# GMSR scenarios

## Environmental impact of pesticides

When comparing the environmental effect of pesticide application for different cropping systems, we are faced with multiple challenges. The first is how to calculate the environmental effect on specific organisms, the second how to weight the effect on different organisms. The best current solution to the first problem is advanced eco-toxicological models, such as the TKTD models recommended by EFSA (Ockleford et al., 2018). However, this is quite complex and time consuming, and does not solve the second problem.

Therefore, in some cases, eco-toxicological aspects are ignored completely, and instead active ingredients are weighted by weight alone. This approach has the obvious drawback that highly toxic active ingredients will be favored over less toxic active ingredients, as you will need less of them to achieve the desired effect on the pests.

As a middle ground, the Danish EPA developed heuristic framework where various eco-toxicological indicators are weighted and added together (Miljøstyrelsen, 2012). This approach has later been written into law (Bekæmpelsesmiddelafgiftsloven, 2015). This approach calculates an environmental load from three components, human health, environmental fate, and environment effect. The environmental effect is further divided into organisms, and for some organisms further divided into acute effects described by a LC50 or EC50 number, and chronic effects described by a NOEC number. All the numbers are taken from a PPDB database (*IUPAC Pesticides Properties DataBase*, n.d.). In the present project, we are only interested in the environmental effect on water organisms.

The chronic factor weigh less for compounds that have a short halftime in water. Specifically, they are weighted by the relative average content the first week ($A_7$). This can be found from $DT_{50}$ with the following steps:

1) The degradation rate ($k$) is calculates as $k = \frac{\ln 2}{DT_{50}}$
2) Change in concentration ($C$) over time ($t$) can then be written as $\frac{dC}{dt} = -k\,C$
3) Solving this equation gives us $C(t) = C(0)\,e^{-k\,t}$
4) We can then find the weekly average by integration $A_7 = \frac{\int_0^7 C(t)dt}{7} = \frac{1-e^{-7k}}{7k}$

If $DT_{50}$ is not specified, no degradation is assumed, and we use $A_7 = 1$

Four classes of organisms are considered for the acute effect: Fish (FIa), Daphnia (Da), Algea (Aa), and Aquatic plants (VP). For fish the LC50 value is used, for the others the EC50 value. Each organism has a reference value (R) and a weight (W), which are multiplied together. Neither the law (Bekæmpelsesmiddelafgiftsloven, 2015), nor the report (Miljøstyrelsen, 2012) explains what they represent, or why there are two of them. The acute toxic effects for a specific active ingredient on the reference organisms are calculated as

- $T_{FIa} = W_{FIa}\frac{R_{FIa}}{LC_{50}}$
- $T_{Da} = W_{Da}\frac{R_{Da}}{EC_{50}}$
- $T_{Aa} = W_{Aa}\frac{R_{Aa}}{EC_{50}}$
- $T_{VP} = W_{VP}\frac{R_{VP}}{EC_{50}}$

Two classes of organisms are considered for chronic effects: Fish (FIk) and Daphnia (Dk). The toxic effects are calculated as

- $T_{FIk} = W_{FIa} \frac{R_{FIk}}{\text{NOEC}} A_7$
- $T_{Dk} = W_{Da} \frac{R_{Dk}}{\text{NOEC}} A_7$

The total environment effect is then the sum of the 6 components

- $T = T_{FIa} + T_{Da} + T_{Aa} + T_{VP} + T_{FIk} + T_{Dk}$

The R and W values for the various organisms can be found in Table 0.1 with bluebackground. The LC50, EC50, and NOEC for each active ingredient are from the PPDB, and presented with green background, together the DT50 value. The A7 value calculated from DT50 is presented with yellow background.

*Table 0.1: Toxicity of active ingredients on aquatic organisms. The blue numbers are from the law text. The green numbers are from the PPDB. The yellow numbers are calculated.*

| **Organism** | Fish | Daphnia | Algae | Plants | Fish | Daphnia | Water | Chronic |
|---|---|---|---|---|---|---|---|---|
| Symbol | FIa | Da | Aa | VP | FIk | Dk | | factor |
| Type | LC50 | EC50 | EC50 | EC50 | NOEC | NOEC | DT50 | A7 |
| Unit | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | d | |
| Reference (R) | 0.00021 | 0.0003 | 0.000025 | 0.00036 | 0.000115 | 0.000115 | | |
| Weight (W) | 30 | 30 | 3 | 3 | 3 | 3 | | |
| **Active ingredient** | | | | | | | | |
| fluopyram | 0.98 | 100 | 1.13 | 2.32 | 0.135 | 1.25 | 20.5 | 0.890467 |
| fluroxypyr | 14.3 | 100 | 49.8 | 12.3 | 100 | 56 | 10.5 | 0.800781 |
| glyphosate | 38 | 40 | 19 | 12 | 1 | 12.5 | 9.9 | 0.790521 |
| halauxifen-methyl | 1.33 | 2.21 | 0.855 | 2.13 | 0.0115 | 0.144 | 1.8 | 0.345936 |
| picloram | 8.8 | 44.2 | 60.2 | 102 | 0.55 | 6.79 | 80.8 | 0.970567 |
| propaquizafop | 0.19 | 0.9 | 2.1 | 1.4 | 0.019 | 0.44 | 1 | 0.204489 |
| propyzamide | 4.7 | 5.6 | 2.8 | 1.4 | 0.94 | 0.6 | 21 | 0.892882 |
| prothioconazone | 1.83 | 1.3 | 2.18 | 0.18 | 0.308 | 0.56 | | 1 |
| pyraclostrobin | 0.006 | 0.016 | 0.843 | 1.72 | 0.005 | 0.004 | 2 | 0.375765 |
| tebuconazole | 4.4 | 2.79 | 1.96 | 0.144 | 0.01 | 0.01 | 42.6 | 0.945153 |
| tribenuron-methyl | 738 | 894 | 0.11 | 0.0099 | 560 | 120 | 86.2 | 0.972377 |
| diflufenican | 0.099 | 0.24 | 0.00025 | 0.056 | 0.015 | 0.052 | | 1 |
| florasulam | 100 | 292 | 0.00894 | 0.001 | 119 | 38.9 | 18 | 0.876558 |
| prosulfocarb | 0.84 | 0.51 | 0.049 | 0.69 | 0.31 | 0.045 | 0.94 | 0.192623 |
| pyroxsulam | 87 | 100 | 0.924 | 0.0026 | 10.1 | 10.4 | | 1 |
| indoxacarb | 0.17 | 0.17 | 0.079 | 0.084 | 0.15 | 3.9 | 1.4 | 0.279522 |
| lambda-cyhalothrin | 0.00021 | 0.00023 | 0.005 | | 0.000031 | 0.0000022 | 0.24 | 0.049464 |
| iodosulforon-methyl-sodium | 100 | 100 | 0.07 | 0.00083 | 10 | 10 | 16 | 0.862606 |
| tau-fluvanilate | 0.000794 | 0.000064 | 42 | | 0.000064 | 0.000021 | 1 | 0.204489 |
| metsulfuron-methyl | 110 | 43.1 | 0.113 | 0.00036 | 68 | 3.13 | 115 | 0.979198 |
| bromoxynil | 29.2 | 12.5 | 0.12 | 0.033 | 2 | 3.1 | 13 | 0.834586 |

The toxicity index on the individual types of organisms $\{T_{FIa}, T_{Da}, T_{Aa}, T_{VP}, T_{FIk}, T_{Dk}\}$, as well as the combined effect on the aquatic environment ($T$) is shown in Table 0.2.

*Table 0.2: Environmental effect. The first four columns show the acute toxicity on the species, the next two the chronic toxicity for the two of the species, and the last is an indicator for the combined impact on the aquatic environment. The numbers do not have an absolute meaning except for tax purposes, but they are all per mass.*

| **Organism** | Fish | Daphnia | Algae | Plants | Fish | Daphnia | Combined |
|---|---|---|---|---|---|---|---|
| **Active ingredient** | Fla | Da | Aa | VP | Flk | Dk | effect |
| fluopyram | 0.006429 | 0.00009 | 6.64E-05 | 0.000466 | 0.002276 | 0.000246 | 0.009572 |
| fluroxypyr | 0.000441 | 0.00009 | 1.51E-06 | 8.78E-05 | 2.76E-06 | 4.93E-06 | 0.000628 |
| glyphosate | 0.000166 | 0.000225 | 3.95E-06 | 0.00009 | 0.000273 | 2.18E-05 | 0.000779 |
| halauxifen-methyl | 0.004737 | 0.004072 | 8.77E-05 | 0.000507 | 0.010378 | 0.000829 | 0.020611 |
| picloram | 0.000716 | 0.000204 | 1.25E-06 | 1.06E-05 | 0.000609 | 4.93E-05 | 0.001589 |
| propaquizafop | 0.033158 | 0.01 | 3.57E-05 | 0.000771 | 0.003713 | 0.00016 | 0.047838 |
| propyzamide | 0.00134 | 0.001607 | 2.68E-05 | 0.000771 | 0.000328 | 0.000513 | 0.004587 |
| prothioconazone | 0.003443 | 0.006923 | 3.44E-05 | 0.006 | 0.00112 | 0.000616 | 0.018136 |
| pyraclostrobin | 1.05 | 0.5625 | 8.9E-05 | 0.000628 | 0.025928 | 0.03241 | 1.671554 |
| tebuconazole | 0.001432 | 0.003226 | 3.83E-05 | 0.0075 | 0.032608 | 0.032608 | 0.077411 |
| tribenuron-methyl | 8.54E-06 | 1.01E-05 | 0.000682 | 0.109091 | 5.99E-07 | 2.8E-06 | 0.109795 |
| diflufenican | 0.063636 | 0.0375 | 0.3 | 0.019286 | 0.023 | 0.006635 | 0.450057 |
| florasulam | 0.000063 | 3.08E-05 | 0.008389 | 1.08 | 2.54E-06 | 7.77E-06 | 1.088493 |
| prosulfocarb | 0.0075 | 0.017647 | 0.001531 | 0.001565 | 0.000214 | 0.001477 | 0.029934 |
| pyroxsulam | 7.24E-05 | 0.00009 | 8.12E-05 | 0.415385 | 3.42E-05 | 3.32E-05 | 0.415696 |
| indoxacarb | 0.037059 | 0.052941 | 0.000949 | 0.012857 | 0.000643 | 2.47E-05 | 0.104474 |
| lambda-cyhalothrin | 30 | 39.13043 | 0.015 | 0 | 0.550485 | 7.756828 | 77.45275 |
| iodosulforon-methyl-sodium | 0.000063 | 0.00009 | 0.001071 | 1.301205 | 2.98E-05 | 2.98E-05 | 1.302489 |
| tau-fluvanilate | 7.934509 | 140.625 | 1.79E-06 | 0 | 1.102324 | 3.359464 | 153.0213 |
| metsulfuron-methyl | 5.73E-05 | 0.000209 | 0.000664 | 3 | 4.97E-06 | 0.000108 | 3.001043 |
| bromoxynil | 0.000216 | 0.00072 | 0.000625 | 0.032727 | 0.000144 | 9.29E-05 | 0.034525 |

To use these numbers, you will need a fate model like Daisy or MACRO to calculate the mass of pesticides leaching through drains, and then multiply the mass with the corresponding combined effect in Table 0.2.

## References


*IUPAC Pesticides Properties DataBase*. (n.d.). Retrieved November 10, 2021, from http://sitem.herts.ac.uk/aeru/iupac/index.htm

Miljøstyrelsen. (2012). *Pesticidbelastningen fra jordbruget 2007-2010* (No. 1; Orientering Fra Miljøstyrelsen). https://mst.dk/service/publikationer/publikationsarkiv/2012/jan/pesticidbelastningen-fra-jordbruget-2007-2010/

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