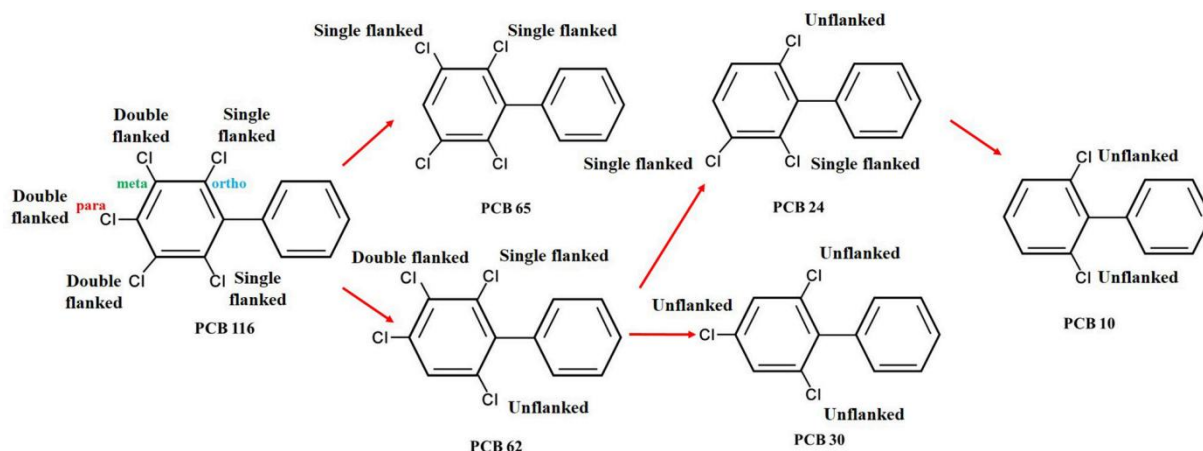




Managing POPs risks in the context of the transition to a sustainable bioeconomy (acronym: POPs_RISKMANbase)

Annex WP2 D2.6

Report Title and Designation:	D2.6	Public report on work package 2 achievements		
Work Package	WP2/KPB2			
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Delivery Date	M27	Delivery date:	March, 2026	
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Version:	I.	Date of change:		
Output type (report):	public	final	interim	other
	x			



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Introduction

The project Managing POPs Risks in the Context of the Transition to a Sustainable Bioeconomy aims to research, assess and support the management of environmental risks associated with persistent organic pollutants, in particular polychlorinated biphenyls (PCBs). PCBs represent a long-term environmental problem due to their persistence, bioaccumulation, binding to sediments, soil and organic matter, as well as the possibility of secondary dissemination in the environment.

Work package WP2/KPB2 builds on the analytical and methodological outputs of WP1/KPB1, which identified sources of contamination, transport pathways, receptors and critical scenarios associated with the occurrence of PCBs. Within KPB2, this knowledge was developed into a measurable, data-processable and model-usable framework that allows for the assessment of POPs /PCB risks in space and time.

The focus of the work package was the processing of outputs focused on the analysis of PCB measurement methods, design of the measurement chain, data collection and management, modeling and risk characterization, data processing in a GIS environment and design of a risk management methodology concept. Special attention was paid to the monitoring of PCBs in the air, as the airborne transport pathway can represent a significant mechanism for the secondary spread of contamination from historical environmental loads.

The results of the KPB2 work package create a link between PCB measurement methodology, data management, GIS processing and model risk assessment. The framework thus prepared allows for the gradual refinement of risk maps, verification of the significance of individual transport routes and support decision-making on monitoring and action priorities.

1. Work package objective

The aim of the WP2 was to develop the analytical outputs of the WP1 into a practically usable framework for monitoring, data processing, modelling and support for the management of POPs /PCB risks. The WP2 therefore focused on creating conditions that would enable the linking of measured data from environmental components with GIS processing, model risk assessment and subsequent decision-making on monitoring and action priorities.

KPB2 was mainly focused on:

- analysis of selected methods and procedures for measuring PCBs in water, sediments, soil and air,
- design of the measurement chain from sample collection to laboratory determination and interpretation of results,
- assessment of options for mobile, aerial or UAS air sampling,
- design of a system for collecting, recording, managing, and controlling data quality,
- creation of a model framework for characterizing POPs /PCB risks,
- linking model evaluation with GIS database and spatial analysis,
- proposal for a risk management methodology concept based on measured, spatial and model data.

The outputs of KPB2 thus create the basis for the practical use of the PCBRISKMAN model in monitoring, updating risk maps, identifying priority sites, and supporting decision-making in affected areas.

2. Implemented activities

The activities of the KPB2 work package were aimed at developing the analytical results of KPB1 into a practically usable framework that allows for the acquisition, processing and interpretation of data necessary for PCB risk assessment.

The following activities were mainly implemented within the work package:

- analysis of available laboratory, field, and monitoring methods usable for the determination of PCBs in water, sediments, soil and air,
- design of the measurement chain from sample collection through its transport, storage, pretreatment, extraction, extract purification, analytical determination to interpretation of results,
- assessment of the possibilities of monitoring PCBs in the air with emphasis on distinguishing between gaseous and particle-bound fractions,
- analysis of technical, safety and operational limitations when using an aerial or UAS platform for air sampling,
- design of a data structure for collecting, managing, and processing data necessary for modeling and GIS analysis,
- defining requirements for data quality, representativeness of sampling, sample location and recording of meteorological conditions,
- design of the PCBRISKMAN model framework based on the source-pathway-receptor (SPR) coupling,
- development of dynamic model parameters, in particular the probability of threat, chronicity of environmental reservoirs and the mobilization factor,
- proposal for the use of GIS tools in the processing of spatial, attribute and temporal data,
- a draft concept for a risk management methodology that connects measurement, modeling, GIS processing and decision-making on measures.

The solution used interdisciplinary approaches linking environmental engineering, risk management, analytical chemistry, contaminant transport modeling, GIS analysis, aviation technology, and decision support.

3. Results achieved

Within the framework of the work package KPB2, partial outputs D2.1 to D2.5 were processed, which are methodologically linked and together create a framework for the practical use of the PCBRISKMAN model.

Output D2.1 – Report on the analysis of selected methods and procedures created a basic methodological overview of available approaches to measuring PCBs in individual environmental compartments. The report dealt with the measurement chain for water, sediments, soil and air and pointed out the importance of proper sampling, pre-concentration, extraction, clean-up of extracts and chromatographic determination of PCBs. It was particularly emphasized that airborne PCB monitoring does not represent direct remote sensing of PCB concentrations, but a combination of sampling, laboratory analysis and spatial interpretation of the results.

Output D2.2 – Data collection and management report developed requirements for the acquisition, recording and management of data needed for risk modelling. Requirements were identified for recording sampling location, sampling time, sampled air volume, meteorological conditions, sampling medium used, laboratory results and measurement uncertainty. The output created the basis for a uniform data structure usable in a GIS database and in a risk model.

Output D2.3 – Modeling and Characterization Report created a model framework for assessing the risks of POPs /PCBs. The model is based on the source-pathway-receptor concept and allows for the analysis and assessment of risk as a combination of the probability of exposure and the severity of the consequences. The model includes parameters such as the basic probability of exposure, the chronicity factor of environmental reservoirs, the time-varying mobilization factor and the dynamic probability of exposure.

Output D2.4 – Report on data processing in the context of GIS elaborated on the use of geographic information systems in the assessment of POPs /PCB risks. The output focused on the GIS database, spatial, attribute and temporal data types, spatial interpolation, surface runoff analysis, hydrogeological modelling, multi-criteria vulnerability analysis of the territory and prediction of development over time. The GIS environment was defined as a key tool for visualization, updating and spatial interpretation of model results.

Output D2.5 – Report on the concept of the risk management methodology integrated the previous results into the design of a practically usable measurement chain concept and risk management methodology. The report elaborated on the design of mobile, aerial or UAS air sampling, the flight strategy, the selection of sampling medium, sample processing, calculation of PCB concentrations, consideration of meteorological conditions, measurement uncertainty and linking the results to a GIS database and risk model.

Based on outputs D2.1 to D2.5, an integrated framework was created that links analytical PCB measurement, data management, model risk assessment, GIS processing and design of

measures. This framework provides a basis for practical verification of monitoring and for decision support in POPs /PCB risk management.

3.1 Overview of the achievement of KPB2 outputs

An overview of the fulfillment of the partial outputs of the KPB2 is presented in the following table.

Table 1 Summary of KPB2 partial outputs and their results

Task / output	Main focus	Result achieved
D2.1	Analysis of selected methods and procedures	A methodological overview of PCB measurements in water, sediments, soil, and air has been developed; a measurement chain and link to the risk model have been proposed.
D2.2	Data collection and management	Proposed framework for the collection, recording, management and quality of data required for modeling and GIS processing.
D2.3	Modeling and characterization	Created PCBRISKMAN modeling framework based on dynamic assessment of sources, transport pathways and receptors.
D2.4	Data processing in the context of GIS	Proposed GIS framework for integrating spatial, attribute and temporal data, propagation modelling and area vulnerability assessment.
D2.5	Concept of risk management methodology	Developed design of a practical measurement chain, sampling strategy, links to GIS and risk model, and PCB risk management methodology.
D2.6	Public report on WP2/KPB2 results	Summary of the main results, benefits and perspectives for further work on the KPB2 work package.

The review confirms that the outputs of KPB2 have created a coherent system of knowledge from the analysis of measurement methods, through data management and modeling, to GIS processing and the design of risk management methodologies.

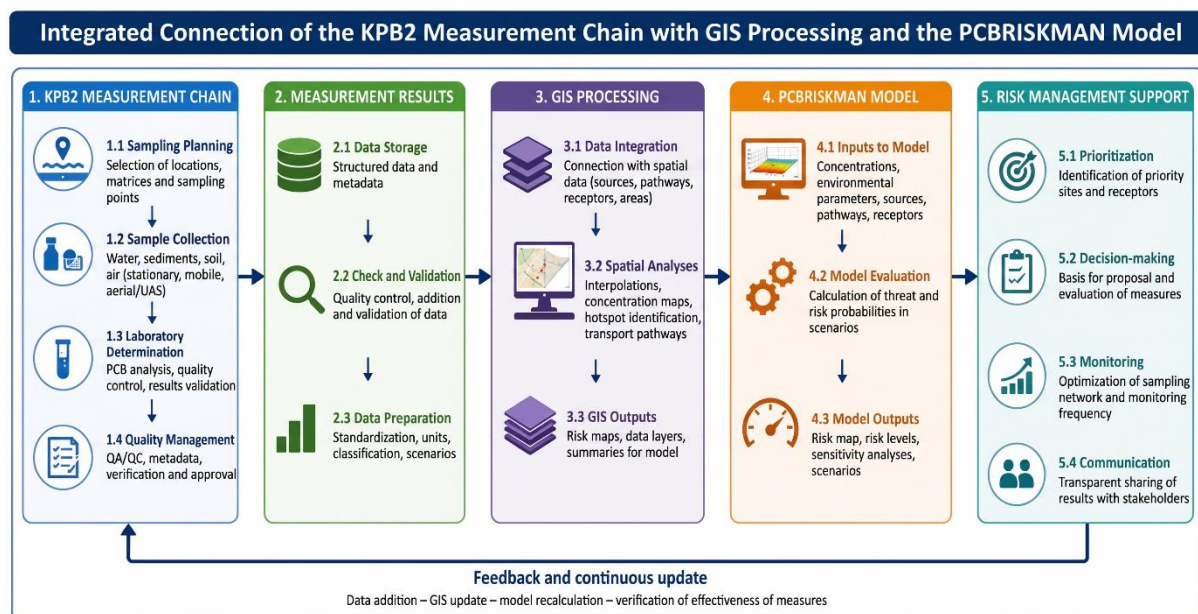


Fig. 1 Integrated connection of the KPB2 measurement chain with GIS processing and the PCBRISKMAN model

4. Work package contribution

The KPB2 work package represents a significant contribution to the development of a methodology for assessing and managing PCB risks, as it links measured data, spatial information, model calculations and decision-making processes. The proposed approach allows for assessing risk as a dynamic phenomenon that changes depending on the properties of the source, transport pathways, environmental conditions, and receptor vulnerability.

The inclusion of air as a potential transport pathway for PCBs is also a significant benefit. The proposed approach to mobile, aerial or UAS air sampling allows to supplement stationary monitoring and verify hypotheses about the airborne transport of PCBs. At the same time, the difference between the sampling-analytical approach and direct remote sensing was methodologically emphasized, thereby increasing the professional accuracy and transparency of the proposed solution.

The results of the KPB2 support decision-making by public administration, professional workplaces and regional actors in planning monitoring, identifying priority sites, updating risk maps and proposing measures to reduce environmental and health risks.

In terms of further development, KPB2 also represents a basis for digital environmental innovation, which can be developed towards a platform using GIS, Digital Twin, AI and decision-making algorithms to support environmental risk management.

5. Alignment with policies and strategic priorities

The results of the KPB2 work package are in line with the strategic priorities of the Slovak Republic and the European Union in the field of environmental protection, reduction of environmental burdens, digital transformation, and support for the transition to a climate-neutral and circular economy. The proposed PCBRISKMAN model contributes to the objectives of the European Green Deal, the EU Zero Pollution Action Plan, the Stockholm Convention on Persistent Organic Pollutants, and broader initiatives aimed at digital support for environmental management.

The outputs of KPB2 are particularly relevant in the context of the EU Zero Pollution Action Plan, which emphasizes the need to prevent, remediate, monitor, and report on water, air and soil pollution. The work package establishes a methodological and data basis for systematic PCB monitoring, assessment of transport pathways, updating risk maps and supporting decision-making on measures to reduce environmental and health risks.

The project also creates the prerequisites for further use of advanced digital technologies supported by the STEP Platform, especially in the areas of clean technologies, digital technologies and data-driven solutions. An integrated approach linking environmental measurement, GIS databases, contamination spread modeling, digital twins, artificial intelligence and decision-making tools can form the basis for intelligent environmental risk management and restoration of contaminated sites.

The results of KPB2 support the development of data-driven solutions enabling more efficient monitoring planning, site prioritization, assessment of the effectiveness of measures, and reduction of the environmental footprint of industrial activities. The project thus contributes to the transformation of traditional approaches to environmental management towards digital, sustainable, and low-carbon solutions.

From a development perspective, KPB2 represents the foundation for building an intelligent RISKMAN platform based on the principles of Digital Twin and AI-driven Decision Support System. Such a platform may be useful not only in addressing historical environmental burdens of PCBs, but also in assessing a broader spectrum of environmental and industrial risks related to the transformation towards a cleaner and more sustainable economy.

6. Social and environmental benefits

The societal benefit of the WP2 lies primarily in the creation of a more transparent and systematic framework for decision-making on the environmental risks of PCBs. Historical PCB contamination affects not only the quality of the environment, but also human health, the food chain, land use, water management, recreation and the overall development of the affected regions.

The proposed framework allows for better planning of monitoring, verification of transport routes and identification of locations where long-term or repeated exposure of populations and ecosystems may occur. Thanks to the connection with GIS tools, the results can be better visualized, interpreted and communicated to public administration and other stakeholders.

The environmental benefit lies in a better understanding of the behavior of PCBs in individual environmental compartments and in the ability to assess risk as a spatially and temporally variable phenomenon. Of particular importance is the linkage of contaminated sediments, soil, water, air and biota, as well as the identification of conditions that may promote secondary mobilization of PCBs.

The results of the work package can contribute to protecting public health, reducing environmental risks, restoring contaminated sites, and strengthening trust in decision-making based on scientific evidence.

7. Prospects for further solutions

Another solution to the project should be aimed at transforming the POPs_RISKMANbase system, whose model core is PCBRISKMAN, into an intelligent digital platform for environmental risk management supported by Digital technologies. Twin, GIS, AI and advanced data analysis. This direction follows on from the results of KPB2, which created a methodological, data and model basis for monitoring, data processing, spatial interpretation and decision-making on PCB risks.

The priority will be to implement pilot monitoring campaigns, verify and refine contamination spread models and create a digital twin of selected contaminated sites. The digital twin would allow linking real-world measured data, GIS layers, meteorological conditions, model parameters and risk development scenarios in space and time. Such an approach can support the simulation of the behavior of PCBs and other persistent pollutants, the evaluation of the effectiveness of proposed measures and the optimization of monitoring or remediation from the point of view of both environmental and economic criteria.

An important perspective is the integration of artificial intelligence and machine learning methods to predict contaminant migration, identify risk scenarios, process measurement uncertainty, and support public administration decision-making. AI-driven Decision Support The system could use data from monitoring, laboratory analyses, meteorological records, GIS layers and model calculations to continuously update risk maps and propose priorities for further action.

The platform can serve as a basis for a regional or transnational environmental risk management system to address environmental pressures, assess contamination pathways and support the restoration of contaminated sites. This approach can also be used in the wider context of the Danube Region and European initiatives focused on clean technologies, digital transformation, zero pollution and restoration of environmentally contaminated sites.

The project results create the prerequisites for future involvement in the activities of the STEP Platform, Horizon programs Europe , Interreg Danube Region Programme and other European schemes supporting clean technologies, industrial decarbonization, digital transformation and sustainable environmental innovation.

Conclusion

Work package KPB2 successfully fulfilled its task by creating a methodological, data and model framework for integrated management of environmental risks associated with persistent organic pollutants. Deliverables D2.1 to D2.5 created an interconnected system including analysis of PCB measurement methods, design of measurement chain, data management, GIS analysis, contamination spread modeling and risk decision support.

The results confirmed the need to assess PCBs and other POPs as a dynamic environmental problem influenced by contamination sources, transport routes, meteorological and hydrological conditions, land properties and receptor vulnerability. The proposed framework therefore represents a significant step towards the creation of an intelligent environmental risk management system based on measured data, modelling, GIS processing and digital technologies.

The project also creates professional and technological prerequisites for the further development of solutions in line with the priorities of the STEP Platform in the field of clean technologies, digital technologies and sustainable industrial transformation. The integration of monitoring, GIS, digital twins, artificial intelligence and decision-making tools represents a promising direction for the development of modern environmental management supporting the restoration of contaminated areas, the protection of public health and the sustainable transformation of industry.

PCBRISKMAN thus represents not only a model framework for PCB risk assessment, but also the basis of a future digital platform for intelligent management of environmental burdens, support for clean technologies and implementation of Zero principles. Pollution, Green Deal and Green Transition in the conditions of the Slovak Republic and the European Union.

Attachment: Public infographic on WP2/KPB2 results

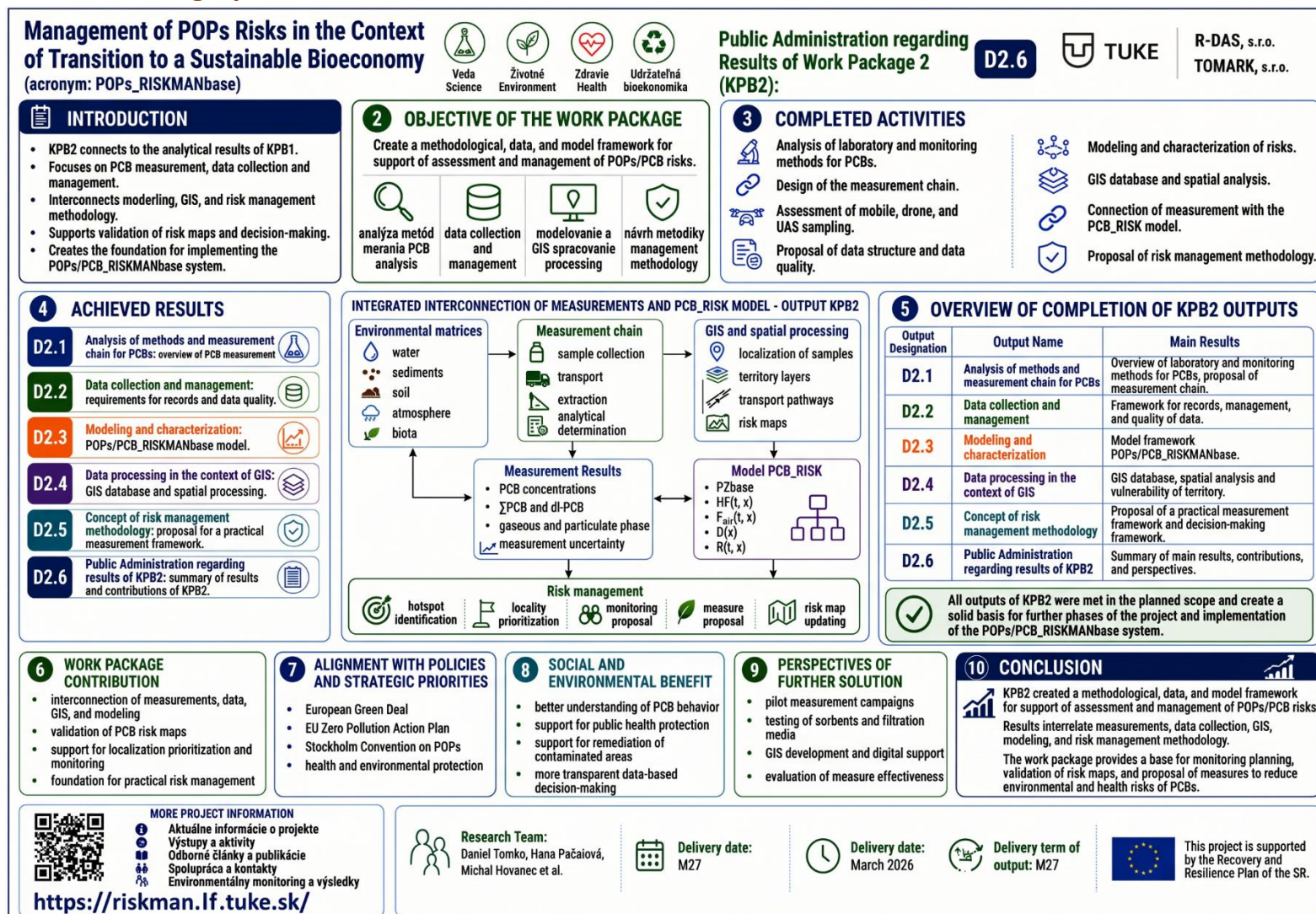


Fig. 2 Summary of the results of the work package KPB2 – measurement chain, GIS processing and PCBRISKMAN model