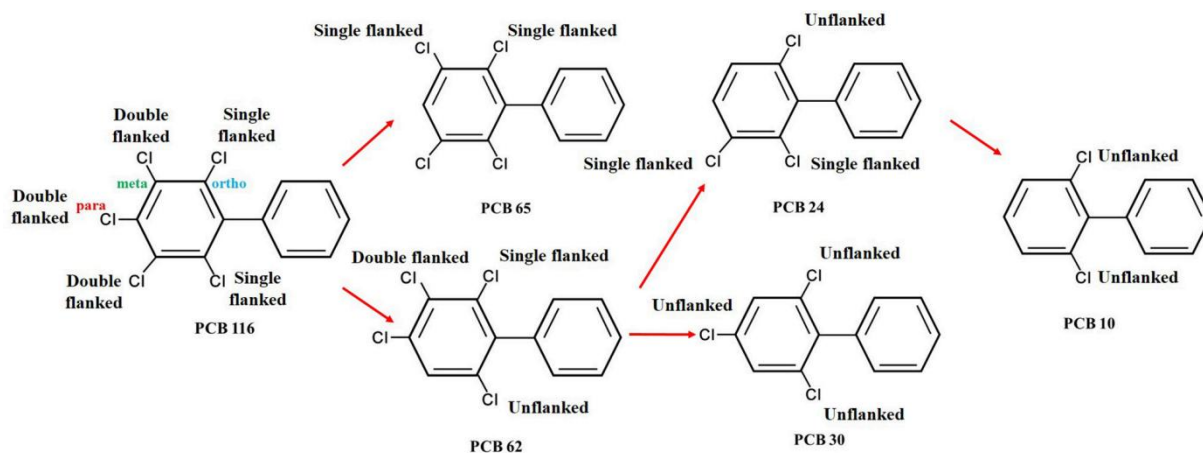




Managing POPs risks in the context of the transition to a sustainable bioeconomy (acronym: POPs_RISKMANbase)

Annex WP3 D3.4

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Introduction

The project Managing POPs Risks in the Context of the Transition to a Sustainable Bioeconomy is focused on research, assessment, and support for 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 WP3/KPB3 builds on the analytical and methodological results of work packages WP1/KPB1 and WP2/KPB2. While KPB1 created the basis for identifying sources, transport pathways, receptors, and critical scenarios, KPB2 developed a measurement, data, model and GIS framework for assessing POPs /PCB risks.

WP3/KPB3 represents a follow-up phase in which the verification framework was prepared, carried out control and evaluation activities of the PCBRISKMAN model and proposed a framework for application-specific research and techno-economic assessment of measures.

Output D3.4 summarizes the main results of the KPB3 work package in a public form. It builds on the partial outputs D3.1, D3.2 and D3.3 and provides an overview of their objectives, implemented activities, achieved results, benefits and perspectives for further solutions. Its aim is not to replace detailed expert reports, but to clearly summarize how KPB3 moved the PCBRISKMAN model from methodology design to preparation of verification, control of computational logic, evaluation of measures and design of the future decision-making platform.

1. Work package objective

The aim of the WP3/KPB3 was to prepare and develop the verification of the PCBRISKMAN model and calculation framework and to assess its usability in the active risk management of PCB sources. The WP3/KPB3 focused on the linkage of the verification framework, control and evaluation activities, selection of measures, calculation of residual risk and design of further application-specific research.

KPB3 was mainly focused on:

- preparation of the verification architecture of the PCBRISKMAN model and definition of the model's control nodes,
- synthesis of underlying outputs of KPB1 and KPB2 for verification and validation purposes,
- design of field, aerial and analytical procedures usable in verifying selected model parameters,
- defining data quality requirements, QA/QC procedures and methods for assessing measurement uncertainties,
- checking the logical and computational continuity between source identification, probability, consequences, and the resulting risk level,
- a proposal for a catalogue of measures and a method of translating their effectiveness into a reduction factor (RF),
- calculation of residual risk after taking the measure and verification of the procedure on the model source Z001,
- draft framework for application-specific research, comparison of alternative measures, supplementing CAPEX/OPEX and future CBA/MCDA assessment,
- creating a basis for further development of the PCBRISKMAN visualization and decision-making platform for practical use.

The outputs of KPB3 thus create a transition between the stage of modeling and assessing risks and the stage of their practical management through the selection, evaluation, verification and economic assessment of appropriate measures.

2. Implemented activities

The activities of the KPB3 work package were focused on the preparation, control and further development of the PCBRISKMAN model. They were based on the results of the KPB1 and KPB2 project stages and gradually developed them into a verification, control and application-oriented framework.

The following activities were mainly implemented within the work package:

- processing of the verification architecture of the PCBRISKMAN model, including the link to the source – transport pathway – receptor (S-P-R) principle,
- defining verification hypotheses and control nodes for selected parts of the model, in particular the dynamic probability $P_z(t)$, the hydro-climatic factor $HF(t)$, the chronicity factor and the spatial interpretation of risk,
- design of field and aerial verification tests, including sampling media, analytical chain, sample volume normalization and consideration of meteorological conditions,
- defining QA/QC procedures, working with measurement uncertainty and the possibility of future use of sensitivity or Monte Carlo analysis,
- checking the consistency of input data, probability calculation, impact estimation and the resulting risk profile of the assessed PCB sources,
- identification of priority sources and locations requiring proposed measures or further monitoring,
- draft catalogue of measures O01 – O27 and methods M01 – M27 according to source type, environmental matrix, dominant risk mechanism and nature of effect,
- linking the effectiveness of measures with the reduction factor RF and the calculation of probability and risk after the measure is taken,
- Model verification of the procedure at source Z001 – CHEMKO Strážske – waste channel,
- proposal of a technical-economic framework for supplementing CAPEX, OPEX, time horizon, discounting and future CBA/MCDA comparison of variants,
- proposal for further development of the model towards GIS visualization, heat map display, risk zoning, monitoring of the effectiveness of measures and decision-making platform.

The solution used interdisciplinary approaches linking environmental engineering, risk management, analytical chemistry, GIS, aviation and unmanned technologies, risk modeling, techno-economic assessment, and decision support.

3. Results achieved

Within the framework of the work package KPB3, partial outputs D3.1 to D3.3 were processed, which are substantively and methodologically linked to each other. Together, they create a framework for the transition from the preparation of model verification to its controlled use in the selection of measures and the design of further application-specific research.

Output D3.1 – Verification and validation preparation report created a methodological and technical basis for the verification process of the PCBRISKMAN model. The report defined the architecture of the verification system, synthesized the underlying outputs of KPB1 and KPB2, specified verification nodes and hypotheses, proposed field and aerial sampling procedures, sampling media, analytical chain, and work with uncertainties. The output also included a proposal for connecting measured data with GIS and a model verification platform.

Output D3.2 – Report on control activities and evaluation developed a check of the logical and computational continuity of the PCBRISKMAN model. The check focused on the link between the identification of the PCB source, the probability estimate, the consequence estimate, the resulting risk level and the proposal of measures. The output identified priority sources, developed a catalogue of measures, introduced the reduction factor RF and showed the method of calculating the residual risk after the adoption of the measure. The model example was processed for source Z001 – CHEMKO Strážske – waste channel.

Output D3.3 – Report on the proposal for a framework for application-specific research followed up on D3.1 and D3.2 and developed a further direction for using the PCBRISKMAN model in verifying the effectiveness of measures and comparing technical and economic options. The report supplemented the framework for CAPEX and OPEX inputs, the need for the quantity or scope of the measure, the time horizon, discounting, future CBA/MCDA assessment, uncertainty of effectiveness and the design of a GIS/visualization and decision-making platform.

Based on these outputs, an integrated framework was created that links verification preparation, computational logic control, action design, residual risk calculation, economic inputs and spatial decision support. This framework provides the basis for practical verification and further development of the PCBRISKMAN system.

3.1 Overview of the achievement of KPB3 outputs

An overview of the fulfillment of the partial outputs of the KPB3 is presented in the following table.

Table 1 Summary of KPB3 partial outputs and their results

Task / output	Focus	Result achieved
D3.1	Verification and validation preparation	Methodological and technical framework for verification of the PCBRISKMAN model has been developed; verification

Task / output	Focus	Result achieved
		nodes, sampling and analytical procedures, QA/QC, uncertainties and GIS links have been defined.
D3.2	Control activities and evaluation	The logical and computational consistency of the model has been verified; priority sources have been identified, a catalogue of measures has been proposed, the reduction factor RF has been calculated and the residual risk has been calculated.
D3.3	Proposal for a framework for application-specific research	Proposed framework for verifying the effectiveness of measures, technical and economic evaluation of options, CAPEX/OPEX, CBA/MCDA and GIS decision-making platform.
D3.4	Public report on KPB3 results	Summary of the main results, benefits and perspectives for further solutions to the KPB3 work package in public form.

The review confirms that the outputs of KPB3 created a coherent system from the preparation of model verification through the control of its logical and computational consistency to the design of a framework for verification of measures, technical and economic assessment and decision-making support (Fig. 1).

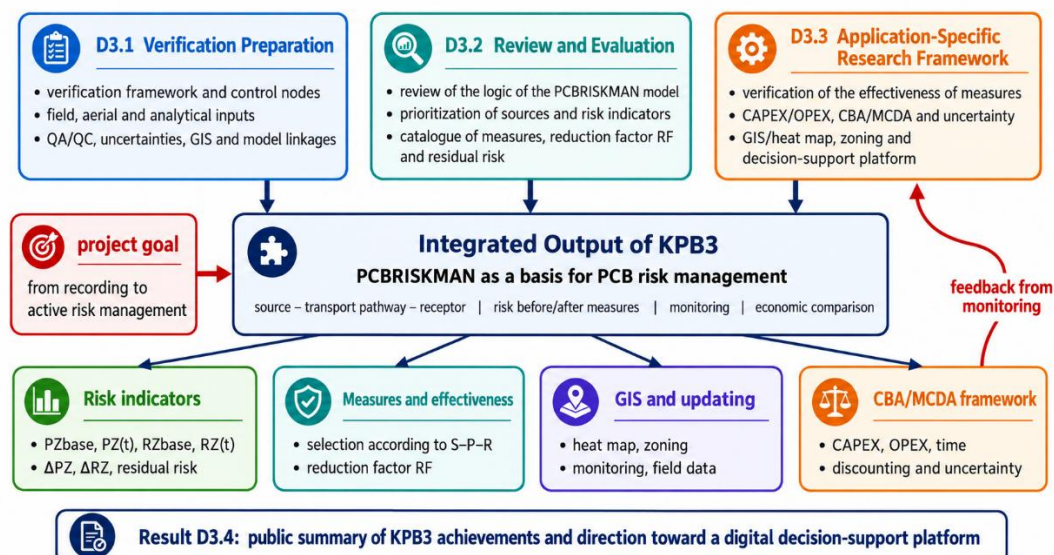


Fig. 1 Logical line of outputs of the KPB3 work package in the PCBRISKMAN model

4. Work package contribution

The KPB3 work package represents a significant contribution to the development of the PCBRISKMAN model. The main contribution of WP3/KPB3 is the creation of a logical link between risk assessment and the design of measures. The PCBRISKMAN model is no longer just a tool for determining the level of risk, but also a framework that allows assessing why a certain source is a priority, which risk mechanism is dominant, which measure is appropriate and what residual risk can be expected after its adoption.

An important result is also the introduction of a catalogue of measures (a total of 27 types, each measure may also include specific methods, denoted M) and a reduction factor RF. This approach allows transparently reflecting the effectiveness of a measure into a change in probability and risk. The example of source Z001 demonstrated that the model can be used to document the initial state, the choice of a measure, its effectiveness and the resulting residual risk.

KPB3 also created a basis for future technical and economic evaluation of measures. The introduction of CAPEX and OPEX inputs, the need to supplement the scope of the measure, the time horizon, discounting and future CBA/MCDA comparisons represent an important step towards practical decision support.

In terms of further development, the proposal for a visualization and decision-making platform PCBRISKMAN, which can connect a spreadsheet calculation model, GIS visualization, heat risk maps, zoning of the territory, monitoring of the effectiveness of measures and economic inputs into a single decision-making framework.



5. Alignment with policies and strategic priorities

The results of the KPB3 work package are in line with the strategic priorities of the Slovak Republic and the European Union in the areas of environmental protection, reduction of environmental burdens, protection of population health, digital transformation, and transition to a sustainable bioeconomy.

The approach developed in KPB3 supports the objectives of prevention, monitoring, reduction and management of pollution. In the context of PCBs and other POPs, it is important not only to identify contaminated sources, but also to decide transparently where action is needed, what type of action is appropriate and how its effectiveness can be verified.

The results of the KPB3 follow the principles of zero pollution, the European Green Deal, evidence-based environmental management and digital decision support. Linking the PCBRISKMAN model with GIS, monitoring, the Digital Twin, AI DSS and CBA/MCDA evaluation represent a move towards a modern digital platform for environmental risk management.

The project also creates the conditions for further use in initiatives focused on clean technologies, digital technologies, sustainable industrial transformation, and the restoration of environmentally contaminated areas. This approach is applicable not only to PCB contamination, but also to a wider spectrum of environmental and industrial risks.

6. Social and environmental benefits

The societal benefit of the KPB3 work package lies primarily in the creation of a transparent framework that supports decision-making on the priorities of interventions in PCB-contaminated sites. Historical PCB contamination is not only a technical or environmental problem, but also affects public health, the food chain, land use, recreation, fisheries, agriculture and public trust in decision-making processes.

KPB3 provides a procedure that allows for better explanation of why a certain source is a priority, by what mechanism it may contribute to risk, and what measures may lead to its reduction. Such an approach can support risk communication towards public administration, professional workplaces, local governments, and other stakeholders.

The environmental benefit lies in better linking risk assessment with the design of measures. The model allows for the distinction between whether it is necessary to intervene at the source itself, limit the transport of contamination or reduce receptor exposure. This is particularly important for PCBs, which are often bound to sediments, fine particles, dust, organic matter and biota and can be repeatedly mobilized due to hydrological or climatic factors.

The outputs of the KPB3 can contribute to protecting public health, reducing environmental risks, better planning of monitoring, more targeted selection of measures, and restoring confidence in data-based decision-making, modeling, control, and ongoing verification of the effectiveness of interventions.

7. Prospects for further solutions

Further project solutions should be directed towards practical verification and expansion of the PCBRISKMAN model in specific locations. The priority will be to supplement high-quality input data from monitoring, verify the effectiveness of selected measures, and link the spreadsheet calculation framework with a spatial GIS visualization and decision-making platform.

An important perspective is to extend the model with a module for comparing options for measures. This module should allow assessing not only the risk effectiveness of a measure, but also its technical feasibility, need for monitoring, CAPEX, OPEX, time horizon of effect, uncertainty and suitability for a specific location. Such an approach will create a basis for future CBA/MCDA evaluation of PCB risk reduction options.

Another direction is the development of GIS and heat map visualization, which will allow spatial interpretation of PCB sources, transport routes, monitoring points, intervention zones and residual risk after measures are taken. In combination with continuous updating of field data, laboratory analyses, biomonitoring, aerial or drone images, a flexible platform for decision support over time can be created.

The PCBRISKMAN model can be further developed towards a digital twin of selected contaminated sites if AI-driven Decision Support System. Such a platform could use measured data, GIS layers, meteorological and hydrological inputs, model parameters, economic data, and feedback from monitoring the effectiveness of measures to continuously update risk maps and recommendations for further action.

The framework can be applied beyond PCB issues, particularly in the assessment of historical environmental burdens, contaminated sediments, industrial sites, dust and water transport routes or other long-term environmental risks. The outputs of KPB3 thus create a basis for further research, pilot validation and involvement in national and European initiatives supporting clean technologies, digital transformation, zero pollution and restoration of environmentally contaminated areas.

Conclusion

The KPB3 work package successfully followed up on the analytical, measurement, modeling and GIS outputs of the previous stages of the POPs_RISKMANbase project. It resulted in a comprehensive framework that links the preparation of the PCBRISKMAN model verification, the check of its logical and computational consistency, the selection of measures, the calculation of residual risk and the design of further application-specific research.

Output D3.1 created a methodological and technical basis for verification and validation of the model. Output D3.2 confirmed the need to control the link between the source, probability, consequences, and the resulting risk level and at the same time developed a catalogue of measures, a reduction factor RF and a calculation of the residual risk. Output D3.3 supplemented the framework for verifying the effectiveness of measures, technical and economic evaluation of options and the development of a future visualization and decision-making platform, thereby directing the project results towards practical use in the field of environmental risk management.

KPB3 thus represents an important step from PCB risk assessment to their active management. It allows moving from identifying the risk source to selecting an appropriate measure, estimating its effectiveness, assessing the residual risk and preparing a technical and economic comparison of options. At the same time, it creates the prerequisites for ongoing verification of the effectiveness of measures and updating the model based on new monitoring data.

Output D3.4 thus concludes the WP3/KPB3 work package in public form and confirms its contribution to the development of the PCBRISKMAN model as a tool to support decision-making in prioritizing resources, selecting measures, assessing residual risk, and future technical and economic comparison of PCB risk reduction options.

Appendix: Schematic summary of KPB3 results in the PCBRISKMAN model

Schematic summary of KPB3 results in the PCBRISKMAN model

