. Contribution to project objective

Higher environmental performance of the brownfield was reached by recognizing impact of contaminants, thus contributing to an improvement of working and living conditions of Łęgnowo Wieś citizens. The stakeholder involvement was visible. By doing so, the undertaken actions directly contributed to the project goal "to improve the environmental management of unused or underused industrial areas (brownfields) through the definition of strategies, tools and actions based on a sustainable integrated approach to make involved Functional Urban Areas (FUAs) cleaner, healthier and more liveable places".

11. Transnational added value – how Pilot Action contributed to other activities implemented by the project & added value for partners

Participation in the GreenerSites project was an opportunity for exchange of knowledge and experience. Thanks to different training opportunities like study visits, pilot site visits and training seminars provided within the project, PP9 acquired useful knowledge on brownfield management, especially from AP Brownfield Authority of Saxony Anhalt, as their solution should be an example for Poland. More beneficial for Bydgoszcz was to observe approaches and strategic solutions of other countries in the field of brownfield revitalisation than some specific technical aspects, as this solution are offered by international companies. The institutional changes and law development is the most important aspects to learn from. Bydgoszcz has shared with partners its technical know-how and experience gained through research activities and work on the inhabited area. Results from the pilot action might be beneficial for partners dealing with the same environmental issues.

12. Compliance with the sustainability principles

The implementation of the project allows to assess the impact of contamination from former chemical plant and impact on improving the quality of life while maintaining social equality, biodiversity and abundance of natural resources. The extended environmental data gained, the forecast of contamination migration and risk analyss allows to assess the condition of the environment not only now, but also in the future, which is crucial considering an inflow of a plume from outside the pilot site.

Result of the pilot will play a crucial role in decision making process and management of the brownfield.

It is crucial to reactivate brownfields, thereby reducing land consumption. Brownfield reactivation offers an opportunity to eliminate contamination and paves the way for environmental protection. The carried out actions within the pilot, allow to properly assess the need for remediation and decide about the residential area nearby.

13. Media coverage

Many press article, local tv and even national tv was engaged in the subject of brownfield site. Some of them mentions GreenerSites activities.

1. 26.04. 2016
   http://www.portalsamorzadowy.pl/fundusze-europejskie/dofinansowanie-dla-bydgoskich-projektow,80006.html

2. 28. 04. 2016
   http://byd.com.pl/wiadomosc/blisko-4-miliony-zlotych-na-bydgoskie-projekty/
3. 20.02. 2017
   https://bydgoszcz.tvp.pl/29157140/wspolpraca-ponad-podzialami-ws-rekultywacji-pozachemowskich-terenow
4. Portal – Bydgoszcz.com – local internet portal – 8.05.2017r.
   https://www.bydgoszcz.com/wiadomosci/1003,przyszlosc-terenow-poprzemyslowych-w-bydgoszczy
5. Homepage of Solec Kujawski, 10.05.2017r.
   http://www.soleckujawski.pl/pl/content/szkolenie-w-bydgoskim-parku-przemys%C5%82owo-technologicznym?v_mobile_version_mode=classical
6. Bydgoszcz inaczej – local internet portal- 8 maja 2017 r.
   http://www.bydgoszczinaczej.pl/artykul/co-z-terenami-poprzemyslowymi/
7. Onet kujawsko-pomorskie, 9.05.2017r.
   http://kujawsko-pomorskie.onet.pl/dzieki-europejskiemu-projektowi-zbadaja-jak-zachem-zanieczyscil-bydgoszcz/prb7cm
8. 5. Local radio – 10.05.2017r., g. 14:49
   http://www.radiopik.pl/2,55333,specjalisci-o-wplywie-dawnego-zachemu-na-srodowi&s=7&si=7&sp=7
9. 18.09.2017, information about local meeting with citizens, (participation of Hanna Lewandowska), not mentioning the project itself, but the pilot area
   http://www.bydgoszcz24.pl/pl/11_wiadomosci/16245_mamy_w_bydgoszczy_bombe_ekologiczna_na_skale_europejska.html
10. Local newspaper wyborcza Bydgoszcz 19.09.2017, information about local meeting with citizens (participation of Hanna Lewandowska), not mentioning the project itself, but the pilot area.
    http://bydgoszcz.wyborcza.pl/bydgoszcz/7,48722,22392979,woda-w-studniach-w-legnowie-jest-zatruta-zbada-krakowska-agh.html?utm_source=facebook.com&utm_medium=SM&utm_campaign=FB_Bydgoszcz_Wyborcza&disableRedirects=true
11. Local newspaper Express bydgoski, 29.09.2017, information about contamination not mentioning the project itself, but the pilot area.
    https://plus.expressbydgoski.pl/magazyn/a/smiertelne-zagrozenie-dla-bydgoszczan-po-zch-zachem-raport,12528194
12. Local newspaper,3.10.2017 tygodnik bydgoski, information about contamination not mentioning the project itself, but the pilot area.
    http://tygodnikbydgoski.pl/wydarzenia/zachem-to-najgrozniejsza-bomba-ekologiczna-w-polsce
13. Local newspaper, 3.10.2017, Gazeta pomorska, information about contamination not mentioning the project itself, but the pilot area.
    https://plus.pomorska.pl/wiadomosci-z-regionu/a/zachem-w-bydgoszczy-jak-nas-trul-tak-wciaz-truje,12544981
14. Local TV Talk of the day, with Director of RDOŚ (GreenerSites stakeholder) – the former chemical factory state of art. 3.10.2017, GreenerSites is not mentioned
    http://bydgoszcz.tvp.pl/34242743/3102017
15. Local newspaper, 6.10.2017, http://tygodnikbydgoski.pl/wydarzenia/przebadaja-studnie-w-okolicach-bylego-zachemu
16. Local TV TVP Bydgoszcz, 7.10.2017, information about contamination not mentioning the project itself, but the pilot area issues time: 5:55. Grzegorz Boroń speaking.
    http://bydgoszcz.tvp.pl/34313453/7092017
17. Express bydgoski, local newspaper, 14.10.2017 information about contamination not mentioning the project itself, but the pilot area issues.

https://plus.expressbydgoski.pl/magazyn/a/odpady-po-zachemie-zagrazaja-ujeciu-wody-dla-bydgoszczy,12574940

18. RadioPIK, local radio, 13.10.2017, information about the tests performer by AGH Uni, no mentioning the project, but the pilot area issues.
http://www.radiopik.pl/2,61312,naukowcy-z-baghb-zbadaja-wode-w-studniach-legnow&s=1&si=1&sp=1
19. Express bydgoski , 14.10.2017 information about the tests performed by AGH Uni, no metnioning the project, but the pilot area issues.
https://plus.expressbydgoski.pl/wiadomosci/a/skazenie-po-zachemie-naukowcy-badaja-wode,12579024
21. National TV – TVP 15.11.2017., mentioning Bydgoszcz former chemical factory problem.
https://panorama.tvp.pl/34825350/bomba-ekologiczna-w-tarnowskich-gorach
22. TVP Bydgoszcz (local tv) 25.10.2017– Samorządni, participation of Bydgoszcz (Grzegorz Boroń, 46:10 min. about GreenerSites monitoring system and risk analysis), local stakeholders, citizens representation
http://bydgoszcz.tvp.pl/34548766/25102017, former chemical factory discussion about contamination
23. Local TV Talk of the day – the former chemical factory state of art. 30.11.2017, 18.30, programme name: Zbliżenia, GreenerSites is not mentioned.
https://bydgoszcz.tvp.pl/35028396/30112017-g-1830
24. Local TV Talk of the day – AGH University presented the former chemical factory state of art. 30.11.2017
http://bydgoszcz.tvp.pl/35028763/30112017

Media coverage as a result of pilot event

30.07.2019

1. Radio PIK
Tereny pozachemowskie w Łęgnowie. Nie jest tak źle?
http://www.radiopik.pl/2,79799,tereny-pozachemowskie-w-legnowie-nie-jest-tak-zl
2. Radio PIK
Co dalej? Spotkanie z mieszkańcami osiedla Łęgnowo
http://www.radiopik.pl/2,79806,co-dalej-spotkanie-z-mieszkancami-osiedla-legnow
2. Gazeta Wyborcza
Zanieczyszczenia z Zachemu. "Nie występuje całkowite ryzyko rakotwórcze"
http://bydgoszcz.wyborcza.pl/bydgoszcz/7,48722,25044328,zanieczyszczenia-z-zachemu-nie-wystepuje-calkowite-ryzyko.html

3. Express Bydgoski
Trucizny po bydgoskim Zachemie nagle znikły z ziemi!?
https://plus.expressbydgoski.pl/trucizny-po-bydgoskim-zachemie-nagle-znikly-z-ziemi/ar/c1-14317445
4. bydgoszcz24.pl
Bomba ekologiczna w Łęgnowie nie tak groźna, jak sądzono?
https://bydgoszcz24.pl/pl/11_wiadomosci/21047_bomba_ekologiczna_w_legnowie_nie_tak_gro_na_jak_s_dzono.html
5. TVP3
Wyniki badań „pozachemowskich" terenów. Czy skażenie zagraża mieszkańcom?
http://bydgoszcz.tvp.pl/43719847/wyniki-badan-pozachemowskich-terenow-czy-skazenie-zagraza-mieszkancom
6. Bydgoszcz Inaczej
Zachem – wyniki badań
http://www.bydgoszczinaczej.pl/artykul/zachem-wyniki-badan/
7. Wyborcza.pl
Spór wokół badań zanieczyszczeń w Łęgnowie. Naukowiec z AGH podważa wyniki
http://bydgoszcz.wyborcza.pl/bydgoszcz/7,48722,25055901,spor-wokol-badan-zanieczyszczen-w-legnowie-naukowiec-z-agh.html
8. Radio PIK
http://www.radiopik.pl/?idp=2&szukaj=&s=6&idx=79806
9. Radio PIK
http://www.radiopik.pl/?idp=21&idx=1636&go=morelist&sp=2
10. Express Bydgoski
https://expressbydgoski.pl/naukowcy-z-agh-wycofuja-sie-z-miejskiego-projektu-dotyczacego-zachemu/ar/c1-14322895?utm_source=facebook.com&utm_medium=express_bydgoski&utm_content=dom&utm_campaign=naukowcy-z-agh-wycofuja-sie-z-miejskiego-projektu-dotyczacego-zachemu&fbclid=IwAR3v0zt3knJn79-ZjaVWsXNWjGLB_j-hNIj5EWQXzUsPvLtcBnWzXgYU8Yk