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Development of REACH Generic Exposure Scenarios for Substances Used as Coformulants in Plant Protection Products

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This article reviews the interactions between the REACH (Registration, Evaluation, Authorization and restriction of Chemicals) regulation and the plant protection product regulation for substances used as coformulants in the European Union, and describes generic exposure scenarios developed for their exposure and risk assessment. The REACH exposure scenarios describe the operational conditions and risk management measures used in the risk assessment of a coformulant, and as such these translate as the boundaries of safe use. The generic exposure scenarios are designed to be simple, and closely integrate with REACH use descriptors and customized exposure models. Clustering of application methods and exposure determinants resulted in four generic exposure scenarios, each covering professional workers or consumers, and application of products in liquid, granular form, or applied on seeds. When used in conjunction with appropriate exposure models, the generic exposure scenarios support efficient first-tier risk assessment of coformulants by utilizing a higher level of abstraction and conservatism than typically used in plant protection product assessments.

KEY WORDS: Exposure scenarios; pesticides; REACH

1. INTRODUCTION

The European Registration, Evaluation, Authorization and restriction of Chemicals (REACH) legislation requires a holistic risk assessment of all the potential uses of a substance across many industrial sectors, including use in plant protection products.(1) Within the boundaries laid out in the regulation, a manufacturer or importer of a substance must generate substance-specific data(2–4) and carry out a hazard assessment,(5) as well as exposure assessments of all identified uses for both human health(6,7) and the environment.(8) Finally, safe use must be demonstrated through risk characterization.(9) The risk assessment is documented in a chemical safety report, and communicated along with summaries of the data, to the European Chemicals Agency (ECHA) in a registration dossier. The conditions of safe use derived from this risk assessment must then be communicated within the supply chain to the downstream user via the extended Safety Data Sheet (SDS). Formal development of exposure scenarios as an integral part of exposure and risk assessment,(10) as well as downstream user communication, is explicitly foreseen within the legislation.

Coformulants manufactured and imported in quantities >10 t/year and used in plant protection products have no regulatory exemption from the REACH human health exposure assessment,

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unlike substances used in cosmetics and food contact materials (REACH, Article 14(5)). Furthermore, there are no comparable regulatory exemptions from the REACH environmental exposure assessments for any use sector.

In parallel to the requirements imposed by REACH on a coformulant manufacturer or importer, E.U. plant protection product legislation requires that the active substance must be approved, and the end-use plant protection product manufactured by the formulator must be authorized.[11] This overlap between plant protection and chemical legislation is unusual, in that most countries tend to strictly separate the scope of chemical and plant protection product legislation.[12] The situation in the European Union seems to have arisen by legislative accident, in that Article 15(1) appears to exempt coformulants from registration, but fails to do so due to the fact that the referenced lists do not hold coformulants. Effectively, this has continued the status quo, as prior to the entry into force of REACH, new substances used as coformulants in plant protection products were required to be notified.[13] The same interaction between REACH and the Biocidal Product Regulation for coformulants also exists, in that biocidal coformulant uses must also be considered within a REACH risk assessment. A somewhat similar example of general chemical and sector-specific legislative overlap is observed with the Canadian Environmental Protection Act and pharmaceutical legislation.[14] Because the latter does not contain elements addressing environmental protection (unlike the relevant pesticides legislation), registration of active pharmaceutical ingredients under the general chemicals legislation is also required. Similar to REACH, the U.S. EPA makes a broader coformulant assessment, and considers potential residential sources of exposure to substances with pesticide coformulant uses (e.g., cleaning products, paints, etc.); however, legislative scope limits this to human health effects only.[12,15]

Coformulants tend to be commodity chemicals with a multitude of industrial and wide dispersive uses; thus, any credible risk assessment must acknowledge these other potential sources of exposure, particularly for the environment. Assessing coformulants under chemicals legislation has significant efficiency advantages in that it places the responsibility for data generation and risk assessment with the substance manufacturer, thus covering a multitude of downstream users. The diversity in uses also brings challenges for risk assessment, in particular with adequate information flow on identified uses, operational conditions, and risk management measures up the supply chain from sector-specific end users.

Against this background, generic exposure scenarios (GESs) have been prepared as an aid to the human health and environmental exposure assessment of coformulants in plant protection products. The benefits to registrants are a standardized conceptual model of the uses in the crop protection industry. For the downstream user (formulators), the benefit is a standardized and readily interpreted description of the safe use conditions for each coformulant, supplied as exposure scenarios in the extended SDS. Specification of appropriate operational conditions (e.g., a maximum coformulant use rate) and risk management measures (e.g., use of gloves for mixing and loading) allows simple assimilation into the overall safe use conditions specified for each plant protection product, and comparison with the specified good agricultural practice (GAP).

The approach taken to develop the GES followed that described previously and in various regulatory guidance documents.[10,16–20] Unlike some approaches taken by other industry sectors, no differentiation was made within the GES on the basis of substance toxicity or physical properties.[21,22] The developed GESs reflect the typical activities involved in the foreseen uses of plant protection products, with an explicit aim to be simple and integrate directly with European Crop Protection Association (ECPA) customized first-tier exposure assessment models and tools. The initial steps involved clustering of different plant protection products and the associated activities involved in their use, followed by mapping to the standardized REACH use descriptor terminology.[23]

2. METHODS

2.1. Development of Generic Exposure Scenarios

Exposure scenarios describing the industrial manufacture of formulations (mixtures) were assumed to be broadly equivalent in nature, and thus equally applicable to industrial manufacturing sites in the plant protection sector. Consequently, the scope of the exposure scenarios to be developed was limited to those uses specific to the plant protection industry.

The ultimate purpose of an exposure scenario is to aid development of the exposure assessment,

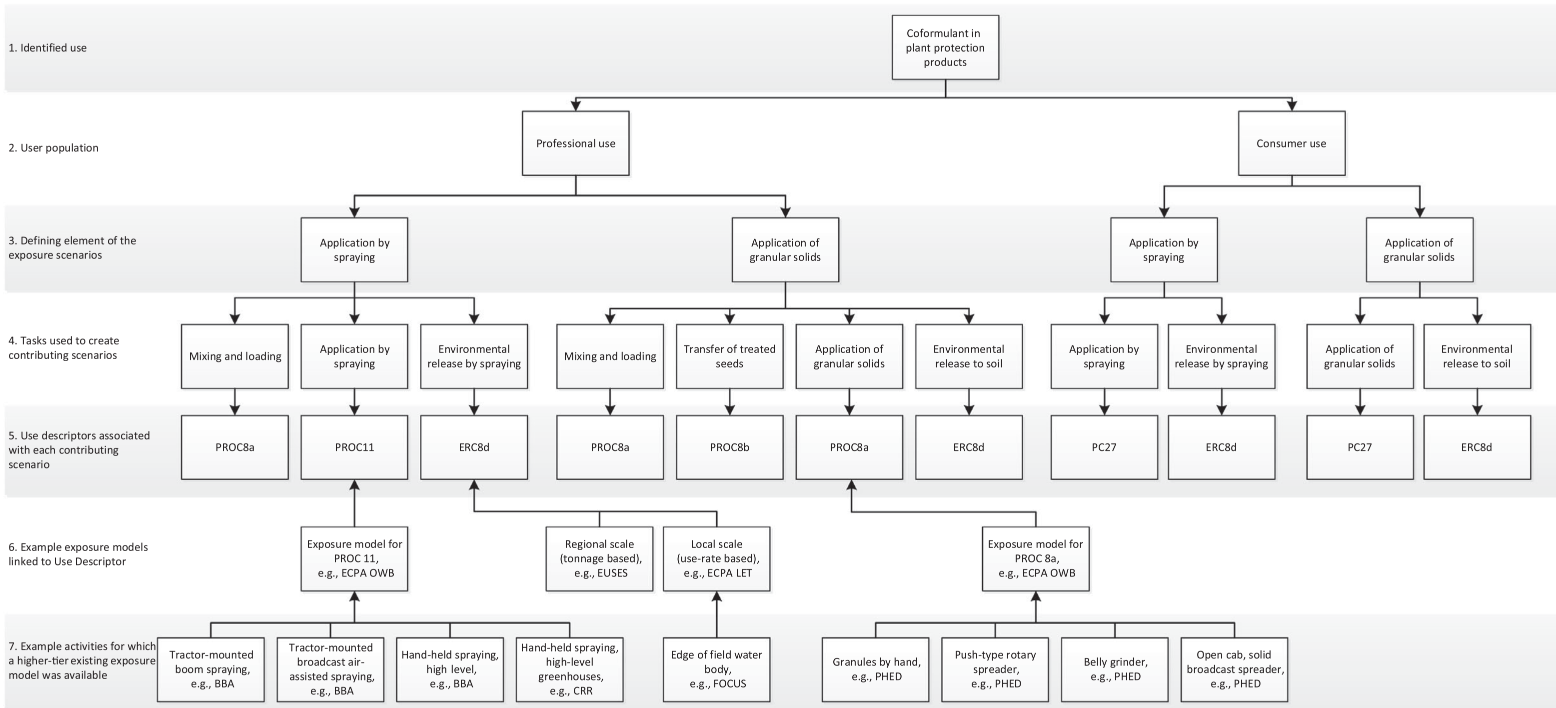

Fig. 1. The diagram depicts the minimum four generic exposure scenarios (row 3) required to cover the majority of plant protection products, on the basis of exposed population (row 2) and application method. Individual tasks that dictate the contributing scenarios and their relation to the associated use descriptors are presented in rows 4 and 5. Rows 3–5 are the exposure scenarios, contributing scenarios, and use descriptors to be communicated in the extended SDS. The operational conditions and risk management measures to be communicated are derived from the worst cases in rows 6 and 7. Examples of ECPA exposure models developed specifically for these contributing scenarios are provided, as well as their relation to the underlying existing exposure models that thus define the activities covered by the generic exposure scenario (scope).[24,27,28]

thus necessitating at least some alignment with the exposure models anticipated to be used. As a result, the development of plant protection product worker and environmental exposure models carried out in parallel to this work heavily influenced elements of the use mapping[24] by providing a ready list of potential tasks and exposure determinants. Furthermore, alignment with a custom set of exposure models allowed a tradeoff between exposure scenario and contributing scenario complexity (granularity), and exposure model conservatism. Unwanted complexity in contributing scenarios (Fig. 1, row 7) could be pushed into the exposure model by calculating the reasonable worst case for a given determinant (Fig. 1, row 6), rather than a separate contributing scenario for each permutation of an exposure determinant (Fig. 1, row 4). The ECPA-customized exposure models are available for download, free of charge, at http://www.ecpa.eu/industry-resources/reach-registration-evaluation-authorisation-and-restriction-chemicals, and will be described elsewhere.

Initial attempts at use mapping focused on population, environmental setting, application method, and formulation type. The latter is a well-established formalism within the plant protection industry that describes the physical nature of the formulation as a two-letter code, e.g., water-dispersible granules (WG), emulsifiable concentrate (EC), etc.[25] After an initial focus on formulation type (driven by established exposure models), it was realized that less granularity was actually required, given that any substance could potentially be used in all of the 63 formulation types. An explicit goal was to keep the number of exposure scenarios as small as possible, recognizing this would necessitate an increase in conservatism in the ECPA-customized exposure models.

In the case of the environmental contributing scenarios, a more granular description (i.e., more differentiation) could lead to the impression of greater modeling accuracy. However, this is misleading as it would also necessitate an assignment of tonnage by the manufacturer to each differentiated scenario in the exposure model, with an inherently increased uncertainty in those values. Furthermore, unless differentiated (and justified) emission fractions were assigned to these additional contributing scenarios, the end result in terms of total emissions and calculated environmental exposure would be the same.

As an example, formulation type will be used to illustrate the practical consequences of unnecessary granularity in exposure scenarios. Using one of the most common software solutions for SDS generation, for a hazardous substance, each process category (PROC)/environmental release category (ERC) adds approximately an additional page to the extended SDS. Roughly, three extended SDS pages are thus required to cover a product for mixing and loading, spraying, and environment. Focusing on the most common formulation types (e.g., EC, WP, SL, SP, SC, CS, and WG), separate exposure predictions for each would be required to be documented in the chemical safety report at similar page count, and the results transferred to SDS software. An additional 21 pages would thus be added to the other nonagrochemical exposure scenarios listed in the extended SDS. An additional seven use entries in the IUCLID database should be maintained. Furthermore, the coformulant manufacturer should identify the yearly tonnage used in each of the seven formulation types for the environmental risk assessment. Finally, the recipient of the SDS must search its portfolio for all uses of the coformulant in the seven formulation types, and compare the conditions of use with the seven separate exposure scenarios. Use of the coformulant in any of the other 56 formulation types would not be permitted without the formulator having to carry out a downstream user risk assessment. Clearly, removing the formulation type as a distinguishing element of the GES results in a shorter SDS, with an increased likelihood of manufacturer adoption, and an increased ease in interpretation by the SDS recipient.

The overriding approach in the GES development was thus to keep the exposure scenarios as simple as possible, and only introduce complexity where fundamentally required, e.g., dispersal of solids and liquids cannot be considered to be the same. If safe use cannot be demonstrated in the first-tier assessment, the risk assessor is always free to reintroduce complexity on a case-by-case basis, with further exposure scenarios, contributing scenarios, or higher-tier models, in response to the substance and use-specific requirements for refined operational conditions and risk management measures.

3. RESULTS

3.1. Worker Contributing Scenarios

Population was initially used to differentiate the end users of plant protection products into two groups. Farmers are considered to be professional workers, and home users to be consumers (note that the latter are often referred to as "amateurs" in the plant protection context). The two populations are depicted in the second row of Fig. 1. For the end use of plant protection products considered here, the industrial worker population is not relevant.

At a high level, plant protection products can be divided into two groups on the basis of their physical state during application, and the resulting difference in potential exposure. This differentiation leads to the bifurcation in the third row in Fig. 1, with either application of liquids by spraying, or the application of granular solids or seeds treated with pesticides. The result is a minimum of four GESs to cover plant protection product uses.

The individual tasks involved in each of the application methods ultimately determine the potential exposure to the substance in question, but again at a high level, these can be simplified to: (1) opening end-use packaging and loading of dispersal equipment ("mixing and loading"), (2) followed by use of the dispersal equipment (dispersal of granular solids or spraying diluted liquids). The REACH exposure assessment methodology allows these tasks and their associated exposures to be treated as contributing scenarios, which are grouped together within a given exposure scenario, and depicted in the fourth row of Fig. 1.

The fifth row of Fig. 1 assigns each professional contributing scenario (task) a standardized PROC use descriptor to nominally aid in communication.[23] Each consumer contributing scenario is assigned a product category (PC). Table I lists the standardized REACH definitions for the relevant use descriptors.

3.1.1. Generic Exposure Scenario for Spraying (GES1)

The GES for professional spraying consists of two worker contributing scenarios (Table II). Mixing and loading typically involves simple pouring of liquids or solids from containers into spray tanks along with mixing and dilution by water. Although there is a move toward closed mixing and loading systems, in the worst case, this is done without the use of local exhaust ventilation, specialized couplings, or engineering controls that are commonly found at dedicated industrial transfer points. This contributing scenario was thus assigned to PROC 8a on the basis that a simple manual transfer of larger quantities of chemicals is involved, and that the dedicated engineering controls required for PROC 8b cannot be assumed. PROC 5 (mixing or blending in batch processes) could have been considered; however, the scope of this PROC explicitly excludes the transfer step (charging). Similarly, while PROC 9 (transfer of substance or mixture into small containers) could be considered, the scope is restricted to filling lines with their small quantities and associated industrial exposure controls. PROC 19 (manual activities with hand contact) could potentially have been used instead; however, the degree of exposure expected from the examples given to define this PROC was not commensurate with good handling practice for plant protection products. Ultimately, the loss of the clear link to the actual task for which exposure is predicted (transfer of the concentrated plant protection product) would have been lost.

The variety of activities (or scope) that the contributing scenario covers is ultimately set by the exposure model used for the exposure prediction. If the ECPA Operator Worker Bystander (OWB) tool is used for exposure prediction (Fig. 1, row 6), the following activities are covered and the worst-case exposure value is reported and used in the risk assessment (Fig. 1, row 7): loading of tractor-mounted/trailed boom sprayers, loading of tractor-mounted/trailed broadcast air-assisted sprayers, and loading of hand-held spray equipment.[24] The operational conditions are set by the most significant exposure determinant, the maximum application rate of the substance, reported in kg/ha, and the area assumed treated with plant protection products. Relevant risk management measures result from any personal protective equipment (PPE) the risk assessor may have specified during calculation of the maximum application rate, e.g., use of protective gloves during the mixing and loading task.

The worker contributing scenario for spraying of a plant protection product (usually diluted with water) was easily assigned to PROC 11 because this is a nonindustrial spraying scenario (Fig. 1, row 5). As an example, use of the ECPA OWB exposure model for the exposure prediction inherently covers tractor-mounted/trailed boom sprayers, tractor-mounted/trailed broadcast air-assisted sprayers, use of hand-held spray equipment for high-level targets (including in greenhouses), as well as the indirect exposure of workers on field reentry and bystanders.[24]

No additional or more differentiated contributing scenarios were added for the default case (e.g., tractor vs. backpack spraying, or based on formulation type) because it was considered to bring limited benefit at the expense of an increase in GES

Table I. Use Descriptors Used in the Generic Exposure Scenarios and Their Default Descriptions[23]

Use Descriptor Code	Description
PROC 8a	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at nondedicated facilities
PROC 8b	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities
PROC 11	Nonindustrial spraying
PC 27	Plant protection products
ERC 8d	Wide dispersive outdoor use of processing aids in open systems

and SDS complexity, as outlined above with the example of formulation type. However, additional granularity for workers at the contributing-scenario level does not have the same overhead as for environmental assessment at the exposure-scenario level (Fig. 1, row 3 and row 4). Instead, it was decided that these exposure determinants would be subsumed into the respective ECPA-customized exposure models by selecting the worst-case value from available exposure models (e.g., loading dry powders vs. pastes or liquids). For example, the seemingly disparate tasks of tractor and backpack spraying are linked by the primary exposure determinant "use rate" (i.e., kg substance/ha). In the simplest approach, the most conservative use rate could be reported as an operational condition, thus covering both application methods. This approach would limit the tractor use rate to the maximum use rate derived from the higher exposure backpack spraying, but this could be entirely sufficient for coformulants with large exposure limits (DNELs). The most efficient and flexible approach is to report both values as operational conditions within the same contributing scenario, provided that risk management measures remain the same (e.g., only use of gloves for mixing and loading). However, if this PPE commonality diverges (e.g., use of a respirator for backpack spraying), a separate contributing scenario may be the better option. Ultimately, several approaches are possible depending on the substance use and hazard profile, but practical feasibility is often heavily influenced by the constraints imposed by SDS authoring software, databases, and templates.

3.1.2 Generic Exposure Scenario for Granular Solids (GES2)

The second GES covering the professional use of plant protection products that are granular solids in the form they are applied, as well as seeds coated with seed treatments, only involves contributing scenarios where substances are transferred (Fig. 1 and Table II).

The mixing and loading worker contributing scenario considers the transfer of seed treatments, as well as granular plant protection products and treated seeds, into dispersal equipment. Because the loading of the dispersal equipment is not usually conducted in industrial settings with dedicated equipment, this was assigned to PROC 8a on the basis that a manual transfer of larger quantities of chemicals is involved, and that the dedicated engineering controls required for PROC 8b cannot be assumed. Similar considerations for the alternative use descriptors PROC 5, 9, and 19 apply as for GES1.

Use of the ECPA OWB tool for this contributing scenario encompasses the transfer of treated seeds and granular plant protection products that occurs during loading of tractor-mounted broadcast spreaders, the loading of mechanical equipment with solid and liquid products for the treatment of seeds, and the loading of manual belly-grinders and "push-type" spreaders. This clustering is consistent with previous works considering inhalation activity classes (transfer of powders, granules, or pelletized material) and dermal exposure operations.[20,26]

The second worker contributing scenario (Table II) was developed for the transfer of treated seeds from a batch seed treater into bags. Because this is expected to occur in a dedicated setting where containment and engineering controls are specifically designed for seed treatment, such as local exhaust ventilation, PROC 8b was assigned.[23] The alternative use descriptor PROC 19 could have been applied; however, as for GES1, this would lose the clear link between use descriptor to the task (i.e., transfer), and could imply that direct exposure of workers is acceptable practice.

The third worker contributing scenario (Table II) considers the delivery and dispersion of treated seeds, and plant protection products, into or onto the soil. The assignment of an appropriate use

Table II. Generic Exposure Scenarios for Substances Used as Coformulants

	Full Generic Exposure Scenario Title	Use Descriptor	Full Contributing Scenario Title	Scope of the Contributing Scenario When the ECPA-Customized Exposure Models Are Used (OWB & LET)[24]
GES1	Use as a coformulant in plant protection products, spray applications by professionals	PROC 8a	Mixing and loading of plant protection products into delivery equipment	Loading of tractor-mounted/trailed boom sprayers, loading of tractor-mounted/trailed broadcast air-assisted sprayers, and loading of hand-held spray equipment.
		PROC 11	Delivery and dispersion of plant protection products	Tractor-mounted/trailed boom sprayers, tractor-mounted/trailed broadcast air-assisted sprayers, use of hand-held spray equipment for high-level targets (including in greenhouses), worker reentry (indirect exposure), and indirect exposure of bystanders.
		ERC 8d	Spray application of plant protection products containing coformulants (indoor or outdoor)	Spray application to an agricultural field with an adjacent shallow waterbody.
GES2	Use as a coformulant in plant protection products, seed, and granular applications by professionals	PROC 8a	Mixing and loading of plant protection products into seed treatment or delivery equipment	Loading of tractor-mounted broadcast spreaders, the loading of mechanical equipment with solid and liquid products for the treatment of seeds, and the loading of manual belly-grinders and "push-type" spreaders.
		PROC 8b	Transfer of treated seeds from batch treater into bags	Transfer of chemicals from/to vessels/ large containers at dedicated facilities.
		PROC 8a	Delivery and dispersion of agrochemical plant protection products or treated seeds	Manual spreading (by hand), mechanical spreading (belly grinders and push-type rotary spreaders), and from open-cab tractor-mounted broadcast spreaders.
		ERC 8d	Direct application of plant protection products (granules or treated seeds) containing coformulants to soil (indoor or outdoor)	Direct application to soil in an agricultural field with an adjacent shallow waterbody.
GES3	Use as a coformulant in plant protection products, spray applications by consumers	PC 27	Spray application of agrochemical plant protection products	Loading of hand-held spray equipment. Use of hand-held spray equipment for high-level targets.
		ERC 8d	Spray application of plant protection products containing coformulants (indoor or outdoor)	Spray application to an agricultural field with an adjacent shallow waterbody.
GES4	Use as a coformulant in plant protection products, seed and granular applications by consumers	PC 27	Manual spreading of granular plant protection products or treated seeds	Manual spreading by hand/spoon/cup, push rotary spreader, or belly-grinder, of granular plant protection products or treated seeds on residential lawns/turf, gardens (flowers, fruits, and vegetables), and trees (fruits, nuts, shrubs, and ornamentals).
		ERC 8d	Direct application of plant protection products (granules or treated seeds) containing coformulants to soil (indoor or outdoor)	Direct application to soil in an agricultural field with an adjacent shallow waterbody.

descriptor in this case was less obvious. Because the task clearly involves a transfer from the mechanical equipment holding the treated seeds or granules, a PROC 8 use descriptor was considered to be most relevant. Although the equipment used typically has features to minimize worker exposure, the use does not take place at dedicated facilities; hence, PROC 8a rather than PROC 8b was assigned. As an alternative, the use descriptor PROC 0 ("other") could also have been used to more accurately define the dispersion of solid plant protection products. Because PROC 0 is user defined, the easy recognition that it is a task that involves transfer of material is lost (PROC 0 can be used by registrants for any task not fitting the standard use descriptors). Furthermore, because the task description is not standardized, it is open to deviations in description by each registrant, and overall transparency is lost. Of the contributing scenarios described by the standard use descriptors, this is perhaps the best candidate for the future development of a new agrochemical-specific use descriptor.

Use of the ECPA OWB tool for the PROC 8a exposure prediction encompasses delivery and dispersion of treated seeds and granular plant protection products from manual spreading (by hand), mechanical spreading (belly-grinders and push-type rotary spreaders), and from tractor-mounted broadcast spreaders (Fig. 1). Similarly to the first contributing scenario, this clustering of activities is consistent with previous works considering task-based exposure.[20,26]

3.1.3. Generic Exposure Scenarios for Consumers (GES3 And GES4)

The two consumer GESs both contain contributing scenarios with the same mixing and loading, and application tasks as the professional exposure scenarios. However, they are not formally differentiated within the REACH use descriptor system, and are simply assigned a single PC based on end use (PC 27; see Table I). Similarly, the exposure models used for these contributing scenarios report the overall combined exposure, rather than separated into individual tasks.

While in principle a similar approach with sole use of the PC 27 use descriptor for professional uses could offer further simplification by combining into a single-worker contributing scenario, this would conflict with the mandatory reporting requirements for PROCs in the IUCLID dossier, and the possibility to assign specific PPE to individual tasks (such as mixing and loading).

3.2. Environment Contributing Scenarios

The use mapping for the environment is relatively straightforward, particularly at the level defined by the use descriptor ERC. All plant protection products uses are wide dispersive uses by definition, and coformulants are not reactive substances within the context of the ERC. This leads to the conclusion that the use descriptor ERC 8b is the most relevant for coformulant exposure scenarios (Table I).

Initial use mapping efforts differentiated on the basis of indoor (ERC 8a) versus outdoor (ERC 8b) use. However, it was later recognized that indoor emissions are merely temporally delayed outdoor emissions, at least as far as the complexity of the standard models used for regional-scale calculations is concerned. For example, coformulants released to air indoors (e.g., greenhouses) will eventually exchange with outdoor air. Furthermore, indoor/outdoor differentiation within the GES can only be meaningful if it leads the exposure models to calculate a higher environmental concentration (indicative of greater risk) in the compartments agricultural soil, surface water, or sediment. Practically, this would require the coformulant manufacturer to identify from the supply chain the tonnage used for both indoor and outdoor uses. To achieve higher predicted concentrations, the tonnages used in indoor applications would have to be comparable or higher than outdoor uses (very unlikely), and the emission fractions for the indoor use must also be greater than those for outdoor use (also unlikely). As a result, use of ERC 8b is considered to be the worst case, and inherently covers any indoor emissions to the environment that may occur. Both professional and consumer exposure scenarios have an environmental contributing scenario.

Specific ERCs (SpERCs) were also developed as a refinement to ERC 8b, and the associated default emission factors, but will be described elsewhere.[24,29,30]

4. DISCUSSION

4.1. Human Health Contributing Scenarios

For several tasks, there were options as to the level of granularity to incorporate into the GES. As an example, the "mixing and loading" task

(PROC 8a) could potentially be further divided into separate mixing (PROC 5) and loading (PROC 8a) contributing scenarios. The main reason for covering these with the single PROC 8a use descriptor was the limited number of scenarios where separated mixing with potential for exposure was identified (definition of PROC 5). The main activity envisaged was opening of end-use packaging, pouring into a spray tank, with subsequent filling with water. Furthermore, the contributing scenario was intended to integrate closely with an exposure model that was based on an experimental data set that combined exposure from both aspects.[31] As a result, only a single combined exposure value for this task was available for reporting against the PROC. While PROC 0 could also have been used to more accurately define the "mixing and loading" scope, the overall transparency is lost in that it is user-defined "free text," and hence open to the inevitable descriptive deviations by each registrant.

Similarly, the decision to keep the mixing and loading task as a contributing scenario, rather than a separate GES, was heavily influenced by the available worker exposure models. The mixing and loading task was integral to the overall exposure calculation, being directly added to the calculated exposure for the spraying task. Both steps are highly correlated (the same worker performing both tasks), and for an exposure modeling tool to calculate a maximum safe use rate, it is necessary for both tasks to lie within the same GES, such that combined exposure can be reported.

Two additional groups were considered in development of the professional GES. A subpopulation often not explicitly considered in REACH exposure assessments for professional workers is that of "bystanders." In crop protection exposure assessments, bystanders are members of the general population who may be accidently exposed during application by spray drift. Similarly, indirect exposure of workers reentering a freshly treated field is also considered in a crop protection exposure assessment. A typical REACH exposure assessment would assume that the worker directly involved in the task would have the highest potential exposure, and explicit assessment of this group was unnecessary.

To align the methodology with that established for plant protection products, both groups should be considered in the GES. However, neither case can be considered to be a formal use of a substance, qualifying for a separate exposure scenario. A separate contributing scenario could be used, but again neither bystanders nor worker reentry can be considered formal uses of the substance. Bystander exposure occurs in a professional use setting; however, the derived no exposure limit (DNEL) that should be used for risk assessment is that derived for consumer exposure.[9] Furthermore, treating secondary exposures as formal uses with separate formal exposure scenarios would require assignment of an ERC and associated tonnage, adding complexity to the environmental assessment. Ultimately, conflating populations and "artificial" uses would create subsequent reporting complications in IUCLID, particularly when combined with the move toward more mandatory fields in dossier technical completeness checks. As a result, the approach adopted with the least likelihood of complications was to calculate the potential bystander and worker reentry exposures in the same exposure model, and report the details within the contributing scenario of the chemical safety report, leaving the high-level GES/contributing scenario structures unchanged.

Niche application methods for plant protection products were not considered (crop dusting, dipping, brushing, etc.). Some aspects of these may already be covered by the developed contributing scenarios (e.g., mixing and loading). In addition, exposure scenarios developed by other industry sectors for the substance may also be relevant in exposure prediction (e.g., brushing of paints). On the other hand, if an additional exposure model is available, the scope of the exposure scenario can be broadened simply by adding the output to the exposure calculations (see Table II, last column). As long as the numerical predicted exposure value remains lower than the worst-case exposure predicted from the other models, no further modification of the exposure scenario would be required for the increase in scope. However, care must be taken with such steps that the operational conditions and risk management measures are still correct, and that the human health and environmental assessments remain aligned, e.g., a new worker application method must also remain within the applicability domain of the models used for environmental exposure assessment.

The intrinsic physical state of a substance provides an opportunity to refine the reasonable worst-case exposure expected during transfer of a formulation, i.e., for a liquid substance, assuming exposure can arise as a dusty powder is not relevant. Table III sets out the relevant contributing exposure scenarios based on the physical state of the substance at room temperature. An intrinsically liquid substance

Table III. Relevance of the Substance's Intrinsic Physical State to the Generic and Contributing Exposure Scenarios

Generic Exposure Scenario	Contributing Scenario	Possible Formulation Physical States	Substance Intrinsic Physical State	
			Solid	Liquid
GES1 & GES3 (spray)	Mixing & loading (PROC 8s)	Solid or liquid	Relevant	Relevant
	Spraying (PROC 11)	Liquid	Relevant	Relevant
	Environment (ERC 8d)	Liquid	Relevant	Relevant
GES2 & GES4 (granules)	Mixing & loading (PROC 8a)	Solid or liquid	Relevant	Relevant
	Bagging treated seeds (PROC 8b)	Solid	Relevant	Minimal relevance
	Distribution of granules (PROC 8a)	Solid	Relevant	Minimal relevance
	Environment (ERC 8d)	Solid	Relevant	Minimal relevance

Note: A liquid substance cannot be present at significant concentration in a solid form before affecting the exposure potential (e.g., reducing dustiness, or forming a paste), thus modifying assumptions on the reasonable worst case.

can only be present in a solid formulation at a limited concentration before it changes the form of the formulation, e.g., solid powder becomes a paste, etc. On the other hand, a solid substance can be present in a dissolved liquid, paste, powder, or granular formulation. Only granules are usually applied directly as a solid, with the other formulation types typically facing aqueous dissolution and dilution before spraying (e.g., WG).

The final step for a risk assessor utilizing the GES is communication of the substance-specific exposure scenarios to downstream users. Table IV is an example of how the results of a worker risk assessment for spraying of plant protection products using GES1 could be communicated to formulators in the extended SDS, using the current format specified by the ECHA.[32] In this particular example, no PPE is specified, thus minimizing the potential for conflict with the registered and legally binding use conditions of plant protection products currently on the market. The limitation on the coformulant use rate is the primary operational condition controlling exposure. Should a plant protection product formulator receiving this extended SDS require a higher coformulant use rate for a specific product, then the usual options of scaling, performing a downstream user risk assessment, or refinement of the risk assessment by the supplier would be possible.

4.2. Environment Contributing Scenarios

For the environmental risk assessment of a substance used as a coformulant, the tonnage used must be assigned to the exposure scenario. Use of the four GESs thus requires an appropriate split of this tonnage. It is very unlikely that a substance manufacturer would be in the position to determine across its customer base the quantity of substance used in spray versus granular applications. However, some inferences from Table III can be drawn. For a substance that is a liquid, the majority of substance tonnage can be assigned to GES1 and GES3. For substances that are intrinsically solid, in the absence of any other information, a greater tonnage should be assigned to GES1 and GES3, than to GES2 and GES4, based on the market preference for products applied as liquids rather than solids.[33]

4.3. Selection of Models for Use with Generic Exposure Scenarios

It is important to emphasize that the REACH use descriptors are formally independent of any particular exposure model, despite being hard-coded into some programs, e.g., ECETOC TRA. Ultimately, the risk assessor must consider whether the use scenario in question fits the applicability domain of the exposure model being used, beyond the simplistic level of "referring to the same PROC."

The GESs described here are the result of extensive simplification and are intended for use in conjunction with the ECPA-customized exposure models, which compensate for this simplicity with their conservatism (Fig. 1, row 6).[24] Although there is no *a priori* reason why the standard exposure models used under REACH should not be used to provide predictions for each worker contributing scenario (e.g., ECETOC TRA, Chesar, and ART), justification is required given the specialized use pattern of plant protection products. For example, while a prediction for "PROC 11" may be offered by a given model, it would still need to be justified that this prediction is valid for the exposure scenario in

Table IV. Example of a Contributing Scenario Intended for a Coformulant Extended Safety Data Sheet

1. Exposure scenario title: Use as a co formulant in plant protection products, spray applications by professionals

2. Contributing worker scenario: PROC 11—Delivery and dispersal of plant protection products

Description: The spray application of PPPs using tractor-mounted/trailed boom sprayers, tractor-mounted/trailed broadcast air-assisted sprayers, and hand-held spray equipment (knapsack sprayers and mist blowers) for high-level targets and indoor greenhouse spraying, as well as the indirect exposure of workers on field reentry and bystanders.

Product characteristics:

Liquids, up to 100% concentration

Amounts used, frequency, and duration of use/exposure:

Tractor-mounted spraying:	Application rate: 3.69 kg/ha Duration: 8 h/day
Hand-held spraying:	Application rate: 1.28 kg/ha Duration: 8 h/day (6 h/day for greenhouses)

Technical and organizational conditions and measures:

All label instructions on the plant protection product must be followed. Preparation of the spray mixture should only be carried out by trained professionals.

Conditions and measures related to personal protection, hygiene, and health evaluation:

Personal protective equipment (PPE): None specified.

Other conditions affecting workers exposure:

Ventilation conditions at workplace: Good natural ventilation; 1 air change per hour for greenhouses.

Place of use: Outdoors and indoors.

3. Exposure estimation and reference to its source

Worker exposure estimates were obtained with the ECPA OWB tool by specifying a maximum risk characterization ratio of 0.9 for the overall exposure scenario.

Contributing scenario	Dermal exposure [mg/kg bw]	Inhalation exposure [mg/m³]
PROC 11: Tractor-mounted spraying	4.85	0.0531
PROC 11: Hand-held spraying	0.741	4.49

4. Description of the boundaries set by the ES as a guidance to downstream users

The above exposure scenario may be scaled using the ECPA OWB tool with the stated maximum risk characterization ratio, and using the parameters: application rate, personal protection (PPE), and respiratory protection (RPE).

Note: Exposure calculated using the ECPA OWB model for a hypothetical substance with the following parameters: vapor pressure = 1 Pa, physical state = solid, DNEL $_{\text{worker, inhalation}}$ = 10 mg/m^3, DNEL $_{\text{worker, dermal}}$ = 10 mg/kg bw. A full GES in a SDS would contain additional worker and environmental contributing scenarios.

question, and lies within that model's applicability domain.

In the case of the REACH environmental assessment models, it should be noted that the standard modeling implementation used does not take into account the direct application of substances to agricultural soil.[8] Furthermore, the environmental emissions at the local scale are more appropriately assessed as wide dispersive (e.g., kg/ha), rather than point source emissions (Fig. 1, ERC 8d row 6).[24]

While higher-tier plant protection product exposure models are clearly applicable (row 7, Fig. 1), careful selection and justification of parameters is required so that restriction of the GES scope does not result, e.g., through use of a model for a specific formulation type.[34] The worst-case selection of parameters for higher-tier models (either REACH or plant protection) may not always be obvious, and is complicated by the correlation of different contributing scenarios to overall exposure. Experience with higher-tier exposure models has demonstrated the variability that arises in parameter selection between risk assessors, even for relatively simple and well-defined scenarios.[35]

Recognizing that use of coformulants is also subject to plant protection legislation, any assessment performed under REACH should be at least as conservative as if it were performed using those approaches. Detailed justification for the conservative nature of the ECPA-developed exposure models, as well as their advantages over higher-tier alternatives in screening-level assessments, will be described elsewhere.

5. CONCLUSION

The GESs describing the professional and consumer use of plant protection products were developed to reflect the typical activities involved in the uses of plant protection products in the context of the European REACH legislation. The explicit aim was to be simple and map directly to custom first-tier exposure assessment models. The approach taken to shift complexity from many slightly differentiated contributing scenarios into the conservative ECPA-customized exposure models supports minimizing the number of GESs, with a limited number of exposure determinants. This allows the risk assessor to perform assessments in an information-poor environment, as can be expected for a coformulant manufacturer attempting to cover the multitude of formulations and crop uses a given substance could be used in. Obviously, this may result in a restrictive maximum coformulant use rate, which the downstream user may need to address through scaling or a higher-tier risk assessment. Ultimately, widespread use of these GESs by manufacturers and importers will contribute toward the standardized, efficient, and holistic risk assessment of substances used both in plant protection products and in the broader European marketplace.

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REFERENCES

1. European Commission. Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Official Journal of the European Union 2006; L396/1.
2. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.7a: Endpoint Specific Guidance, Version 4.0. Helsinki, Finland: European Chemicals Agency, 2015.
3. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.7b: Endpoint Specific Guidance, Version 2.0. Helsinki, Finland: European Chemicals Agency, 2014.
4. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.7c: Endpoint Specific Guidance, Version 2.0. Helsinki, Finland: European Chemicals Agency, 2014.
5. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Part B: Hazard Assessment, Version 2.1. Helsinki, Finland: European Chemicals Agency, 2011.
6. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.14: Occupational Exposure Estimation, Version 2.1. Helsinki, Finland: European Chemicals Agency, 2012.
7. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.15: Consumer Exposure Estimation, Version 2.1. Helsinki, Finland: European Chemicals Agency, 2012.
8. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.16: Environmental Exposure Estimation, Version 2.1. Helsinki, Finland: European Chemicals Agency, 2012.
9. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Part E: Risk Characterisation, Version 2.0. Helsinki, Finland: European Chemicals Agency, 2012.
10. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Part D: Exposure Scenario Building, Version 1.2. Helsinki, Finland: European Chemicals Agency, 2012.
11. European Commission. Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market. Official Journal of the European Union, 2009; L309/1.
12. OECD. OECD survey on how pesticide ingredients other than the stated pesticide active ingredient(s) are reviewed and regulated: Survey results, Series on Pesticides No. 55, ENV/JM/MONO(2010)45, OECD, Paris, 2010.
13. European Chemicals Bureau. Substances incorporated into agrochemical products. P.108 in Manual of Decisions for Implementation of the Sixth and Seventh Amendments to Directive 67/548/EEC on Dangerous Substances (Directives 79/831/EEC and 92/32/EEC), Chapter 5.15. European Chemicals Bureau, Joint Research Centre, 2006.
14. Canadian Environmental Protection Act. Chapter 33, Article 81(6)a, 1999.
15. Swayze KM, Cleveland CB. Joint inerts task force: Partnership of suppliers and registrants to defend inert ingredients within United States regulatory system. Journal of ASTM International, 2010; 7(9):1–8.
16. Marquart H, Northage C, Money C. Exposure scenarios for workers. Journal of Exposure Science and Environmental Epidemiology, 2007; 17:S16–S25.
17. CEFIC. REACH Practical Guide on Exposure Assessment and Communication in the Supply Chains, Part II. Brussels: CEFIC, 2010.
18. Ahrens A, Traas T. Environmental exposure scenarios: Development, challenges and possible solutions. Journal of Exposure Science and Environmental Epidemiology, 2007; 17:S7–S15.
19. Marquart J, Brouwer DH, Gijsbers JHJ, Links IHM, Warren N, Hemmen JJ. Determinants of dermal exposure relevant for exposure modelling in regulatory risk assessment. Annals of Occupational Hygiene, 2003; 47(8):599–607.

20. Marquart H, Schneider T, Goede H, Tischer M, Schinkel J, Warren N, Fransman W, Spaan S, Tongeren Mv, Kromhout H, Tielemans E, Cherrie JW. Classification of occupational activities for assessment of inhalation exposure. Annals of Occupational Hygiene, 2011; 55(9):989–1005.
21. Money C, Margary A, Noij D, Hommes K. Generic exposure scenarios: Their development, application, and interpretation under REACH. Annals of Occupational Hygiene, 2011; 55(5):451–464.
22. Zaleski R, Qian H, Zelenka M, George-Ares A, Money C. European solvent industry group generic exposure scenario risk and exposure tool. Journal of Exposure Science and Environmental Epidemiology, 2014; 24:27–35.
23. European Chemicals Agency. Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.12: Use Descriptor System, Version 2.0. Helsinki, Finland: European Chemicals Agency, 2010.
24. European Crop Protection Association. ECPA Guidance on Reach Chemical Safety Assessment for Co-Formulants Used in Crop Protection Products. Brussels: European Crop Protection Association, 2015.
25. CropLife International. Catalogue of Pesticide Formulation Types and International Coding System, Croplife Technical Monograph No. 2, 6th ed. Brussels:CropLife International, 2008.
26. Warren ND, Marquart H, Christopher Y, Laitinen J, Hemmen JJ. Task-based dermal exposure models for regulatory risk assessment. Annals of Occupational Hygiene, 2006; 50(5):491–503.
27. US Environmental Protection Agency. Occupational Pesticide Handler Unit Exposure Surrogate Reference Table. Office of Pesticide Programs, US Environmental Protection Agency, 2012.
28. FOCUS. FOCUS Surface Water Scenarios in the EU Evaluation Process under 91/414/EEC. Report of the FOCUS Working Group on Surface Water Scenarios, 2001, EC Document Reference SANCO/4802/2001-rev.2.
29. Sättler D, Schnöder F, Aust N, Ahrens A, Bögi C, Traas F, Tolls J. Specific environmental release categories — A tool for improving chemical safety assessment in the EC — Report of a multi-stakeholder workshop. Integrated Environmental Assessment and Management, 2012; 8(4):580–585.
30. Reihlen A, Bahr T, Bögi C, Dobe C, May T, Verdonck F, Wind T, Zullo L, Tolls J. SPERCS — A tool for environmental emission estimation. Integr Environ Assess Manag. https://doi.org/10.1002/ieam.1745.
31. Lundehn JR, Westphal D, Kieczka H, Krebs B, Löcher-Bolz S, Maasfeld W, Pick ED. Uniform principles for safeguarding the health of applicators of plant protection products (Uniform principles for operator protections). Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft, 277, Berlin-Dahlem, 1992.
32. European Chemicals Agency. Chesar 2 User Manual Part 6 — Library, Annex 1. Helsinki, Finland: European Chemicals Agency, 2012.
33. Bundesamt für Verbraucherschutz und Lebensmittelsicherheit. List of Authorised Plant Protection Products in Germany. January 2016. Braunschweig, Germany: Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, 2016.
34. European Food Safety Authority. Guidance on the assessment of exposure of operators, workers, residents and bystanders in risk assessment for plant protection products. EFSA Journal, 2014; 12(10):3874.
35. Schinkel J, Fransman W, McDonnell PE, Entink RK, Tielemans E, Kromhout H. Reliability of the advanced REACH tool (ART). Annals of Occupational Hygiene 2014; 58(4):450–468.