



# **PERSISTENCE, BIOACCUMULATION POTENTIAL AND TOXICITY – ‘PBT’**

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## 1. PBT Criteria

Internationally, the principles of Persistence, Bioaccumulation potential and Toxicity as indicators of hazard came to form part of various initiatives in the late 1990s. Organisations such as EU, OSPAR, US EPA and the UK Chemicals Stakeholder Forum have undertaken prioritisation exercises to identify such substances.

Since these characteristics can be indicated by chemical properties, several organisations have agreed threshold criteria by which PBT substances can be identified. As well as P, B and T, it is accepted that very persistent and bioaccumulative substances also present serious concerns even though there may not be evidence of toxicity. These substances have the potential to build up in environmental organisms and long-term subtle effects (such as reduced fertility) could present themselves in the future. Hence, ‘vPvB’ criteria have also been developed.

The standard EU criteria are defined in the Technical Guidance Document for risk assessment, now that PBT assessment is a core feature of marine risk assessment. The criteria are as follows.

Criterion	PBT criteria	vPvB-criteria
P	Half-life > 60 d in marine water or > 40 d in freshwater or half-life > 180 d in marine sediment or > 120 d in freshwater sediment <i>Or not readily or inherently biodegradable</i> <i>Or predicted biodegradability in a time frame of weeks-months</i>	Half-life > 60 d in marine- or freshwater or >180 d in marine or freshwater sediment <i>Or not readily or inherently biodegradable</i> <i>Or predicted biodegradability in a time frame of weeks-months</i>
B	BCF > 2,000 <i>Or log Kow &gt;4.5</i>	BCF > 5,000 <i>Or log Kow &gt;5</i>
T	Chronic NOEC < 0.01 mg/l or CMR or endocrine disrupting effects <i>Or acute L(E)C50 &lt;0.1 mg/l</i>	Not applicable

The italicised entries are ‘screening’ criteria, which can be used to make a preliminary assessment in the absence of measured data.

## 2. Persistence Issues

As part of environmental fate modelling, removal is of extreme importance since this will affect the development of distribution equilibria.

Hence, the fate of any chemical released into the environment will depend on how it degrades and for this reason, degradation rates in the environmental compartments forms a key input of fugacity models. Persistence in the environment is the key to long-term exposure.

Degradation under environmental conditions may proceed by many routes:

- Biodegradation by environmental micro-organisms
- Hydrolysis in water, in wet soils and sediments
- Oxidation in the atmosphere or in water
- Light-catalysed degradation in the atmosphere and at the surface of soils and waters
- Metabolism in higher animals
- In the atmosphere, direct and indirect photolysis can result in the removal of chemicals.
- In water, hydrolysis, oxidation and biodegradation are the main degradation processes.
- In soil and sediment, biodegradation is often the most important factor in the removal of the chemical from the environment.

Standard test methods exist for measuring biotic and abiotic degradation in aqueous conditions. In particular there are several standard methods for screening microbial biodegradation, and these focus on modelling degradation in a wastewater treatment plant.

In the context of EU approaches and methods, two key concepts exist. *Ready biodegradability* is a property by which a substance is degraded rapidly ( $t_{1/2} < 28$  days), under aerobic conditions, by a mixed population of WWTP-type micro-organisms ('activated sludge'). The conditions are unfavourable in terms of microbial population and other organic nutrient sources for the microbes. Hence a readily biodegradable substance can be relied upon to be degraded.

*Inherent biodegradability* is assessed over a longer time period if necessary and may use more favourable test conditions. An inherently biodegradable substance is one which passes an inherent biodegradability test. In the past some authors have used this term to represent 'potential' or 'intrinsic' properties.

Biodegradation can be complete, resulting in the mineralisation of organic chemicals, breaking them down into carbon dioxide and water, and compounds of any other atoms present (e.g. nitrogen, sulfur). Partial degradation to a stable by-product is also possible. Micro-organisms may need to adapt to the presence of a chemical before they begin to utilise it and break it down.

Abiotic degradation via hydrolysis is measured in the context of varying pH and temperatures.

Atmospheric degradation rate (by reaction with hydroxyl radicals) is usually estimated, though many measurements are published in the open literature, particularly by Atkinson.

Persistence in an environmental 'compartment' (i.e. water, sediment, soil or the atmosphere) is sometimes referred to in the context of environmental fate. For instance, a very highly volatile substance may not be 'persistent' in surface water because of volatilisation. However, unless degradation occurs in the atmosphere, the substance does persist in the environment at large.

The rate and extent of degradation in all environmental compartments, and by the various biotic and abiotic mechanisms, depend on the characteristics of the chemical, and vary enormously. Knowledge and/or prediction of chemical characteristics and the degradation processes and rates involved enable the assessment of environmental fate. It is possible to determine whether a substance will completely mineralise in a short time, or persist in the environment for a very long time.

### **3. Bioaccumulation Issues**

The terms bioaccumulation and bioconcentration refer to the uptake and build-up of chemicals that can occur in living organisms. Bioconcentration is the result of uptake of a substance through water-borne exposure, whereas bioaccumulation includes uptake from all media including air, water, soil and food. Standard test methods exist for measuring bioconcentration factor in fish and earthworms.

Bioaccumulation potential is an indicator of concern independent from toxicity, in acknowledgement that accumulative substances may cause subtle long-term effects, which may become evident in the future.

In terms of the standard European PBT criteria, bioaccumulation potential is identified by a BCF of 2000 or higher (usually meaning that concentration in the organism is at least 2000 times greater than the concentration in the test medium).

A high  $\log K_{ow}$  value (octanol-water partition coefficient) indicates an affinity for lipids and can usually be used to predict the potential for bioaccumulation. However, in a living organism, metabolic processes may mean the substance is eliminated and does not build up.

Also, very large molecules are not bioavailable (cannot be absorbed into the body of the organism) and hence will usually not bioaccumulate.

Some substances may accumulate in particular parts of the body, e.g. the liver, fatty tissue, or bones. This level of detail is not normally needed for environmental risk assessment purposes.

### **4. Toxicity Issues**

For a substance to be categorised as Toxic (T) the EU Technical Guidance Document for risk assessment specifies that there should be evidence confirming that it:

- is chronically toxic to aquatic species with a long term NOEC  $\leq 0.01$  mg/l and/or
- is a category 1 or 2 carcinogen, mutagen or reprotoxin or category 3 mutagen or reprotoxin and/or
- causes long-term toxic effects (e.g. endocrine disruption).

Providing evidence to support or refute that the assertion that a substance falls into the T category requires expert review and interpretation of published work. Where data are absent it can also require test programmes to be developed to provide it. PBT substances can be difficult to test in aqueous exposure systems because of their inherent physico-chemical properties. For example, they are often poorly soluble with a tendency to adsorb to surfaces and organic matter. Standard test protocols are not designed for substances with these properties and therefore require adaptation. There are currently no criteria for assessing endocrine effects and interpretation of information requires expert judgement.