



Short communication

Reflection on the landscape of education in the area of exposure modelling

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ABSTRACT

Exposure models are essential for a range of contexts involving exposure science. The Exposure Models Working Group, established under ISES Europe, identified that to improve model use, suitable training and education is required. However, there is currently no formal educational training programme for exposure modelling in Europe. We present results from an online survey disseminated to the European exposure science community to identify modelling training needs. The questionnaire had three sections: background information about the respondents and interests in exposure science, previous attendance of exposure modelling courses, interest in future training and education in exposure modelling and their coverage and format.

A total of 88 survey recipients completed the survey. Most respondents were from governmental organizations (36 %), with 50 % of all respondents having less than 10 years of experience. About two-thirds of the respondents stated that they had previously attended exposure modelling courses. These were mostly focused on specific models, up to one day in duration and took place in-person. Two thirds of respondents expressed interest in attending future exposure modelling training modules, with the most important topics being interpretation of model results and use of models to meet regulatory standards/requirements. Preferred attendance of training courses was virtual or blended. Costs and certificates of attendance seemed less influential when selecting a training course. Our survey suggests that there is a demand for training in exposure modelling and provides insight to inform the development of training modules that are suitable to fulfil the training needs of exposure scientists and practitioners.

1. Introduction

Exposure science plays a central role in the protection of human health and the environment (Fantke et al., 2020). It is a rapidly growing field, and its further development will play a major role in achieving international health goals, such as the Chemicals Strategy for Sustainability (EC, 2020) and UN Sustainable Development Goals (United Nations, 2015). To address these goals, the Europe Regional Chapter of the International Society of Exposure Science (ISES Europe) was established

in 2017 and has identified exposure models as well as education and training as two of the priority areas for development (Fantke et al., 2022).

Exposure models are essential for a range of contexts for exposure science. Computational models contribute to exposure assessment through extrapolating, estimating, generalising, complementing and sometimes even replacing measurements. Models provide complementary tools alongside measurement data, as many exposure scenarios may not be sampled due to ethical issues or study feasibility. Of particular

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importance are the regulatory requirements for exposure models, as most identified uses of chemicals do not have available measurement data, thus, regulators rely largely on modelling approaches (e.g. (EFSA, 2014; ECHA, 2016a, 2016b)). There is a wide range and array of models and tools for different applications and sectors, as summarised in the ISES Europe model inventory, a living document that is publicly accessible via the ISES Europe platform on the ISES Europe Website (<https://ises-europe.org/exposure-platform/data-and-information-sharing>). Though exposure models are essential in exposure science, they often have shortcomings and challenges that need to be addressed (Schlüter et al., 2022). Additionally, the predictive ability of these models is often debated and there is a need for quality controls, including independent evaluation of models and to have transparency with the used model parameters (Spinazze et al., 2019).

The Exposure Models Working Group, established under the auspices of ISES Europe, aims to establish a common understanding of use, documentation, validity and limitations of models and tools for exposure assessment within the exposure science scientific and regulatory communities. A strategy for exposure modelling has been outlined by Schlüter and colleagues (Schlüter et al., 2022), with a clear definition for an exposure model stated as being a “*conceptual or mathematical representation of the exposure process As such it encompasses a concept, set of input parameters and mathematical equations that are defined based on a dataset or another source of past experience regarding exposure phenomena*”. Strategic objectives include (1) improvement of models and tools, (2) development of new methodologies and support for understudied fields, (3) improvement of model use and (4) regulatory needs for modelling. With respect to the first objective, it was identified that to improve model use, it is necessary to consider the human factor. Studies of inter-rater reliability (i.e. the ability of different assessors to reach the same conclusions about a specific case) have shown substantial variation between assessors (Stewart et al., 2000; Kunac et al., 2006; Friesen et al., 2011; Schinkel et al., 2014; Landberg et al., 2015; Riedmann et al., 2015; Lamb et al., 2017). Education and training of exposure model users is therefore key, with researchers advocating that training on the use of models and the interpretation of the results should be an essential part of education courses in exposure assessment (Lamb et al., 2017), as well as broader educational needs in exposure science that creates a workforce in the field qualified to make advances in the development and application of complex predictive exposure modelling tools. However, as highlighted in the ISES Europe strategy for education (Connolly et al., 2022), there is currently no formal educational training programme (at higher educational level) for exposure science in Europe. To address this strategic objective, this group cooperates in designing a curriculum for exposure science that includes exposure models.

To develop exposure science courses, regardless of speciality, it is imperative at the initiation stage to evaluate the educational needs for any educational course, to formulate the different objectives and the remit of the course. The input from experts in the exposure science discipline and from potential employers is essential to identify the needs and to ensure that the needs of the market are met by the courses. In this study, we present the results of a survey that was developed by the ISES Europe Exposure Models Working Group to identify these needs and the requirements for exposure science modelling training.

2. Methods

The questionnaire-based survey (Supplementary Material 1) comprised three sections. These sections were selected to gain an understanding of the needs and landscape for training and courses in exposure modelling for researchers and practitioners, with the aim to develop exposure models and assess exposure using models. The survey was developed by the manuscript co-authors, with iterations of the question set being drafted, circulated for comment, modified, and refined based on received input before finalisation. The first two sections

collected background information about the respondents and their interests in exposure science (Section A) and their previous attendance of exposure modelling courses (Section B). The last section (Section C) questioned about interest in future training and education in exposure modelling, what topics future training modules should cover, and in what format these future training and education sessions should be held. The questionnaire was created with Google Docs and included primarily multiple-choice five-point Likert scale questions, asking respondents how strongly they agree or disagree with a given statement (Joshi et al., 2015). In the event of ‘other’ being selected, free text responses were offered for additional information.

The survey was published on 17th March 2023 and closed at the end of April 2023. The results were downloaded on 17th May 2023. The survey was made available via LinkedIn and shared among an extensive network of experts. This included email contact with ISES members (i.e. over 850 members, including over 111 European members) and the ISES Europe Exposure Models Working Group members, as well as details being included in the ISES newsletter. Authors also further disseminated the survey to their own relevant contacts and encouraged further circulation. The aim was to reach as many scientists in the exposure science field as possible, however, the authors did not receive feedback on the degree to which the survey was forwarded and disseminated and thus it is not possible to estimate the exact number of recipients of the survey and therefore a response rate.

Answers were exported from the survey tool into a Microsoft Excel file and data analysis and graphical representation were conducted using Microsoft Excel 2023 (Microsoft Corporation, Redmond, WA, USA). For the purposes of this analysis, responses to the questionnaire were aggregated and individual responses were kept anonymous.

3. Results

A total of 88 survey recipients completed the online survey.

Section A: Background and interests in exposure science of the respondents.

Most respondents were from governmental organizations (38 %), followed by consultancy (19 %), industry (18 %), academia (14 %), research (9 %) and others (2 %) which includes those retired or self-employed. Twenty-five (28 %) of the respondents had more than 20 years of experience in exposure assessment, 22 % had between 10 and 20 years of experience, and 50 % had less than 10 years-experience (split evenly between 5 to 9 years and 0 to 4 years of experience). The respondents’ main areas of interest in exposure science were occupational (57 %), with 44 % of respondents indicating consumer exposure science and 44 % environmental. Nineteen (22 %) of respondents indicated all three exposure science areas were of interest to them.

Section B: Exposure modelling courses: previous experiences of the respondents.

Many respondents held multiple qualifications. When reviewing the provided data, 59 % of respondents reported their highest qualification as being a Doctor of Philosophy (Ph.D.) or Master of Philosophy (MPhil.), with 40 % of respondents having the highest qualification as being a Master’s level degree qualification. One respondent (1 %) had a certificate / diploma as their highest recorded qualification. Respondents were asked if exposure modelling training was included as part of their formal educational training. Only four holding undergraduate degrees responded positively to this question, with 18 and 14 respondents holding postgraduate qualification at Master’s or Ph.D. / MPhil. level indicating that modelling training was included.

About two-thirds of the respondents (64 %) stated that they had followed courses focussed on exposure modelling. The survey asked the participants to provide details of the name of courses, year, duration of the course and how it was held (virtual or in-person). Fig. 1 details the 52 replies received that reported further information on the courses. Some respondents replied more in general, without providing details, that courses were organised internally in the company or that courses

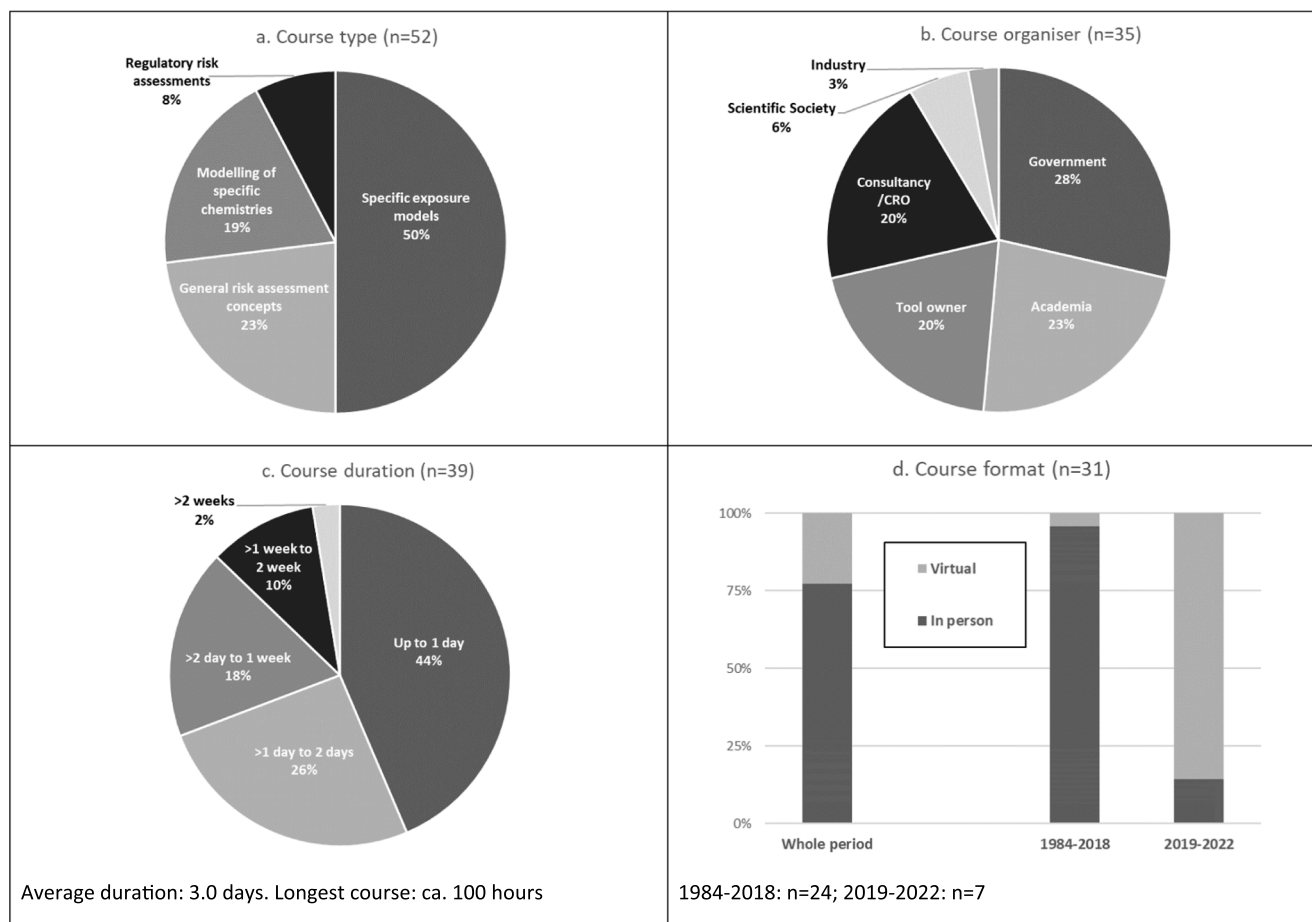


Fig. 1. Responses concerning previous modelling course a. Course type, b. Course organiser, c. Course duration and d. Course format.

were organised at the university (summer school, university lecture), or pre-conference education courses (e.g. ISES, SETAC (this being the Society of Environmental Toxicology and Chemistry), or online training on models.

Section C: Future training and education in exposure modelling: interests of the respondents.

When asked about interest in attending (in-person or virtually) specific training modules focussed on exposure modelling, 67 % of participants responded positively. In addition, they expressed interest and highlighted needs for a training course/module on exposure modelling. The participants of the survey highlighted thematic courses such as the following: developing a deeper understanding of usability and limitations of exposure modelling, exposure-risk assessment, machine learning/artificial intelligence, uncertainty propagation, qualification/evaluation/validation, new method development, big data, advantages and disadvantages/limits of statistical methods, regulations related to exposure, exposure scenarios and modelling, collaboration, dialogue, network forum, automation of calculations, dermal exposure modelling, TK (toxicokinetic) modelling, certification, EUSES (European Union System for the Evaluation of Substances) model, CHESAR model, Stoffenmanager model, Consexpo model, ART (Advanced REACH Tool) model, and updating their own skills as interesting courses follow. Additionally, user inter-variability was also identified as a topic of interest. It should be noted that the above summary is as stated and as such, it is not possible to expand further the intended meaning of some of the given responses which are perhaps less clear.

The participants who were not sure or responded that they were not in need of training provided some additional feedback on their response. Some participants indicated that they felt that their experience in exposure sciences or with their specific tools was already high enough so

that they would not need additional training. One comment suggested that tools should be built and documented well enough that no further training should be required. Another comment voiced a preference for “train the trainer” concepts for their model. Our understanding of this is that this respondent would prefer a program designed to equip individuals with the skills and knowledge necessary to become effective trainers who subsequently deliver training sessions to others. One participant wondered what one would gain from such a course while another just put in “cost” as an explanation. Finally, one comment expressed the opinion that one should be “learning by doing”.

Section C: Future education and training in exposure modelling: topics for modules.

Fig. 2 captures the results from scoring the potential subject/topic for training modules for exposure modelling based on participants’ needs and impact/importance. The following list reports the issue that could be included as a training module with relative scores by participants. This shows that the subjects proposed are all critical to essential. The most important topic would be a module on data interpretation, followed by “Use of models to meet regulatory standards/requirements”. It was remarked that the subjects depend a lot on the audience, so they should be tailored to specific needs and that all the modules cannot be part of one course. In addition, respondents were given the chance to provide subject areas missing and of interest. The free text responses are summarised as follows:

1. Teaching the assumptions of exposure models
2. The relationship of exposure models to exposure measurements
3. Use of literature data for unavailable data
4. The definition of exposure determinants
5. Gaps in current exposure models

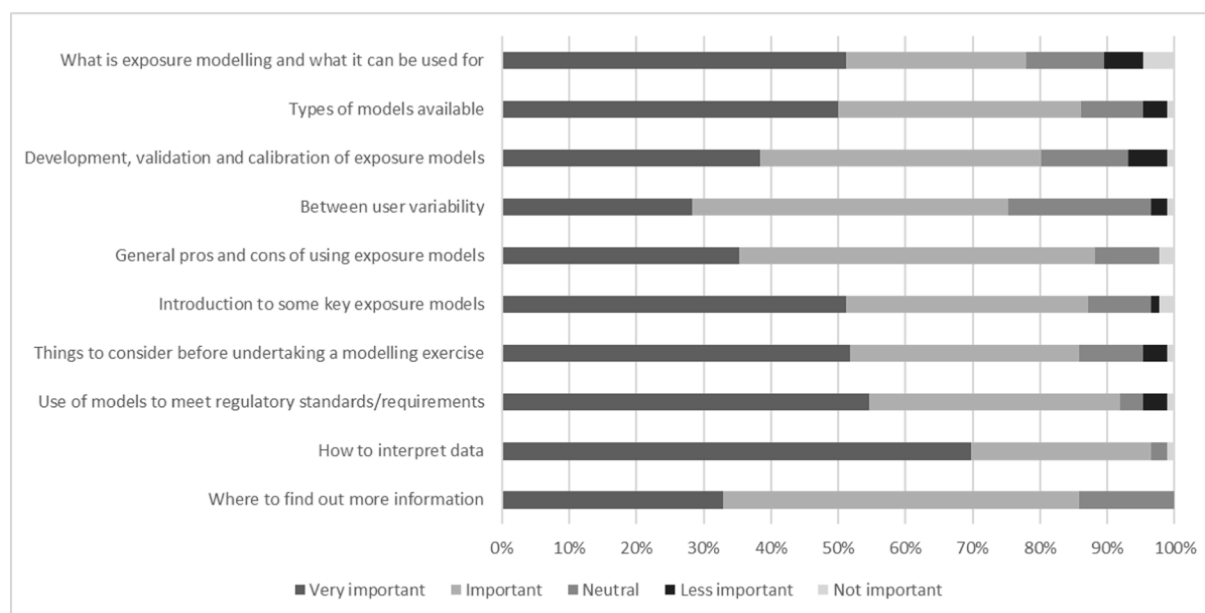


Fig. 2. Responses to Question: “For each of the following topics, please rate the level of importance in these being covered in an exposure modelling course”.

6. Sources of modelling error (including users’ misconception of the exposure scenario)

Two respondents furthermore expressed a wish for a knowledge exchange platform for model users. One of them also wished for model transparency and accessibility which are things the authors feel would require outside developments but are not part of an exposure model training course.

Section C: Future education and training in exposure modelling: format of trainings.

The preferred attendance of such a training course was voted to be

virtual (N = 33; 38 %), in person (N = 25; 28 %) and 24 participants (27 %) replied blended (e.g., theory work virtual and in-person practical session). For the duration of such training, the preference was for “Short blocks focussed on certain topics” and “Full one day course”, while less popular was extended (few days, up to a week) training. Fifty-five (55) percent of the participants replied that they (or their organisation) would be willing to pay for training.

With respect to choosing a course, the highest impact was on the coverage of the course (subject/topics) and based on the lecturer/expertise of course providers (Fig. 3). In the second highest impact level was the organisation delivering the course and the format of delivery of

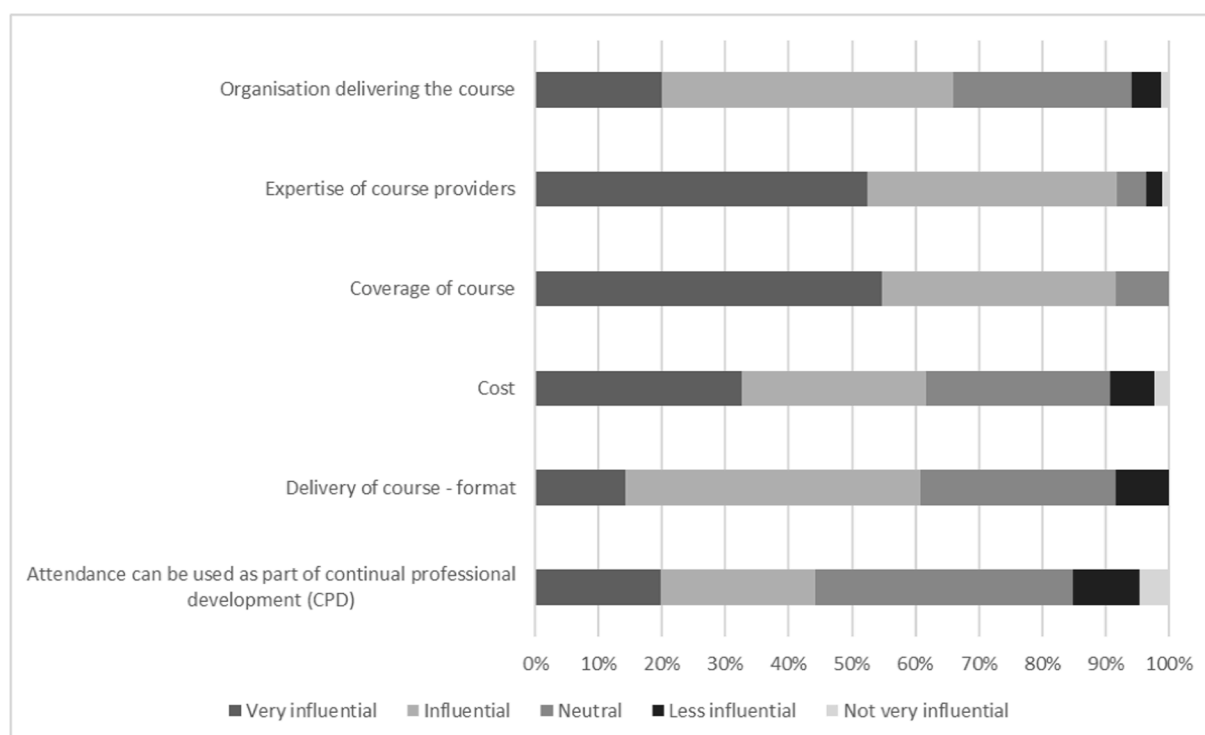


Fig. 3. Responses to Question: “What factors are most influential on your / your organisations decision-making on attending a course on exposure modelling?”.

the course. Costs and certificate of attendance seemed less influential as criteria when selecting a training course.

4. Discussion and conclusions

In this survey we aimed to identify the current needs and requirements for exposure science modelling training via as many scientists working in this domain as possible.

Whilst the membership of ISES is known, it is probably fair to say that the number of exposure scientists in Europe (and beyond) is considerably larger. There are many others in the discipline not members of these organisations but with an interest in exposure modelling (e.g., occupational hygienists, toxicologists, etc). However, due the broad representation of exposure scientists in ISES Europe and the networks that were used by the authors to disseminate the survey it is considered a reasonable assumption that many European scientists in this field had been reached, although due to the snowballing strategy it is not possible to say how much further afield the survey was circulated. We cannot claim that the survey is representative of the views of all European (or even global) exposure scientists but consider that our respondents allowed for good coverage of working areas, exposure science domains, years of experience and qualifications. We therefore consider that the current study results are addressing the evaluation of a training need that has been previously identified as a priority area for exposure science (Schlüter et al., 2022; Kunac et al., 2006). With an increasing demand for experts in this field, specifically on exposure models, these results provide the initial steps for providing educational courses.

An interesting finding of this survey was that many of the courses' respondents had attended in exposure modelling were 'one-off' courses (i.e. conference workshop) or historic (i.e. no longer available). Furthermore, the survey findings highlight that there are experts available who can deliver training. It was also interesting to observe that modelling only featured in a small proportion of undergraduate or postgraduate degree courses. Our survey results also identify that there is still a demand for training in exposure modelling, however, there are very few available courses in this area and no academic course that is regularly available to produce graduates to fill this employer market need.

Another aspect of the survey that provided interesting insights was that the survey showed very little interest in continual professional development certification or gaining recognition for these types of courses. Many disciplines have accreditation of their profession (e.g. toxicology/occupational hygiene) and they require regular attendance of training courses to (re)gain their annual certification within the discipline. However, in contrast to these disciplines, exposure science does not yet have any type of certification/accreditation worldwide, and consequently employers are happy if they are able to hire somebody with demonstrable skills of an exposure modeller, but do not typically request a certificate. This in return may be the reason why respondents did not deem certification of importance. This cause-and-effect dilemma has already been indicated as an area that requires addressing. The future ambitions of the ISES Europe 'European Exposure Science Strategy' for Education is thus to establish awarding bodies for certification and accreditation to assist with developing defined career pathways for graduates and advancing the scientific field. This would not only assist with advancing the exposure science field to achieve recognition and awareness of the discipline, but it would also assist in ensuring high-quality standards among exposure professionals and educational courses, as these experts would receive recognition and be acknowledged with professional accreditation, including continuous professional development (Kunac et al., 2006).

In terms of next steps, the ISES Europe Exposure Models Working Group, in conjunction with the Education, Training and Communication Working Group will move forward with the development of training modules focussed on modelling which is suitable and sufficient in content to fulfil the training needs of our current and future exposure

scientists. To achieve this, we will use our network of established exposure scientists, recognised in the field of modelling to develop and deliver these training modules. We will also continue to explore certification and accreditation of these training modules to allow recognition of continued professional development in this important area.

CRedit authorship contribution statement

K.S. Galea: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **A. Paini:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization. **G. Bachler:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **C. Alejandro-Colomo:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **P. Fantke:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **W. Fransman:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **C. Jung:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **A. Van Nieuwenhuysse:** Writing – review & editing, Data curation, Conceptualization. **N. von Goetz:** Writing – review & editing, Methodology, Data curation, Conceptualization. **A. Connolly:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envint.2024.109103>.

Data availability

Data will be made available on request.

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