Annex XV report

PROPOSAL FOR IDENTIFICATION OF A SUBSTANCE OF VERY HIGH CONCERN ON THE BASIS OF THE CRITERIA SET OUT IN REACH ARTICLE 57

Substance Name : S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-(isopropyl or isobutyl or 2-ethylhexyl) O-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate

EC Number : 401-850-9

CAS Number : 255881-94-8

Submitted by : Belgium

Date : August 2021

CONTENTS

TABLES

ABBREVIATIONS

ATE : acute toxicity estimate
B : bioaccumulative
BOD : biological oxygen demand
BAF : bioaccumulation factor
BCF : bioconcentration factor
BCF$_{ss}$: steady state bioconcentration factor
C&L : classification and labelling
CFU : colony forming units
ChV : chronic value
C.I. : confidence interval
CLP : classification, labelling and packaging
DOC : dissolved organic carbon
DT$_{50}$: disappearance time 50; time in which half of the test item disappears
EC$_{50}$: median effect concentration; concentration that induces 50% of the effect
GC/MS : coupled gas chromatography mass spectrometry
GHS : globally harmonized system of classification and labelling of chemicals
GLP : Good Laboratory Practice
HPLC : high performance liquid chromatography
HRMS : high resolution mass spectrometry
K$_{oa}$: octanol-air partition coefficient
K$_{oc}$: organic carbon-water partition coefficient
K$_{ow}$: octanol-water partition coefficient
LC$_{50}$: median lethal concentration; concentration that is lethal for 50% of the test animals
LoD : limit of detection
LOEC : lowest observed effect concentration
LoQ : limit of quantification
NER : non-extractable residues
NO(A)EL : no observed (adverse) effect level
NOEC : no observed effect concentration
OECD : Organisation for Economic Cooperation and Development
P : persistent
PBT : persistent, bioaccumulative and toxic
QSAR : quantitative structure-activity relationship
REACH : Regulation (EC) No 1907/2006
SVHC : substance of very high concern
T : toxic
TG : test guideline
ThOD : theoretical oxygen demand
TIC : total inorganic carbon
UPLC : ultra performance liquid chromatography
vB : very bioaccumulative
vP : very persistent
WoE : weight of evidence

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EC Number : 401-850-9

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- It is proposed to identify the substance as persistent, bioaccumulative and toxic (PBT) according to Article 57 (d) of Regulation (EC) No 1907/2006 (REACH).

Summary of how the substance meets the criteria set out in Article 57 of the REACH Regulation

A weight-of-evidence determination according to the provisions of Annex XIII of REACH has been used to identify S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-(isopropyl or isobutyl or 2-ethylhexyl) O-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate (referred to as 'EC 401-850-9' in this document) as PBT. All available information such as the results of standard tests, modelling and QSAR results was considered together in a weight-of-evidence approach. EC 401-850-9 is a substance that consists of 6 homologous groups of O,O',S-trialiphatic dithiophosphates. This PBT assessment of EC 401-850-9 is focused on the properties of isopropyl-isopropyl (ip-ip) constituents as these constituents are the most relevant ones with regard to their PBT profile.

Persistence

Detailed analysis of the available data from the biodegradation simulation study in fresh water pointed out that the isopropyl-isopropyl (ip-ip) constituents degrade very slowly in fresh water, exhibiting a half-life of more than 200 days. The outcome of the ready biodegradation screening studies performed on EC 401-850-9 support the findings of the simulation study as EC 401-850-9 screens as potentially P/vP.

Finally, since EC 401-850-9 contains ip-ip constituents with P/vP properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets both the 'persistence' (P) and 'very persistent' (vP) criteria in accordance with Annex XIII, points 1.1.1 (b) and 1.2.1 (a), of the REACH Regulation.

Bioaccumulation

Based on the results from an experimental aquatic bioaccumulation study with three constituents of EC 401-850-9, lipid normalised steady state BCFs of 3794 L/kg and 2403 L/kg were determined for the isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents, respectively. These BCF values represent a less conservative scenario as a possible growth dilution was not accounted for in the BCF calculations. Modelling data support findings from experimental data on bioaccumulation of ip-ip and ib-ib constituents of EC 401-850-9. Consequently, it is concluded that isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents meet the 'bioaccumulation' criterion (B) (BCF value > 2000 L/kg) of REACH Annex XIII.

Finally, since EC 401-850-9 contains isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents with B properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets the 'bioaccumulation' criterion (B) in accordance with Annex XIII, point 1.1.2, of the REACH Regulation.

Toxicity

In the 21 day long-term immobilisation and reproduction test with daphnia magna that was performed on EC 401-850-9 with predominantly the isopropyl-isopropyl constituents, a LOEC of 5.9 µg/L and a NOEC of 1.8 µg/L was determined. The NOEC is less than 0.01 mg/L, which is the threshold for T laid down in Annex XIII of REACH. Consequently, it is concluded that EC 401-850-9 and isopropyl-isopropyl (ip-ip) constituents meet the 'toxicity' criterion (T) (NOEC < 0.01 mg/L) in accordance with Annex XIII, point 1.1.3 (a), of the REACH Regulation.

Overall conclusion

In conclusion, as the isopropyl-isopropyl (ip-ip) constituents meet the PBT criteria and their relative concentration in EC 401-850-9 largely exceeds 0.1% (w/w), EC 401-850-9 is proposed to be identified as a PBT substance according to Article 57(d) of the REACH Regulation.

Registration dossiers submitted for the substance? Yes

PART I

Justification

1. Identity of the substance and physical and chemical properties

1.1 Name and other identifiers of the substance

Table 1 : Substance identity

EC number:	401-850-9
EC name:	S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-(isopropyl or isobutyl or 2-ethylhexyl) O-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate
CAS number (in the EC inventory):	255881-94-8
CAS number: **Deleted CAS numbers:**	255881-94-8 --
CAS name:	Phosphorodithioic acid, mixed O,O-bis(2-ethylhexyl and iso-Bu and iso-Pr) S-[3a,4,5,6,7,7a-hexahydro-4,7-methano-1H-inden-5(or 6)-yl] esters
IUPAC name:	S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-(2-ethylhexyl or isobutyl or isopropyl) O'-(2-ethylhexyl or isobutyl or isopropyl) phosphorodithioate
Index number in Annex VI of the CLP Regulation:	015-146-00-0
Molecular formula:	The various constituents have the following molecular formula: - ip-ip constituents: $C_{16}H_{27}O_2PS_2$ - ip-ib constituents: $C_{17}H_{29}O_2PS_2$ - ib-ib constituents: $C_{18}H_{31}O_2PS_2$ - ip-eh constituents: $C_{21}H_{37}O_2PS_2$ - ib-eh constituents: $C_{22}H_{39}O_2PS_2$ - eh-eh constituents: $C_{26}H_{47}O_2PS_2$
Molecular weight range:	346.5 – 486.8 g/mol
Synonyms:	Hi-TEC 511 Hi-TEC 511 Performance additive X-4261 Reaction product of dicyclopentadiene and dithiophosphoric acid

Structural formulas:

where R = isopropyl/isobutyl/2-ethylhexyl

It should be noted that the identification of EC 401-850-9 as a PBT substance is based on the experimentally determined properties of the isopropyl-isopropyl constituents (ip-ip).

1.2 Composition of the substance

Name: S-(tricyclo[5.2.1.02,6]deca-3-en-8(or 9)-yl) O-(2-ethylhexyl or isobutyl or isopropyl) O'-(2-ethylhexyl or isobutyl or isopropyl) phosphorodithioate

Description: EC 401-850-9 is a substance consisting of six homologous groups of O,O',S-trialiphatic dithiophosphates. In each of these six groups, two constitutional isomeric structures can be recognised (see Annex I) and are represented by several stereo-isomers.

Table 2 : Constituents other than impurities/additives

Constituents[1]	**Typical concentration**	**Concentration range**	**Remarks**
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-isopropyl O’-isopropyl phosphorodithioate	confidential	confidential	ip-ip constituents
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-isopropyl O’-isobutyl phosphorodithioate	confidential	confidential	ip-ib constituents
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-isobutyl O’-isobutyl phosphorodithioate	confidential	confidential	ib-ib constituents
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-isopropyl O’-2-ethylhexyl phosphorodithioate	confidential	confidential	ip-eh constituents
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-isopropyl O’-2-ethylhexyl phosphorodithioate	confidential	confidential	ib-eh constituents
S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O-2-ethylhexyl O’-2-ethylhexyl phosphorodithioate	confidential	confidential	eh-eh constituents

1.3 Identity and composition of degradation products/metabolites relevant for the SVHC assessment

Not relevant for this SVHC dossier.

1.4 Identity and composition of structurally related substances (used in a grouping or read-across approach)

Not relevant for this SVHC dossier.

1.5 Physicochemical properties

In this table the values for physical properties of EC 401-850-9 as given in the report in the registration dossier are presented. As EC 401-850-9 is a substance comprising different constituents and several impurities, it makes it difficult to assess the accuracy and relevance of physicochemical endpoints reported in Table 3 for the constituents of EC 401-850-9 without detailed information about the test item identity/composition.

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[1] Confidential information on the constituents can be consulted in Annex I.

Table 3 : Overview of physicochemical properties for EC 401-850-9

Property	Description of key information	Value [Unit]	Reference/source of information
Physical state at 20°C and 101.3 kPa		pale yellow liquid	LSR Report N° 87/ETS009/404 (reliability score of 2)
Melting/freezing point	OECD TG 102	Indeterminable	LSR Report N° 87/ETS009/404
Boiling point		not determined	
Vapour pressure	OECD TG 104	11 Pa @ 20°C 16 Pa @ 25°C	LSR Report N° 87/ETS009/404
Density	OECD TG 109	1.075 g/cm³ @ 20°C	LSR Report N° 87/ETS009/404
Water solubility	OECD TG 105	1.4 mg/L @ 20°C	LSR Report N° 87/ETS009/404
Partition coefficient n-octanol/water (log value)	OECD TG 107	>6.6	LSR Report N° 87/ETS009/404

The values given above for properties like the water solubility and the vapour pressure are very unlikely to reflect the real values for the various constituents of EC 401-850-9. Indeed, the values presented in the registration dossier(s) for EC 401-850-9 differ by 3 to 7 orders of magnitude compared to the EPI Suite estimated values for the different constituents of EC 401-850-9. The result of the water solubility study (Envigo Report YT76QR, reliability score of 1) on the most soluble constituents (ip-ip constituents show a water solubility of 50 µg/L) indicates that the EPI Suite estimated values are much more reliable. EPI Suite estimations are based on fragments. Only one estimated value is reported for each constituents group as the models cannot distinguish between isomers.

Table 4 : EPI Suite estimations (US EPA, 2012) for the constituents of EC 401-850-9

EPI SUITE ESTIMATED PHYSICOCHEMICAL PROPERTIES FOR SPECIFIC CONSTITUENTS						
Property	**ip-ip**	**ip-ib**	**ib-ib**	**ip-eh**	**ib-eh**	**eh-eh**
molecular weight (g/mole)	346	361	375	417	431	487
vapour pressure (mPa)	3.4	1.6	0.7	0.05	0.019	0.003
water solubility (µg/L) (WATERNT)	17	5	1.5	0.04	0.012	0.00035
water solubility (µg/L) (WSKOW)	40	13	3.9	0.12	0.037	0.00049
Henry’s law constant (Pa.m³/mol)	19	26	34	79	105	327
log Kow (KOWWIN)	6.1	6.6	7.1	8.6	9.0	11.0
log Koa (KOAWIN)	8.2	8.6	9.0	10.1	10.4	11.9
log Koc (MCI method)	4.6	4.9	5.1	5.9	6.2	7.3

2. Harmonised classification and labelling

EC 401-850-9 is covered by Index number 015-146-00-0 in part 3 of Annex VI to the CLP Regulation as follows:

Table 5 : Classification according to Annex VI, Table 3.1 (list of harmonised classification and labelling of hazardous substances) of Regulation (EC) No 1272/2008

Index No	**International Chemical Identification**	**EC No**	**CAS No**	**Classification**		**Labelling**			**Spec. Conc. Limits, M-factors and ATEs**[2]	**Notes**
				Hazard Class and Category Code(s)	**Hazard statement code(s)**	**Pictogram, Signal Word Code(s)**	**Hazard statement code(s)**	**Suppl. Hazard statement code(s)**		
015-146-00-0	*S*-(tricyclo(5.2.1.$0^{2,6}$)deca-3-en-8(or 9)-yl *O*-(isopropyl or isobutyl or 2-ethylhexyl) *O*-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate	401-850-9	255881-94-8	Aquatic Acute 1 Aquatic Chronic 1	H400 H410	GHS09 Wng	H410			

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[2] Acute Toxicity Estimate

3. Environmental fate properties

3.1 Degradation

3.1.1 Abiotic degradation

3.1.1.1 Hydrolysis

A hydrolysis study with the constituents of EC 401-850-9 is executed according to OECD TG 111 in 1987 (LSR Report N° 87/ETS010/527, reliability score of 2). The study consists of a preliminary test and of a definitive test.

From the preliminary test it can be concluded that the estimated half-life for hydrolysis at pH 9 is 31 days at 50°C. The results obtained at pH 4 and 7 are more difficult to interpret and necessitated proceeding to a definitive test.

The definitive hydrolysis study was carried out with the constituents of EC 401-850-9 at pH 4 and 7 and at temperatures ranging from 50 to 70°C. Estimated half-lives at pH 4 for tests at 50-70°C range from 33 to 243 days and at pH 7 measured values for the same temperature interval range from 107 to 326 days. The substance is also stable at the physiologically significant pH value of 1.2 at a temperature of 37°C, conditions considered in an additional part of the study. It is not possible to derive a precise hydrolysis rate constant from the trials in a reliable way due to divergent experimental results.

Nevertheless, from this hydrolysis study, it is concluded to be highly unlikely that the substance will hydrolyse to a relevant extent; this study indicates that half-lives at 12°C and at various pH values are in the order of magnitude of 1 year.

3.1.1.2 Oxidation

Experimental data on oxidation of EC 401-850-9 are not available.

Since EC 401-850-9 is not expected to partition to the air compartment (see section 3.2.3) oxidation in the air compartment is not considered to be a relevant degradation process.

3.1.1.3 Phototransformation/photolysis

Experimental data on phototransformation of EC 401-850-9 are not available.

3.1.1.3.1 Phototransformation in air

The QSAR program AOP v1.92 in EPI Suite with an overall hydroxyl radicals reaction rate constant of 2.36 x 10^{-10} cm^3/molecule.sec estimates the half-life for the ip-ip constituents in air to be 0.544 hours. The half-life for reaction with ozone is estimated to be 1.375 hours.

3.1.1.4 Summary on abiotic degradation

In water, EC 401-850-9 is expected to be hydrolytically stable as the substance does not present functional groups that result in hydrolysis. The hydrolysis study that was performed with the constituents of EC 401-850-9 indicates that the half-lives at 12°C and at various pH values are in the order of magnitude of 1 year.

Degradation in the air compartment is considered to be not relevant taking into account the low volatility of the substance. No experimental information is available on photodegradation and there are no indications that aquatic photodegradation or phototransformation in soil will have a significant impact on the overall persistence of EC 401-850-9.

3.1.2 Biodegradation

3.1.2.1 Biodegradation in water

3.1.2.1.1 Estimated data

The degradation pattern of the constituents of EC 401-850-9 can be evaluated by various QSAR estimation programs. It should be noted that most of these estimation methods predict how and/or at what rate organic compounds are expected to biodegrade. However, they do not predict half-lives in environmental compartments and so they do not provide a direct method to assess whether the persistence criterion of Annex XIII of REACH is met or not. These methods provide mainly a qualitative description of the biodegradation potential.

A first model and one that is also used by the registrant(s) is the Catalogic 301C model developed by the Laboratory of Mathematical Chemistry in Bulgaria. This QSAR model predicts that the primary biodegradation of the constituents of EC 401-850-9 will take place by a chemical reaction called oxidative desulfurization, i.e. the substitution of the double bonded sulfur atom with an oxygen atom. Catalogic modelling shows that all 12 constituents of EC 401-850-9 can undergo this type of reaction with a predicted half-life of 1 to 2 days. On the contrary, further biodegradation of the formed monothiophosphates is estimated to be quite slow and these degradation products can be persistent. This conclusion remains to a certain extent uncertain as the rate of oxidative desulfurization is not well established and it is not clear whether the predicted degradation products could react further (a)biotically (e.g. by hydrolysis or ring opening).

It is noted that the Catalogic model consists of a metabolism simulator and an endpoint model. Microbial metabolism is simulated by the rule-based approach. However, a good understanding on how the prediction of oxidative desulfurization is established is not included in the QSAR Model Reporting Format, and it is not clear on which literature and what rules the QSAR prediction is based. This makes it difficult to evaluate the reliability of the prediction for this specific case and to evaluate to what extent oxidative desulfurization will take place in real field conditions.

Further, it should be noted that none of the twelve constituents of EC 401-850-9 are fully in the applicability domain of the Catalogic model because they are out of the structural domain due to the fact that they contain 16 to 24 % of unknown fragments, i.e. fragments not recognised by the model. This observation adds more uncertainty to the prediction presented here.

Another useful source of information on the potential metabolic pathways of the constituents of EC 401-850-9 is the EAWAG-BBD Pathway Prediction System (formally from the University of Minnesota). This program estimates that three types of biodegradation can be relevant for the various constituents, namely 1) bt0103, which is the oxidative desulfurization of the dithiophosphate functionality, 2) bt0241, which is the hydroxylation of a tertiary carbon atom and 3) bt0242, which is the hydroxylation of a secondary carbon atom. It should also be noted that the probability that these biotransformation reactions takes place is categorized by the program as "neutral" and not as (very) likely. That means that according to this estimation program the likelihood that these reactions occur in aerobic conditions is rather low.

Another QSAR method that is also publicly available is Biowin v.4.10, which is integrated in EPI Suite (US EPA, 2012) developed by the US Environmental Protection Agency. Biowin estimates aerobic and anaerobic biodegradability of organic chemicals using seven different submodels. As indicated in the REACH Guidance chapter 11, (p. 49 & 62), the results of three submodels can be used to screen the potential of biodegradation. Based on the combination of the results for Biowin 2 (all constituents show a probability value of 1.00) and Biowin 3 (values ranging from 2.53 to 2.87), all the constituents would be readily biodegradable. In contrast with this result, the combination of Biowin 6 (probability values varying between 0.0017 and 0.02) and Biowin 3 (values ranging from 2.53 to 2.87) indicates that the constituents are potentially persistent and more degradation relevant information is generally warranted. Further, it is observed that the P=S functionality is not included in the fragments in Biowin models 2, 3 and 6. Considering the conflicting predictions with Biowin, and taking into account that a crucial functionality is not recognized as a fragment, it is not possible to come to a reliable conclusion in this way regarding the biodegradability of the constituents of EC 401-850-9.

A further method that evaluates ready biodegradability of substances is the VEGA model. The VEGA model reports that only moderately similar compounds with known experimental values have been found in the training set. Some atom-centered fragments of the EC 401-850-9 constituents have not been found in the compounds of the training set or are rare fragments. In the VEGA dataset two trialkyldithiophosphates are found, namely malathion and phenthoate (substances with CAS numbers 121-75-5 & 2597-03-7). Based on the VEGA model results for these two trialkyldithiophosphates, it can be concluded that all constituents of EC 401-850-9 are likely to be not readily biodegradable.

Based on the above information, QSAR data are considered not sufficiently reliable to conclude on the potential persistence of EC 401-850-9 and other information must be considered.

3.1.2.1.2 Screening tests

Three screening tests for the biodegradation potential of EC 401-850-9 are available. In these tests, techniques that could enhance the bioavailability of the test item are applied to a varying degree. In all these tests nominal test item concentrations greater than 1 mg/L were applied. The real water solubility of the constituents of EC 401-850-9 is estimated to be substantially lower (cf. Section 1.5) and therefore a reliability score of 2 or lower is deemed appropriate.

The oldest ready biodegradability test was carried out in 1987 (LSR Report N° 87/ETS007/510, reliability score of 2). The study was a closed bottle test performed according to OECD guideline 301D. The test was executed with a mineral salts medium inoculated with sewage effluent. The test item was applied as an ultrasonic dispersion in distilled water to give a nominal concentration of 2 mg/L. The test was run in triplicate vessels. The oxygen consumption in the vessels with test item was equivalent to 2% of the ThOD. Sodium benzoate was degraded by 66% in the absence of test material and 63% in its presence, confirming that the test item was inhibitory to bacteria under the conditions of the test. Based on this study EC 401-850-9 cannot be considered to be readily biodegradable.

A second ready biodegradability test with EC 401-850-9 was performed in 1996 (M.S.I. Report N° 6B061G, reliability score of 3). The study was a modified MITI I test executed according to OECD guideline 301C. Nominal test item concentration was 100 mg/L which is way above its the water solubility. The test item was exposed to activated sludge and a basal medium over a period of 28 days. The activity of the sludge was shown to be satisfactory as the reference substance (aniline) biodegradation mounted to 56% after 7 days, based on BOD measurements. Biodegradation of the test item was monitored by measuring the BOD and the residual test substance concentration. Degree of degradability based on BOD measurement was 0% and based on residual test item concentration maximum 4%. Based on this study EC 401-850-9 cannot be considered to be readily biodegradable.

In 2011, Roberts and Daniel conducted an enhanced biodegradability study according to the modified OECD 301D guideline (Brixham Environmental Laboratory Report N° BR0410/B, reliability score of 2). The applied enhancements included the use of silicone oil as a solvent and Synperonic PE 105 as a surfactant. The modifications further included increasing the test volume and extending the test duration up to 63 days. The study used a test substance concentration of 1 mg/L (i.e. above the water solubility) and an activated sludge concentration of 2 mg/L. A positive (sodium benzoate) and a negative (2,4-di-tert-butylphenol) control substance were added to the test systems. The level of biodegradation is measured as O_2 consumption. After 28 days, 12% degradation is found after direct addition of EC 401-850-9, 7% degradation is found when added in combination with silicone oil and 41% degradation is found when added with silicone oil and surfactant. A maximum degradation level of 46% is found after 35 days and at the end of the test after 63 days degradation amounted to 35%. It is important to note that the negative control 2,4-di-tert-butylphenol when added in combination with silicone oil and surfactant also showed substantial O_2 consumption (up to 30%). Therefore, the percentage biodegradation claimed in this study is overestimated. Based on this study EC 401-850-9 cannot be considered to be readily biodegradable.

Because the pass level (60% ThOD) in these screening biodegradation tests is never reached, independent of the fact whether enhancements are applied or not, one can only conclude that the substance is not readily biodegradable and is potentially persistent.

3.1.2.1.3 Simulation tests (water and sediments)

An aerobic mineralisation study in surface water according to OECD Guideline 309 is available with the isopropyl-isopropyl constituents (ip-ip) of EC 401-850-9 (Maischak H., reliability score of 1). The study included a main test executed according to GLP protocol and three supporting tests that were not executed according to GLP. The various tests on their own are considered to be reliable with restrictions but analysing the tests together in a combined manner, the study as a whole can be considered as reliable without restrictions.

In another preliminary study (Envigo Report YT76QR, reliability score of 1) the water solubility of the ip-ip constituents was verified. This study demonstrated that the actual solubility of the ip-ip constituents is 50 µg/L, while the limit of quantification (LoQ) is 0.5 µg/L. As the LoQ is about two orders of magnitude lower than the water solubility, a simulation study in surface water can be executed and monitored using test item concentrations below the water solubility. So reduced bioavailability of the test substance can be avoided in this simulation test and does not jeopardize the reliability or the relevance of the results.

Aerobic Mineralization in Surface Water Study (Maischak H.)

The main GLP test for aerobic mineralization in surface water was conducted in 2018 with non-adapted surface water over a period of 91 days according to OECD TG 309. Besides the main test, three supporting non-GLP tests were performed in order to be able to come to a more reliable interpretation of the results of the main test. It is noted that the main test is executed with non-radiolabelled test item which prevented the establishment of a mass balance. The data resulting from specific chemical analysis of the parent compound and its metabolite(s) are carefully examined and it has been concluded that under the circumstances of this study the ip-ip constituents of EC 401-850-9 do not biodegrade to a relevant extent.

The relevant characteristics of this main study can be summarized as follows:

- test guideline: OECD 309 with some adaptations
- study type: laboratory shake flask test determining aerobic primary degradation
- mineralization is not monitored
- surface water from the river Örtze (Saxony, Germany) collected @ 15.7°C
- surface water characteristics: pH = 7.23, DOC = 4.07 mg/L, TIC = 8.01 mg/L
- colony forming units: 8.85 x 10^7 CFU/L
- handling: suspended coarse particles were removed prior to use by sieving
- test duration: 91 days
- temperature: 12°C ± 2°C
- test item: ip-ip constituents of EC 401-850-9
- test item concentrations: 10 µg/L and 50 µg/L
- reference item: sodium benzoate
- reference item concentration: 18 mg/L (while 10 µg/L is advised in § 31 of TG 309)
- sterile control: performed with surface water that is autoclaved twice
- blank control: performed with surface water without test and/or reference item
- test volumes: 100 mL in 250 mL headspace flasks
- oxygen concentration during study: 9.3 – 11.2 mg/L
- pH during study: 6.82 – 7.28
- sampling schedule: day 0, 1, 3, 5, 7, 14, 21, 31, 91
- extraction was performed with acetronitrile in combination with ultrasound
- analytical determination with UPLC-HRMS

The degradation of the test item is monitored by specific chemical analysis of the parent compound and its potential metabolites. Because radiolabelling is not applied it is not possible to establish the mass balance in a reliable way. Furthermore and based on the information available in the study report, it was not possible to assess in a reasonable way to what extend NER[3] formation is taking place.

At the end of this simulation study at day 91, the concentration of the test item has diminished substantially: at a test item concentration of 10 µg/L the residual percentage declined to 14% and at 50 µg/L only 5% of the test item is retrieved in the reaction mixture. At the same time, it is observed that only 1 metabolite is formed and this only in a very minute fraction, i.e. never more than 1.5% compared with the parent compound. The metabolite is identified as the corresponding phosphorothioate, i.e. S-(tricyclo[5.2.1.$0^{2,6}$]deca-3-en-8(or 9)-yl) O,O′-diisopropyl phosphorothioate. This observation clearly demonstrates qualitatively that the disappearance of the test item in this study is not caused by (bio)degradation but nearly completely by dissipation out of the reaction mixture. If biodegradation would occur, one should detect the degradation products as biodegradation takes place in many intermediate steps and cannot occur instantaneously. Therefore, nearly total absence of degradation products in the chromatograms demonstrates that biodegradation is hardly taking place. It should also be pointed out that dissipation of the test item is certainly not that fast that it would make biodegradation impossible to occur. Even after 3 months test item is still present in the reaction mixture.

As dissipation is taking place to a relevant extent a degradation rate cannot be determined in a direct manner. However, in the study also sterile controls are carried out and as these sterile controls are executed in the same manner as the replicates with viable microorganisms, it is possible to determine a biodegradation rate based on a comparison between the concentrations from viable and sterile set ups.

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[3] Non-extractable residues.

Unfortunately, the sterile controls were only sampled on day 31 and 91 and so only the results from these sampling points can be used. The percentages residual test item were as follows (cf. study report table 15, p. 39) :

- @ 10 µg/L viable experiment: 31 d = 29%, 91 d = 14%
- @ 10 µg/L sterile experiment: 31 d = 32%, 91 d = 10%
- @ 50 µg/L viable experiment: 31 d = 35%, 91 d = 5%
- @ 50 µg/L sterile experiment: 31 d = 31%, 91 d = 6%

Comparing the viable with the sterile experiment at the same sampling day and the same concentrations one can see qualitatively that biodegradation is hardly taking place if not at all:

- @ 10 µg/L, 31 d : 3% extra disappearance
- @ 10 µg/L, 91 d : -4%, no extra disappearance
- @ 50 µg/L, 31 d : -4%, no extra disappearance
- @ 50 µg/L, 91 d : 1% extra disappearance

Qualitatively, it is reasonable to conclude that in this experiment biodegradation is hardly taking place. Transforming this qualitative observation in a quantified parameter cannot be done in the usual way as the mass balance is not at all fulfilled. In fact, two processes contribute simultaneously to the disappearance of the test item, i.e. dissipation out of the testing system and (bio)degradation. It is clear that dissipation is considerably more relevant than biodegradation. As we are dealing here with a kinetically biphasic system (dissipation and biodegradation) and we only dispose of a few measured data points, one can only approximatively calculate a half-life for biodegradation.

The most reliable method to estimate a half-life in this case is to consider the relative amounts of test item that remain in the viable and the sterile experiments. Assuming that in the sterile experiment no degradation is happening as abiotic degradation was demonstrated to be negligible in the hydrolysis study and no photodegradation is occurring as the test is performed in the dark. Looking at the data point with the highest extra disappearance of 3% in the viable test (i.e. experiment at 10 µg/L and 31 days) and assuming that dissipation of the substance is happening at the very start of the test so that only 32% of the substance is really bioavailable in the test (which represents a less conservative scenario), a biodegradation of 9.38% (=3/32) at 31 days can be estimated. Considering 9.38% of biodegradation of ip-ip constituents at day 31 and using a first-order kinetic model, a rate constant k of 0.00318 d^{-1} is derived leading to a biodegradation half-life of 218 days. It should be noted that using the other data points would only lead to still greater half-life estimations.

Another issue in the interpretation of this simulation study, is the question whether the study is valid or not. According to the registrant, the validity criteria relating to the reference substance sodium benzoate that is used as functional control are not fulfilled. Consequently, the activity of the inoculum used in the main study would not be sufficient and for that reason the study would be invalid and cannot be used to assess the persistence of EC 401-850-9.

The question whether the study is valid and can be interpreted in a reasonable way is of course crucial. It is correct that the OECD 309 guideline, paragraph 51, stipulates that if the reference substance is not degraded within the expected time interval (usually less than 14 days for sodium benzoate), the validity and the relevance of the test must be further verified. In the same paragraph, the guideline mentions that in surface waters usually employed the degradation rate constant for the reference substance aniline at 20°C is on average 0.8 d^{-1} (half-life = ± 0.9 d). Aniline and sodium benzoate are the two common reference substances that are typically recommended for biodegradation tests and so, it is reasonable to assume that sodium benzoate shows a similar intrinsic degradation rate as aniline. The guideline also explicitly states that the reference substance concentration should be 10 µg/L (paragraph 31). It is obvious that these values for the reference item concentration and its degradation rate constant are linked to each other. In this simulation study the sodium benzoate concentration is 18 mg/L (i.e. 1800 times higher than the concentration advised in the guideline) and so a direct comparison with the validity criterion expressed in a relative manner (e.g. >60% degradation within 14 days) is not appropriate. The relative degradation rate of the reference item is lower than expected, not because the inoculum in this study is insufficiently active but simply because the inoculum is overloaded.

Another way to assess the activity of the inoculum is to consider the measured degradation rate in absolute terms, and not in relative terms. This is not the standard approach, but it can nevertheless provide a reasonable indication of the activity of the inoculum used in the test. As mentioned in the above paragraph, the inoculum in a simulation test is considered to be sufficiently active if the mineralization half-life of the reference substance is 0.9 days (at 10 µg/L). This means that on average viable microbial communities in a simulation test mineralize the reference substance at an initial rate of ca. 7.7 µg/L/d. In the main study, 8% CO_2 formation is measured after 21 days and 59% after 89 days (without solvent). Based on the value found after 21 days, one can calculate that on average the mineralization rate is 69 µg/L/d (18000 µg/L * 0.08/21 d). Based on the CO_2 formation after 89 days, the mineralization rate becomes 119 µg/L/d (18000 µg/L * 0.59/89 d). It is correct that the influence of the growth of the microbial population is difficult to take into account, but the fact that the absolute mineralization rates found in this test are substantially higher than the rates found in studies performed with standard reference substance levels indicates that the inoculum in this study actually was viable.

Furthermore, the substance EC 401-850-9 has been tested in a 3-hour respiration inhibition test (SPL N° 1491/0071, reliability score of 2) under aerobic conditions (see section 5.4). No effect on respiration was seen up to the concentration tested (1000 mg/L) which exceeds by far the water solubility of the test item. Based on this study, it is concluded that that EC 401-850-9 does not affect activated sludge microorganisms.

Consequently, this simulation test is considered to be reliable without restrictions. It should not be dismissed and it can be used in the assessment of the persistence of EC 401-850-9.

Non-GLP complementary simulation test

Because the registrant was of the opinion that the main test was not valid and could not be used in the biodegradability assessment of EC 401-850-9, a complementary test was executed shortly after the main simulation test. This test is equivalent to a simulation test, but was not carried out according to the GLP protocol.

The relevant characteristics of the complementary test are summarized as follows:

- test type: simulation biodegradation test in surface water
- GLP protocol: no
- mineralisation is not monitored
- surface water from the river Leine (Germany)
- surface water characteristics: "more" undissolved organic matter than in Örtze water
- test duration: 69 days
- temperature: 12°C
- test item: ip-ip constituents of EC 401-850-9
- test item concentrations: 10 µg/L and 50 µg/L
- reference item: sodium benzoate
- reference item concentration: 17.14 mg/L
- sterile control: yes
- test volumes: 200 mL in 300 mL headspace flasks

- sampling schedule: day 0, 28, 36, 69

It is noted that the degradation pattern observed in this complementary test is completely in line with the pattern that is seen in the main test. Also, in this test it is not possible to establish a mass balance. Disappearance from the reaction mixture occurs gradually during the whole test duration, both in the viable test item replicates and in the sterile control replicates. At the lower test concentration (10 µg/L) 14% of the test item is retrieved in the viable replicates at the end of the test, while in the sterile controls only 10% is retrieved. The same pattern is seen at the higher test concentration (50 µg/L). This proves that disappearance of the test item is caused by dissipation and that biodegradation is not taking place at all. Indeed, residual concentrations are even higher in the viable replicates than in the sterile replicates. In theory, the half-life for biodegradation would be infinite.

Another similarity between this complementary test and the main test is the fact that in both tests only 1 metabolite is found in low amounts. In both tests, the metabolite is the same and is found to be S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O,O'-diisopropyl phosphorothioate. In fact, in the complementary test the concentration of the metabolite is a bit higher and the highest relative level is observed in the 10 µg/L replicate at day 36. One can estimate a degradation half-life based on the concentrations of the parent compound (9.29 nmol/L) and the metabolite (1.22 nmol/L) at day 36 (Sum of parent and metabolite = 10.55 nmol/L). Proceeding in this way, a first order degradation half-life of 202 days is estimated. Because no other metabolites are formed, this calculation method provides an alternative but nevertheless reliable estimation of the degradation half-life. The value of 202 days determined in this way is also very well in line with the value of 218 days derived in the evaluation of the data from the main test. Both approaches lead to estimated half-lives greater than 200 days.

It is also important to note that in the complementary test, in contrast to the main test, the viability of the microorganisms is not an issue at all. The reference item is degraded for 50% after 5 days incubation, showing that the microorganisms in this study are without doubt sufficiently active. In that respect the complementary test is even more indicative than the main test. In the main test the viability of the microorganisms could be questioned, but it should be noted that the results of both tests are very much in line with each other. Therefore, it is concluded that the absence of biodegradation in the main study is not triggered by the inactiveness of the microbes but by the inherent persistence of the test item.

3.1.2.2 Biodegradation in soil

Specific data on the biodegradation of EC 401-850-9 in soil are not available.

3.1.2.3 Summary and discussion on biodegradation

The results derived from QSAR estimations and screening biodegradation tests do not allow to come to a robust conclusion on the biodegradation characteristics of EC 401-850-9.

Information from different QSAR methods is quite divergent and provides (only) qualitative information on the type of biodegradation reactions that can occur with the constituents EC 401-850-9.

A few ready tests (OECD 301 C and D tests) were performed with EC 401-850-9. In these tests, EC 401-850-9 concentrations above the water solubility are used and in one of the tests several enhancements are applied. The pass level is not reached in any of these ready tests, and so it is concluded that EC 401-850-9 is not readily biodegradable.

The key source of information regarding the potential biodegradation of EC 401-850-9 is the simulation study that is carried out with the ip-ip constituents of EC 401-850-9 in fresh water. Although this simulation test shows some shortcomings such as the lack of a mass balance and some uncertainty on the microbial activity of the inoculum, it allows to come to a reliable estimation of the half-life of the ip-ip constituents in fresh water. An analysis of the data from the main test as well as from the complementary tests both resulted in an estimated half-life of the ip-ip constituents of more than 200 days.

3.1.3 Field data

Field data are not available.

3.1.4 Summary and discussion of degradation

There are no indications that EC 401-850-9 degrades abiotically in the environment. The hydrolysis study that was performed at various pH values demonstrates that the half-lives at 12°C are in the order of magnitude of 1 year. Experimental data on phototransformation of EC 401-850-9 are not available. Considering the low volatility of the substance degradation in the air compartment is not expected to be relevant. There are no indications that aquatic photodegradation or phototransformation in soil will have a significant impact on the overall persistence of EC 401-850-9.

The results derived from QSAR estimations and screening biodegradation tests on EC 401-850-9 do not allow to come to a robust conclusion on the biodegradation potential of EC 401-850-9 in environmental compartments. However, the outcome of the ready biodegradation screening studies performed on EC 401-850-9 support the findings of the simulation study as EC 401-850-9 screens as potentially P/vP. The key source of information regarding the potential biodegradation of EC 401-850-9 is the biodegradation simulation study that is carried out with the ip-ip constituents of EC 401-850-9 in fresh water. Analysis of the data of this study resulted in an estimated half-life of the ip-ip constituents of more than 200 days. Consequently, it is concluded that EC 401-850-9 meets the ‘persistence’ (P) and ‘very persistent’ (vP) criteria of REACH Annex XIII (degradation half-life in fresh water > 60 days).

3.2 Environmental distribution

3.2.1 Adsorption/desorption

In the registration dossier, one study (SPL N° 1491/0072) is presented that examines the adsorption capacity of EC 401-850-9. The study is executed according to EU method C.19 (HPLC method). According to this study the log K_{oc} value varies from 5.57 to >5.63 depending on the constituent that is measured.

The KOCWIN program (v2.00) in EPI Suite (US EPA, 2012) estimates log K_{oc} values for the ip-ip constituent as follows: based on the MCI method 4.59; based on the log K_{ow} method 4.21. The estimated log K_{oc} values for all other constituents are consistently higher, up to 7.3 for the eh-eh constituent. Therefore, all constituents of EC 401-850-9 are expected to adsorb significantly to suspended solids, sediments and soils.

3.2.2 Volatilisation

Volatilisation from water is determined by the vapour pressure and by the water solubility of a substance. EC 401-850-9 consists of 6 groups of constituents and the vapour pressure and the water solubility of the specific constituents can vary several orders of magnitude. Therefore, the Henry's law constants for the various constituents will diverge substantially. A reliable measured Henry's law constant for EC 401-850-9 is not available.

In this SVHC dossier, the focus is on the ip-ip constituent of EC 401-850-9 and for this constituent EPI Suite estimates a Henry's law constant of 19 Pa.m³/mol (i.e. unitless value of 0.008). For the constituents with longer alkyl chains the estimated vapour pressure decreases less than the water solubility, so for these constituents slightly greater Henry's law constants are estimated.

According to the modified Grain method used in EPI Suite (US EPA, 2012), the estimated vapour pressure at 25°C is 3.4 mPa. So, EC 401-850-9 is considered to show a low volatility.

3.2.3 Distribution modelling

EC 401-850-9 consists of 6 groups of constituents whose physical properties like water solubility, vapour pressure and log K_{ow} vary substantially. Consequently, the estimated distribution after release of EC 401-850-9 in the various environmental compartments will depend on the constituents that are considered. Because the evaluation of the PBT properties pointed out that the ip-ip constituents are the most critical ones, the current assessment of the environmental distribution is focused on these constituents.

The environmental distribution of the ip-ip constituents is assessed via the level III fugacity model that is incorporated in EPI Suite (US EPA, 2012). The available values for various key physical properties are nearly always obtained via experiments on the whole substance and therefore these experimental values are less accurate for the ip-ip constituents. Instead, the following values estimated by the submodels in EPI Suite are used to evaluate the environmental distribution: vapour pressure = 3.38 mPa; Henry's law constant = 19 Pa.m³/mol; log K_{ow} = 6.1; log K_{oc} = 4.59.

The following distributions are predicted for the ip-ip constituents by the level III fugacity model in EPI Suite. Considering the uses of EC 401-850-9 that are reported in the registration dossier release to only air is not relevant.

Table 6 : Distributions estimated by EPI Suite (Level III Fugacity Model)

Release (%)	Air	Water	Soil	Sediment
Equal to water/air/soil	0.03	9.3	71.5	19.2
Only to water	0.03	32.6	0.07	67.3
Only to soil	0	0.01	99.96	0.03

Based on this analysis, it is assumed that the ip-ip constituents will mainly distribute to soil and sediment and to a lesser extent to water.

3.2.4 Field data

Field data are not available.

3.2.5 Summary and discussion of environmental distribution

EC 401-850-9 exhibits a high potential to adsorb to organic matter and a low potential to volatilise from water. Further, according to fugacity modelling, EC 401-850-9 is expected to be mainly distributed to the soil and sediment compartment, and to a lesser extent in the water compartment. The air compartment is not expected to be a relevant route of distribution.

3.3 Data indicating potential for long-range transport

The potential for long-range transport is not discussed in this dossier. Taking into account the estimated distribution in the various environmental compartments, there are no indications that the substance will mainly reside in the mobile compartments air and water.

3.4 Bioaccumulation

3.4.1 Bioaccumulation in aquatic organisms (pelagic & sediment organisms)

Experimental data.

The bioaccumulation potential of EC 401-850-9 in aquatic species was examined in a bioconcentration study from 1997 (M.S.I. Report N° 6B062G, reliability score of 2). The study was carried out according to the OECD 305C protocol that was valid at that time and that protocol shows some deviations from the current OECD 305 guideline. Consequently, some elements cannot be evaluated as it is done nowadays, but in general the study is well conducted and follows GLP principles. Therefore, it is considered that this study is valid with a Klimisch reliability score of 2 and can be used to evaluate the bioaccumulation potential of EC 401-850-9.

The study is carried out with a mixture of 3 constituents of EC 401-850-9, namely with the O,O’-diisopropyl constituent (ip-ip or C3), the O,O’-diisobutyl constituent (ib-ib or C4) and the O,O’-di-2-ethylhexyl constituent (eh-eh or C8) in a 1:1:1 ratio. The main characteristics of the study are the following:

- study protocol: OECD 305C (v1981)
- set up: continuous flow-through system
- test item: mixture of C3, C4 and C8 (ratio 1:1:1)
- test item concentrations: 50 µg/L & 500 µg/L
- dispersant: Hydrogenated Castor Oil (HCO-30)
- dispersant concentration: 20 x test item concentration
- test fish: *Cyprinus carpio*
- body weight: 22-37 g
- fat content fish: 4.4%
- sampling points uptake period: 2, 4, 6, 8 weeks
- elimination period: 13 days

The results of the study indicate that steady state is reached after 6 weeks of exposure, both in the high and the low exposure experiment. In order to determine the BCF_{ss} the average of the measured test item concentrations in the sampled fish after 6 and 8 weeks is used.

Proceeding in this way, the following non-normalized steady state BCFs were obtained for the various homologues:

diisopropyl, high exposure:	2059 L/kg
diisopropyl, low exposure:	3339 L/kg
diisobutyl, high exposure:	718 L/kg

- diisobutyl, low exposure: 2115 L/kg
- di-2-ethylhexyl, high exposure: < 5 L/kg (below LoQ in fish)
- di-2-ethylhexyl, low exposure: < 49 L/kg (below LoQ in fish)

After application of lipid normalisation (fish fat content in this study = 4.4%) the steady-state BCFs that should be compared with the criteria in Annex XIII of REACH become:

- diisopropyl, high exposure: 2340 L/kg
- diisopropyl, low exposure: 3794 L/kg
- diisobutyl, high exposure: 816 L/kg
- diisobutyl, low exposure: 2403 L/kg

Although HCO-30 is used as a dispersant, it is not clear whether the constituents at the high exposure level are fully solubilised and that is probably the reason why the measured BCFs for the higher exposure level are systematically less than those for the lower exposure level. The BCF values determined based on the low test concentration (50 µg/L) are considered to be more reliable than those determined based on the high test concentration (500 µg/L; above the water solubility limit of the constituents) considering the low solubility of the 3 constituents (cf. Table 4). Furthermore, it is important to note that these lipid normalised BCF values represent a less conservative scenario as a possible growth dilution was not accounted for in the BCF calculations. It is further noted that in the older version of the OECD 305 guideline dispersants are allowed if the concentration is below the toxicity of the dispersant and not above 100 mg/L. The concentrations of HCO-30 used in this test were 10 and 1 mg/L and hence they are below the limit indicated in the guideline. Also, no mortality or sublethal effects were observed in the test. Therefore, it seems that HCO-30 does not cause toxic effects in the fish, its use can be considered to be acceptable and does not affect the validity of the study.

This study with various constituents clearly demonstrates that the aquatic bioaccumulation potential is higher for the ip-ip constituent than for the ib-ib constituents. The aquatic bioaccumulation potential of the eh-eh constituent is much lower.

QSAR data

The bioaccumulation potential of EC 401-850-9 can also be examined with QSAR models. A well-known model that provides quantitative estimates is the BCFBAF model (v.3.02) of EPI Suite (US EPA, 2012). This model was run for the ip-ip and ib-ib constituents. The model cannot distinguish between the isomers of the constituents since the model calculation is based on fragments. The predictions can be considered to be within the applicability domain when considering the parametric domain and the fragments. When checking the training set for similar substances, the phosphorodithioate functional group with the isopropyl chains is relatively well represented, but in structures that are quite different to the three ring carbon structure. There is no such structure in the training set. No correction factors were applied in the regression method and the Arnot-Gobas model is considered to provide the most reliable estimates.

The Arnot-Gobas model predicts that the ip-ip constituents would have a higher bioaccumulation potential than the ib-ib constituents, the highest prediction being a BCF of 9333 L/kg from the Arnot-Gobas lower trophic model. The experimentally determined BCF for both constituents fall within the 95% confidence interval of the Arnot-Gobas predictions.

Predicted values are as follows:

- ip-ip constituents : regression method BCF : 4898 L/kg
A-G method BCF : 9333 L/kg (95% C.I. = 2344-20417 L/kg)

BCFBAF kM model half-life : 27 days (for 10 g fish)
- ib-ib constituents : regression method BCF : 12303 L/kg
A-G method BCF : 6457 L/kg (95% C.I. = 1585-14125 L/kg)
BCFBAF kM model half-life : 52 days (for 10 g fish)

Overall, long biotransformation half-lives are predicted, indicating a high bioaccumulation potential.

Another model that in theory could be used to evaluate the bioaccumulation potential of EC 401-850-9 is the BCF Baseline Model (v.04.11) of CATALOGIC (v.5.14.1.5). However, the ip-ip and ib-ib constituents are not well represented in the model and they are out of domain, both structural and metabolic. Furthermore, the training sets (BCF and metabolic database) do not contain similar structures. The substituted phosphorodithioate functional group with the isopropyl chains is present in the training set (in 4 substances), but in much smaller molecules and not substituted to the three ring carbon structure. This means there is high uncertainty with these predictions and they are considered unreliable.

The predictions from the BCFBAF model are in line with the experimentally found BCFs for ip-ip and ib-ib constituents and add to the reliability of the laboratory study.

3.4.2 Bioaccumulation in terrestrial organisms (soil dwelling organisms, vertebrates)

Experimental data on the bioaccumulation potential in terrestrial organisms are not available for EC 401-850-9.

The potential for terrestrial bioaccumulation can be screened by combining the log K_{ow} and the log K_{oa}. The estimation program KOAWIN v1.10 presents the following log K_{oa} values for the various constituents of EC 401-850-9 :

- isopropyl-isopropyl : log K_{oa} = 8.21 / log K_{ow} = 6.1
- isobutyl-isopropyl : log K_{oa} = 8.58 / log K_{ow} = 6.7
- isobutyl-isobutyl : log K_{oa} = 8.95 / log K_{ow} = 7.1
- 2-ethylhexyl-isopropyl : log K_{oa} = 10.05 / log K_{ow} = 8.6
- 2-ethylhexyl-isobutyl : log K_{oa} = 10.41 / log K_{ow} = 9.0
- 2-ethylhexyl-2-ethylhexyl : log K_{oa} = 11.89 / log K_{ow} = 11.0

All the estimated log K_{oa} values are greater than 5 and all the estimated log K_{ow} values are greater than 2. Therefore, all the constituents screen as potentially bioaccumulative in air-breathing organisms.

3.4.3 Field data

Field data on the bioaccumulation potential of the EC 401-850-9 constituents are not available.

3.4.4 Summary and discussion of bioaccumulation

The fish bioaccumulation study that is executed in 1997, with 3 constituents of EC 401-850-9, (M.S.I. Report N° 6B062G, reliability score of 2) is considered to be reliable with restrictions and can thus be used to assess the bioaccumulation potential of the substance. BCFs depend on the exposure level that was employed. For the 3 constituents that were tested the following aquatic BCFs were considered to be most accurate:

- diisopropyl :	3794 L/kg
- diisobutyl :	2403 L/kg
- di-2-ethylhexyl :	< 56 L/kg

It should be noted that these BCF values represent a less conservative scenario as it is not possible to account for the potential effect of growth dilution. Modelling data from EPI Suite support findings from experimental data on bioaccumulation of the ip-ip and ib-ib constituents of EC 401-850-9. Consequently, it is concluded that isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents meet the 'bioaccumulation' criterion (B) (BCF value > 2000 L/kg) of REACH Annex XIII.

Finally, since EC 401-850-9 will contain isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents with B properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets the 'bioaccumulation' criterion (B) in accordance with Annex XIII, point 1.1.2, of the REACH Regulation.

Terrestrial bioaccumulation was not experimentally examined. Nevertheless, as the log K_{oa} values of all the constituents are greater than 8 and the log K_{ow} values of all the constituents are greater than 6, EC 401-850-9 screens as potentially bioaccumulative in terrestrial organisms.

4. Human health hazard assessment

The evaluation of the T criterion is only based on the environmental toxicity of EC 401-850-9. Therefore, human health hazards are not discussed in this dossier.

5. Environmental hazard assessment

5.1 Aquatic compartment (including sediment)

5.1.1 Fish

5.1.1.1 Short-term toxicity to fish

Only one experimental fish toxicity test (LSR Report N° 87/ETS011/511, reliability score of 3) is available for EC 401-850-9. The test is carried out according to OECD guideline 203 with rainbow trout as test species. The animals were exposed at 15°C for 96 hours to five concentrations of the test substance. Acetone was employed as solubilizer and the nominal test concentrations ranged from 313 mg/L to 5000 mg/L. Measured concentrations at the start of the test ranged from 5.6 mg/L to 17 mg/L and the measured end concentrations ranged from 2.3 mg/L to 4.5 mg/L.

LC_{50} values were calculated by arranging the measured start and end concentrations in ascending order. Proceeding in this way, the 96 hour LC_{50} values based on measured concentrations are estimated to lie between 2.9 mg/L and 10.9 mg/L.

It must be noted that because of the much lower real water solubility of EC 401-850-9 (water solubility value of ip-ip constituents is 50 µg/L) and the reduced accuracy of the analytical determinations, the LC_{50} value determined in this experiment has a very low reliability.

It is noted that ECOSAR v1.11 in EPI Suite (US EPA, 2012) estimates a fish LC_{50} value of 18 µg/L for the ip-ip constituent of EC 401-850-9. However, this prediction is not considered meaningful because the log K_{ow} of the constituents is more than 5, which means that no effects are expected at the water solubility level.

5.1.1.2 Long-term toxicity to fish

Experimental data on long-term toxicity to fish are not available.

It is noted that ECOSAR v1.11 in EPI Suite (US EPA, 2012) estimates a fish ChV of 6 µg/L for the ip-ip constituents of EC 401-850-9. However, the long-term toxicity model for fish cannot be considered valid because of the low R^2 value of 0.063 and the chronic toxicity values of the training set chemicals are too scattered and do not show any correlation with log K_{ow}.

5.1.2 Aquatic invertebrates

5.1.2.1 Short-term toxicity to aquatic invertebrates

Two acute toxicity tests on *Daphnia magna* are available for EC 401-850-9.

The oldest test dates from 1987 (LSR Report N° 87/ETS012/512, reliability score of 2) and is performed according to EU method C.2 or OECD guideline 202. In this test, five nominal concentrations of EC 401-850-9 were employed ranging from 0.08 mg/L to 1.2 mg/L. The median effect concentration EC_{50} was found to be 0.22 mg/L based on the number of immobile daphnia and 0.12 mg/L based on the number of immobile and/or floating daphnia. Considering that during the test a maximum 4-fold decrease in concentration is observed, a reasonable worst case LC_{50} value is 0.03 mg/L.

A more recent acute toxicity test on *Daphnia magna* was conducted in 2006 (SPL N° 1491/0074, reliability score of 2). The test was also carried out according to OECD guideline 202. In this case the daphnia were only exposed to a saturated EC 401-850-9 solution with a nominal concentration of 0.13 mg/L. No immobilisation was observed in 20 daphnids exposed to this saturated solution. At the end of the 48 hour test period measured concentrations dropped to 0.050 mg/L and 0.043 mg/L. Given this decline in measured test concentrations, it is considered justifiable to base the results on the geometric mean measured test concentration. In this way, it is concluded that the EC_{50} value is greater than 0.077 mg/L.

It is noted that ECOSAR v1.11 in EPI Suite (US EPA, 2012) estimates a daphnia LC_{50} value of 0.5 µg/L for the ip-ip constituents of EC 401-850-9. However, this prediction is not considered meaningful because the log K_{ow} of the constituents is more than 5, which means that no effects are expected at the water solubility level.

5.1.2.2 Long-term toxicity to aquatic invertebrates

A 21 days *Daphnia magna* immobilisation and reproduction test was carried out according to EU method C.20 which is equivalent to OECD guideline 211 (SPL N° 1491/0084, reliability score of 2). The test was performed with the following starting EC 401-850-9 concentrations: 0.0013, 0.0041, 0.013, 0.041 and 0.13 mg/L under semi-static conditions. Because of the low water solubility of the test material, these test concentrations were prepared by dilution of a saturated solution prepared by centrifugation of a dispersion at a concentration of 50 mg/L. The mentioned concentrations are based on chemical analysis of a saturated solution prepared during the acute toxicity to *Daphnia magna* test. There was a decline in measured concentrations over the test media renewal periods. This could be due to possible adsorption to glassware or waste material in the test vessels, adsorption to algal cells given as food and/or bioaccumulation in the test organisms. Given the variability in measured concentrations over each media renewal period, it was considered appropriate to recalculate the results based on time-weighted mean measured test concentrations. Surprisingly these time-weighted test concentrations turned out to be a bit higher than originally determined: 0.0018, 0.0059, 0.014, 0.051 and 0.18 mg/L.

The 21 day EC_{50} value based on immobilisation of the parental daphnia generation was calculated to be 0.046 mg/L, while the 21 day EC_{50} value for reproduction was determined to be 0.021 mg/L.

The LOEC and the NOEC values based on the time weighted mean measured test concentrations were 0.0059 and 0.0018 mg/L respectively. Based on the original approach to determine the concentrations the LOEC and NOEC would be 0.0041 and 0.0013 mg/L respectively.

In theory, the test item that is used in this test is EC 401-850-9, but it should be noted that the real composition of the test item is likely to deviate from the original EC 401-850-9 composition. Indeed, at the start of the experiment EC 401-850-9 is dispersed in tap water and this dispersion is stirred for 48 hours. Then the undissolved test material is removed by centrifugation and the test is continued with the saturated solution that is obtained. Although the water solubility of the various constituents is not experimentally measured, it is justifiable to assume that the solubilities will differ substantially. The ip-ip constituents are expected to be predominantly found in the preparation and more bioavailable compared with the other constituents of EC 401-850-9 as ip-ip constituents are more water soluble and they have a lower molecular weight. Taking into account that the constituents of EC 401-850-9 are relatively big molecules that differ only in the presence of carbon atoms in the alkyl chains, it is reasonable to assume that their toxicological profiles are also very similar. Consequently, it is concluded that the NOEC and LOEC determined in this long-term daphnia study is also a reliable NOEC and LOEC for the most abundant constituents in the study, i.e. the ip-ip constituents.

It should be noted that also the ECOSAR submodule in EPI Suite (US EPA, 2012) predicts that daphnia are the most vulnerable organisms for the ip-ip constituents of EC 401-850-9. The estimated LC_{50} and ChV for daphnia are respectively 0.45 µg/L and 0.04 µg/L. It should be noted that an acute to chronic toxicity estimation method has been applied and as the prediction for the LC_{50} value is not considered meaningful, also the ChV should be seen as less reliable.

However, it can be seen from this model that the class of dithiophosphates exhibit a much higher toxicity to aquatic organism than substances in the class of neutral organics with the narcosis mode of action. It is noted that this class of dithiophosphate esters contains substances like malathion (CAS n° 121-75-5), disulfoton (CAS n° 298-04-4), dimethoate (CAS n° 60-51-5), phosmet (CAS n° 732-11-6), methidathion (CAS n° 950-37-8) and ethoprophos (CAS n° 13194-48-4) which are all organophosphate insecticides. Their common mode of action is the inhibition of acetylcholinesterase. This observation supports the highly ecotoxicological profile of EC 401-850-9.

5.1.3 Algae and aquatic plants

A growth inhibition test (SPL N° 1491/0070, reliability score of 2) on the green algae *Scenedesmus subspicatus* was performed according to OECD guideline 201. The algae were exposed for 72 h to a measured test concentration at the start of 0.40 mg/L under constant illumination. As the measured test concentration declined during the test, it was considered justifiable to base the results on the geometric mean of the measured concentrations. On this basis, the EC_{50} was determined to be greater than 0.23 mg/L.

5.1.4 Sediment organisms

Experimental studies on sediment organisms are not available for EC 401-850-9.

5.2 Terrestrial compartment

Experimental studies on terrestrial organisms are not available for EC 401-850-9.

5.3 Atmospheric compartment

No data available.

5.4 Microbiological activity in sewage treatment systems

A toxicity test on microorganisms (SPL N° 1491/0071, reliability score of 2) from an activated sludge was conducted in aerobic conditions according to OECD guideline 209. The bacteria were exposed during 3 hours to EC 401-850-9 at a nominal concentration of 1000 mg/L which exceeds by far the water solubility of the test item. Under these conditions, no effect on respiration of the activated sewage sludge was observed.

It is concluded that at saturation EC 401-850-9 does not affect activated sludge microorganisms.

5.5 Toxicity to birds

No data available.

5.6 Other effects

Not relevant for this dossier.

5.7 Summary and discussion of the environmental hazard assessment

Experimental studies on the ecotoxicological effects of EC 401-850-9 are only available for aquatic organisms. Based on the results from studies with fish (rainbow trout), daphnia (*Daphnia magna*) and algae (*Scenedesmus subspicatus*), it is concluded that daphnia is the most sensitive aquatic species. These ecotoxicological studies are in theory carried out with the EC 401-850-9 composition as it is manufactured. However, considering the methodology that is used to prepare the test material in the various ecotoxicological tests, ip-ip constituents are expected to be predominantly found in the preparation used for the tests.

The most severe toxic effects were found in the 21 day long-term immobilisation and reproduction test with daphnia magna. In this study the LOEC appeared to be 5.9 µg/L and the NOEC 1.8 µg/L. Consequently, it is concluded that EC 401-850-9 and isopropyl-isopropyl constituents meet the toxicity criterion (T) (NOEC < 0.01 mg/L) in accordance with Annex XIII, point 1.1.3 (a), of the REACH Regulation.

6. Conclusions on the SVHC Properties

6.1 CMR assessment

Not relevant for the identification of the substance as SVHC in accordance with Article 57 (d) of REACH.

6.2 PBT and vPvB assessment

6.2.1 Assessment of PBT/vPvB properties

A weight-of-evidence determination according to the provisions of Annex XIII of REACH is used to identify the substance as PBT. All available information such as the results of standard tests, modelling and QSAR results was considered together in a weight-of-evidence approach. EC 401-850-9 is a substance that consists of six homologous groups of O,O',S-trialiphatic dithiophosphates. This PBT assessment of EC 401-850-9 is focused on the properties of isopropyl-isopropyl (ip-ip) constituents as these constituents are the most relevant ones with regard to their PBT profile.

6.2.1.1 Persistence

The hydrolysis study (LSR Report N° 87/ETS010/527, reliability score of 2) that was performed with EC 401-850-9 indicates that the substance is stable to hydrolysis. Based on this study, it is concluded that the half-lives for hydrolysis at 12°C and at various pH values are in the order of magnitude of 1 year. There are no indications that oxidation or phototransformation are relevant degradation processes for EC 401-850-9 under real environmental conditions. Abiotic degradation of EC 401-850-9 is thus not a relevant degradation mechanism.

The results derived from screening biodegradation tests and QSAR estimations do not allow to come to robust quantitative conclusions on the persistence of EC 401-850-9. An experimental degradation simulation study is the only study that can provide a definitive half-life that can be compared directly to the persistence and very persistent criteria as defined in Annex XIII of REACH. However, the outcome of the ready biodegradation screening studies performed on EC 401-850-9 support the findings of the available simulation study as EC 401-850-9 screens as potentially P/vP. A simulation study in fresh water is available for the ip-ip constituents of EC 401-850-9 (Maischak H., reliability score of 1). Although the study showed some shortcomings, it is possible to calculate a reliable biodegradation half-life for these constituents. Half-lives were calculated from the main study and from a complementary study and both approaches led to a biodegradation half-life of more than 200 days for the ip-ip constituents of EC 401-850-9. Consequently, it is concluded that the ip-ip constituents of EC 401-850-9 meet the 'persistence' (P) and 'very persistent' (vP) criteria of REACH Annex XIII (degradation half-life in fresh water > 60 days).

6.2.1.2 Bioaccumulation

In order to evaluate the aquatic bioaccumulation potential of EC 401-850-9, an experimental study (M.S.I. Report N° 6B062G, reliability score of 2) according to an older version of the OECD TG 305 is executed. The steady state BCFs for three constituents of EC 401-850-9 are determined at two exposure levels. For the lower exposure levels the lipid normalised steady state BCFs are as follows: ip-ip constituents: 3794 L/kg; ib-ib constituents: 2403 L/kg; eh-eh constituents: <49 L/kg. These BCF values represent a less conservative scenario as a possible growth dilution effect was not accounted for in the BCF calculations. As the values for the ip-ip and the ib-ib constituents exceed the threshold for B set out in Annex XIII of REACH (i.e. 2000 L/kg), it is concluded that both constituents must be identified as B for aquatic organisms. Since EC 401-850-9 will contain isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents with B properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets the 'bioaccumulation' criterion (B) in accordance with Annex XIII, point 1.1.2, of the REACH Regulation.

Experimental data on the bioaccumulation potential in air-breathing organisms is not available, but it is noted that all constituents of EC 401-850-9 meet the screening criteria for terrestrial bioaccumulation.

6.2.1.3 Toxicity

All the experimental studies on aquatic toxicity are in principle performed with the composition of EC 401-850-9 as the substance is manufactured and marketed. However, it is reasonable to assume that in practice the test item consisted mainly of the ip-ip constituents of EC 401-850-9. The various ecotoxicity tests pointed out that daphnia is the most sensitive aquatic species. The most severe toxic effects were found in the 21 day long-term immobilisation and reproduction test with *Daphnia magna*. In that study, the LOEC appeared to be 5.9 µg/L and the NOEC 1.8 µg/L. As these values are less than the ecotoxicity threshold of 10 µg/L laid down in Annex XIII of REACH, it is concluded that EC 401-850-9 and isopropyl-isopropyl (ip-ip) constituents meet the T criterion.

6.2.2 Summary and overall conclusions on the PBT and vPvB properties

A weight-of-evidence determination according to the provisions of Annex XIII of REACH has been used to identify S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-(isopropyl or isobutyl or 2-ethylhexyl) O-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate (referred to as 'EC 401-850-9' in this document) as PBT. All available information such as the results of standard tests, modelling and QSAR results was considered together in a weight-of-evidence approach. EC 401-850-9 is a substance that consists of 6 homologous groups of O,O',S-trialiphatic dithiophosphates. This PBT assessment of EC 401-850-9 is focused on the properties of isopropyl-isopropyl (ip-ip) constituents as these constituents are the most relevant ones with regard to their PBT profile.

Persistence

Detailed analysis of the available data from the biodegradation simulation study in fresh water pointed out that the isopropyl-isopropyl (ip-ip) constituents degrade very slowly in fresh water, exhibiting a half-life of more than 200 days. The outcome of the ready biodegradation screening studies performed on EC 401-850-9 support the findings of the simulation study as EC 401-850-9 screens as potentially P/vP.

Finally, since EC 401-850-9 contains ip-ip constituents with P/vP properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets both the 'persistence' (P) and 'very persistent' (vP) criteria in accordance with Annex XIII, points 1.1.1 (b) and 1.2.1 (a), of the REACH Regulation.

Bioaccumulation

Based on the results from an experimental aquatic bioaccumulation study with three constituents of EC 401-850-9, lipid normalised steady state BCFs of 3794 L/kg and 2403 L/kg were determined for the isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents, respectively. These BCF values represent a less conservative scenario as a possible growth dilution was not accounted for in the BCF calculations. Modelling data support findings from experimental data on bioaccumulation of ip-ip and ib-ib constituents of EC 401-850-9. Consequently, it is concluded that isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents meet the 'bioaccumulation' criterion (B) (BCF value > 2000 L/kg) of REACH Annex XIII.

Finally, since EC 401-850-9 contains isopropyl-isopropyl (ip-ip) and isobutyl-isobutyl (ib-ib) constituents with B properties at a concentration ≥ 0.1 % (w/w), it is concluded that EC 401-850-9 meets the 'bioaccumulation' criterion (B) in accordance with Annex XIII, point 1.1.2, of the REACH Regulation.

Toxicity

In the 21 day long-term immobilisation and reproduction test with daphnia magna that was performed on EC 401-850-9 with predominantly the isopropyl-isopropyl constituents, a LOEC of 5.9 µg/L and a NOEC of 1.8 µg/L was determined. The NOEC is less than 0.01 mg/L, which is the threshold for T laid down in Annex XIII of REACH. Consequently, it is concluded that EC 401-850-9 and isopropyl-isopropyl (ip-ip) constituents meet the 'toxicity' criterion (T) (NOEC < 0.01 mg/L) in accordance with Annex XIII, point 1.1.3 (a), of the REACH Regulation.

Overall conclusion

In conclusion, as the isopropyl-isopropyl (ip-ip) constituents meet the PBT criteria and their relative concentration in EC 401-850-9 largely exceeds 0.1% (w/w), EC 401-850-9 is proposed to be identified as a PBT substance according to Article 57(d) of the REACH Regulation.

6.3 Assessment under Article 57(f)

Not relevant for this dossier.

Part II

7. Registration and C&L notification status

7.1 Registration status

Table 7 : Registration status

From the ECHA dissemination site[4]	
Registrations	☒ Full registration(s) (Art. 10) ☐ Intermediate registration(s) (Art. 17 and/or 18)

7.2 CLP notification status

Table 8 : CLP notifications

	CLP Notifications[5]
Number of aggregated notifications	2
Total number of notifiers	21

8. Total tonnage of the substance

Table 9 : Tonnage status

Total tonnage band for the registered substance (excluding the volume registered under Art 17 or Art 18)[6]	10-100 t/a
Tonnage information from public sources other than registration dossiers (if available)	not available

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[4] Registration dossier, https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/14867 (accessed 27 July 2021)

[5] C&L Inventory database, https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/118684 (accessed 27 July 2021)

[6] Administrative information, https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/14867/1/2 (accessed 27 July 2021)

9. Information on uses of the substance

Table 10 : Uses of the substance

	Use(s)	**Registered use**	**Use in the scope of Authorisation**
Uses as intermediate	/	/	/
Formulation or repacking	Industrial formulation of lubricant additives, lubricants and greases Formulation into mixture	Yes	Yes
Uses at industrial sites	General industrial use of lubricants and greases in vehicles or machinery ○ Use of non-reactive processing aid at industrial site (no inclusion into or onto article) ○ Use of functional fluid at industrial site Industrial use of lubricants and greases in open systems ○ Use of non-reactive processing aid at industrial site (no inclusion into or onto article) Industrial use of lubricants and greases in high energy open processes Use of non-reactive processing aid at industrial site (no inclusion into or onto article)	Yes	Yes
Uses by professional workers	Professional use of lubricants and greases in open systems ○ Widespread use of non-reactive processing aid (no inclusion into or onto article, indoor) ○ Widespread use of non-reactive processing aid (no inclusion into or onto article, outdoor) General professional use of lubricants and greases in vehicles or machinery ○ Widespread use of functional fluid (indoor) Widespread use of functional fluid (outdoor)	Yes	Yes
Consumer uses	/	/	/
Article service life	/	/	/

10. Information on structure of the supply chain

No information available.

11. Additional information

11.1 Substances with similar hazard and use profiles on the Candidate List

There are no similar substances on the Candidate List.

11.2 Alternatives

Information on potential alternatives is not available.

11.3 Existing EU legislation

EC 401-850-9 is covered by Index number 015-146-00-0 in Annex VI to the CLP Regulation.

11.4 Previous assessments by other authorities

EC 401-850-9 is not assessed by other authorities.

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SPL Project Number 1491/0071, X#4261: Assessment of the inhibitory effect on the respiration of activated sewage sludge (2006).

SPL Project Number 1491/0072, X#4261: Determination of adsorption coefficient (2006).

SPL Project Number 1491/0074, X#4261: Acute toxicity to *Daphnia Magna* (2006).

SPL Project Number 1491/0084, X-4261: *Daphnia Magna* Reproduction Test (2008).

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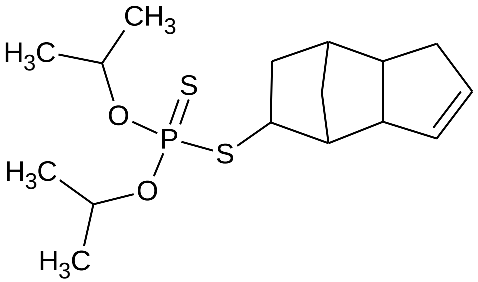
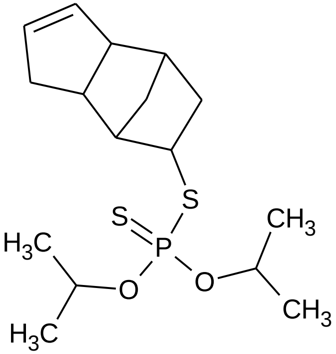
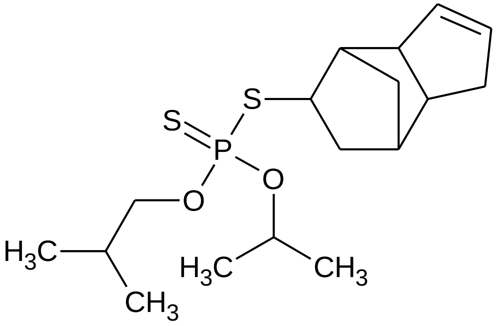
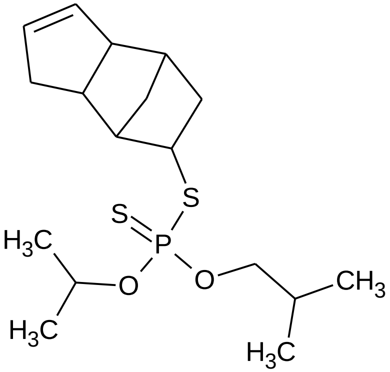
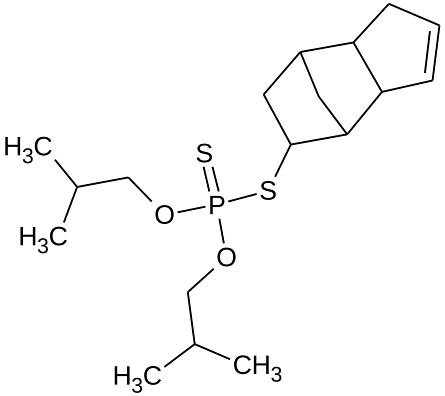
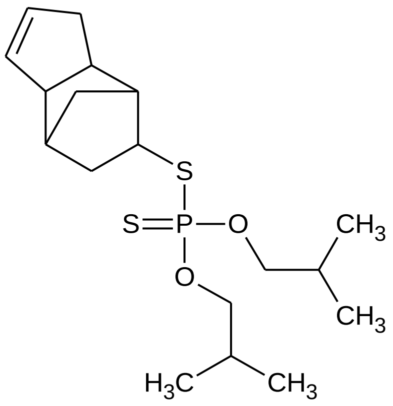
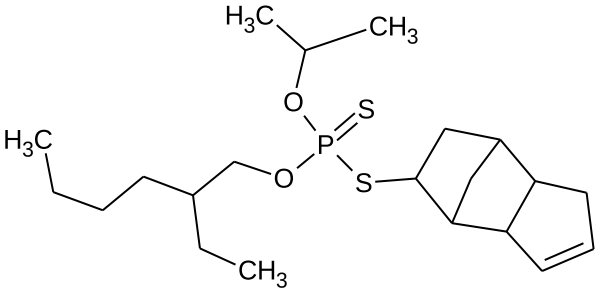
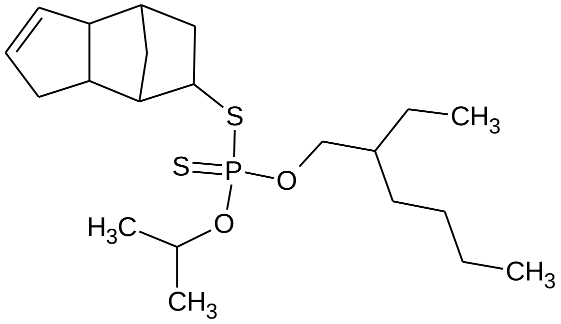
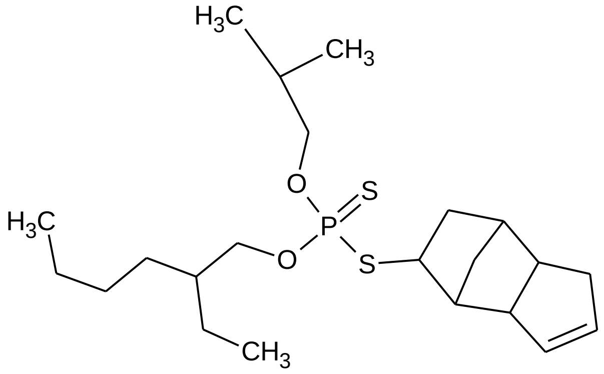
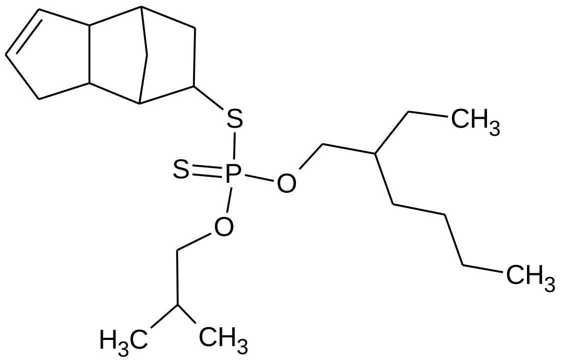
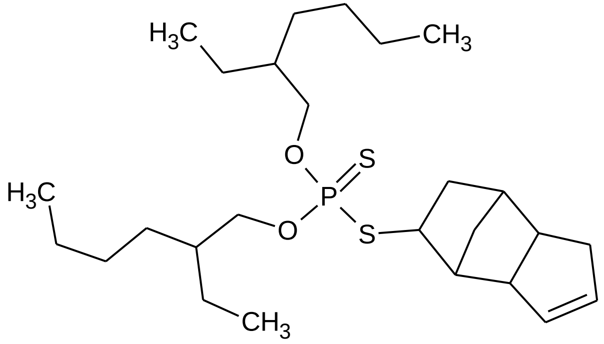
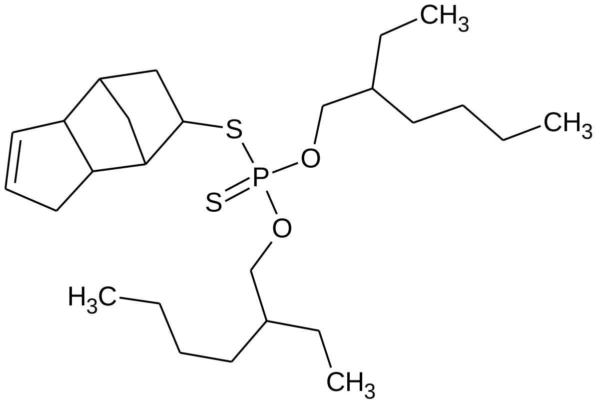
https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/14867/1/2
(last visited on 27 July 2021).

Annex I – Structural isomers of EC 401-850-9

Constituents	Remarks	Structural (constitutional) isomer 1 – Each structural isomer has several stereoisomers	Structural (constitutional) isomer 2 – Each structural isomer has several stereoisomers
S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-isopropyl O′-isopropyl phosphorodithioate	ip-ip constituent	 CC(C)OP(=S)(OC(C)C)SC1CC2CC1C1C=CCC21	 CC(C)OP(=S)(OC(C)C)SC1CC2CC1C1CC=CC21
S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-isopropyl O′-isobutyl phosphorodithioate	ip-ib constituent	 CC(C)COP(=S)(OC(C)C)SC1CC2CC1C1C=CCC21	 CC(C)COP(=S)(OC(C)C)SC1CC2CC1C1CC=CC21

S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-isobutyl O′-isobutyl phosphorodithioate	ib-ib constituent	 CC(C)COP(=S)(OCC(C)C)SC1CC2CC1C1C=CCC21	 CC(C)COP(=S)(OCC(C)C)SC1CC2CC1C1CC=CC21
S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-isopropyl O′-2-ethylhexyl phosphorodithioate	ip-eh constituent	 CCC(CCCC)COP(=S)(OC(C)C)SC1CC2CC1C1C=CCC21	 CCC(CCCC)COP(=S)(OC(C)C)SC1CC2CC1C1CC=CC21

S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-isobutyl O′-2-ethylhexyl phosphorodithioate	ib-eh constituents	 CC(C)COP(=S)(OCC(CC)CCCC)SC1CC2CC1C1C=CCC21	 CC(C)COP(=S)(OCC(CC)CCCC)SC1CC2CC1C1CC=CC21
S-(tricyclo[5.2.1.0^{2,6}]deca-3-en-8(or 9)-yl) O-2-ethylhexyl O′-2-ethylhexyl phosphorodithioate	eh-eh constituents	 CCC(CCCC)COP(=S)(OCC(CC)CCCC)SC1CC2CC1C1C=CCC21	 CCC(CCCC)COP(=S)(OCC(CC)CCCC)SC1CC2CC1C1CC=CC21