December 2017

How to decide whether a substance is a polymer or not and how to proceed with the relevant registration

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1. Introduction

This example describes part of the information gathering for a substance consisting of several repeating units. Therefore, it is important to know whether it is a polymer or not. The substance is a liquid organic substance, obtained from a chemical reaction. The substances used as starting materials react in such a way that one or more units are linked together (covalently bound).

The company that wants to register the substance, produces the substance in a volume of more than 10 tonnes per year. Therefore, the information requirements from Annex VII and Annex VIII of REACH are relevant, as well as the obligation to perform a Chemical Safety Assessment and submit a Chemical Safety Report as part of the registration dossier. NOTE: For a polymer the information requirements do not depend on the annual volume of the polymer, but on the annual volume of the monomers and other reactants used to manufacture the polymer.

This example will mainly illustrate:

- How to determine whether the substance is a polymer or not?
- If it is not a polymer, you need to register it as such (either as a mono-constituent, a multi-constituent or a UVCB substance)
- What are the consequences for data gathering depending on the options outlined above?

Within the example, there are multiple scenarios where existing information leads to different routes of further data gathering. Not all routes will be completely described. For some routes, only a limited description of next steps and relevant issues is provided in this example.

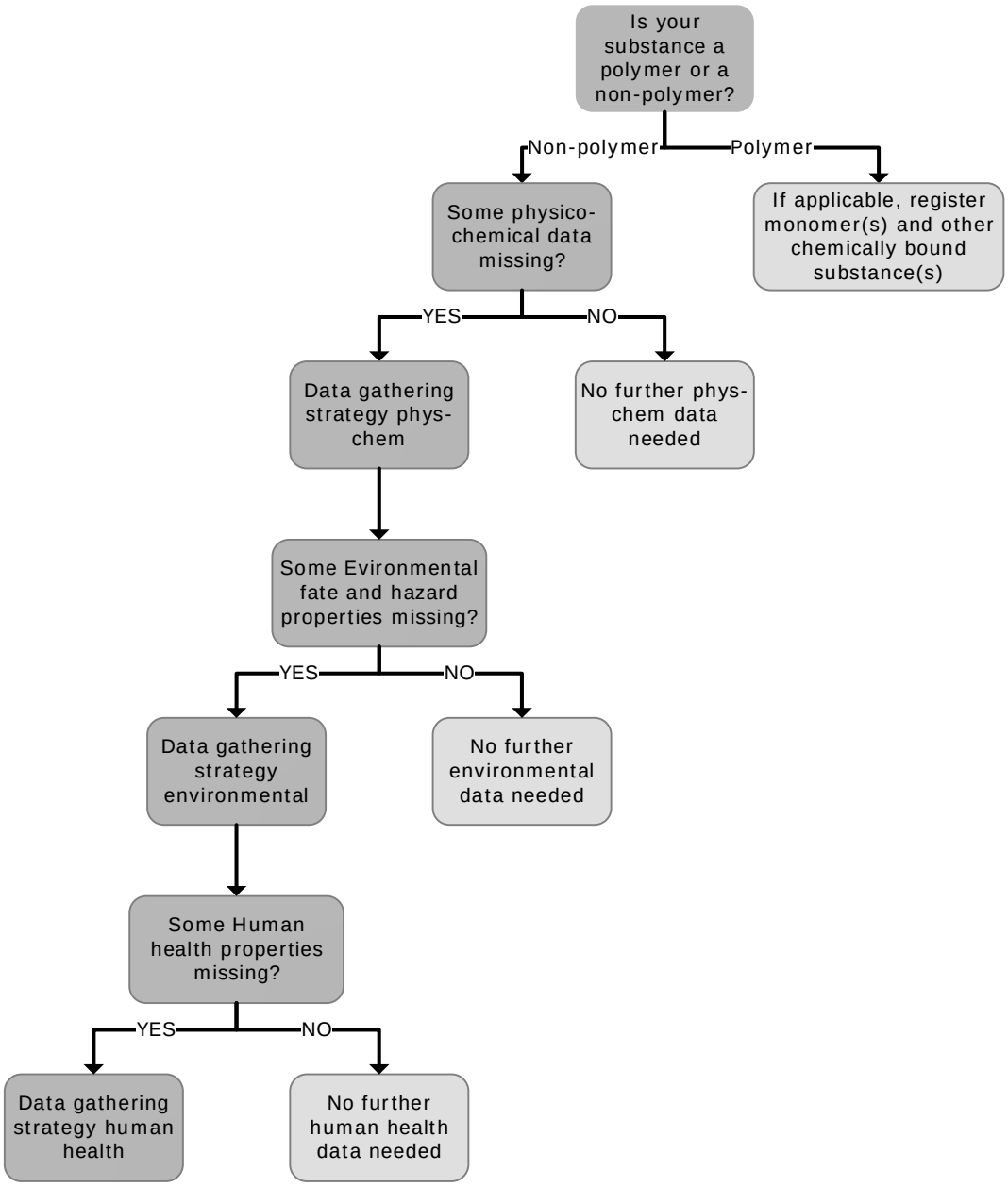
All the Guidance documents referred to in this document are found on a dedicated ECHA web-page[1].

More information is provided in Chapters I and II of the Practical Guide for SME managers and REACH coordinators – How to fulfil your information requirements at tonnages 1-10 and 10-100 tonnes per year[2] (referred to as Practical Guide for SMEs on information requirements).

The flow charts of this example is illustrated in Figure 1.

[1] See https://echa.europa.eu/guidance-documents/guidance-on-reach.
[2] See https://echa.europa.eu/practical-guides.

Figure 1: Flow chart on steps to undertake to gather data depending on whether your substance is a polymer or not



!	If the substance is a polymer, the steps for gathering data on the monomer(s) and (chemically-bound) reactants are the same as for a substance that is not a polymer.

2. Substance identification – polymer or not

2.1. Introduction – manufacture of a (potential) polymer

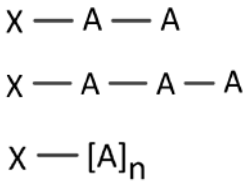
You manufacture a chemical substance in a solution to which you add several substances (reactants) that react with each other, in such a way that several molecular units become linked. It is assumed that the reactants are added in such quantities that, once the reaction is completed, the original reactants are present in only low quantities (< 1 %).

Suppose that you start with reactant X and monomer A and in the manufacturing process, X and A react together in the presence of a catalyst. Monomer A can also react with itself to form repeating units. The connections of the reactant and monomer units are called covalent bonds. X is consumed in the reaction, but one unit X remains at the end of the chain of the units A. The units of A are now linked together (covalently bound), and are thus strictly speaking not A anymore, but modified to A' since they have a bond to another A' or X' molecule which they did not have before. (For simplicity, A and X are used in the text and figures).

The reaction is terminated once all initial substances have been consumed (fully reacted or are still present in only low quantities (< 1 %) or the polymerisation is quenched (stopped). The catalyst could be removed e.g. by filtration.

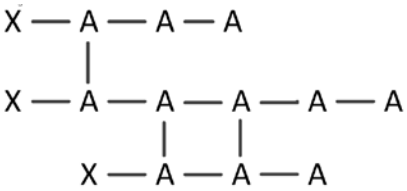
The resulting substance could then be: X-A-A, or X-A-A-A up to a large number of A's, often written as X-$[A]_n$, where n stands for the number of units, as illustrated in Figure 2.

Figure 2: Examples of simple chemical structure with repeating units.



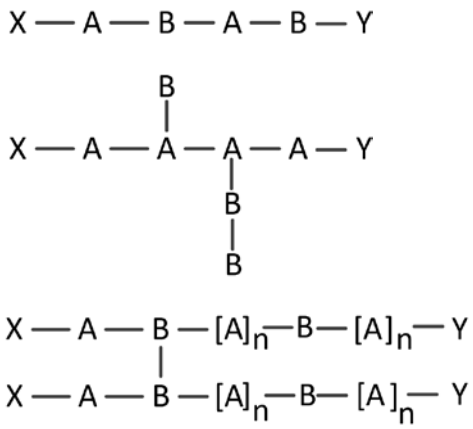
The form does not have to be linear; chains of X-$[A]_n$ can also be connected (cross-linked) with other chains X-$[A]_n$, as illustrated in Figure 3.

Figure 3: Example of cross-linked chemical structures with repeating units.



In other cases, there may be more than one reactant involved in the reaction: for example X and Y react with monomers A and B. This would result in (a) substance(s) with the composition of e.g. X-A-B-A-B-Y (linear or branched), or cross-linked structures of X-A-B-[A-B]$_n$-Y, or more complex structures with different numbers of repeating units, as illustrated with 'n' and 'm' in Figure 4.

Figure 4: Examples of more complex structures having several monomers, and possibly cross-linked structures.



Although you know that this reaction occurs, you do not know exactly how many of the monomer units A are linked together, and, therefore how long the chain usually is. The information on the number of connected repeating units and the respective concentration of each constituent with its number of repeating units is what determines whether the substance is considered as a polymer under REACH.

2.2. What is a polymer?

Although the chains described in Figures 2-4 look like a polymer, you will have to check if the polymer definition actually applies. The definition is quoted in the box below, and further explained in the Guidance for monomers and polymers.

In the various examples described in Figures 2-4, the substance would consist of the monomer units “A” and/or “B” , and you will have to determine how many of them are linked together, and what their molecular weight distribution is.

Polymer definition
A polymer is a substance consisting of molecules characterised by the sequence of one or more types of monomer unit. Such molecules must be distributed over a range of molecular weights. Differences in the molecular weight are primarily attributable to differences in the number of monomer units.
In accordance with REACH (Article 3(5)), a polymer is defined as a substance meeting the following criteria:

- > 50% of the weight of that substance consists of polymer molecules (see definition below); and,
- the amount of polymer molecules presenting the same molecular weight must be < 50% of the weight of the substance.

In the context of this definition:
A "**polymer molecule**" is a molecule that contains a sequence of at least 3 monomer units, which are covalently bound to at least one other monomer unit or other reactant.
A "**monomer unit**" means the reacted form of a monomer substance in a polymer (for the identification of the monomeric unit(s) in the chemical structure of the polymer the mechanism of polymer formation may, for instance, be taken into consideration).
A "**sequence**" is a continuous string of monomer units within the molecule that are covalently bound to one another and are uninterrupted by units other than monomer units. This continuous string of monomer units can possibly follow any network within the polymer structure.
"**Other reactant**" refers to a molecule that can be linked to one or more sequences of monomer units but which cannot be regarded as a monomer under the relevant reaction conditions used for the polymer formation process.

2.3. Example of the application of the polymer definition

Table 1 exemplifies the polymer definition: based on the production method described in section 2.1, several descriptions are proposed.

Table 1: Exemplification of the polymer definition, depending on the composition

Table 1		
Information	**Question**	**Result**
Your substance consists of X bound to a sequence of repeating coupled molecular units A, suspended in solution.	Could your substance be a polymer?	Yes, if the molecules making up the chemical composition of the substance consist of the repeating units of A and meet the polymer definition. Note: It is assumed that the solvent can be removed without changing the chemical composition of the molecule.
Composition (example 1) The solution contains fractions (by weight) with the following sequences: 5 % X-A 20 % X-A-A, 40 % X-A-A-A, (n=3, could be written as X-$[A]_3$) 20 % X-$[A]_4$, 10 % X-$[A]_5$- and 5 % X-$[A]_6$	Which of these fractions can be seen as a polymer molecule, and what is the total of these polymeric fractions?	The fractions X-A- and X-A-A are not polymeric, but the fractions X-A-A-A and higher are polymeric, as they contain at least three units attached to a fourth one. Thus the polymeric fractions make up 40 + 20 + 10 + 5 = 75 % . → the substance is a polymer
Composition (example 2) The solution contains fractions (by weight) with the following sequences: 20 % X-A 35 % X-A-A 15 % X-A-A-A, (n=3, could be written as X-$[A]_3$) 15 % X-$[A]_4$ 10 % X-$[A]_5$- and 5 % X-$[A]_6$	Which of these fractions can be seen as a polymer molecule, and what is the total of these polymeric fractions?	The fractions X-A and X-A-A are not polymeric, but the fractions X-A-A-A and higher are polymeric, as they contain at least three units attached to a fourth one. Thus the polymeric fractions make up 15 + 15 + 10 + 5 = 45 %. → the substance is **not** a polymer Note: This substance type is often referred to as oligomer.
	If the substance is **not** a polymer, is it a mono- or multi-constituent, or a UVCB substance?	As there is not a single fraction at 80 % or higher, the substance is not a mono-constituent. If the quantities of the fractions vary, the substance is a UVCB, and if they are fixed, the substance could be regarded as a multi-constituent (see: Guidance for monomers and polymers)

!	**Oligomer explanation** An Oligomer refers to a string of monomer units where the number of units in a chain is small, for example it consists usually of 2 or 3 units that are linked together and occasionally contains small quantities of also 4 or 5 or more units linked together. A number of oligomeric substances are included the "No-Longer Polymer List". Check if one of those is a substance your manufacture/import. Then check on the ECHA webpage if your substance is already registered.

In order to characterise your substance it is essential that you establish the molecular weight distribution in terms of monomeric units. The preferred method to define the "average molecular weight" and "molecular weight" is called "Gel Permeation Chromatography" (GPC), and is described in OECD TG 118. You will need access to a laboratory with experience in this methodology to carry out the test. If the GPC is not possible, the OECD TG 118 provides references to other methods.

2.4. Consequences for registration

If your substance is a polymer, the polymer itself is exempted from registration. However, the monomer(s) (represented as A and/or B) and reactant(s) (represented as X and/or Y) will all need to be registered as separate registrations unless the quantity of each used in manufacturing the polymer is below 1 tonne per year or they are already registered 'up the supply chain'. For further details, please see Guidance for monomers and polymers.

If your substance is not a polymer you have to register it as such (as any other substance). Thus the essential question you need to answer is: "is it a mono-constituent or multi-constituent or a UVCB substance?"

Table 2 outlines some analytical results and their consequences for registration under REACH. For more information on how to decide between a mono-constituent, multi-constituent or UVCB substance, see the Guidance for identification and naming of substances under REACH and CLP.

2.5. Analytical methods

Table 2 illustrates some scenarios on how to analyse and determine whether your substance is a polymer or not. The method of choice is usually Gel Permeation Chromatography (GPC) for substances with higher molecular weight. However, for substances with low molecular weight Gas Chromatography (GC) or High Pressure Liquid Chromatography (HPLC) may provide enough information to decide whether your substance is a polymer or not. Relevant methods for substance identification required for registration of any organic substance are given below.

Table 2: Example of analysis used to determine if a substance obtained by polymerisation reaction is a polymer or not

Table 2		
Analytical method	**Results**	**Conclusions next steps**
Scenario 1		
GPC and/or GC or HPLC performed on substance X-$[A]_n$	More than 50 % of polymer molecules are present, and none of the polymer molecules with the same molecular weight is > 50 % Peaks in chromatogram can be linked to constituents that contain different number of repeating units A, with reactant X attached.	**Substance is a polymer**. Registration of A and X is needed in your supply chain. For monomer (A) and reactant (X) present (covalently bound) in the polymer, you will need to either (i) join an existing registration or (ii) register yourself if you are manufacturing or importing it into the EU. You are advised to repeat analysis by GPC and/or other confirmatory analysis to cover variation in the production process.
Scenario 2		
GPC and/or GC or HPLC analysis performed on substance X-$[A]_n$-$[B]_m$-Y	Less than 50 % of polymer molecules are present. Results show the substance contains constituents with 1 to 4 repeating units of A and B, reacting with reactants X and Y	**Substance is probably not a polymer** but a substance of different oligomers (several monomeric units linked together). A repeated analysis of different batches is advised, and if large variation between batches is shown, your substance is not a polymer and needs to be registered as such.
Repeat the analysis performed on substance X-$[A]_n$-$[B]_m$-Y	Confirm whether there is a large variation between the batches in terms of the concentrations of the different constituents present, and also if the substance consists of constituents with different number of repeating units.	**Substance is definitely not a polymer.** Registration of the substance as such is needed.
Scenario 3		
Multiple GPC and/or GC or HPLC analyses performed on substance X-$[A]_n$	Less than 50 % of polymer molecules are present. Results show a clear and unvarying distribution of two constituents: 60 % with unit n=1 and 40% with units n=2.	**Substance** consists of specific oligomers and thus **seems to be multi-constituent substance**. Confirmation of structures needed (see 1st row of this table). Registration of the substance as such is needed.

!	**General for all scenarios above** In principle, you always need to confirm the structure of the substance you need to register (and presence of other constituents) by ultra-violet spectroscopy (UV), infra-red spectroscopy (IR), nuclear magnetic resonance spectroscopy (NMR) and/or mass spectrometry (MS) and quantification of constituents by gas chromatography (GC) or high-pressure liquid chromatography (HPLC) and/or determination of molecular weight distribution. You will need gel permeation chromatography (GPC) for higher molecular weights. Consult a specialist in polymer analysis for advice on the best strategy to follow.

As indicated above, the GPC and/or GC or HPLC results need to be linked with the expected or confirmed structures, which can assist to determine the numbers of repeating units.

For example, if your substance consists of four constituents with a distribution of different molecular weights there need to be four peaks in the chromatogram, which also have to correspond with the expected molecular weights. Confirmation of the substance identity by other analytical methods is also necessary.

Even if your substance is a UVCB, you have to make every reasonable effort to identify the structure of each constituent present in a quantity of 10% or more in the substance as manufactured. You also need to identify and document any constituents present if they are relevant for the classification and/or for the PBT assessment[3] of your substance, independently from their concentrations. If that proves to be technically impossible, you have to document and provide a scientific justification in the registration dossier. Unknown constituents should be identified as far as possible by a generic description of their chemical nature. The analysis and evaluation of whether your substance is a polymer requires advanced scientific expertise.

3. Information gathering for physico-chemical, human health and environmental properties

We assume that your substance is an oligomeric substance, i.e. a substance with several monomeric units linked together (covalently bound) that does not fulfil the requirements of a polymer (scenario 3 of Table 2 above), and that you need to gather information for physico-chemical, human health and environment properties.

We assume also that you manufacture and/or import between 10 and 100 tonnes per year. Hence you have to fulfil the information requirements of Annexes VII and VIII of REACH.

3.1. Information gathering programme for physico-chemical properties

!	For physico-chemical properties there is no difference in data requirements for substances manufactured or imported in the range of 1-10 tonnes per year or 10-100 tonnes per year.

[3] See https://echa-term.echa.europa.eu/home

Table 1: Information gathering for (some of) the physico-chemical properties

Table 3		
What you know	**What you need to do**	**Remarks**
You have to register the oligomeric substance	Gather internal information, e.g. at the technical department	Internal information is always a good starting point
Scenario 1: All physico-chemical information is available		
You have reliable internal information available for all relevant physico-chemical properties	No further actions to be taken with regard to gathering of physico-chemical information	Usually tests performed according to the prescribed guideline are reliable. Information from handbooks or publications can be reliable, once it is confirmed by a scientific expert. They can be used in a weight of evidence approach.

Table 3

What you know	What you need to do	Remarks
Scenario 2: Most, but not all, physico-chemical information is available		
You have reliable information for the following physico-chemical properties: • melting point • relative density • surface tension • flash point • flammability • explosive properties • self-ignition temperature • oxidising properties	To fulfil the information requirements, you need to gather information for the following physico-chemical properties: • boiling point • vapour pressure • water solubility • partition coefficient n-octanol/water First you will check if there is a possibility to 'waive' the data requirement for some properties. For example, the vapour pressure does not need to be determined when the melting point is >300°C. It can also be that testing is technically impossible or scientifically unjustified. Then you will check if data is available already for any of the remaining properties. Data may be available in open literature such as handbooks or databases or maybe from older study reports. You need to assess carefully if such data is (i) reliable, (ii) provides a relevant value for assessment of the specific intrinsic property of your substance and (iii) is not linked to any copyright (issue that you need to take into account before you can use that information). Finally if data is still missing, you need to check how such data can be generated. A test will almost always give the most reliable data and should therefore be always considered when there is no ground for waiving. However, alternatives to testing, such as comparison with a group of similar substances or estimation with a QSARs[4], may in some cases be possible.	Granulometry (particle size distribution) information is not relevant because your substance is a liquid. Usually tests performed according to the prescribed guideline are reliable. Information from handbooks or publications can be reliable, once it is confirmed by a scientific expert. To confirm the 'reliability' of publications, you usually need more than one source of information. If you want to use information from a handbook or database[5], you have to check carefully if the tested substance is the same as the one you want to register (with regard to purity/ impurities) and that data was derived with a reliable test method. The same applies to old reports from studies that were performed before test methods were standardised. Advanced scientific expertise is required if data is generated with alternative methods (e.g. QSAR prediction, read-across or interpolation of data from a group of similar substances). The use of, justification for and documentation of such an approach is subject to very specific rules. For more information consult the *Practical guide on how to report guide on (Q)SARs*[6] to fulfil your information requirements under REACH. Physico-chemical properties that determine hazard classification according to the CLP Regulation must be performed in compliance with GLP-criteria. However, already existing data that has not been gathered according to GLP can be acceptable.

[4] See https://echa-term.echa.europa.eu/home

[5] An overview of accepted handbooks and databases and the requirements for such data to be used can be found in ECHA Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.7a.

[6] https://echa.europa.eu/practical-guides

!	Once you have information available for every property, you have to check if your substance has physico-chemical properties that may lead to unwanted effects which lead to physical hazard classification according to the CLP Regulation such as flammability or explosiveness. If that is the case, then you will have to do a risk characterisation in your Chemical Safety Report.

If you consider alternatives to standard tests, note that the presence of many unknown constituents in the substance will make it impossible to fulfil the information requirements by the use of QSARs or read-across to other substances.

3.2. Information gathering programme for environmental properties

Table 4: Information gathering for (some of) the environmental properties

Table 4		
What you know	**What you need to do**	**Remarks**
You have to register the oligomeric substance. Tonnage 10-100 tpa	Gather internal information, e.g. at the 'technical' department.	Internal information is always a good starting point.
Scenario 1: All environmental information is available		
You have reliable internal information available for all relevant environmental properties.	No further actions with regard to gathering of environmental information.	Usually tests performed according to the prescribed guideline are reliable. Information from publications can also be reliable, once it is confirmed by a scientific expert.
Scenario 2 Not all environmental information is available		
You have reliable internal information available for the following environmental endpoints: • ready biodegradability • algal growth inhibition • toxicity to (STP) microorganisms You already know that you are the only (potential) registrant for this substance. You are not aware of a substance that is similar to your substance.	To fulfil the REACH Annex VII and VIII environmental fate and hazard information requirements for your substance, you need to gather information for the following properties: • hydrolysis • adsorption/desorption screening • degradation • short-term toxicity to aquatic invertebrates • short-term toxicity to fish As there are no other (potential) registrants and you did not find any similar substances, you therefore will have to gather this data yourself. You can waive some tests if it is technically not possible or scientifically unjustified to perform some of them. For the remaining properties, check if data already exists, e.g. in handbooks, You can waive (not to perform) some tests using other adaptations (read-across, QSARs, weight of evidence). If data is still missing, then perform a test.	Usually tests that are performed according to the prescribed guideline are reliable. Information from publications can also be reliable, once it is confirmed by a scientific expert. To confirm the reliability of publications, you usually need more than one source of information. When a substance is known to be readily biodegradable, no hydrolysis test needs to be performed. A hydrolysis test is scientifically unjustified when the substance does not contain chemical groups that can be hydrolysed. It is technically not possible to test any of the environmental properties when the substance is flammable when in contact with water. For the adsorption - instead of testing, it is advised that data is firstly generated from read-across or QSAR calculation (see chapter II.1.2 of the Practical Guide for SMEs on information requirements). All environmental fate and hazard tests shall be conducted in accordance with generally recognised test guidelines and must be in compliance with criteria for 'Good Laboratory Practice' (GLP).

!	Once you have information available for every property, you have to check if your substance has an environmental fate or hazard that may lead to unwanted effects (such as, for example, toxicity towards aquatic organisms). In practice this is done by checking if the substance needs to be classified for the environment according to the CLP Regulation. If the substance needs to be classified for the environment, you will have to label and classify it and also do an exposure assessment and risk characterisation. You need to document these in your Chemical Safety Report. Using the outcome of the environmental hazard studies (i.e. toxicity to fish, aquatic invertebrates and algae), you also have to derive the level below which no negative effects are expected. These thresholds are called Predicted No Effect Concentrations (PNECs) and advanced scientific expertise is required for their derivation.

3.3. Information gathering programme for human health properties

Table 5: Information gathering for (some of) the human health properties

Table 5		
What you know	**What you need to do**	**Remarks**
You have to register the oligomeric substance.	Gather internal information, e.g. at the technical department.	Internal information always is a good starting point.
Scenario 1: All human health information is available		
You have reliable internal information available for all relevant human health properties.	Since all the required information is already available, there are no further actions to be taken with regard to gathering of human health information.	Usually tests that are performed according to the prescribed guideline are reliable. Information from publications can also be reliable, once it is confirmed by a scientific expert.
Scenario 2: Most, but not all, human health information is available		
You have reliable information for the following human health properties: • skin irritation/corrosion (*in vivo* study) • eye irritation(*in vivo* study) • skin sensitisation • *in vitro* gene mutation in bacteria • acute oral toxicity You already know that you are the only (potential) registrant for this substance. You are not aware of a substance that is similar to your substance.	To fulfil the REACH Annex VIII human health information requirements for your substance, you need to gather information for the following properties: • *in vitro* cytogenicity study in mammalian cells • *in vitro* gene mutation study in mammalian cells • acute inhalation toxicity • short-term repeated dose toxicity • screening for reproductive/developmental toxicity You will perform/ subcontract the required human health tests yourself. To avoid unnecessary duplication of animal tests, you investigate the most appropriate test guideline to perform the screening study for reproductive/developmental toxicity, so that you can fulfil also the requirements of the short-term repeated dose toxicity (28-day treatment). You decide to perform the combined repeated dose toxicity study with the reproduction/developmental toxicity screening test.	*The REACH annexes have changed in 2016, and* in vitro *testing has become the standard requirement for three properties:* (i) skin irritation and corrosion, (ii) eye irritation, (iii) skin sensitisation. Because your information for skin irritation and corrosion and eye irritation are from *in vivo* studies, you need to prepare a scientific justification as to why you are not submitting an *in vitro* test (to comply with the current Annex VII requirements). Otherwise you dossier is not complete. For skin sensitisation, you may have to complete your information using the *in vitro* methods in line with the current Annex VII requirement. Usually tests performed according to the prescribed guideline are reliable. Information from publications can also be reliable, once it is confirmed by a scientific expert. To confirm the reliability of publications, you usually need more than one source of information. All human health tests need to be performed in accordance with Good Laboratory Practice (GLP) Scientific expertise is required to decide, based on the results of the *in vitro* mutagenicity tests, if *in vivo* mutagenicity testing is needed (see Chapter II.2.3 of the Practical Guide for SMEs on information requirements)

!	Once you have information available for the required properties, you have to check if your substance does have a human health property that may lead to unwanted effects such as acute dermal toxicity. In practice this is done by checking if the substance needs to be classified for the unwanted properties according to the CLP Regulation. If your substance needs to be classified, then you will have to do an exposure assessment and risk characterisation in your Chemical Safety Report. Using the outcome of the human health studies, you also have to derive the level below which no negative effects will occur. These thresholds are called Derived No Effect Levels (DNELs) and advanced scientific expertise is required for their derivation.