CONCEPT OF MODERNISATION AND OPTIMISATION OF DEPOSITION MEASUREMENTS IN POLAND

Task 3: Determination of the optimum number of measurement points for precipitation chemistry monitoring on the national scale and selection of their detailed locations with justification
Task 4: Estimation of the annual operating costs of the precipitation chemistry measurement system in Poland

Report commissioned by the Chief Inspectorate of Environmental Protection for the implementation of the project **"Strengthening of atmospheric deposition assessment in Poland based on Norwegian experience**" under the Environment, Energy and Climate Change Programme, Climate Change Mitigation and Adaptation sub-programme, funded by the European Economic Area Financial Mechanism 2014-2021

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WARSAW, 2022

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1 Introduction

A network of measurement stations, well-designed in terms of location and with appropriately selected measuring range, serving under the key national and international measurement programmes is one of the main elements of the process of optimization of wet atmospheric deposition measurements in Poland. Properly selected locations and measuring range guarantee reliable, quality measurements. Based on measurements results, it will be possible to make a spatial assessment of deposition of particular precipitation pollutants in the area of Poland.

2 Purpose of the Project

The purpose of the project is to develop a concept for the modernisation and optimisation of atmospheric deposition in Poland using the Norwegian experience as part of the project entitled “Strengthening of atmospheric deposition assessment in Poland based on Norwegian experience” under the Environment, Energy and Climate Change Programme, the Climate Change Mitigation and Adaptation sub-programme, financed by the European Economic Area Financial Mechanism 2014-2021.

3 Basis for the Study

The basis for the study is Agreement No. GIOŚ/ZP/380/2021/DMŚ/MFEOG, concluded on 22 December 2021 between the State Treasury – the Chief Inspectorate of Environmental Protection (the CIEP) and the Institute of Meteorology and Water Management – National Research Institute (the IMWM-NRI).

4 Scope of the Study

The present study provides an overview and analysis of suburban and regional background monitoring stations as well as the stations of the Integrated Monitoring of the Natural Environment (IMNE) operating within the framework of the State Environmental Monitoring (SEM) in terms of meeting the criteria and possibility of carrying out measurements of atmospheric wet deposition at those sites. The analysis included also the IMWM-NRI stations currently implementing the measurement programme of atmospheric precipitation chemistry in Poland, stations at which research is conducted for the purposes of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM), European Monitoring and Evaluation Programme (EMEP) and additional meteorological stations of IMWM-NRI. The analysis included studies carried out by the team of the Norwegian Institute for Air Research (NILU) concerning deposition distribution for selected pollutants.

In addition, the report provides an estimate of the annual costs of conducting measurements and analyses of physicochemical samples of precipitation along with organisational issues of conducting precipitation chemistry monitoring.

5 Review and evaluation of stations for the atmospheric wet deposition measurement network

5.1 Assumptions made and methodology of the station review

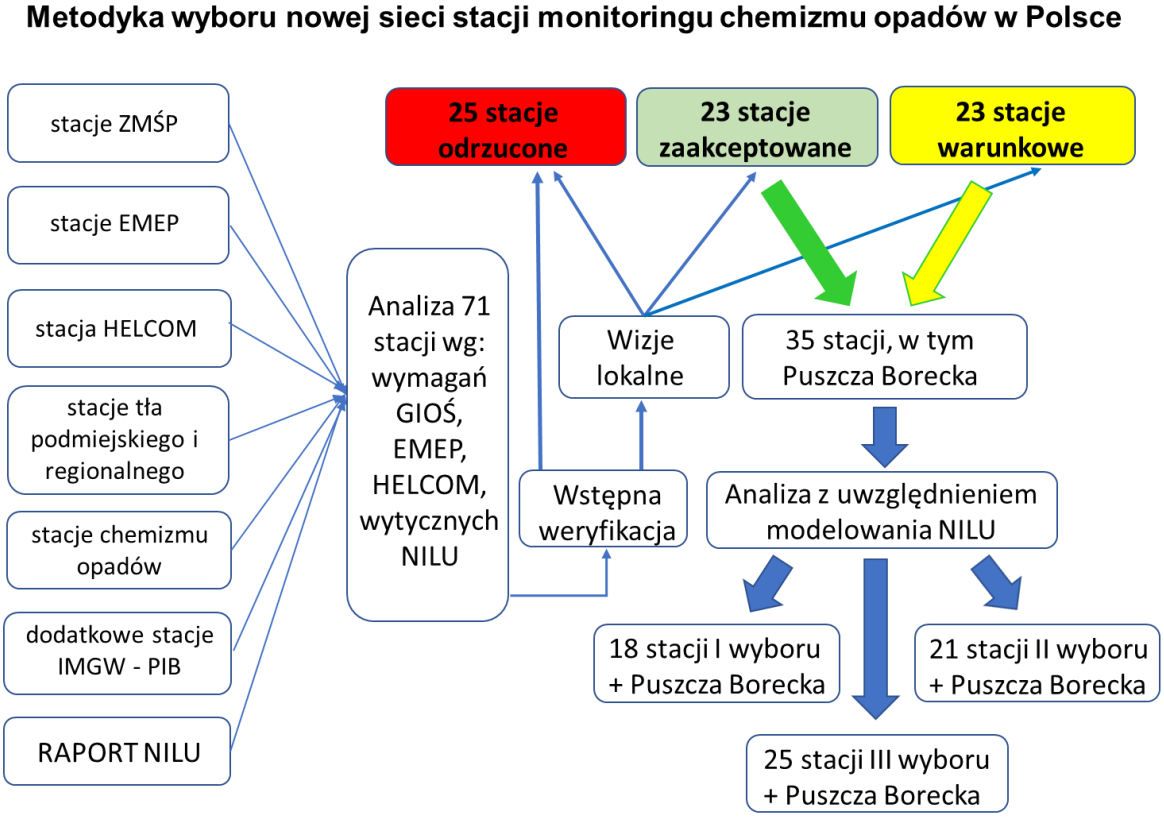
In order to carry out the task, a set of input data was prepared, including information on suburban and regional background monitoring stations, IMNE, EMEP, HELCOM stations as well as precipitation chemistry monitoring stations and additional IMWM-NRI stations (Figure 5.1).

Key / stations / Poland's border / Voivodeship borders

Figure 5.1 Presentation of 71 stations selected for evaluation for modernisation of atmospheric deposition measurements in Poland (developed by IMWM-NRI)

The following diagram (Figure 5.2) presents the methodology for selection of the stations for the monitoring network of precipitation chemistry in Poland. The methodology was based on the analysis of requirements for wet deposition measurement stations, requirements of EMEP, HELCOM, NILU guidelines and preliminary verification of available

information on the given stations. In the next step, a tour was made around the stations considered for inclusion in the new network in order to check their location in detail. After preliminary verification and inspection of stations, they were classified into 3 categories: stations not meeting the criteria (red), stations meeting the criteria (green) and conditional stations, where it is necessary to deviate from the requirements for measuring stations (yellow). From the two categories: stations meeting the criteria and conditional stations, 35 locations required to be determined according to the description of the subject of the contract were selected. The selected group of 35 stations was subjected to even more extensive analysis, in terms of spatial distribution, so that about 25 locations could be selected without compromising the representativeness and operation of the new precipitation chemistry monitoring system. In addition, if e.g. for economic reasons it was not possible to carry out measurements at 25 stations, a selection of 18 and 21 stations was proposed. The Puszcza Borecka station was added to each of the proposed selections as a station to remain in the network unconditionally, in accordance with the Contracting Party's guidelines.



Methodology of selection of the new network of precipitation chemistry monitoring stations in Poland
IMNE stations / EMEP stations / HELCOM station / suburban and regional background stations / precipitation chemistry stations / additional IMWM-NRI stations / NILU REPORT
Analysis of 71 stations according to: requirements of the CIEP, EMEP, HELCOM, NILU guidelines
25 rejected stations / 23 approved stations / 23 conditional stations
Local visits / 35 stations, including Puszcza Borecka
Preliminary verification / Analysis incorporating NILU modelling
18 1st choice stations + Puszcza Borecka / 21 2nd choice stations + Puszcza Borecka / 25 3rd choice stations + Puszcza Borecka

Figure 5.2 Diagram presenting the adopted methodology for selecting new measurement network stations (developed by IMWM-NRI)

5.2 Criteria indicated in the description of the subject of the contract for the location of precipitation chemistry measurement points

The following criteria indicated in the description of the subject of the contract were taken into account in the evaluation of the station locations:

1. General criteria: the chemistry measurement point should be located at a distance of at least
    - 10km from significant emission sources (industry and large cities) and should not be directly affected by them,
    - 100m from houses heated with coal, fuel oil or wood,
    - 50m from roads with light traffic,
    - 500m from major roads and should not be affected by them,
    - 1km from livestock farms,
    - 200m from grazing livestock.
2. Specific criteria:
    - the collector should be installed on flat, open ground,
    - there should be grass or another dust-free surface in the immediate vicinity of the collector,
    - the collector should not be located in the immediate vicinity of trees (location rules as for air quality monitoring stations),
    - the collector shall be placed as far as possible from obstacles higher than itself,
    - the collector should be positioned so that its receiving surface is approximately 1.5m above the ground,
    - the collector requires an electricity supply.
3. Additional criteria:
    - representativeness for a specific area taking into account the modelling results;
    - the presence of personnel when it is necessary to carry out routine activities, e.g. changing the precipitation container, or measurements, e.g. pH.

Pursuant to the provisions of the description of the subject of the contract, deviations from the above rules were allowed in justified cases.

5.3 Developed documentation of proposed locations of measurement points

According to the criteria defined above, documentation of the proposed locations of the measurement points was prepared. The station description sheet (Figure 5.3 – sheet template) includes:

- a detailed description of the neighbourhood of the measurement point,

- the proposed location for the establishment of the measuring device (wet precipitation collector) together with the reasons for this choice and information on the landowner,
- up-to-date photographic documentation,
- layout plan of the station surroundings.

Data wizytacji:

KARTA OPISU STACJI

I. DANE PODSTAWOWE

Nazwa i adres stacji:				
Rodzaj stacji: (miejska, podmiejska, pozamiejska)				
Współrzędne geograficzne:	z dokumentacji		zweryfikowane na stacji	
Właściciel gruntu:				
Instytucja odpowiedzialna za funkcjonowanie stacji				

II. OPIS OBSZARU WOKÓŁ STACJI

	NW - NE	NE - SE	SE - SW	SW - NW
10 km od przemysłu				
100 m od domów z niską emisją				
50 m od dróg o małym natężeniu				
500 m od dróg o dużym natężeniu				

Nazwa i adres stacji:				
1 km od hodowli zwierząt				
200 m od pastwisk				
Niepylące otoczenie				
Zadrzewienie				
Zagospodarowanie pobliskiego terenu (uprawy (jakie), las, osiedle, łąka, park, sad, uprawy, maszty, zbiorniki wodne, itp.)				
Informacje dodatkowe				

Nazwa i adres stacji:	0			
III. OPIS TERENU STACJI				
	NW - NE	NE - SE	SE - SW	SW - NW
Przeszkody wyższe od kolektora (rodzaj, wysokość)				
Rodzaj podłoża (roślinność, utwardzenie terenu, spadek, itp.)				
Wielkość ogródka (kontener, ogródek czy pobornik, potencjalne zamontować kolektor, Obecność urządzeń meteo w punkcie pomiarowym (klatka, deszczomierz, itp.)				
Ogrodzenie terenu i zabezpieczenie przed dostępem osób niepowołanych				
Dostęp do prądu (lokalizacja skrzynki energetycznej)				
Dodatkowe informacje (możliwość postawienia nowego kolektora, itp.)				
Podpisy osób wizytujących stację				

Nazwa i adres stacji:	
Materiał dokumentacyjny/fotograficzny:	

Figure 5.3 Template of station sheet (developed by IMWM-NRI)

5.4 Preliminary verification of stations

In the first step of the station review, the documentary material provided by the Contracting Party was analysed and a set of stations with the highest risk of not fulfilling the requirements for a new measurement network was determined. As a result of preliminary verification and consultations with the Contracting Party, information was obtained on the impossibility of constructing a collector at 6 stations (Wieniec Zdrój, Rymanów Zdrój, Kraśnik, Nałęczów, Radzyń Podlaski, Uniejów), and in the case of one station information was obtained on high impact of the Bełchatów mine and power plant on measurement results (Parzniewice). The mentioned stations (7 stations) were initially rejected and not taken into consideration during site visits.

5.5 Station inspections

A total of 64 stations were visited between 29 March 2022 and 18 May 2022. During the visits, the stations were assessed in terms of the location criteria listed in subsection 5.2 and photographic documentation was made. According to the previously adopted methodology, stations were classified into 3 categories: stations not meeting the criteria (red), stations meeting the criteria (green) and conditional stations (yellow) (Table 5.1). The table also includes stations rejected in the initial verification described in Section 5.4.

Table 5.1 List of stations according to the following classification: stations not meeting the criteria (red), stations meeting the criteria (green) and stations approved conditionally (yellow) (developed by IMWM-NRI)

No.	Suburban and regional background monitoring stations		Stations of IMWM-NRI		IMNE stations	
1	Belsk Duży		Białystok		Karkonosze	
2	Borówiec		Chojnice		Koniczynka	
3	Borsukowizna		Dźwirzyno		Łysogóry	
4	Ciechocinek		Gdańsk Świbno		Parsęta	
5	Czerniawa		Gorzów Wlkp.		Poznań Morasko	
6	Florianka		Hel		Roztocze	
7	Gajew		Jarczew		Wigry	
8	Gołuchów		Kalisz		Wolin	
9	Granica		Kasprowy Wierch			
10	Guty Duże		Katowice			

No.	Suburban and regional background monitoring stations		IMNE stations	
11	Inowrocław		Legnica	
12	Iwonicz Zdrój		Lesko	
13	Kaszów		Łeba	
14	Krasnobród		Nowy Sącz	
15	Kraśnik		Olsztyn	
16	Krempna		Poznań	
17	Legionowo		Racibórz	
18	Liniewko Kościerskie		Sandomierz	
19	Nałęczów		Sulejów	
20	Osieczów		Suwałki	
21	Otwock		Śnieżka	
22	Parzniewice		Świnoujście	
23	Piaski		Toruń	
24	Puszcza Borecka		Ustka	
25	Radzyń Podlaski		Wieluń	
26	Rymanów Zdrój		Włodawa	
27	Smolary Bytnickie		Zielona Góra	
28	Solec Zdrój			
29	Szarów			
30	Szymbark			
31	Uniejów			

No.	Suburban and regional background monitoring stations	
32	Ustroń	
33	Wieniec Zdrój	
34	Wrocław	
35	Zielonka	
36	Złoty Potok	

Table 5.2 Summary of station assessments (developed by IMWM-NRI)

Assessment	Suburban and regional background monitoring stations	IMNE	IMWM-NRI	Total
stations meeting the criteria	**5**	**3**	**15**	**23**
conditional stations	**13**	**2**	**8**	**23**
stations not meeting the criteria	**18**	**3**	**4**	**25**
Total	**36**	**8**	**27**	**71**

As a result of the assessment, 23 stations were classified as meeting the criteria for wet deposition measurement stations: 5 monitoring stations of suburban and regional background, 3 stations of the IMNE and 15 stations of the IMWM-NRI. 23 stations were recognized as conditional stations: 13 stations of monitoring of suburban and regional background, 2 stations of the IMNE and 8 stations of the IMWM-NRI. In total 25 stations were classified as stations not fulfilling criteria: 18 monitoring stations of suburban and regional background, 3 IMNE stations and 4 IMWM-NRI stations.

Rejected stations (apart from 7 stations rejected at the initial verification stage), not meeting an important set of criteria:

- Roztocze: no possibility of electricity connection, no open area, dense forest (shrubbery), tall trees,
- Iwonicz Zdrój: no open area, dense forest (shrubbery), tall trees and other obstacles, close proximity of roads with heavy traffic, car parks, houses with low emissions, no fenced area, easy access of outsiders,
- Zielonka: tall trees and other obstacles, dusty environment: cultivated fields, operation of agricultural machinery, no fenced area, easy access for outsiders,
- Inowrocław: no open terrain, high trees and other obstacles, brine graduation towers, easy access for outsiders,

- Ciechocinek: no fenced area, easy access for outsiders, brine graduation towers, proximity of a playground and a low emission building,
- Łysogóry: high trees, bushes and other obstacles, close proximity of houses with low emissions, no fenced area, easy access for outsiders,
- Krasnobród: no open area, dense shrubbery, tall trees and other obstacles, no fenced area, easy access for outsiders,
- Smolary Bytnickie: high trees, bushes and other obstacles, dusty environment: cultivated fields, operation of agricultural machinery, no fenced area, easy access for outsiders,
- Czerniawa: high trees, bushes and other obstacles, close proximity to roads with heavy traffic, car parks,
- Nowy Sącz: no open land, tall trees and other obstacles, close proximity to roads with heavy traffic, car parks, houses with low emissions,
- Solec Zdrój: close proximity to roads with heavy traffic, car parks, houses with low emissions, no fenced area, easy access for outsiders,
- Legionowo: close proximity to roads with heavy traffic, car parks, houses with low emissions,
- Wrocław: close proximity to roads with heavy traffic, close proximity to livestock farms,
- Suwałki: close proximity to roads with heavy traffic, houses with low emissions,
- Ustka: close proximity of the harbour, beach,
- Borsukowizna: dusty surroundings: cultivated fields, operation of agricultural machinery, easy access of outsiders,
- Koniczynka: dusty environment: cultivated fields, operation of agricultural machinery,
- Poznań: restricted access – airport area, proximity to runway, parking.

Conditional stations for which an exception for not meeting one of the criteria is granted:

- Gorzów Wielkopolski, Katowice, Legnica, Lesko, Poznań Morasko: proximity to roads with low or medium traffic intensity,
- Florianka, Gajew: livestock farms, pasture land,
- Liniewko Kościerskie, Gdańsk Świbno, Olsztyn, Zielona Góra, Parsęta: single houses with low emissions,
- Krempna, Osieczów: proximity to individual trees,
- Borówiec, Krempna: accessibility for the public (need to fence the station),
- Guty Duże, Kaszów, Piaski, Szarów, Ustroń, Złoty Potok: need to extend the station area,
- Szymbark: sloping terrain,
- Swinoujscie: sandy subsoil.

5.6 Selection of 35 measurement points

As a result of the above analysis, 35 locations required to be selected according to the description of the subject of the contract were selected from the categories of stations

meeting the criteria and conditional stations. Of these 35 stations, five stations were selected to meet EMEP station requirements, of which two are to meet EMEP level 2 (extended level) requirements and three are to meet EMEP level 1 (basic level) requirements. Four stations were also selected to meet HELCOM programme requirements. The selected group of 35 stations was further analysed so that about 25 locations could be selected without compromising the representativeness and performance of the new precipitation chemistry monitoring system. In addition, if, for e.g. for economic reasons it would not be possible to carry out measurements at 25 stations, a selection of 18 and 21 stations was proposed. The Puszcza Borecka station was added to each of the selections. The following categorisation was proposed: 1st choice stations – 19 stations, 2nd choice stations – 22 stations, 3rd choice stations – 26 stations. For each of the stations identified as meeting the requirements and selected 35 measurement points a station sheet was developed. The station sheets can be found in the Appendices hereto.

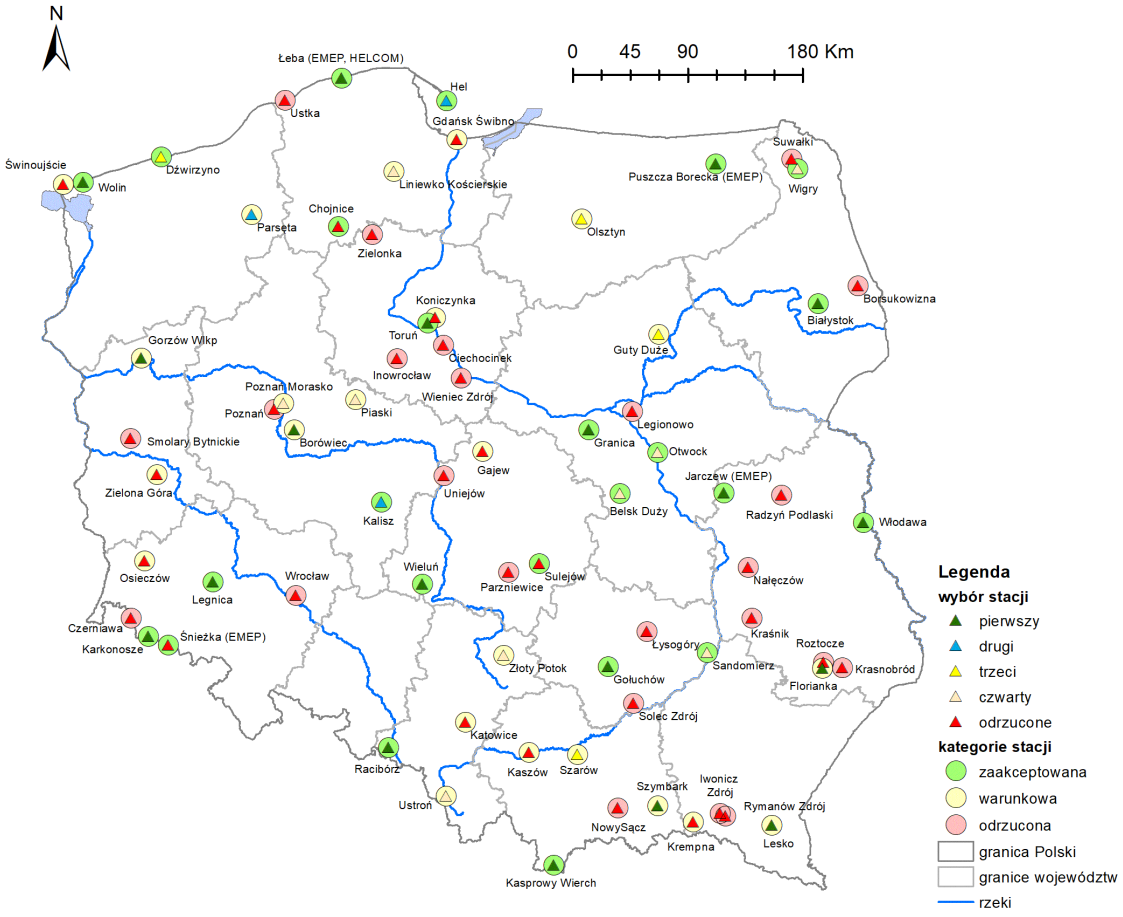


Figure 5.4 Presentation of all 71 analysed stations with indication of stations meeting the criteria (approved stations – green), conditional stations (yellow) and stations not meeting the criteria (rejected stations – red) and marking the selected 35 stations (4th choice) and stations of 1st, 2nd and 3rd choice (coloured triangles) (developed by IMWM-NRI)

In accordance with the provisions of the description of the subject of the contract, when selecting 35 locations, they were chosen in the first place from among the stations monitoring the suburban and regional background, as well as the IMNE stations operating

within the SEM. In case of lack of SEM stations meeting the location criteria, meteorological stations of IMWM-NRI were suggested. The 35 locations were selected in such a way that it would be possible to conduct measurements of wet atmospheric deposition on the entire area of the country. Figure 5.5 presents locations of the selected 35 measurement points. The following locations were proposed as EMEP stations: Łeba, Puszcza Borecka, Jarczew, Szymbark and Karkonosze. As HELCOM stations, the following were selected: Wolin, Dźwirzyno, Łeba and Hel.

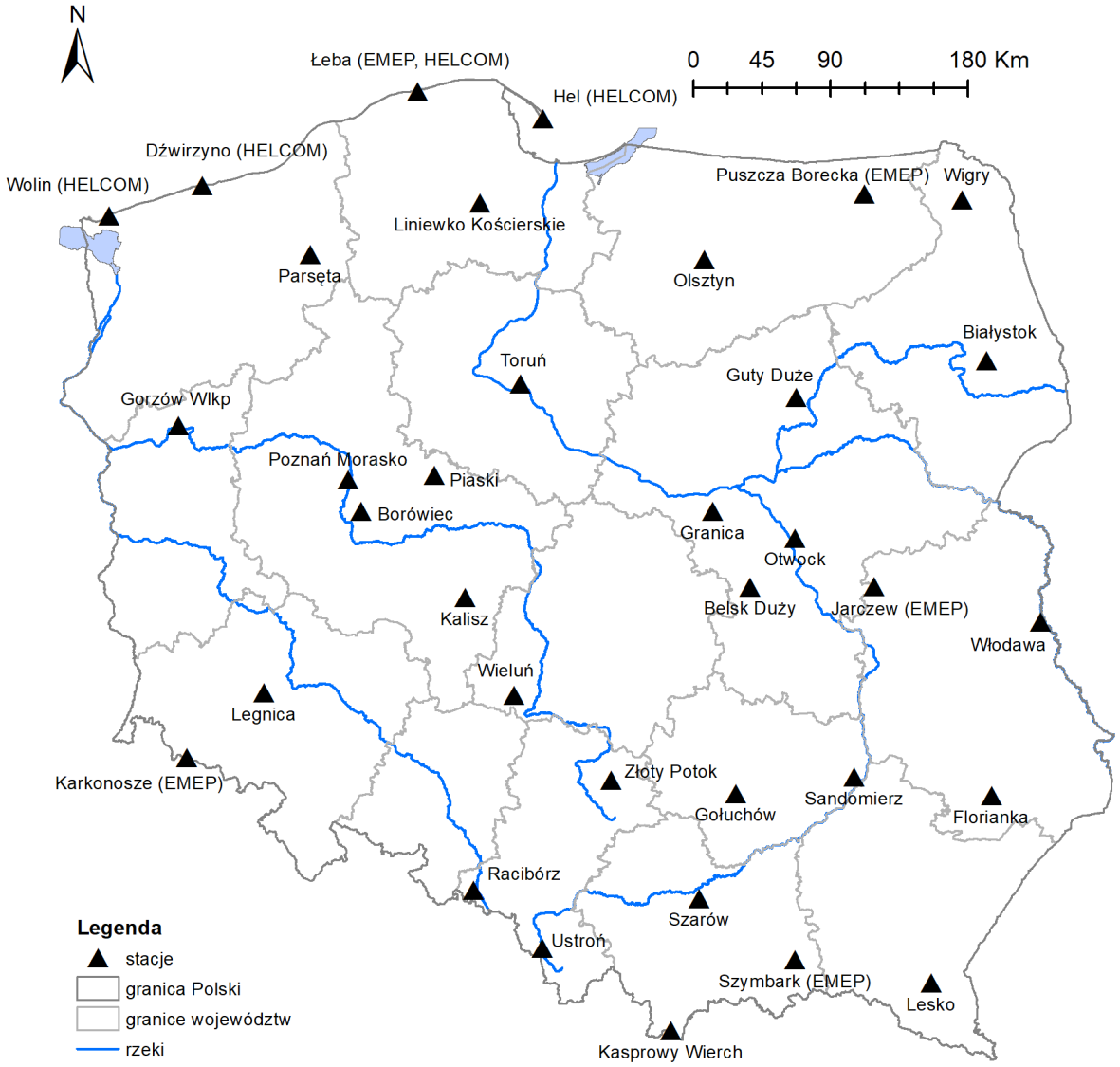


Figure 5.5 Location of 35 selected atmospheric precipitation chemistry measurement stations with indication of EMEP and HELCOM station proposals (developed by IMWM-NRI)

As a result of a broader analysis, in terms of spatial distribution, 19 (1st choice stations), 22 (2nd choice stations) and 26 stations (3rd choice stations) were proposed for selection. All 35 locations were considered as 4th choice stations. The following table and figures present the variants of the precipitation chemistry monitoring system.

Table 5.3 List of variants of station selection for the precipitation chemistry monitoring system (developed by IMWM-NRI)

No.	Station name	1st Choice	2nd Choice	3rd Choice	4th Choice
1	Belsk Duży				x
2	Bialystok	x	x	x	x
3	Borówiec	x	x	x	x
4	Dźwirzyno			x	x
5	Florianka	x	x	x	x
6	Gołuchów	x	x	x	x
7	Gorzów Wlkp.	x	x	x	x
8	Granica	x	x	x	x
9	Guty Duże			x	x
10	Hel		x	x	x
11	Jarczew	x	x	x	x
12	Kalisz		x	x	x
13	Karkonosze	x	x	x	x
14	Kasprowy Wierch	x	x	x	x
15	Legnica	x	x	x	x
16	Lesko	x	x	x	x
17	Liniewko Kościerskie				x
18	Łeba	x	x	x	x
19	Olsztyn			x	x
20	Otwock				x

No.	Station name	1st Choice	2nd Choice	3rd Choice	4th Choice
21	Parsęta		x	x	x
22	Piaski				x
23	Poznań Morasko				x
24	Puszcza Borecka	x	x	x	x
25	Racibórz	x	x	x	x
26	Szarów			x	x
27	Sandomierz				x
28	Szymbark	x	x	x	x
29	Toruń	x	x	x	x
30	Ustroń				x
31	Wieluń	x	x	x	x
32	Wigry				x
33	Włodawa	x	x	x	x
34	Wolin	x	x	x	x
35	Złoty Potok				x
	Total	**19**	**22**	**26**	**35**

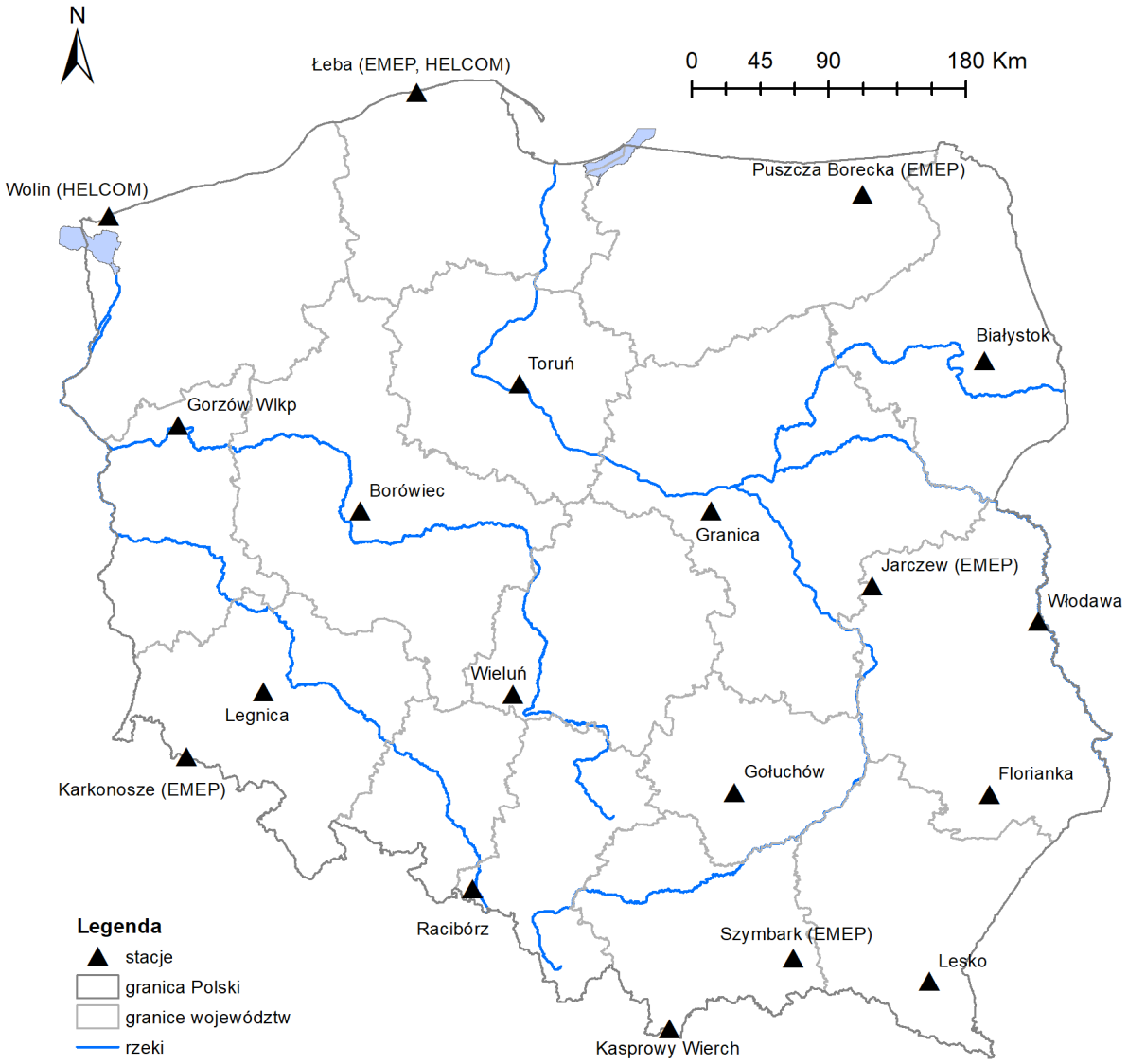


Figure 5.6 Proposal of 19 1st choice stations (developed by IMWM-NRI)

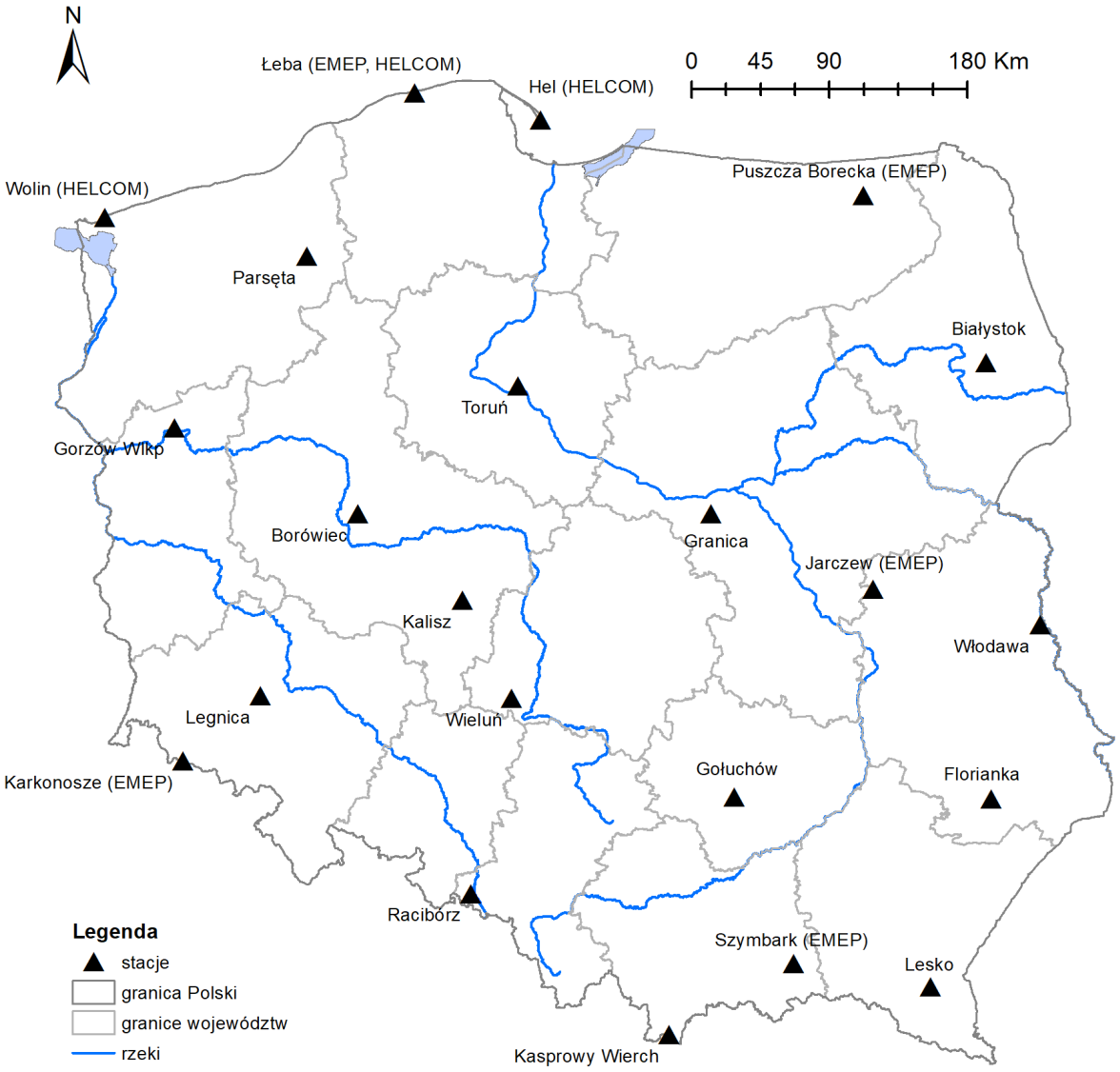


Figure 5.7 Proposal of 22 2nd choice stations (developed by IMWM-NRI)

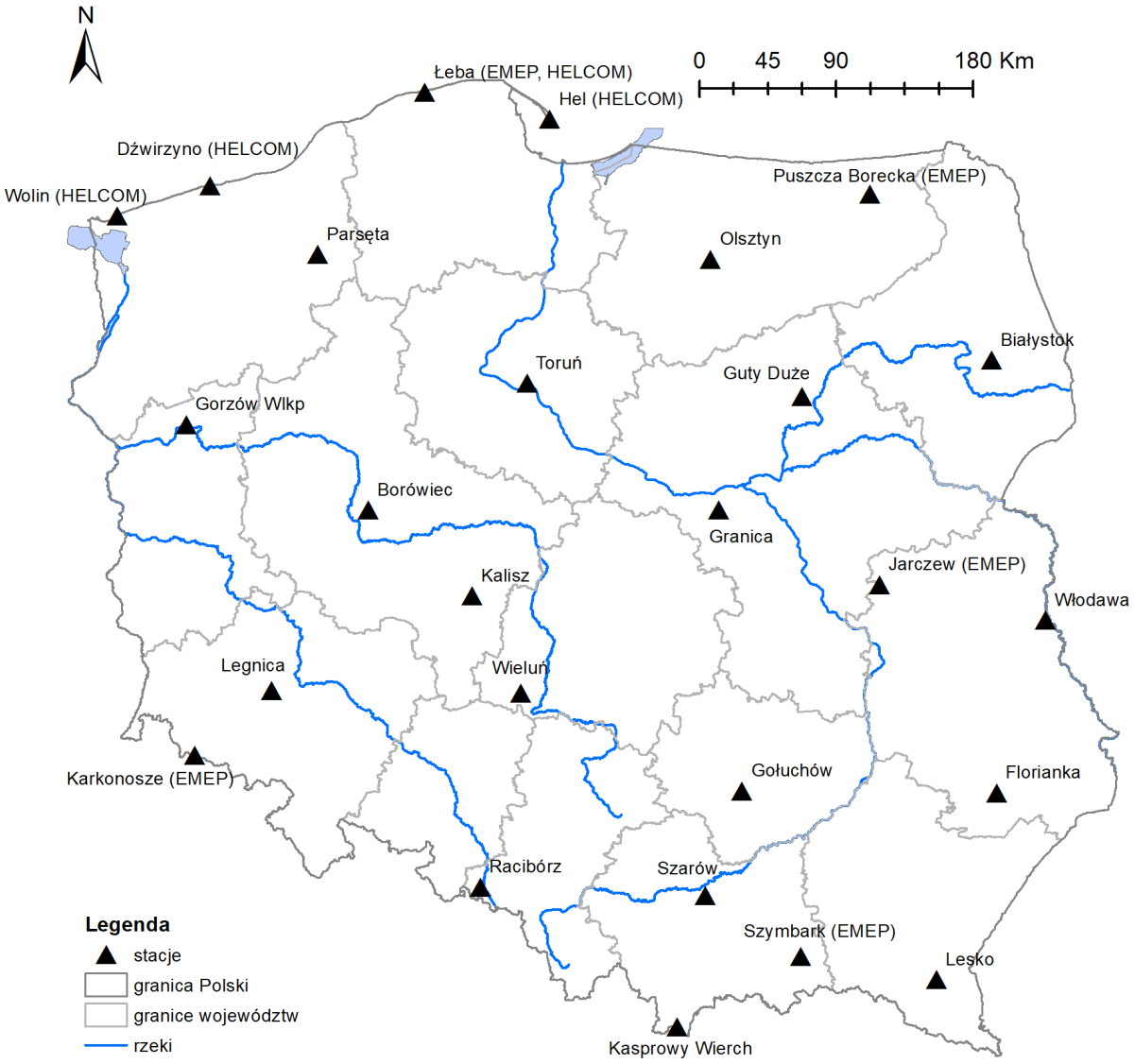


Figure 5.8 Proposal of 26 3rd choice stations (developed by IMWM-NRI)

6 Station assessment including deposition modelling of selected pollutants

6.1 Participation in a videoconference with representatives of NILU

As part of the task, a videoconference was held where NILU representatives presented analyses on deposition distribution for selected precipitation pollutants. The results of the presented analyses were taken into account in the evaluation of the stations for the creation of a new wet atmospheric deposition measurement network.

The deposition distribution analysis performed by the team from NILU used monthly wet atmospheric deposition data from 2015-2019, estimated from two EMEP models: the air quality model run by the Meteorological Synthesis Centre – West (MSC-W) for acidic compounds, i.e. oxidised sulphur (SO_2, SO_4), oxidised nitrogen (NO_2, PAN, HNO_3, HONO, NO_3) and reduced nitrogen (NH_3, NH_4), and the GLEMOS model used by the Meteorological Synthesis Centre – East (MSC-E) for heavy metals Cd, Hg, Pb. Measurement data from 2015-2019 were also used, from currently operating 22 precipitation chemistry stations and 2 suburban and regional background stations operating within the EMEP programme (Jarczew, Puszcza Borecka). The deposition data included the following components: SO_4^{2-}, NH_4^+, Ca^{2+}, Cl^-, H^+, K^+, Mg^{2+}, Na^+.

In the analysis presented here, the hierarchical clustering method was used to compare data in order to identify differences between stations, the so-called dissimilarity analysis. As a result of the calculations, 25 regions (clusters) of spatial representativeness of a given station/group of stations were distinguished. Selected pollutants were analysed: oxidised sulphur compounds (SOx), oxidised nitrogen compounds (OXN), reduced nitrogen compounds (RDN) and heavy metals: cadmium (Cd), lead (Pb) and mercury (Hg). The results obtained are presented in maps and tables.

The results of the analysis showed that oxidised sulphur compounds, oxidised nitrogen compounds and reduced nitrogen compounds were characterised by a more homogeneous distribution of areas representing one station than heavy metals. The results for heavy metals showed large differentiation between the western and eastern parts of Poland and between the north and south of the country, with more clusters in the south-eastern part. It is noteworthy that, irrespective of the pollutant considered, the north-western part of Poland is characterised by a smaller number of clusters, i.e. higher similarity.

6.2 Determination of the minimum and optimum number of measuring stations necessary for monitoring of precipitation chemistry for each of the pollutants.

On the basis of the review of requirements for measurement networks that carry out research for HELCOM, EMEP and precipitation chemistry and taking into account the analysis of deposition distribution for selected pollutants, which was conducted by NILU representatives, the minimum and optimum number of measurement sites necessary for monitoring of precipitation chemistry for each of the pollutants were identified.

Determination of minimum and optimum numbers of measurement sites took into account summary of physicochemical parameters for various types of measuring stations compiled in the report entitled “Determination of optimum range of substances and parameters which should be tested within precipitation chemistry (wet precipitation)”. In

that report, 7 types of stations were distinguished, depending on the planned research programme, in relation to measurements for precipitation chemistry, the HELCOM and EMEP programmes: basic stations (type 1), specialist stations (type 2), basic stations and HELCOM (type 3), basic stations and EMEP level 1 (type 4), basic stations and EMEP level 2 (type 5), basic stations and EMEP level 1 and HELCOM (type 6), basic stations and EMEP level 2 and HELCOM (type 7). The measurement range requirements are summarised in Table 6.1. In the next step of the current task, measurement ranges were assigned to the selected 35 stations in order to define the appropriate research programme.

Table 6.1 List of types of atmospheric deposition measurement stations and their corresponding measurement parameters (developed by IMWM-NRI)

No.	Parameter / station type	1	2	3	4	5	6	7
1.	SO_4^{2-}	x	x	x	x	x	x	x
2.	NO_3^-	x	x	x	x	x	x	x
3.	NH_4^+	x	x	x	x	x	x	x
4.	H^+ (pH)	x	x	x	x	x	x	x
5.	At^+	x	x	x	x	x	x	x
6.	K^+	x	x	x	x	x	x	x
7.	Ca^{2+}	x	x	x	x	x	x	x
8.	Mg^{2+}	x	x	x	x	x	x	x
9.	Cl^-	x	x	x	x	x	x	x
10.	conductivity	x	x	x	x	x	x	x
11.	Pb	x	x	x	x	x	x	x
12.	Cd	x	x	x	x	x	x	x
13.	total nitrogen	x	x	x	x	x	x	x
14.	total phosphorus	x	x	x	x	x	x	x
15.	Cu	-	x	x	x	x	x	x
16.	Zn	-	x	x	x	x	x	x

No.	Parameter / station type	1	2	3	4	5	6	7
17.	As	-	x	x	x	x	x	x
18.	Cr	-	x	x	x	x	x	x
19.	Ni	-	-	x	x	x	x	x
20.	HCO_3^-, at pH>6 (calculated from pH at pH<6)	-	-	-	x	x	x	x
21.	Hg	-	x	x	-	x	x	x
22.	PAHs	-	x	x	-	x	x	x
23.	PCBs (polychlorinated biphenyls)	-	-	x	-	x	x	x
24.	HCB (hexachlorobenzene)	-	-	-	-	x	-	x
25.	chlordan	-	-	-	-	x	-	x
26.	HCHs (hexachlorocyclohexane)	-	-	-	-	x	-	x
27.	DDT/DDE (dichlorodiphenyl-trichloroethane and dichlorodiphenyl-dichloroethylene)	-	-	-	-	x	-	x
28.	PBDE	-	-	x	-	-	x	x

Key:
Station types:
1. Basic chemistry monitoring stations
2. Specialised chemistry monitoring stations
3. Basic chemistry monitoring and HELCOM stations
4. Basic chemistry monitoring and EMEP level 1 stations
5. Basic chemistry monitoring and EMEP level 2 stations
6. Basic chemistry monitoring, EMEP level 1 and HELCOM stations
7. Basic chemistry monitoring, EMEP level 2 and HELCOM stations

In the process of optimising the number of stations necessary for monitoring the precipitation chemistry for each of the pollutants, the results from the NILU report and supplementary material were used, as well as the experience from the studies conducted for the current wet deposition assessment system and from other monitoring programmes for air quality measurements.

In accordance with the guidelines described in the report entitled “Determination of optimum range of substances and parameters which should be tested within precipitation

chemistry (wet precipitation)", two types of stations were selected for conducting precipitation chemistry at which the parameters should be tested:

- basic – at basic chemistry monitoring stations (type 1),
- basic + specialised – at specialised chemical monitoring stations, i.e. conducting research extended to include the following indicators: heavy metals: chromium, copper, nickel, zinc, mercury and PAHs (type 2).

The summary of proposed analyses for basic chemistry monitoring stations included lead and cadmium as metals to be tested at each station. An additional analysis of the current locations of the precipitation chemistry monitoring stations was performed to determine at which stations an expanded scope of testing should be conducted. As the metals: chromium, copper, nickel and zinc were not included in the NILU modelling analysis, an analysis of the deposition of these heavy metals was carried out for the 22 stations of the current precipitation chemistry monitoring for the five-year period 2015-2019, which is the same period covered by the NILU analysis. Calculations of five-year average deposition of each metal were made. The results are presented in Figures 6.1 – 6.4.

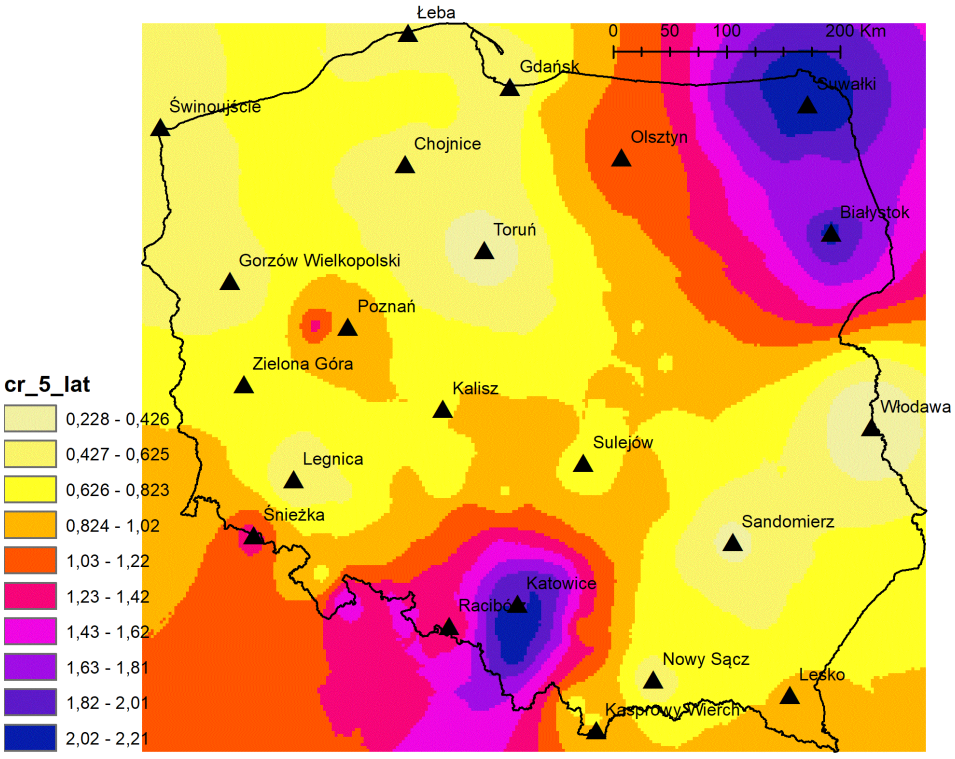


Figure 6.1 Spatial distribution of mean chromium deposition [g/ha] for the period 2015-2019 based on data from 22 stations of current monitoring of precipitation chemistry (developed by IMWM-NRI)

The results of the analysis showed that the highest chromium pollution was identified in the north-eastern Poland in the region of Suwałki and Białystok as well as in the area of Upper Silesia, where data are currently collected at the stations in Katowice

and Racibórz (Fig. 6.1). On the other hand, the smallest deposition of chromium is observed in south-eastern Poland (Włodawa, Sandomierz, Nowy Sącz), in the area of northern Poland (Toruń, Chojnice, Gdańsk-Świbno, Łeba) as well as north-western and western Poland (a belt stretching from Świnoujście, through Gorzów Wlkp. to Legnica).

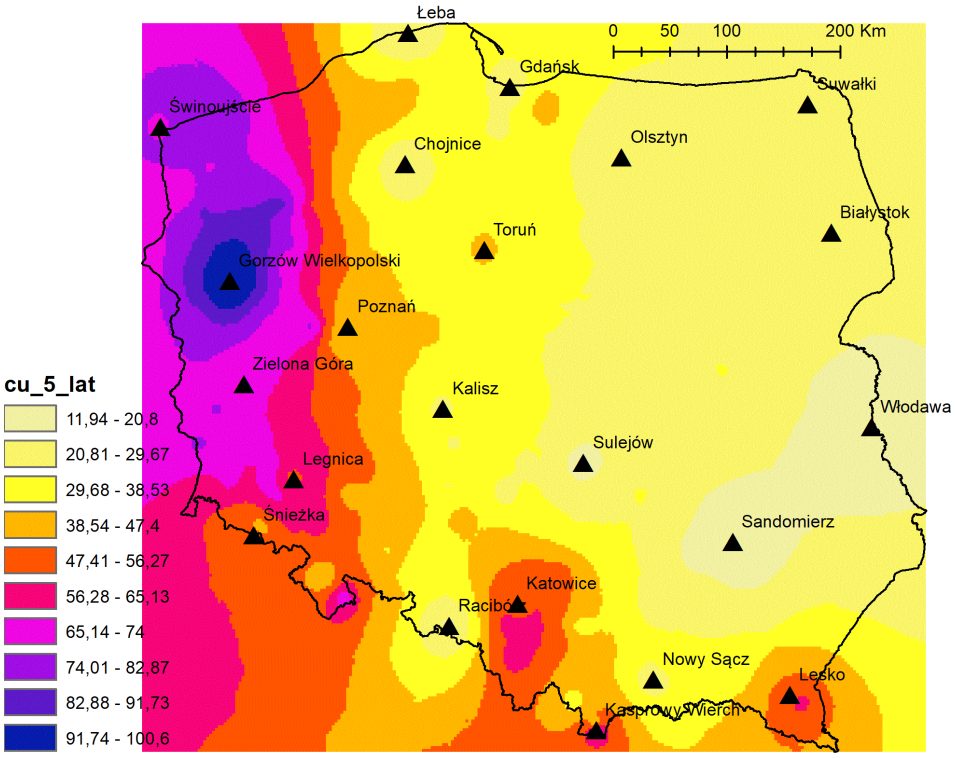


Figure 6.2 Spatial distribution of mean copper deposition [g/ha] for the period 2015-2019 based on data from 22 stations of current monitoring of precipitation chemistry (developed by IMWM-NRI)

Based on the analysis (Figure 6.2), it was found that the highest deposition of copper with precipitation in the period 2015-2019 occurred along the western border of the country along a belt from Świnoujście, through Gorzów Wlkp. to Zielona Góra. The smallest values of wet deposition of Cu during the discussed five-year period were identified in the area covered by measurement stations in Włodawa, Sandomierz and Sulejów and Nowy Sącz, and pointwise in the south near the Racibórz station, and in the north in the area of Łeba, Gdańsk-Świbno and Chojnice.

The highest nickel risk was observed in areas of southern Poland – from the west in the region of Śnieżka and Śnieżnik through Upper Silesia, southern Lesser Poland (Kasprowy Wierch, Nowy Sącz) to the south-eastern border of the country (Lesko) (Fig. 6.3). Higher nickel deposition was also associated with the coastal region (Gdańsk-Świbno), but also with the Suwałki area. The lowest values were observed in the belt stretching from Włodawa to Sandomierz and in central Poland in the north-south belt

(Chojnice, Kalisz) and pointwise in Olsztyn and at the north-western end of our country (Świnoujście).

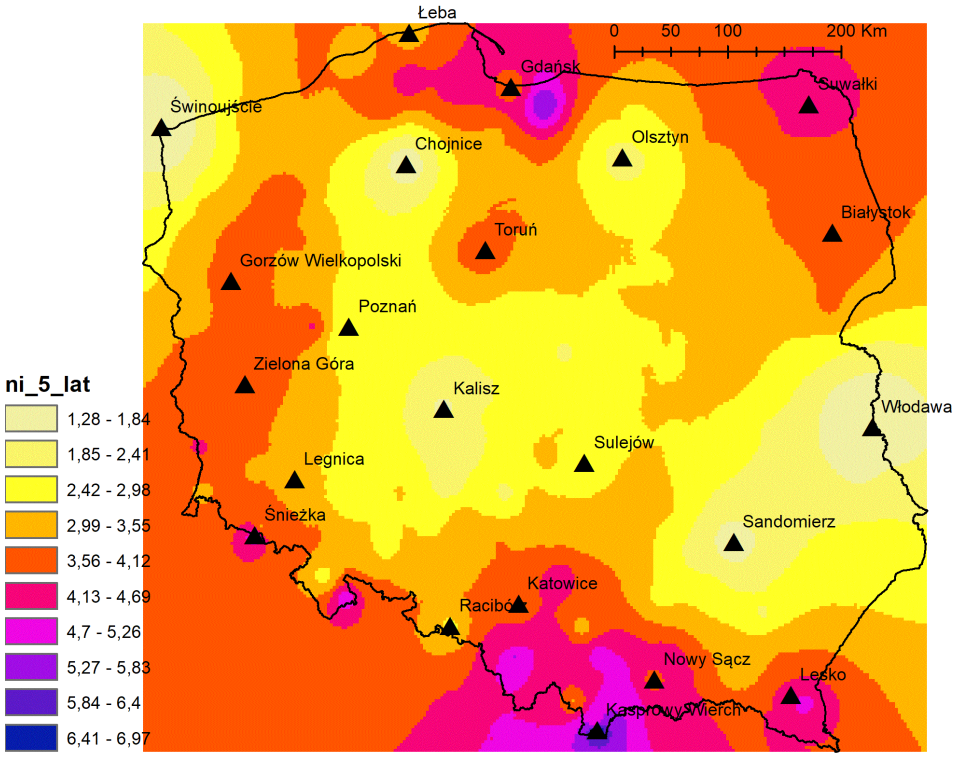


Figure 6.3 Spatial distribution of mean nickel deposition [g/ha] for the period 2015-2019 based on data from 22 stations of the current monitoring of precipitation chemistry (developed by IMWM-NRI)

The highest wet deposition of zinc was found in three clusters: in north-eastern Poland (Suwałki, Białystok), in the region of Upper Silesia (Katowice) and in southernmost Poland – Kasprowy Wierch and Lesko. The least amount of zinc was deposited with precipitation in two large areas of northern and central Poland – in the region of Gorzów Wlkp. and Zielona Góra, and also in Poznań, Chojnice and Łeba and pointwise in Olsztyn. Decreased Cu deposition was also observed in a belt from Włodawa, through Sandomierz to Nowy Sącz. Pointwise relatively low Cu deposition values were recorded in the Racibórz area during 2015-2019.

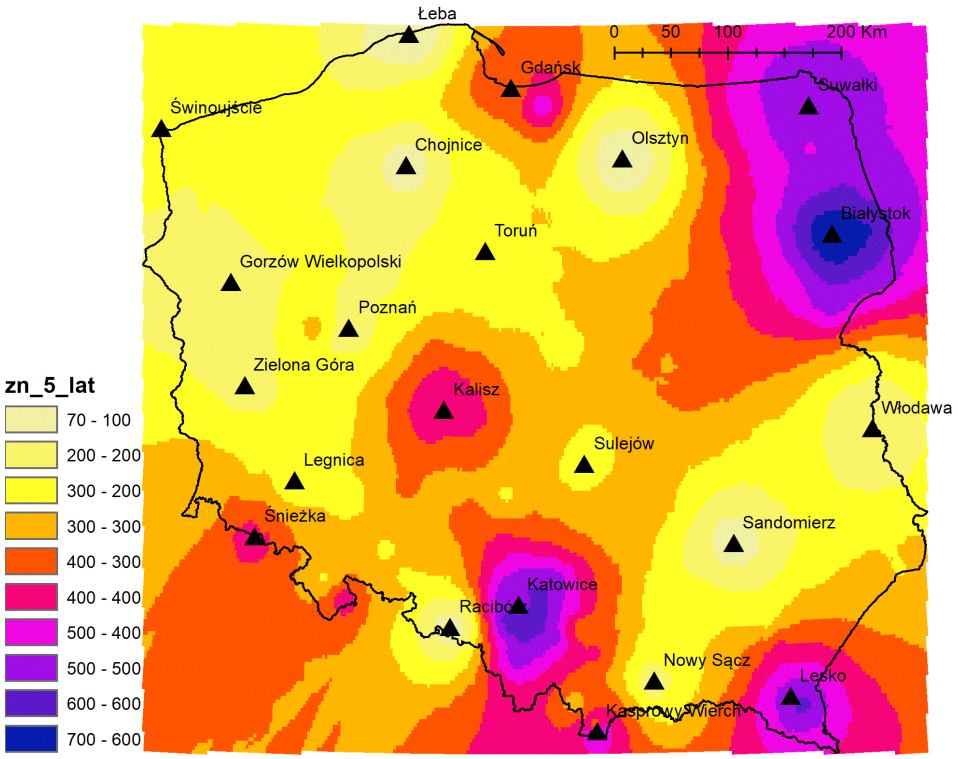


Figure 6.4 Spatial distribution of mean zinc deposition [g/ha] for the period 2015-2019 based on data from 22 stations of current monitoring of precipitation chemistry (developed by IMWM-NRI)

The analysis shows that there is a need to monitor the listed heavy metals in areas with both high and, by comparison, low wet deposition.

On the basis of the NILU report and supplementary material sent by the Norwegian party, it is possible to determine the representativeness of the stations operating in the current precipitation chemistry network in Poland and the representativeness of the stations indicated for measurements after network optimisation.

As shown in the NILU report (NILU 2021) acid/acidifying compounds require monitoring throughout the country, while for heavy metals the north-south and east-west divide is more pronounced, with smaller concentrations in the south-eastern part of the country. This indicates a greater number of sources in the south-eastern part of Poland. It is proposed that regardless of the relationship, a denser network be maintained in the south-eastern part of the country and a sparser network in the north-western part. There is also a need to maintain monitoring stations for the Polish coast, especially for pollution associated with shipping.

The NILU Report (NILU 2021) presents maps of the spatial distribution of 25 clusters of Cd, Pb and Hg dissimilarities with 22 stations of the current precipitation chemistry monitoring, suburban and regional background stations, as well as the ZMSP (integrated monitoring) stations superimposed on them. In the supplementary material,

more than 35 stations preliminary considered for the new chemistry monitoring system were superimposed on the developed maps. The maps prepared in this way (Figures 6.5, 6.6, 6.7) made it possible to accurately estimate the representativeness of each location under consideration.

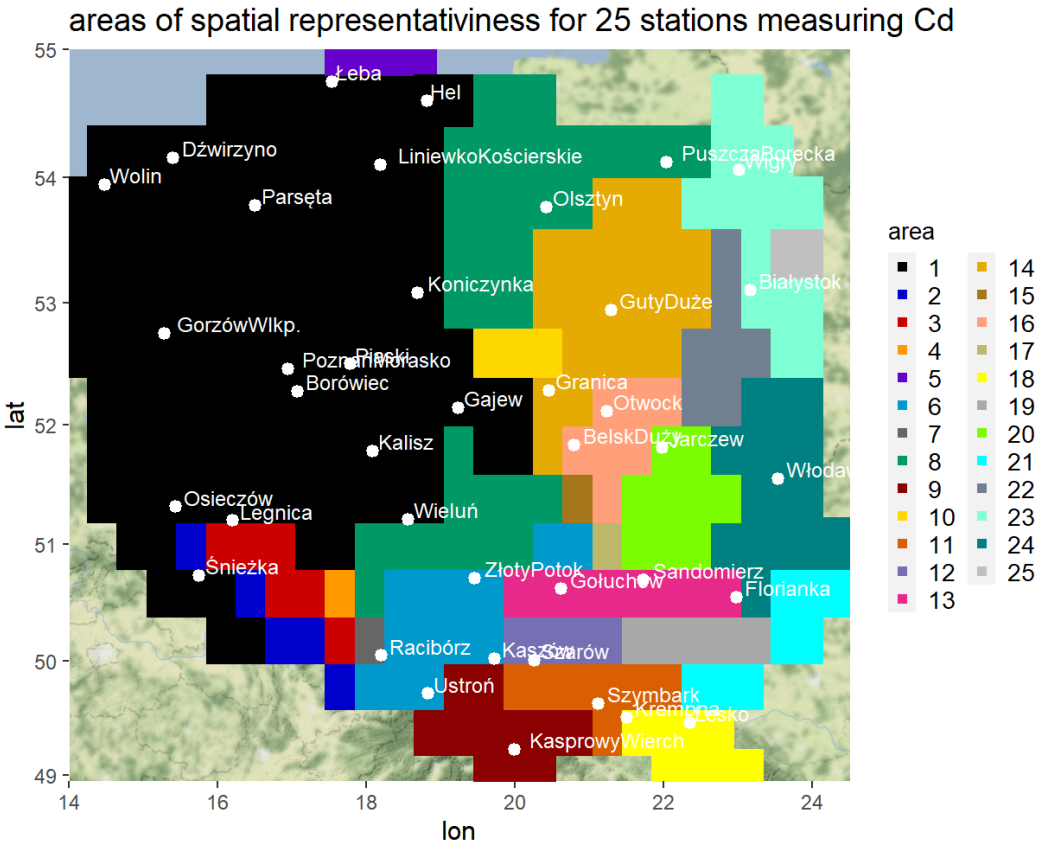


Figure 6.5 Spatial distribution of 25 Cd dissimilarity clusters with more than 35 stations preliminary considered for precipitation chemistry measurements marked (NILU supplementary material)

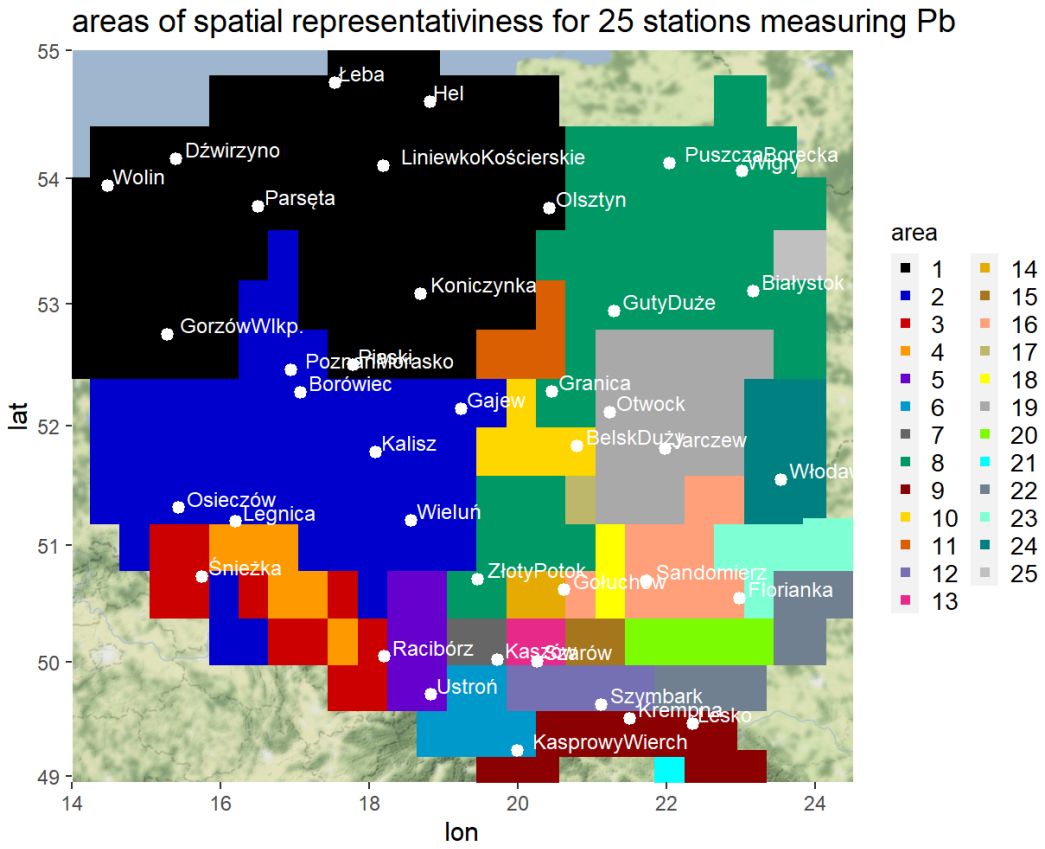


Figure 6.6 Spatial distribution of 25 Pb dissimilarity clusters with more than 35 stations preliminary considered for precipitation chemistry studies marked (NILU supplementary material)

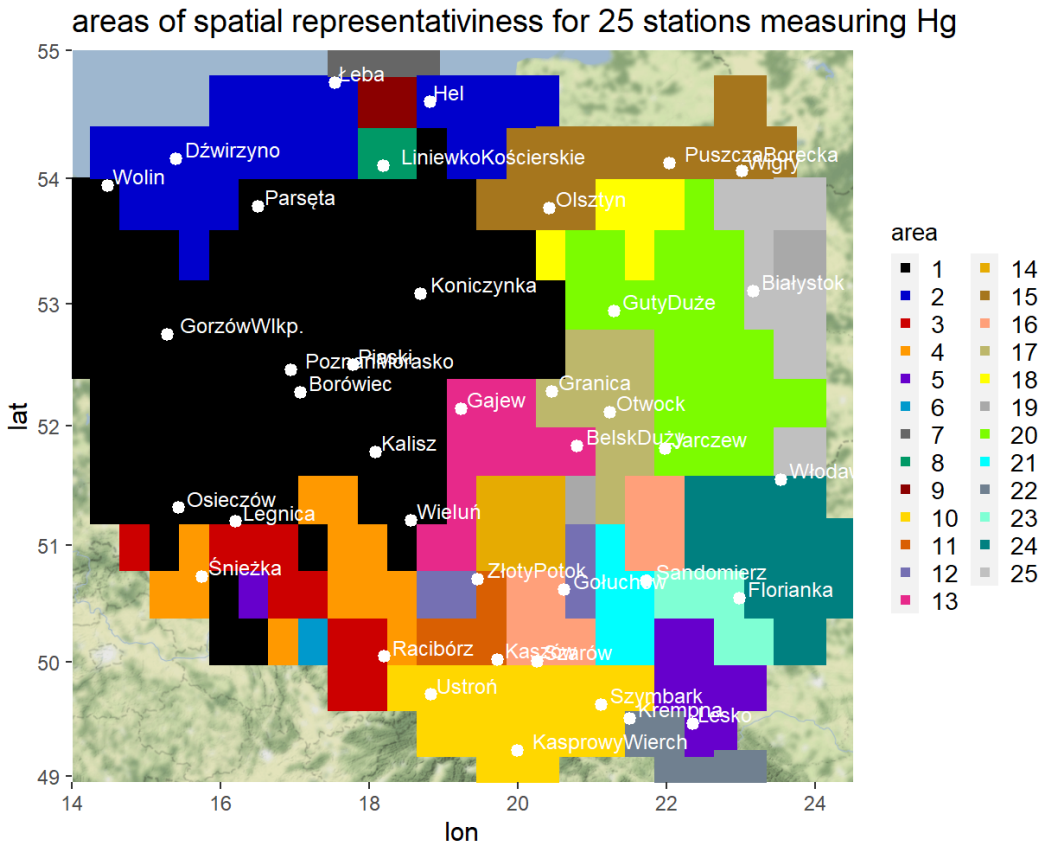


Figure 6.7 Spatial distribution of 25 Hg dissimilarity clusters with more than 35 stations preliminary considered for precipitation chemistry studies marked (NILU supplementary material)

In accordance with earlier assumptions, cadmium and lead were assigned to the basic group of parameters measured at all chemistry stations in Poland. The presented NILU analysis showed that it is not necessary to measure Cd and Pb at every station, since over a large area of western Poland these parameters do not show variability. Greater variability in cadmium and lead is observed in the south, southeast and east.

Considering the above analysis and previous assumptions, it is suggested that cadmium and lead measurement be carried out at each station for a period of, e.g., 5 years. After this period, it would be necessary to repeat the analysis with modelling and carry out a verification of the location and consider whether there is a need to change the number of stations measuring cadmium and lead in precipitation.

Mercury is an element indicated to be measured at specialized chemistry stations, as well as at HELCOM stations and at EMEP Level 2 stations, where there is an obligation to measure this substance both in the air and in precipitation. As in the case of cadmium and lead, the NILU analysis shows a large area in the west of the country demonstrating no variability, while a large variation in mercury is found in eastern, central and southern Poland. After analysing the above distributions, the stations selected for mercury measurement are: Bialystok, Borówiec, Granica, Legnica, Lesko, Puszcza Borecka, Szymbark, Torun, Wlodawa, Wolin (Table 6.2).

The NILU analysis also shows that all stations designated as EMEP: Łeba, Puszcza Borecka, Jarczew, Szymbark and Karkonosze in the case of cadmium, but also for the other indicators analysed in the NILU report, are located in separate clusters, which proves the representativeness of the selected EMEP stations in relation to the analysed substances.

Verification of sites for PAH measurements, not covered by NILU modelling, was based on measurements conducted for the purpose of regional background assessment. Data are currently collected by the Chief Inspectorate of Environmental Protection at the Osieczów, Zielonka and Puszcza Borecka stations (CIEP 2021). In the new precipitation chemistry monitoring system, it is proposed to continue the measurements at the Puszcza Borecka station and in new locations: Granica and Borówiec (Table 6.2).

In accordance with the requirements of Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (2004/107/EC), measurements of total deposition of heavy metals and PAHs shall be taken in at least three sampling points of the national regional background. Measurements of these elements shall be taken at the Puszcza Borecka station (continuation) as well as at two other stations of regional background, i.e. at the Borówiec and Granica stations.

Hg (mercury) is a parameter to be analysed at HELCOM and at EMEP level 2 stations, as are PCBs (polychlorinated biphenyls), also foreseen for EMEP level 2 and HELCOM stations. However, for EMEP level 2, measurement of substances such as chlordane, DDT/DDE (dichlorodiphenyltrichloroethane and dichlorodiphenyldichloroethylene), HCB (hexachlorobenzene) HCHs (hexachlorocyclohexane) should be included, as shown in Table 6.2.

Taking into account all the analyses, at the first choice stations (18 stations and Puszcza Borecka) an extended measurement programme, provided for specialised stations for monitoring of precipitation chemistry, is proposed (Table 6.2). For additional stations included in the 2nd, 3rd and 4th choices, which are not included in the set of 1st choice stations, a basic set of measurements is proposed. In addition, the parameters listed in EMEP and HELCOM programmes respectively should be included.

The optimum number of measurement stations for monitoring of wet atmospheric deposition was considered to be 26 (3rd choice), including 19 stations with extended scope (specialist stations for monitoring of chemistry) of type 2 and 7 stations with basic measurement scope of type 1. The minimum number of stations allowing to for atmospheric precipitation chemistry monitoring was assumed to be the 19 1st choice stations.

Table 6.2 List of station types divided into 4 choice classes and corresponding measurement parameters of specialised indicators and additional programmes (developed by IMWM-NRI)

No.	Station name	Choice				Type of station		Type 2 chemistry specific indicators and additional indicators according to the programmes: EMEP 1, EMEP 2, HELCOM and the requirements of DIRECTIVE 2004/107/EC													
		1st	2nd	3rd	4th		Other programmes	Cu	Zn	As	Cr	Hg	Ni	PAHs	HCO_3^-	HCB	chlordan	DDT/DDE	HCHs	PCBs	PBDE
1	Belsk Duży				x	1															
2	Bialystok	x	x	x	x	2		x	x	x	x	x									
3	Borówiec	x	x	x	x	2	2004/107/EC	x	x	x	x	x		x							
4	Dźwirzyno			x	x	1	HELCOM	x	x	x	x	x	x	x						x	x
5	Florianka	x	x	x	x	2		x	x	x	x										
6	Gołuchów	x	x	x	x	2		x	x	x	x										
7	Gorzów Wlkp.	x	x	x	x	2		x	x	x	x										
8	Granica	x	x	x	x	2	2004/107/EC	x	x	x	x	x		x							
9	Guty Duże			x	x	1															
10	Hel		x	x	x	1	HELCOM	x	x	x	x	x	x	x						x	x
11	Jarczew	x	x	x	x	2	EMEP 1	x	x	x	x		x		x						
12	Kalisz		x	x	x	1															
13	Karkonosze	x	x	x	x	2	EMEP 1 or 2*	x	x	x	x	x	x	x	x	x	X	x	x	x	
14	Kasprowy Wierch	x	x	x	x	2		x	x	x	x										
15	Legnica	x	x	x	x	2		x	x	x	x	x									
16	Lesko	x	x	x	x	2		x	x	x	x	x									

No.	Station name	Choice				Type of station	Other programmes	Type 2 chemistry specific indicators and additional indicators according to the programmes: EMEP 1, EMEP 2, HELCOM and the requirements of DIRECTIVE 2004/107/EC													
		1st	2nd	3rd	4th			Cu	Zn	As	Cr	Hg	Ni	PAHs	HCO_3^-	HCB	chlordan	DDT/DDE	HCHs	PCBs	PBDE
17	Liniewko Kościerskie				x	1															
18	Łeba	x	x	x	x	2	EMEP 1, HELCOM	x	x	x	x	x	x	x	x					x	x
19	Olsztyn			x	x	1															
20	Otwock				x	1															
21	Parsęta		x	x	x	1															
22	Piaski				x	1															
23	Poznań Morasko				x	1															
24	Puszcza Borecka	x	x	x	x	2	EMEP 2, 2004/107/EC	x	x	x	x	x	x	x	x	x	x	x	x	x	
25	Racibórz	x	x	x	x	2		x	x	x	x										
26	Szarów			x	x	1															
27	Sandomierz				x	1															
28	Szymbark	x	x	x	x	2	EMEP 1 or 2*	x	x	x	x	x	x	x	x	x	x	x	x	x	
29	Toruń	x	x	x	x	**2**		x	x	x	x	x									
30	Ustroń				x	1															
31	Wieluń	x	x	x	x	**2**		x	x	x	x										

No.	Station name	Choice				Type of station	Other programmes	Type 2 chemistry specific indicators and additional indicators according to the programmes: EMEP 1, EMEP 2, HELCOM and the requirements of DIRECTIVE 2004/107/EC													
		1st	2nd	3rd	4th			Cu	Zn	As	Cr	Hg	Ni	PAHs	HCO_3^-	HCB	chlordan	DDT/DDE	HCHs	PCBs	PBDE
32	Wigry				x	1															
33	Włodawa	x	x	x	x	**2**		x	x	x	x	x									
34	Wolin	x	x	x	x	**2**	HELCOM	x	x	x	x	x	x	x						x	x
35	Złoty Potok				x	1															

* alternative option - discussed in detail in section 6.3 below

Key:
Station types:
Basic chemistry monitoring stations
Specialised chemistry monitoring stations

Variables:
DDT/DDE (dichlorodiphenyltrichloroethane and dichlorodiphenyl dichloroethylene)
HCHs (hexachlorocyclohexane)
HCB (hexachlorobenzene)
PCBs (polychlorinated biphenyls)
HCO_3^- , at pH>6 (calculated from pH at pH<6)
PAHs

6.3 Stations in the HELCOM and EMEP programmes

In addition, detailed analyses were carried out on the selection of stations for measurements under the HELCOM and EMEP programmes.

HELCOM

Taking into account modelling results presented in the NILU report (NILU Report 2021), the currently operating measurement station located in Łeba may be considered representative in the following range:

- for SOX (sulphur oxides) – from Jastrzębia Góra to Koszalin; it does not include areas on the west Coast,
- for OXN (oxidised forms of nitrogen) – from Jastrzębia Góra to Koszalin; does not include areas on the west Coast,
- for RDN (reduced forms of nitrogen) – representative for the whole coast,
- Cd – representative for a very small section from Jastrzębia Góra to Łeba,
- Hg – representative for a very small section from Jastrzębia Góra to Łeba,
- Pb – the station is located in a vast cluster with similar Pb deposition characteristics.

The above analysis clearly identifies the need for additional stations in the central and western coastal areas to study deposition of pollutants into the Baltic Sea.

Based on the conducted visits and analyses, stations are finally recommended for the study of deposition of pollutants to the Baltic Sea:

1. Łeba – a good location for information on deposition to the Baltic Sea and continuation of the historical series;
2. Hel – an excellent location for studying deposition of pollutants to the Baltic Sea – the station protruding into the sea area, surrounded by the sea on three sides, fills the information gap in relation to the representativeness of the Łeba station;
3. Dźwirzyno – location directly on the shore in the central coastal region, very important due to information gap in deposition of pollutants to the Baltic Sea in relation to area representativeness of the Łeba station;
4. Wolin – located directly on the shore in the west Coast area, very important due to information gap in deposition of pollutants to the Baltic Sea in relation to area representativeness of the Łeba station.

EMEP

Based on the conducted visits and analyses, stations are finally recommended for the purpose of pollutant deposition measurements for EMEP and to collect data under the EMEP programme:

1. Puszcza Borecka – a station operating in EMEP, regional station for GAW/WMO, having rich observing programme of air pollution and precipitation, implementing EMEP level 1 and partially level 2 programme; located in vast forest area, in a lake region, in north-eastern Poland; continuation of historical series, this station was

indicated by the Contracting Party as unconditionally remaining in the network; meeting requirements; selected as EMEP level 2 station (extended scope);

2. Łeba – a station operating within EMEP, regional station for GAW/WMO, results used in the HELCOM programme; located in a coastal area, good location for collecting data on deposition to the Baltic Sea, as well as for EMEP purposes, meeting requirements; continuation of historical series;
3. Jarczew – a station operating within EMEP, regional station for GAW/WMO; lowland station, agricultural region, central-eastern region of the country; meeting requirements; continuation of historical series;
4. Karkonosze – a high-mountain station, located in the highest parts of the Karkonosze Mountains, the same mountain group as Śnieżka (distances approx. 17 km from the station on Śnieżka) in the close vicinity of Szrenica summit (1362 m); fulfils the requirements; station operating within IMNE; proposed to replace the EMEP station operating on Śnieżka;

   It is recommended to maintain a station carrying out research for the EMEP programme in the Karkonosze region. It is necessary to continue the long-term series of observations of atmospheric pollution and precipitation in the high mountain region in south-western Poland.

5. Szymbark – a station located in mountainous region in southern Poland, in north-western part of Beskid Niski, acting within IMNE under the name Beskid Niski (Szymbark is the previous name), meeting the requirements, located on a gentle slope (deviation from the assumptions), a new proposal for EMEP location.

Taking into account the results of modelling presented in the NILU report, each of these five stations has its own area of representativeness (it is located in a separate cluster) for all the examined elements. It follows that the network has been evenly distributed over the country's area and that the locations so selected represent well the diversity of conditions that may affect the spatial distribution of the pollutants under study.

Out of five recommended locations for an EMEP level 2 station (extended range), the first one is proposed to be the Puszcza Borecka station, which is constantly improving its potential and already performs some elements of level 2.

The second station of level 2 should be located in a part of Poland that is distant from Puszcza Borecka. Therefore, it is recommended to choose either Szymbark (1st choice) or Karkonosze (1st choice) as EMEP level 2 stations. From a geographical point of view, Szymbark seems to be a better choice. However, both mentioned stations are new locations proposed for EMEP. Level 1 activities should be the first priority when extending the monitoring network in areas with few locations. It is suggested to include both stations into EMEP as level 1 stations first and then, after several years of measurements, to conduct additional analysis to make the final decision.

7 Estimation of annual costs and organisational issues of the precipitation chemistry measurement system in Poland

As part of the task, annual costs of conducting measurements and physicochemical analyses of precipitation samples were estimated together with organisational issues of conducting precipitation chemistry monitoring.

7.1 Estimated annual costs of conducting measurements of precipitation chemistry

In order to estimate the annual operating costs of precipitation chemistry measurements, the following were taken into account:

- costs of leasing/using the land for the collector,
- the cost of electricity needed to operate the collector,
- labour costs of a possible station manager, e.g. for sampling, daily pH measurement,
- costs of transporting samples from measurement stations to branches of the Central Research Laboratory of the Chief Inspectorate of Environmental Protection (CRL CIEP),
- costs of sending samples from CRL CIEP branches to laboratories designated to perform physicochemical analyses,
- the costs of reagents needed for physicochemical analyses.

In order to estimate the costs of land lease for the precipitation collectors, it was assumed that 1 m^2 of land is needed for the collector foundation. A review of websites presenting land rental offers in various parts of the country (morizon.pl, komercyjne.pl, otodom.pl, gratka.pl, olx.pl, nieruchomości-online.pl) was carried out. The analysis covered land properties in 14 locations. Due to insufficient number of land offers for rent in particular locations, the research was extended to the neighbouring towns. Land rental prices are at varied levels and result mainly from the location of the land. The land rental offer with the lowest price per m^2 was found in Legnica, land for rent with the highest price was located at the seaside: Łeba, Dźwirzyno. The table below presents land rental rates in particular locations and calculation of average price of renting 1 m^2 area per month.

Table 7.1 Summary of net land rental rates per month in individual locations (developed by IMWM-NRI)

No.	Location	Net price per 1 m²	Average net rental price per 1 m² in individual locations
1.	Toruń	PLN 2.30 – PLN 3.00	PLN 2.77
2.	Kalisz	PLN 2.50 – 4.42 PLN	PLN 3.31
3.	Legnica	PLN 0.13 – 2.40 PLN	PLN 1.53
4.	Lesko	PLN 2.50 – 10.00 PLN	PLN 5.17
5.	Łeba	8.33 PLN – 150.00 PLN	PLN 58.69

6.	Dźwirzyno	PLN 0.54 – 200 PLN	PLN 67.98
7.	Olsztyn	PLN 1.20 – 3.50 PLN	PLN 2.57
8.	Bialystok	PLN 2.19 – 3.00 PLN	PLN 2.55
9.	Włodawa	PLN 0.33 – 1.50 PLN	PLN 1.05
10.	Jarczew	PLN 0.16 – 0.59 PLN	PLN 0.38
11.	Sandomierz	PLN 0.71 – 1.56 PLN	PLN 1.28
12.	Gorzów Wielkopolski	PLN 0.57 – 3.24 PLN	PLN 2.27
13.	Racibórz	PLN 1.04 – 4.44 PLN	PLN 2.28
14.	Wieluń	PLN 1.00 – 2.05 PLN	PLN 1.68
Average net rental price per 1 m² of space per month			**PLN 10.97**

The average net price of renting 1 m^2 of land is PLN 10.97 net/month. The **estimated gross annual cost of leasing land for one rainfall collector is PLN 161.92**.

The following assumptions were made to estimate the energy costs. According to the technical specification of the manufacturer of automatic precipitation collectors: https://www.eigenbrodt.de/en/info-center/downloads/prospects-and-catalog the maximum energy load of the collector type NSA 1981/KE with cooling and heating function of the precipitation sample chamber is: 430 watts + 160 watts (cooling) or 100 watts (heating). The collector was assumed to operate at maximum power throughout the year: 8760 h/y, cooling for 6 months: 4380 h/y and heating for 6 months: 4380 h/y. The maximum amount of energy consumed by the collector in a year can be: 4906 kWh. The average cost of electricity in 2022 (http://www.cena-pradu.pl/tabela.html, accessed May 2022) is: 0.66 PLN gross per kWh. The **annual estimated cost of electricity consumption by one collector is: PLN 3,237.96**.

In order to estimate the costs of work of a potential station manager for e.g. sampling, daily pH measurement it was assumed that these activities may take about 16.5 h/month. Assuming that the average month of full-time employment is 168 h, the work of the precipitation chemistry measurement station custodian constitutes 0.1 full-time employment. According to the announcement of the President of the Central Statistical Office of 11 May 2022, the average salary in the first quarter of 2022 was PLN 6,235.22: https://stat.gov.pl/sygnalne/komunikaty-i-obwieszczenia/lista-komunikatow-i-obwieszczen/komunikat-w-sprawie-przecietnego-wynagrodzenia-w-pierwszym-kwartale-2022-roku,271,36.html. Assuming the cost of full-time work at the level of the average salary, the **annual estimated cost of the station supervisor's work is: PLN 7,482.26.**

The costs of transport of precipitation samples from measurement stations to CRL CIEP branches were estimated on the assumption that employees of CRL CIEP branches will collect samples from stations within a given voivodeship every 2 weeks. The following distances were calculated in kilometres from the location of a CRL CIEP branch to a given station. The cost of driving 1 km was calculated on the basis of the mileage rate for a vehicle with an engine capacity of 900 cm^3 in accordance with the Regulation of the Minister of Infrastructure of 25 March 2002 on the conditions for determining and the manner of refunding costs of use of passenger cars, motorbikes and mopeds not owned by the employer (Journal of Laws No. 27 item 271 as amended): https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu20020270271. This rate is PLN 0.8358 per kilometre.

Table 7.2 Comparison of costs of sample transport to CRL CIEP branches from individual locations, taking into account 4 variants of selection of the number of stations to precipitation chemistry measurement system (developed by IMWM-NRI)

				Wersja wyboru				koszty		cena za km	0,8358
				I	II	III	IV	I	II	III	IV
	Województwo	Oddział CLB GIOŚ	Stacja	odległość w kilometrach				koszt przejazdu w obie strony			
1	Warmińsko-mazurskie	Olsztyn	Puszcza Borecka	127	127	127	127	212,3 zł	212,3 zł	212,3 zł	212,3 zł
			Olsztyn			6	6	- zł	- zł	10,0 zł	10,0 zł
								212,3 zł	212,3 zł	222,3 zł	222,3 zł
2	Podlaskie	Białystok	Białystok	0	0	0	0	- zł	- zł	- zł	- zł
			Wigry				130				217,3 zł
											217,3 zł
3	Lubelskie	Lublin	Jarczew	100	100	100	100	167,2 zł	167,2 zł	167,2 zł	167,2 zł
			Włodawa	100	100	100	100	167,2 zł	167,2 zł	167,2 zł	167,2 zł
			Florianka	100	100	100	100	167,2 zł	167,2 zł	167,2 zł	167,2 zł
								501,5 zł	501,5 zł	501,5 zł	501,5 zł
4	Podkarpackie	Rzeszów	Lesko	90	90	90	90	150,4 zł	150,4 zł	150,4 zł	150,4 zł
								150,4 zł	150,4 zł	150,4 zł	150,4 zł
5	Małopolskie	Kraków	Kasprowy W. - Zakopane, Sienkiewicza 26C	115	115	115	115	192,2 zł	192,2 zł	192,2 zł	192,2 zł
			Szymbark	128	128	128	128	214,0 zł	214,0 zł	214,0 zł	214,0 zł
			Szarów			25	25			41,8 zł	41,8 zł
								406,2 zł	406,2 zł	448,0 zł	448,0 zł
6	Świętokrzyskie	Kielce	Gołuchów	31	31	31	31	51,8 zł	51,8 zł	51,8 zł	51,8 zł
			Sandomierz				90				150,4 zł
								51,8 zł	51,8 zł	51,8 zł	202,3 zł
7	Śląskie	Katowice	Racibórz	80	80	80	80	133,7 zł	133,7 zł	133,7 zł	133,7 zł
			Złoty Potok				110				183,9 zł
			Ustroń				125				209,0 zł
								133,7 zł	133,7 zł	133,7 zł	526,6 zł
8	Opolskie	Opole	brak								
9	Dolnośląskie	Wrocław	Karkonosze - Szklarska Poręba, Okrzei 28	137	137	137	137	229,0 zł	229,0 zł	229,0 zł	229,0 zł
			Legnica	70	70	70	70	117,0 zł	117,0 zł	117,0 zł	117,0 zł
								346,0 zł	346,0 zł	346,0 zł	346,0 zł
10	Lubuskie	Zielona Góra	Gorzów Wlkp.	112	112	112	112	187,2 zł	187,2 zł	187,2 zł	187,2 zł
								187,2 zł	187,2 zł	187,2 zł	187,2 zł
11	wielkopolskie	Poznań	Borówiec	24	24	24	24	40,1 zł	40,1 zł	40,1 zł	40,1 zł
			Kalisz		130	130	130		217,3 zł	217,3 zł	217,3 zł
			Poznań Morasko				6				10,0 zł
			Piaski				77				128,7 zł
								40,1 zł	257,4 zł	257,4 zł	396,2 zł
12	Zachodniopomorskie	Szczecin	Wolin	100	100	100	100	167,2 zł	167,2 zł	167,2 zł	167,2 zł
			Parsęta		190	190	190		317,6 zł	317,6 zł	317,6 zł
			Dźwirzyno			145	145			242,4 zł	242,4 zł
								167,2 zł	484,8 zł	727,1 zł	727,1 zł
13	Pomorskie	Gdańsk	Łeba	116	116	116	116	193,9 zł	193,9 zł	193,9 zł	193,9 zł
			Hel		105	105	105		175,5 zł	175,5 zł	175,5 zł
			Liniewko Kościerskie				45				75,2 zł
								193,9 zł	369,4 zł	369,4 zł	444,6 zł
14	Kujawsko-pomorskie	Bydgoszcz	Toruń	50	50	50	50	83,6 zł	83,6 zł	83,6 zł	83,6 zł
								83,6 zł	83,6 zł	83,6 zł	83,6 zł
15	Mazowieckie	Warszawa	Granica	55	55	55	55	91,9 zł	91,9 zł	91,9 zł	91,9 zł
			Guty Duże			127	127			212,3 zł	212,3 zł
			Belsk				77				128,7 zł
			Otwock				24				40,1 zł
								91,9 zł	91,9 zł	304,2 zł	473,1 zł
16	Łodzkie	Łódź	Wieluń	114	114	114	114	190,6 zł	190,6 zł	190,6 zł	190,6 zł
								190,6 zł	190,6 zł	190,6 zł	190,6 zł

Podsumowanie odbioru prób	I	II	III	IV
Koszt pojedyńczego odbioru prób	2 756,5 zł	3 466,9 zł	3 973,4 zł	5 116,8 zł
Koszt odbioru prób co 2 tygodnie przez rok	**71 668,2 zł**	**90 139,4 zł**	**103 308,2 zł**	**133 036,0 zł**

The annual estimated cost of transporting samples from stations to CRL CIEP branches is, for 19 stations: PLN 71,668.20, for 22 stations: PLN 90,139.40, for 26 stations: PLN 103,308.20, for 35 stations: PLN 133,036.00.

Estimation of costs of sending samples from CLB CIEP branches to laboratories appointed to perform physicochemical analyses was made on the basis of the price list of postal parcels sent by Poczta Polska: https://cennik.pocztapolska.pl/usluga,krajowy_paczka_pocztowa.html. The price of an economy parcel of maximum dimensions of 60x50x30 cm and weight up to 10 kg was assumed to be PLN 24 gross. The **cost of sending 26 parcels per year from 15 branches of the CLB GIOŚ is PLN 9,360.** The estimation does not include 1 CRL CIEP branch, due to the lack of preselected stations in the Opolskie Voivodeship.

Estimation of costs of purchase of chemical reagents necessary to carry out physicochemical analyses of samples taken within the framework of the precipitation chemistry measurement system in Poland took into account the current prices and annual consumption of reagents used in the laboratories of the Institute of Meteorology and Water Management, RCL CIEP, IEP-NRI and in laboratories carrying out measurements commissioned by IEP-NRI. Estimation was made on the basis of commercial offers received from suppliers:

- VWR International Sp. z o.o. (offer number 2502295772 of 19.05.2022)
- ANITEPO Sp. z o.o. (offer No. OE 762/ANITEPO/2022 of 16.05.2022)

and price lists available on the distributors' websites: VWR International, Pol-Aura, LGC Standards, Merck Life Science.

The following assumptions were made for the purposes of estimation:

- samples taken at the atmospheric deposition measuring stations shall be tested by two laboratories, each capable of performing the complete set of measurements,
- these laboratories will test samples taken from both primary and specialised precipitation chemistry monitoring stations, as well as from stations implementing the EMEP and HELCOM programmes, and sampling for the requirements of Directive 2004/107/EC,
- on average, it is assumed that there will be 10 daily samples taken at EMEP and HELCOM stations,
- estimation of annual costs of purchase of reagents necessary for determination of pH, conductivity, selected inorganic ions, heavy metals, total phosphorus, total nitrogen and PAHs was carried out considering 4 variants of selection of the number of stations (19, 22, 26, 35),
- Estimation of annual costs for purchase of reagents necessary for determination of additional components in the framework of EMEP (level 2) and HELCOM programmes was performed for one laboratory performing a given type of measurements for samples taken at one station.

The estimated annual costs of purchase of reagents for measurements of basic parameters of precipitation samples, inorganic ions, heavy metals and PAHs collected within the precipitation chemistry measurement system in Poland are presented in Table 7.3.

Table 7.3 List of estimated annual costs of purchase of chemical reagents necessary for measurements of selected parameters and components of precipitation samples taking into account 4 variants of choosing the number of stations (developed by IMWM-NRI)

	Selected number of stations			
Component/parameter to be determined	**19**	**22**	**26**	**35**
pH, specific electrical conductivity	PLN 6,424.44	PLN 6,424.44	PLN 6,424.44	PLN 6,424.44
Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, K^+, Na^+, Ca^{2+}, Mg^{2+}	PLN 19,562.68	19,562.68	PLN 19,562.68	PLN 19,562.68
Cd, Pb, Cu, Zn, Cr, Ni, As	PLN 51,449.79	PLN 58,454.70	PLN 67,664.58	PLN 87,509.31
total phosphorus	PLN 4,030.29	PLN 4,030.29	PLN 4,030.29	PLN 4,030.29
total nitrogen	PLN 13,278.76	PLN 13,278.76	PLN 13,278.76	PLN 13,278.76
PAHs	PLN 13,036.47	PLN 13,036.47	PLN 13,036.47	PLN 13,036.47
Hg	PLN 38,820.00	PLN 42,055.00	PLN 45,290.00	PLN 45,290.00

Table 7.4 shows the estimated annual costs for the testing of additional variables, such as HCB, DDT/DDE, HCHs, PCBs, PBDEs and chlordane, which can be measured in samples taken at EMEP (level 2) or HELCOM stations.

Table 7.4 Summary of estimated annual costs of purchase of chemical reagents necessary for measurement of selected variables in samples collected at stations implementing EMEP programmes (level 2) or HELCOM stations (developed by IMWM-NRI)

Component/parameter to be determined	**Annual cost**
HCB, DDT/DDE, HCHs, chlordane	2 482,59 zł
PBDE	PLN 15 099,93
PCBs	PLN 3 057,41

The annual estimated cost of purchase of chemical reagents necessary to perform measurements of the selected parameters and components of precipitation samples collected within the precipitation chemistry measurement system in Poland is for 19 stations: PLN 146,602.44, 22 stations: 156,842.35 PLN, 26 stations: PLN 169,287.23, 35 stations: PLN 189,131.96. This cost does not include conducting tests of additional components listed in table 7.4.

The total annual estimated cost of operation of the precipitation chemistry monitoring system by number of stations is presented in Table 7.5.

Table 7.5 Total annual cost [PLN] of operation of the precipitation chemistry monitoring system by number of stations (developed by IMWM-NRI)

	1 station	**19 stations**	**22 stations**	**26 stations**	**35 stations**
Annual land rental cost	161.92	3,076.48	3,562.24	4,209.92	5,667.20
Annual cost of electricity consumption	3,237.96	61,521.24	71,235.12	84,186.96	113,328.60
Annual labour cost of station supervisor	7,482.26	142,162.94	164,609.72	194,538.8	261,879.10
Sum of station labour costs	**10,882.40**	**206,760.66**	**239,407.08**	**282,935.60**	**380,874.90**
Transport of samples to CLB branches of the Chief Inspectorate of Environmental Protection		71,668.20	90,139.40	103,308.20	133,036.00
Sending samples to the laboratory		9,360.00	9,360.00	9,360.00	9,360.00
Sum of transport and shipping costs		**81,028.20**	**99,499.40**	**112,668.20**	**142,396.00**
Cost of reagents for physico-chemical analyses*		**146,602.44**	**156,842.35**	**169,287.23**	**189,131.96**
Total cost		**434,391.30**	**495,748.83**	**564,891.03**	**712,402.86**

* not incorporating the costs of testing of additional components included in Table 7.4

7.2 Organisational issues of the precipitation chemistry measurements

In the case of installation at the precipitation chemistry measurement stations of wet weather collectors taking weekly samples in the automatic two-week mode, it is necessary to ensure a visit of employees of CRL CIEP branches at each of the station every fortnight. In the case of stations with permanent staff and the possibility of storing samples in refrigeration units, visits to the stations could be limited to one per month. After collecting samples from stations within a given voivodship, samples should be sent/transported to a laboratory designated to perform physicochemical analyses. It is recommended to designate 2 laboratories to perform the full set of measurements. Such a solution will enable continuity of analyses in case of e.g. failure of one of the laboratories and additionally will allow for control of data quality through comparative measurements in case of potential doubtful results of analyses.

It should be borne in mind that total deposition should be measured at stations collecting data for Directive 2004/107/EC. Sampling for both heavy metals and PAHs shall be conducted in two separate collectors as described in Chapter 6 on page 36 of the report entitled “Determination of optimum range of substances and parameters which should be tested within precipitation chemistry (wet precipitation)”. The Directive permits wet deposition sampling instead of total deposition sampling if the equivalence of the two methods can be demonstrated, i.e. the difference between them does not exceed 10%.

At some stations it is necessary to supplement the measuring apparatus with a rain gauge. This concerns the following locations: Borówiec, Guty Duże, Liniewko Kościerskie, Piaski, Ustroń, Złoty Potok.

In many locations it is necessary to fence in the metering station (Szarów), or to extend the area around the container (Guty Duże, Liniewko Kościerskie, Piaski, Ustroń, Złoty Potok).

For some stations other technical works will be necessary. At the station in Belsko Duże, there is a need to bring electricity to a clearing where a collector could be located. At the Granica station, there are periodic problems with power supply, voltage drops occur; in this case it will be necessary to provide a UPS. At the Karkonosze station, due to frequent heavy snowfalls and long-lasting high snow cover, it is necessary to place the collector on an elevation, at a height of 2m above the ground. At the Wigry station, the meteorological cage is not oriented according to WMO requirements; the door of the cage should be located on the northern side; it is necessary to make a change accordingly at the station.

In the case of the Kasprowy Wierch station, due to the much higher weight of the new automatic collector in relation to the manual collector currently operating at the station, it will be necessary to obtain the consent of the author of the steel platform design to install the device. If it is not possible to install the new device, the Ustroń station (currently in the 4th choice group) is proposed as an alternative station for Kasprowy Wierch.

Additional and detailed organisational requirements can be found in the station sheets (Appendixes 1-35).

8 Summary

Within the framework of this study, the review and analysis of suburban and regional background monitoring stations as well as IMNE stations functioning within the framework of SEM was made in terms of meeting the criteria and possibilities to measure wet atmospheric deposition at those locations. The analysis included also the IMWM-NRI stations currently implementing the measurement programme of atmospheric precipitation chemistry in Poland, stations at which research is conducted for the purposes of HELCOM, EMEP and additional meteorological stations of IMWM-NRI. The analysis took into account the study of the NILU team concerning analysis of wet deposition distribution for selected pollutants.

In addition, the report provides an estimate of the annual costs of conducting measurements and analyses of physicochemical samples of precipitation along with organisational issues of conducting precipitation chemistry monitoring.

9 Literature

CIEP 2021, State Environmental Monitoring, Chief Inspectorate of Environmental Protection: Ocena zanieczyszczenia powietrza na stacjach monitoringu tła regionalnego w Polsce w roku 2020 w zakresie składu pyłu PM10 i PM2,5 oraz depozycji metali ciężkich i WWA. Warsaw 2021

CIEP 2022a: Chief Inspectorate of Environmental Protection**,** developed by IMWM-NRI: Koncepcja modernizacji i optymalizacji pomiarów depozycji w Polsce. Wykonanie analizy polskich i zagranicznych dokumentów i opracowań oraz systemów monitoringu i danych Państwowego Monitoringu Środowiska pod kątem zaprojektowania nowego systemu prowadzenia badań i ocen depozycji atmosferycznej, Report prepared on commission from the CIEP for the purposes of implemenation of the project: Strengthening of atmospheric deposition assessment in Poland based on Norwegian experience, Warsaw 2022

CIEP 2022b: Chief Inspectorate of Environmental Protection**,** developed by IMWM-NRI: Koncepcja modernizacji i optymalizacji pomiarów depozycji w Polsce. Określenie optymalnego zakresu substancji i parametrów, które należałoby badać w ramach chemizmu opadów atmosferycznych (opad mokry), Report prepared on commission from the CIEP for the purposes of implemenation of the project: Strengthening of atmospheric deposition assessment in Poland based on Norwegian experience, Warsaw 2022

NILU report 2021: *Hierarchical Clustering Dissimilarity Analyses. Optimizing the Polish Deposition Network*, Joana Soares, Wenche Aas, Sabine Eckhardt, Cristina Guerreiro, NILU - Norwegian Institute for Air Research, 2021