Document title	Results of the SOM analysis for hazardous substances
Code	2-2
Category	CMNT
Agenda Item	2 – Results of the prior analyses
Submission date	5.8.2020
Submitted by	Secretariat, ACTION WP6
Reference	

Background

Sufficiency of measures (SOM) analysis is one of the activities agreed through the Strategic Plan for the BSAP update (cf. activity 2.5). It is carried out by the HELCOM ACTION project and the HELCOM SOM Platform. The SOM analysis supports the update of the BSAP by assessing what kind of improvements in environmental state and pressures can be achieved with existing measures by 2030-2035, and whether these are sufficient to achieve good environmental status (GES) in the Baltic Sea. The methodology for the SOM analysis has been developed by the ACTION project with guidance from the SOM Platform, and it has been endorsed by GEAR 22-2020 (Outcome, para 4.21).

This document presents the results of the SOM analysis for (selected) hazardous substances. The results provide a basis for evaluating proposed actions in the HELCOM BSAP UP workshop on hazardous substances and litter (BSAP UP WS-HZ 2020) by identifying gaps in existing measures to achieve good environmental status. In addition to the main result, i.e. the probability of achieving GES with existing measures, the document presents findings on which pressures contribute to state components, what are the pressure reductions from existing measures, how effective are measure types in reducing pressures, and which activities contribute to pressures. The results provide supporting information for evaluating where new measures are likely needed (geographically and by pressure/state) and what types of measures are likely effective in reducing certain pressures and improving state.

The SOM analysis presents the first attempt to quantify the effects of existing measures and policies on the environment and achieving objectives. It presents a Baltic Sea level assessment on the overall sufficiency of existing measures for a variety of environmental topics. The results of the analyses are based mainly on expert elicitation, and thus they should be interpreted appropriately. The findings do not provide complete and final answers on the reductions in pressures or improvements in state and should thus also be considered in relation to other relevant results and assessments.

This document presents the first results of the SOM analysis for hazardous substances, which may be amended and revised in the autumn 2020.

Action

The workshop is invited to take note of the information and use it to support discussion and the evaluation of proposed new actions in the workshop.

Table of Contents

Results of the SOM analysis for hazardous substances

Background information for understanding and interpreting the results

The sufficiency of measures (SOM) analysis involves estimating the status of the marine environment at a specific future point in time, given measures in existing policies, their implementation status and projected development of human activities over time (Figure 1).

The main components of the analysis are assessing: the contribution of activities to pressures (Step 3), the effect of existing measures on pressures (Step 4), the effect of development of human activities on pressures (Step 5), and the effect of changes in pressures to environmental state (Step 6). The result is the state (in terms of pressure reductions or improvements in environmental components) in 2030-2035, which can then be compared to the threshold for good environmental status (GES), where currently available (Step 7). This allows assessing the probability to achieve GES with existing measures.

Note the distinction between pressure inputs and pressures (Figure 1). For a variety of reasons, the input of a pressure is often measured rather than the pressure itself, for example: ease of measurement, generation of data relevant to regulation, and/or the presence of significant time lags. In the SOM analysis, pressure inputs and pressures have been distinguished from each other, and their relationship is one of the following: 1) pressure input and pressure are equivalent or assumed to be equivalent, 2) pressure input and corresponding pressure are present in the analysis but no connection is made between them, or 3) only the pressure is present in the model.

A detailed description of the SOM methodology and data collection is presented in this document.

The methodology for the SOM analysis is designed to accommodate the broad array of topics relevant in the HELCOM region, and to enable a regional-level analysis. It balances between state-of-the-art knowledge, availability of data, and advice taken onboard from various HELCOM meetings and bodies.

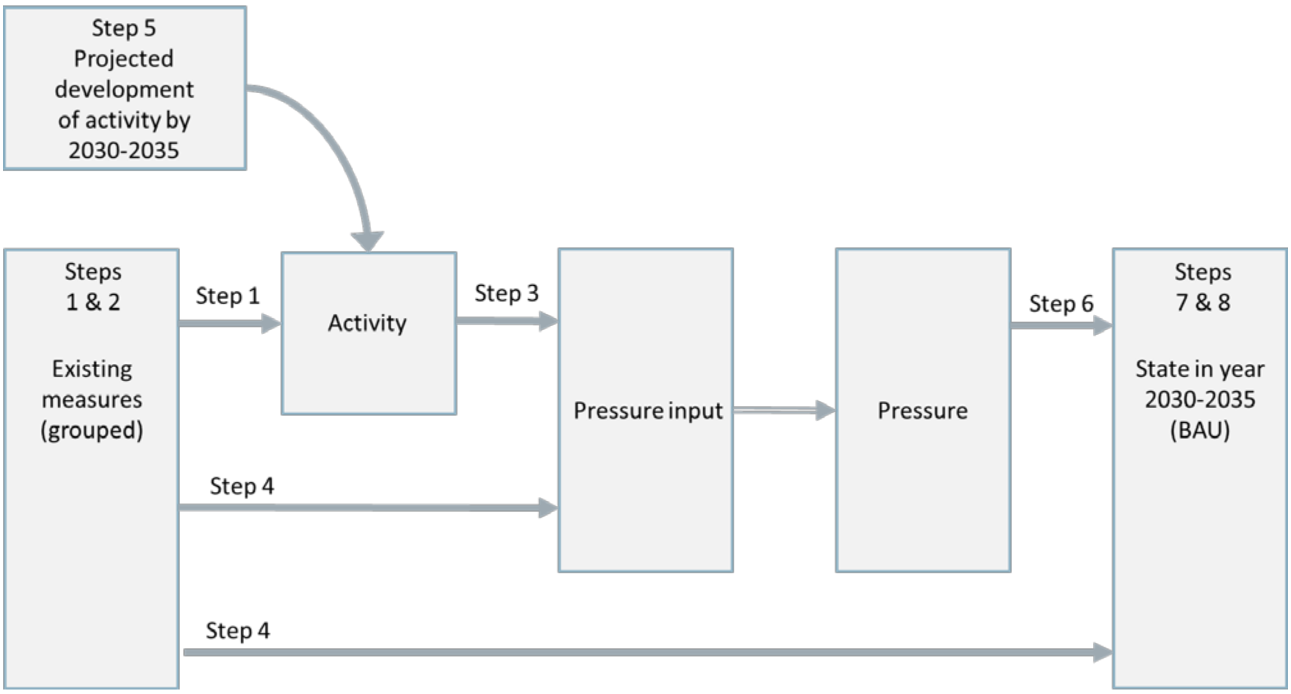


Figure 1. General schematic of the main components of the SOM analysis

Step 1. Existing measures and measure types, including activity-measure links
Step 2. Time-lags for measure effects on pressures
Step 3. Contribution of activities to pressures
Step 4. The effects of measure types
Step 5. Projected development of human activities
Step 6. Effect of changes in pressures on state components
Step 7. Comparison of business-as-usual and good status and gap assessment
Step 8. Effect of time lags in the recovery of state components

The SOM results are presented in the format of percent shares or probabilities. The main finding of the analysis is the probability to achieve GES or specific state improvements/pressure reductions, taking into consideration the effects of existing measures and changes in the activities on pressures. The contribution of activities to pressures, the effect of measures on pressures, and the significance of pressures to state components are presented as percent values (e.g. how many percent would the measure reduce the pressure). Results are presented mainly in tables, which show the the most likely (expected) values and standard deviations. Standard deviation is a way of showing the variation in the values. When it is high, values are spread over a wider range, and when it is low, values are closer to the most likely value. Figures and graphs presenting distributions are mainly included in the annexes. They show the same results as the tables but allow either more detailed information or alternative visualisation of the results.

For the data that are based on expert surveys, the confidence rating gives the most common answer to experts' assessment of the confidence in their own survey responses on a low-moderate-high scale. More detailed information on how each result has been calculated is presented in a separate document.

This document presents the results based on the expert-based data (survey responses). Literature data on the effectiveness of measures has been collected but are not included at this point. The projected development of human activities is based on the most likely future development until 2030 (for details, see the methodology document).

Application of the SOM approach to hazardous substances

The SOM analysis for hazardous substances evaluates the sufficiency of measures in achieving good status, considering the effects of existing measures and future development of human activities. The spatial resolution (level of detail) differs across the data components of the SOM analysis. All assessment areas are based on the 17 HELCOM scale 2 sub-basins and the assessment area ranges from the single Baltic Sea to individual sub-basins. However, for hazardous substances, all expert data are reported at the Baltic Sea scale, while data on existing measures and their implementation status exists at the sub-basin level. When the topic of hazardous substances interacts with other topics, e.g. birds, mammals and benthic habitats, smaller spatial scales may be used to reflect spatial variation in those topics. Table 1 shows the origin and spatial resolution for the data components in the SOM analysis for hazardous substances.

Table 1. Data for hazardous substances (more information on data collection is available in the methodology document).

Data component	Origin of data	Spatial resolution
Activity-pressure contributions	Expert evaluation	Whole Baltic Sea
Existing measures	Literature review, Contracting Parties	17 sub-basins
Effectiveness of measures	Expert evaluation	Whole Baltic Sea
Development of human activities	Literature review, existing data and projections	Whole Baltic Sea
Pressure-state links	Expert evaluation	Whole Baltic Sea
Time lags	Expert evaluation	Whole Baltic Sea

Hazardous substances have been considered in a variety of ways in the SOM analysis. The primary focus is on the full analysis of four selected substances which are evaluated at each step of the SOM analysis. These substances are mercury, perfluorooctane sulphonate (PFOS), tributyltin (TBT), and diclofenac, which were selected to represent a variety of chemical attributes and management regimes. The input of these substances is tracked by the pressure inputs: *input of mercury, input of PFOS, input of TBT, and input of diclofenac* (Figure 2), input being defined as new emissions to the environment or release/resuspension of loads otherwise removed from the system (e.g. dredging releasing buried TBT) caused by human activity. The concentrations of these substances are then tracked as the state components*: concentration of mercury, concentration of PFOS, concentration of TBT, and concentration of diclofenac* (Figure 1). These [1] reflect the structure of the HELCOM indicators ”Metals (lead, cadmium and mercury)”, ”Perfluorooctane sulphonate”, ”TBT and imposex”, and ”Diclofenac”, as well as MSFD criteria D8C1. These states have established HELCOM GES thresholds (mercury, PFOS) or preliminary test thresholds (TBT, diclofenac) and are evaluated only for the[2] primary testing matrices[3] (water, sediment, biota). It is important to note that these selected substances are only indicative of a much broader number of substances and substance groups with potentially harmful effects in the Baltic Sea.

[1] Marine Strategy Framework Directive criteria D8C1 – Primary: Within coastal and territorial waters, the concentrations of contaminants do not exceed the following threshold values:
(a) for contaminants set out under point 1(a) of criteria elements, the values set in accordance with Directive 2000/60/EC;
(b) when contaminants under point (a) are measured in a matrix for which no value is set under Directive 2000/60/EC, the concentration of those contaminants in that matrix established by Member States through regional or subregional cooperation;
(c) for additional contaminants selected under point 1(b) of criteria elements, the concentrations for a specified matrix (water, sediment or biota) which may give rise to pollution effects. Member States shall establish these concentrations through regional or subregional cooperation, considering their application within and beyond coastal and territorial waters.
Beyond territorial waters, the concentrations of contaminants do not exceed the following threshold values:
(a) for contaminants selected under point 2(a) of criteria elements, the values as applicable within coastal and territorial waters;
(b) for contaminants selected under point 2(b) of criteria elements, the concentrations for a specified matrix (water, sediment or biota) which may give rise to pollution effects. Member States shall establish these concentrations through regional or subregional cooperation.

[3] Diclofenac is tested in both seawater and biota but neither matrix has been designated as the primary testing matrix. For the SOM analysis, seawater is used due to the better geographic coverage of samples.

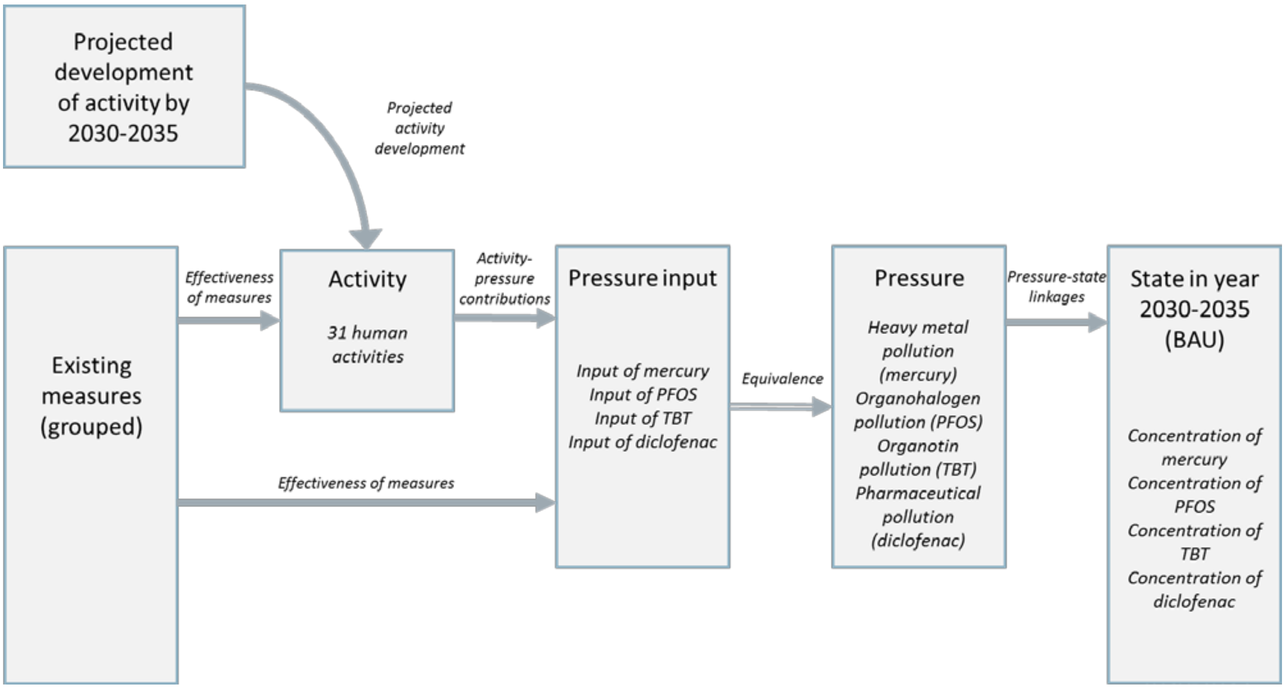


Figure 2. Schematic of the SOM analysis for the four analysed hazardous substances (mercury, PFOS, TBT, diclofenac). The pressure input and pressure relevant to each substance are assumed to be equivalent.

Hazardous substances are also considered in the SOM analysis as more general pressures on the Baltic Sea environment. In the expert surveys on pressure-state linkages, six general pollution pressures related to hazardous substances could be selected when identifying the most significant pressures linked to any of the state components included in the SOM analysis: *Heavy metal pollution, Organohalogen pollution, Organotin pollution, Pharmaceutical pollution, Hydrocarbon pollution, Radioactive pollution* (Figure 3). These pressures are more broadly defined than the HELCOM indicators but do correspond with the MSFD criteria D8C1 (see footnote 1). These pressures are included in the SOM analysis to capture the overall effects of hazardous substances on the environment, to not limit the analysis to the four substances, and to accommodate the varying knowledge of hazardous substances of experts in other fields, e.g. marine mammals, waterbirds, etc. Management and monitoring of hazardous substances requires the substance specific approach taken for mercury, PFOS, TBT and diclofenac. However, accounting for the overall impact of hazardous substances in the SOM analysis is facilitated via this more general approach.

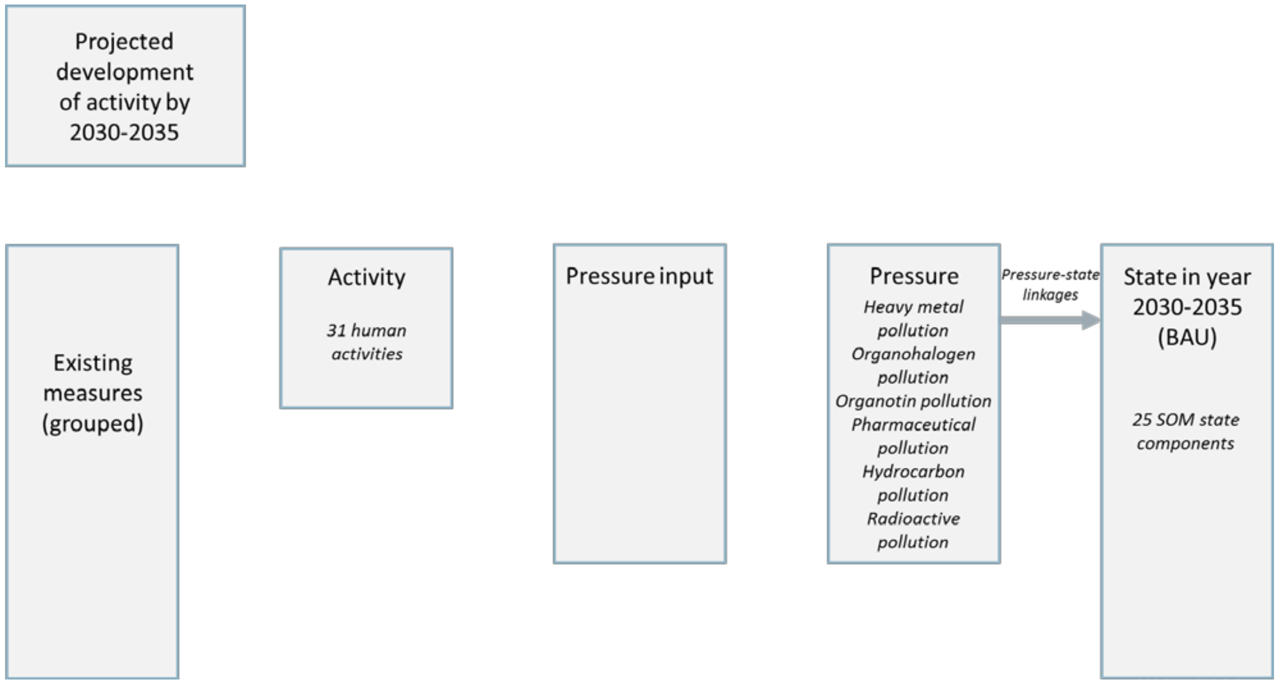


Figure 3. Schematic of the SOM analysis for general hazardous substance pressures. No connection is made between these pressures and existing measures, human activities, or pressure inputs in the SOM analysis. The pressures also represent broad classes of substances rather than specific substances.

Are existing measures sufficient for achieving good status?

Concentrations of mercury and PFOS have established HELCOM GES thresholds and concentrations of TBT and diclofenac are currently evaluated by applying preliminary GES thresholds. Thus, it is possible to evaluate whether existing measures are sufficient in achieving GES. The assessment compares the state improvement from existing measures to the state improvement required to achieve GES. The calculation of sufficiency of measures takes into account all the components of the SOM analysis: the activity-pressure contributions, effectiveness of measure types in reducing pressure inputs, links between existing measures and measure types, projected pressure input reductions from existing measures, development of human activities, significance of pressures to state components and pressure reductions required to achieve GES. The analysis assumes that all existing measures are fully implemented and that there are no time lags between the input of hazardous substances and their concentrations.

The sufficiency of measures result is presented as the probability of achieving GES as a function of the total pressure reduction by substance at the scale of the entire Baltic Sea (Figure 4). The function shows what is the probability (%) to achieve GES (y-axis) with each level (%) of total pressure reduction (x-axis) from the 2016 concentration level.

Figure 4 shows the expected reduction in pressures as the black line. 80% of the pressure reduction observations fall within the grey shaded area (area between 10th and 90th percentile). Not that when the pressure reductions are small, these are not necessarily visible in the figure. Pressure reductions are calculated based on the reduction in pressure inputs (input of mercury, TBT, PFOS and diclofenac) (Table 6), significance of different pressures to the concentrations of these substances (Table 4), and spatial weighting to account for the target area of existing measures.

In Figure 4, the dashed line shows what is the maximum achievable pressure reduction including only those pressures that can be reduced with measure types and that are linked to concentrations of mercury, PFOS, TBT and diclofenac in the SOM analysis. It is defined based on the significance of pressures to the concentrations (Table 4). In the case of mercury, TBT, PFOS and diclofenac, the SOM analysis has been able to account for 67-85% of the pressures linked to the substances, but several significant pressures are also excluded, such as the effects of eutrophication and change in hydrologic conditions (see Table 4).

Table 2 includes the same information as Figure 4 in a table format, showing the expected pressure reductions from existing measures, the probability to achieve GES with such a pressure reduction, and the maximum pressure reduction that could be achieved with the pressures that are included in the SOM analysis.

Figure 4 (right panel) and Table 3 provide additional information on the pressure-state linkages and the certainty of the estimates. Figure 4 (right) shows the probability distribution for the required reduction in total pressure (x-axis) to reach GES, based on expert responses. The figure indicates that experts have differing opinions about the pressure reductions required and that there is substantial uncertainty about the required pressure reductions (multiple peaks, distributions are wide). For example, in the case of mercury, experts seem to agree that pressure reductions that are lower than 40% will not be sufficient to achieve GES but have varying views on the size of the pressure reductions needed. Thus, there is considerable uncertainty about the link between pressure reductions and achieving GES for these four hazardous substances.

Table 3 shows the average of the mostly likely total pressure reduction required to reach GES for each substance, based on the expert responses. For all substances, experts have evaluated that it would take around 45-70% pressure reductions to achieve GES. The standard deviations are quite high compared to the most likely value, indicating that the estimates are rather uncertain. For example, there is a 95% probability that the required pressure reduction to achieve GES for diclofenac is between 29% and 62%. Confidence in Table 3 depicts the most common rating of expert’s confidence in their own responses to the question on total pressure reduction required to reach GES.

Overall, the results of the analysis indicate that existing measures are not sufficient in achieving GES for the concentrations of mercury, TBT, PFOS and diclofenac. Reductions in concentrations are around 20% for mercury, around 12% for PFOS and close to zero for TBT and diclofenac (Table 2). The probability to achieve GES is zero for mercury, TBT and diclofenac, and around 14% for PFOS (see Table 2, column Probability to achieve GES (%) with expected pressure reduction).

The near zero projections of the probability of achieving GES for TBT and diclofenac may be due to few or no existing measures to control their inputs (or remove them from historic deposits), and aspects such as natural processes (e.g. sediment burial and retention) are not included in this evaluation. The result from PFOS is unexpected due to widespread good status of PFOS through the Baltic Sea in 2016 (37/38 areas in good state; HELCOM 2018). This could potentially be a result of experts evaluating the state of PFOS for all potential testing matrices rather than for the primary matrix of fish muscle. The secondary matrix seawater fails to achieve good status in all tested areas (0/8 areas in good status; HELCOM 2018). Alternatively, this may reflect concerns about future input from legacy sources or broader concern about PFAS generally.

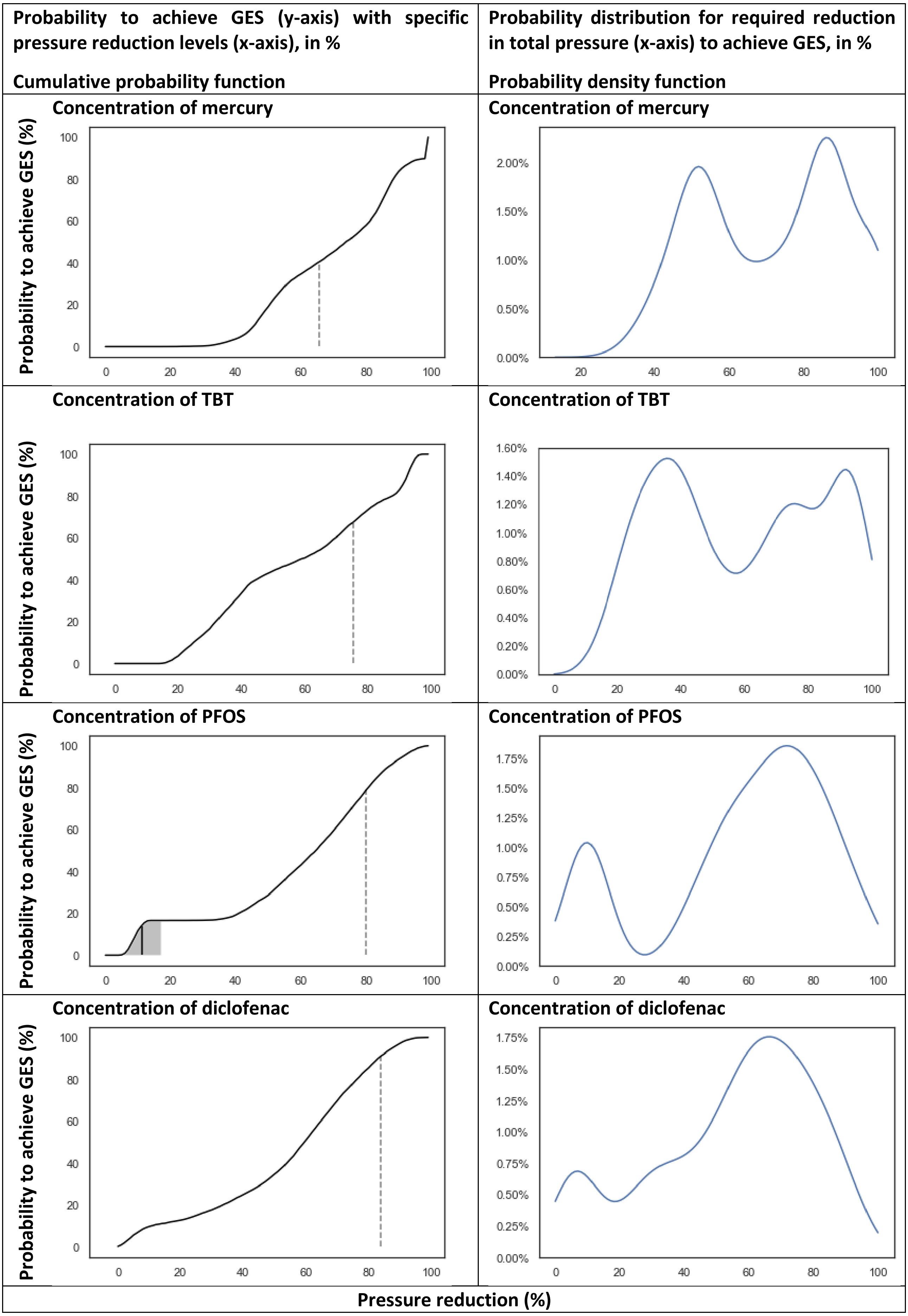


Figure 4. Probability distributions of pressure-state linkages

Left panel: Probability of achieving GES as a function of total pressure reduction for concentration of mercury, TBT, PFOS and diclofenac from 2016 level. The cumulative probability function shows the probability (%) to achieve GES (y-axis, vertical) with each level (%) of total pressure reduction (x-axis, horizontal). The expected reduction in total pressure is shown as a black line and 80% of the observations fall inside the grey shaded area (not always visible in the figure, see Table 2). The dashed line shows the maximum achievable pressure reduction including those pressures that are linked to the concentration of the substance and can be reduced with measure types included in the SOM analysis, calculated based on the significance of pressures to the concentration. For example, the expected reduction in mercury concentration is 19.8%, which has a 0% probability to lead to achieving GES (see Table 2).

Right panel: Probability distribution for required reduction in total pressure (x-axis) to achieve GES for concentration of mercury, TBT, PFOS and diclofenac, in %. The probability density function shows the probability distribution of the pooled expert responses on how much pressures should be reduced to achieve GES. Pressure reduction is presented on the x-axis and probability on the y-axis. The graphs have multiple peaks and the distributions are wide, which indicate that expert have varying views on the pressure reductions required to achieve good state. For example, some experts are of the opinion that reductions around 10% would be sufficient to achieve GES for PFOS, while others consider that reductions around 70-80% are required.

Table 2. Sufficiency of measures in achieving GES for concentrations of mercury, TBT, PFOS and diclofenac in the Baltic Sea. The table presents the expected values and the 10-90 percentile in brackets, which shows the range in which 80% of the observations fall in.

State	**Assessment area**	**Expected total pressure reduction (%)** (x-axis) [10 percentile – 90 percentile]	**Probability to achieve GES (%) with expected pressure reduction** (y-axis) [10 percentile – 90 percentile]	**Maximum possible pressure reduction with pressures included in the SOM analysis (%)** (x-axis, dashed line)
Mercury concentration	Baltic Sea	19.8 [15.5-24.3]	0 [0-0]	66.7
TBT concentration	Baltic Sea	2.6 [-2.4-7.5]	0 [0-0]	76.4
PFOS concentration	Baltic Sea	12.4 [5.9-19.4]	13.9 [0.2-16.7]	80.9
Diclofenac concentration	Baltic Sea	-0.8 [-2.82.2]	0 [0-0.8]	84.9

Table 3. Mostly likely percent total pressure reduction required to reach GES for each substance. Standard deviation is given in parentheses. Note: values are calculated directly from expert survey data and will differ somewhat from model results. Confidence depicts the most common rating of expert's confidence in their own responses to the question on total pressure reduction required to reach GES.

Colour scale for the percent reduction in pressures required to reach GES in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the reduction required estimate (based on the relative size of the standard deviation to the expected value): low: ○○●, moderate: ○●●, high: ●●●

State	**Mercury concentration**	**TBT concentration**	**PFOS concentration**	**Diclofenac concentration**
Most likely pressure reduction required (%)	69.0 (15.5) ●●●	55.0 (27.2) ○●●	51.3 (20.9) ○●●	45.6 (24.0) ○●●

Confidence	Moderate	Moderate	Moderate	Moderate
Number of experts	11	8	8	11

What are the pressures contributing to the state components?

This section presents the significance of different pressures to the concentrations of mercury, TBT, PFOS and diclofenac based on the responses to the expert surveys. They are all assessed at the Baltic Sea scale and enable comparisons across substances. Based on the responses, the number of pressures affecting the concentration varies from 3 (diclofenac) to 9 (mercury) (Table 4).

Confidence in Table 4 depicts the most common rating of expert's confidence in their own responses to the significance of pressures question, and it is high for most substances. As expected, the most significant pressure is in all cases the pollution associated with the specific hazardous substance in question, with significance of 47-81%, but also several other pressures are considered to affect the concentrations. Change in hydrologic conditions is evaluated to be significant for the concentrations of all substances, and physical disturbance of marine habitats is particularly significant for TBT concentration.

Table 4. Significance of pressures (%) affecting the concentration of mercury, TBT, PFOS and diclofenac in the Baltic Sea.

Colour scale for the significance of the pressure to the state variable (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%

Pressures for which we cannot quantify the link between the pressure input, pressure and state in the SOM analysis are highlighted in grey, e.g. we cannot link reductions in nutrient inputs to reductions in the effects of eutrophication and further to concentrations of hazardous substances.

State component Pressure	Mercury concentration	TBT concentration	PFOS concentration	Diclofenac concentration
Effects of non-indigenous species		7.3		
Physical disturbance of marine habitats		21.8	2.1	3.8
Physical loss of marine habitats	7.8			
Effects of marine litter (excluding bycatch in ghost nets)			8.5	
Effects of eutrophication	3.3	1.8		
River, lake, or land habitat loss/degradation	5.6	1.8	12.8	
Hydrocarbon pollution	2.2			
Radioactive pollution	4.4			
Organohalogen pollution (e.g. PFOS, PCBs, PBDEs, dioxins)			66.0	
Organotin pollution (e.g. TBT)		47.3		
Heavy metal pollution	47.8	5.5		
Pharmaceutical pollution	5.6			81.1
Change in hydrologic conditions	18.9	14.5	10.6	15.1
Human-induced food web imbalance	4.4			
Confidence	High	High	High/ moderate	High
Number of experts	11	7	6	9

What are the time lags between pressure and state?

Information on time lags between reducing the pressure inputs and concentrations was collected from experts, who evaluated how long it would take to achieve GES assuming sufficient measures were implemented. Table 5 shows the distribution and average of the answers for the four substances.

The likely time lag for mercury is considered to be the longest out of the substances, with an average of 38 years. Achieving GES for TBT and PFOS with sufficient measures is evaluated to take on average 14 and 17 years, respectively, while time lag for diclofenac is considerably smaller, on average 5 years. These expert evaluations indicate that even with sufficient measures, it takes time to achieve GES concentrations in the Baltic Sea for the selected (and likely other) hazardous substances.

The main reported factors contributing to the time lag for mercury were high retention in sediments leading to long-term release into the Baltic Sea, slow burial rates, and that it is non-degradable. The primary reported factors for TBT were its long degradation time and local sedimentation rates. Degradation time and sedimentation rates were also reported for PFOS, in addition to the long residence time of water in the Baltic Sea. The primary reported factor influencing diclofenac was its degradation time.

Additional information on time lags related to hazardous substances will be produced in HELCOM ACTION project WP5.

Table 5. Time lags in achieving GES with sufficient measures. Responses with clear reference to time lags due to lags in the implementation of measures have been excluded.

Time lag	Mercury	TBT	PFOS	Diclofenac
0 years (no time lag)	0	0	0	0
0-5 years	0	0	1	6
6-10 years	1	4	1	1
11-25 years	4	1	3	1
26-50 years	3	1	1	0
51-100 years	3	0	0	0
More than 100 years	0	0	0	0
Excluded	0	2	1	3
Average	37.7	14.2	16.7	5.0
SD	24.7	11.1	11.0	5.0
Confidence	1.9	2.0	2.2	2.1
Number of experts	11	6	6	8

What are the reductions in pressure inputs from existing measures?

Table 6 shows the effects of existing measures in reducing the input of hazardous substances to the Baltic Sea. They are based on the activity-pressure contributions, effectiveness of measure types, links between existing measures and measure types, and projected development of activities. The activity-pressure and the effectiveness of measures data are at the Baltic Sea level, and thus the total pressure reductions are presented as an average for the entire Baltic Sea. The projected pressure reductions account for the joint impacts across the measure types, as well as the spatial area where the pressures can be reduced to avoid overestimating the pressure reductions.

Of the four hazardous substances, the *input of mercury* is expected to be reduced the most (on average 37.4%). *Input of PFOS* is expected to decrease on average 10.8% in the Baltic Sea. Negative values for the *input of TBT* and *diclofenac* imply that the input of these substances is projected to increase. This happens when the pressure reductions from existing measures are unable to compensate for the pressure increases caused by the projected future development of activities. For TBT, measures to control inputs (other than a ban on use) are not applied in the Baltic Sea, and therefore this result is influenced only by the projected development of activities, for example activities that may increase release from existing sources or deposits (e.g. shipping infrastructure). For the *input of diclofenac*, existing measures are implemented in the Bay of Mecklenburg, Arkona Basin, and Bornholm Basin. In the other sub-basins, projected future changes in the activities lead to increased inputs of diclofenac.

Further details on the effectiveness of different measure types and activity-pressure contributions can be found in Tables 7 and 8.

Table 6. Projected total reductions (%) in the input of hazardous substances from existing measures in the Baltic Sea. The table depicts the most likely/expected values of reductions in pressure inputs and gives standard deviations in parenthesis.

Colour scale for the pressure reductions in percent (based on the expected value):
<0%, 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the pressure reductions (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Pressure Area	Input of mercury	Input of TBT	Input of PFOS	Input of diclofenac
Baltic Sea	37.4 (2.7) ●●●	-5.7 (2.7) ○●●	18.1 (5.3) ●●●	-2.1 (1.0) ○●●

How effective are measure types in reducing pressure inputs?

This section presents the percent effectiveness of measure types in reducing the input of mercury, TBT, PFOS and diclofenac from a specific activity. Data on the effectiveness of measure types originate from expert surveys and are at the Baltic Sea scale.

In the following, percent effectiveness is presented per pressure input, activity and measure type, and pooled over experts. The effectiveness estimates can be compared across measure types to assess, on average, how effective they are in relation to each other in reducing the pressure from the specific activities, or across activities to assess which measure type could be the most effective for each activity.

Tables 7.1 – 7.4 present the expected percent effectiveness of the measures type and its standard deviation. Confidence in Tables 7.1 – 7.4 depicts the most common rating of expert's confidence in their own responses to the effectiveness of measure types question. Annex 1 presents the distributions of the effectiveness of measure types in controlling the input of the four substances for additional information.

The input of mercury is influenced by eight different activities (Table 7.1). In this case, each measure type can only reduce the pressure from a single activity. The measure types of *local/state/national targets to eliminate coal fired energy production* and *treatment of scrubbing water from ships before disposal to reduce mercury* are the only two that are possible to reduce the pressure input more than 60%. They reduce the pressure input from the activities *non-renewable energy generation (fossil fuel and nuclear powerplants)* and *transport – shipping (incl. anchoring, mooring)*, respectively. The effectiveness of the rest of the measure types ranges between 20-60% in reducing the input.

Estimates of the effectiveness of measure types are used to assess the effects of existing measures in reducing the input of hazardous substances to the Baltic Sea and to calculate pressure reductions from existing measures by 2030-2035.

Table 7.1 Effectiveness of measure types (%) in reducing the potential *input of mercury.* The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the expected effectiveness, and standard deviation is given in parenthesis. Measure types that are not relevant for the activity are labelled as NA.

Colour scale for the effectiveness of a measure type in percent (based on the expected value):
0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Activity / Measure type	Non-renewable energy generation (fossil fuel and nuclear powerplants)	Transport – land (cars and trucks, trains), including infrastructure	Industrial uses (oil, gas, industrial plants)	Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)	Solid waste (e.g. land-based disposal of dredged material, landfill, solid waste streams)	Restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)	Transport – shipping (incl. anchoring, mooring)	Activities and sources outside the Baltic Sea Region
Local/state/national targets to eliminate coal fired energy production	68.9 (29.5) ○●●	NA	NA	NA	NA	NA	NA	NA
Continued application of the EU Emissions Trading System	31.9 (17.8) ○●●	NA	NA	NA	NA	NA	NA	NA
Updated EU mercury storage regulation	NA	NA	29.2 (21.90) ○○●	NA	NA	NA	NA	NA
Sand capping or removal of existing cellulose deposits	NA	NA	29.2 (22.9) ○○●	NA	NA	NA	NA	NA
Ban on manufacturing processes where mercury or mercury compounds are used as a catalyst (e.g. In vinyl chloride monomer production	NA	NA	21.8 (22.8) ○○●	NA	NA	NA	NA	NA
Ban on manufacturing processes where mercury is used as an electrode (e.g. in chlor-alkali production; Na or K methylate/ethylate production	NA	NA	29.8 (23.2) ○○●	NA	NA	NA	NA	NA
Ban on export of Mercury (II) sulphate (HgSO4, CAS RN 7783-35-9) and Mercury (II) nitrate (Hg(NO3)2, CAS RN 10045-94-0)	NA	NA	21.4 (22.1) ○○●	NA	NA	NA	NA	NA
Treatment of scrubbing water from ships before disposal to reduce mercury	NA	NA	NA	NA	NA	NA	65. (30.4) ○●●	NA

Reduce re-suspension from sediments, by limiting restructuring of seabed to areas with low concentrations	NA	NA	NA	NA	NA	49.9 (25.1) ○●●	NA	NA
Tighter allowed contamination levels during dredging activities	NA	NA	NA	NA	NA	42.9 (24.6) ○●●	NA	NA
Perform dredging under conditions (low water pH and temperature) that lower desorption from sediments, i.e. Preferable during winter	NA	NA	NA	NA	NA	26.7 (22.9) ○○●	NA	NA
Increased fuel efficiency standards	NA	37.0 (25.7) ○○●	NA	NA	NA	NA	NA	NA
Increased electrification of transportation fleets	NA	40.2 (23.5) ○●●	NA	NA	NA	NA	NA	NA
Minamata convention	NA	NA	NA	NA	NA	NA	NA	45.1 (16.6) ○●●
Paris agreement	NA	NA	NA	NA	NA	NA	NA	43.6 (19.9) ○●●
EU mandatory use of dental amalgam separators retaining at least 95% of amalgam particles	NA	NA	NA	39.4 (24.2) ○●●	NA	NA	NA	NA
5% increase in EU mandatory WEEE recycling levels	NA	NA	NA	NA	35.8 (31.2) ○○●	NA	NA	NA
Further restrictions on storage and disposal of waste/dredged material containing mercury	NA	NA	NA	NA	43.3 (29.8) ○○●	NA	NA	NA
Eurasian Economic Union restrictions on hazardous substances in electrical products	NA	NA	NA	NA	29.6 (21.3) ○○●	NA	NA	NA
Confidence	Moderate	Low-High	Low	Moderate-High	Moderate	Moderate	Moderate-High	Moderate
Number of experts	11	11	10-11	11	6	11	11	11

Table 7.2 shows the effectiveness of measure types to in reducing the input of TBT from three activities. In this case, each measure type can only reduce the pressure from one activity. Each activity has one measure type which has an effectiveness of over 60%. They are: *reduce re-suspension from sediments, by limiting restructuring of seabed to areas with low concentrations* for activity *restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)*, *boat washing restrictions* for *tourism and leisure activities (boating, beach use, water sports, etc.)*, and *in water hull cleaning regulation* for *transport – shipping (incl. anchoring, mooring)*.

Table 7.2 Effectiveness of measure types (%) in reducing the potential *input of TBT.* The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the expected effectiveness, and standard deviation is given in parenthesis. Measure types that are not relevant for the activity are labelled as NA.

Colour scale for the effectiveness of a measure type in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Activity / Measure type	Restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)	Tourism and leisure activities (boating, beach use, water sports, etc.)	Transport – shipping (incl. anchoring, mooring)
Reduce re-suspension from sediments, by limiting restructuring of seabed to areas with low concentrations	64.3 (21.1) ○●●	NA	NA
Tighter allowed contamination levels during dredging activities	56.4 (15.7) ●●●	NA	NA
Perform dredging under conditions (low water pH and temperature) that lower desorption from sediments, i.e. Preferable during winter	30.3 (20.2) ○○●	NA	NA
Restrictions on anchoring zones in highly contaminated areas	NA	NA	32.5 (23.7) ○○●
In water hull cleaning regulation	NA	NA	62.0 (23.7) ○●●
Implement technologies for the degradation of TBT from sediment (e.g. chemical oxidation, bioremediation)	46.1 (20.8) ○●●	NA	NA
Boat washing restrictions	NA	69.0 (33.1) ○●●	NA
Monitoring of tin in leisure boat hulls	NA	19.1 (11.7) ○○●	NA
Confidence	Moderate	Moderate	High
Number of experts	10	10	10

Table 7.3 shows the effectiveness of measure types in reducing the input of PFOS from five activities. The input from activities *transport – air, including infrastructure* and *urban uses (land use), including storm water runoff* can only be reduced by a single measure type. *Clean-up of contaminated sites* is the most effective measure type in reducing the pressure input from the activities *industrial uses (oil, gas, industrial plants)* and *solid waste (e.g. land-based disposal of dredged material, landfill, solid waste streams)*. The measure type *implement technologies to remove PFOS from wastewater (e.g. activated carbon or high pressure membrane*

systems) is the most effective measure type for reducing the pressure input from *waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering waste water systems e.g. microplastics, pharmaceuticals, etc.)*.

Table 7.3 Effectiveness of measure types (%) in reducing the potential *input of PFOS.* The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the expected effectiveness, and standard deviation is given in parenthesis. Measure types that are not relevant for the activity are labelled as NA.

Colour scale for the effectiveness of a measure type in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Activity **Measure type**	**Transport – air, including infrastructure**	**Urban uses (land use), including storm water runoff**	**Industrial uses (oil, gas, industrial plants)**	**Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)**	**Solid waste (e.g. land-based disposal of dredged material, landfill, solid waste streams)**
Stockholm convention PFOS accepted use and specific exemptions limited to: insect baits, metal plating in a closed loop, fire-fighting foams	NA	NA	28.8 (21.6) ○○●	29.8 (27.0) ○○●	19.3 (24.7) ○○●
Stockholm convention PFOS lists no accepted uses or exemptions	NA	NA	52.2 (21.4) ○●●	32.5 (28.0) ○○●	29.8 (27.9) ○○●
Clean-up of contaminated sites	NA	NA	59.4 (28.5) ○●●	NA	57.2 (26.8) ○●●
Restoration/upgrading of old landfill sites	NA	NA	NA	NA	48.9 (22.9) ○●●
Limits on PFOS concentrations in sludge used in commercial applications	NA	NA	NA	39.4 (22.3) ○●●	NA
Implement technologies to remove PFOS from wastewater (e.g. activated carbon or high-pressure membrane systems)	NA	NA	NA	53.4 (21.9) ○●●	NA
Stockholm convention ban on PFOS fire-fighting foams	NA	70.4 (27.9) ○●●	NA	NA	NA
Stockholm convention ban on PFOS in aviation hydraulic fluid	35.4 (29.9) ○○●	NA	NA	NA	NA
Confidence	Moderate	Moderate	Moderate	Moderate	Moderate
Number of experts	12	11	11	9-10	9-10

Table 7.4 shows that the input of diclofenac is mainly influenced by the activity *waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)*. For the reduction of this pressure input, the measure types *technical upgrade of wastewater treatment plants: e.g. granular activated carbon (GAC) adsorption, ozonation, UV light, nanofiltration etc.* and *alter prescription practices to lower consumption (drug dosage, pack size, alternative medicine, convert OTC access to prescription)* are the most effective ones.

Table 7.4 Effectiveness of measure types (%) in reducing the potential *input of diclofenac.* The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the most likely/expected effectiveness, and standard deviation is given in parenthesis. Measure types that are not relevant for the activity are labelled as NA.

Colour scale for the effectiveness of a measure type in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Activity **Measure type**	**Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)**
Technical upgrade of wastewater treatment plants: e.g. granular activated carbon (GAC) adsorption, ozonation, UV light, nanofiltration etc	58.2 (22.5) ○●●
Improved application of existing WWT technologies (e.g. increasing the sludge retention time, use of both nitrification and denitrification treatment steps)	30.0 (29.2) ○○●
Improved pharmaceutical take-back schemes	32.7 (22.1) ○○●
Increase public awareness of pharmaceutical take-back schemes	35.4 (19.3) ○●●
Alter prescription practices to lower consumption (drug dosage, pack size, alternative medicine, convert OTC access to prescription)	50.5 (21.2) ○●●
Confidence	High
Number of experts	11

Which activities contribute to pressures?

Table 8 shows the contribution of activities to the input of hazardous substances. Expert elicitation was used to estimate the activity-pressure relationships for the pressure concerning the input of hazardous substances (further differentiated to mercury, PFOS, TBT and diclofenac), and the assessment was done at the level of the entire Baltic Sea.

For hazardous substances, 19 different activities were identified to contribute to the pressure input (see Table 8), with the number of activities for each of the four substances varying between 5 to 12 (mercury 12, PFOS 9, TBT 10, and diclofenac 5).

For mercury, the two activities that contribute the most to the pressure are *activities and sources outside the Baltic Sea Region* (23%) and *non-renewable energy generation* (22%). Also, industrial uses have a rather strong impact (19%), while all other activities contribute with less than 10% to the input of mercury.

The activity *transport – air, including infrastructure* contributes the most to the input of PFOS (31%). Other activities that contribute between 12-17% to the pressure input are *activities and sources outside the Baltic*

Sea Region, as well as *waste waters and solid waste*. Other activities contribute with less than 10% to the input of PFOS.

For TBT, the activity with the highest contribution to the pressure is *restructuring of seabed morphology* (74%), while the other activities have only minor contributions (less than 10%).

For diclofenac, the activities with the highest contribution to the pressure are waste waters (70%) and *solid waste* (24%), while the other three activities contribute less than 10% (*agriculture*, *urban uses (land use), including storm water runoff*, and *tourism and leisure activities*).

Table 8. Activity-pressure contributions (%). The activity-pressure contributions show the percentage share the activity contributes to the input of hazardous substances. The table depicts the most likely/expected contribution (%), and standard deviation is given in parenthesis. The activity-pressure contributions for hazardous substances were assessed at the scale of the entire Baltic Sea. Activities that are not relevant for the substance are labelled as NA.

Colour scale for the contribution of the activity to the pressure in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the activity-pressure contribution estimate (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●

Activity	Input of mercury	Input of PFOS	Input of TBT	Input of diclofenac
Agriculture	NA	NA	1.0 (0.5) ○●●	2.2 (1.7) ○○●
Forestry	9.7 (1.1) ●●●	NA	NA	NA
Non-renewable energy generation (fossil fuel and nuclear powerplants)	22.1 (4.1) ●●●	NA	NA	NA
Canalisation and other watercourse modifications (dams, culverting, trenching, weirs, large-scale water deviation)	5.1 (0.6) ●●●	NA	NA	NA
Transport – air, including infrastructure	NA	31.3 (5.0) ●●●	NA	NA
Urban uses (land use), including storm water runoff	NA	7.6 (7.1) ○○●	1.0 (0.5) ○●●	2.2 (1.7) ○○●
Industrial uses (oil, gas, industrial plants)	18.1 (7.6) ○●●	7.8 (7.1) ○○●	NA	NA
Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)	5.1 (0.6) ●●●	13.2 (3.9) ●●●	6 (6.0) ○○●	71.0 (28.2) ○●●
Solid waste (e.g. land-based disposal of dredged material, landfill, solid waste streams)	5.1 (0.6) ●●●	18.3 (8.0) ○●●	4.5 (5.2) ○○●	22.4 (30.3) ○○●
Aquaculture – marine, including infrastructure	0.5 (0.1) ●●●	NA	NA	NA
Renewable energy generation (wind, wave and tidal power), including infrastructure	NA	NA	1.0 (0.5) ○●●	NA

Activity	Input of mercury	Input of PFOS	Input of TBT	Input of diclofenac
Extraction of minerals (rock, metal ores, gravel, sand, shell)	5.1 (0.6) ●●●	NA	NA	NA
Extraction of oil and gas, including infrastructure (e.g. pipelines)	0.5 (0.1) ●●●	0.8 (0.1) ●●●	NA	NA
Restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)	5.1 (0.6) ●●●	NA	73.4 (14.9) ●●●	NA
Tourism and leisure activities (boating, beach use, water sports, etc.)	NA	NA	1.0 (0.5) ○●●	2.2 (1.7) ○○●
Tourism and leisure infrastructure (piers, marinas)	NA	0.8 (0.1) ●●●	NA	NA
Transport – shipping (incl. anchoring, mooring)	NA	NA	1.0 (0.5) ○●●	NA
Transport – shipping infrastructure (harbours, ports, shipbuilding)	0.5 (0.1) ●●●	8.4 (1.3) ●●●	10.0 (10.4) ○○●	NA
Activities and sources outside the Baltic Sea Region	23.3 (4.2) ●●●	12.0 (3.8) ○●●	1.0 (0.5) ○●●	NA
Number of experts	6	6	6	6

Summary of the results

Overall, the results of the analysis indicate that existing measures are not sufficient in achieving good GES for the concentrations of mercury, TBT, PFOS or diclofenac. Reductions in concentrations are around 20% for mercury, around 12% for PFOS and close to zero for TBT and diclofenac (Table 2). The probability to achieve GES with existing measures is zero for mercury, TBT and diclofenac, and around 14% for PFOS. substances.

The near zero projections of the probability of achieving GES for TBT and diclofenac are a result of few to no existing measures controlling their input from new or existing sources. Note, the SOM analysis has not been able to fully include important natural processes, such as burial and degradation, in these calculations.

Despite the extensive bans on PFOS, experts still estimated that major reductions are required in the input of PFOS (Figure 4 and Table 4). Available additional measures to control PFOS primarily involve further tightening of Stockholm Convention restrictions on its use and clean-up of contaminated areas. Input of mercury is heavily influenced by regional use of fossil fuels and global inputs from multiple sources (Table 8) which will require significant long-term investments to control adequately.

When interpreting the results, the assumptions and generalizations that were made when collecting the input data and defining and using the data on activity-pressure contributions, measure type effectiveness and pressure-state linkages need to be taken into account. The input data are based mainly on expert elicitations rather than existing models and data, and reflect substantial uncertainty. For more information on the SOM methodology, data collection and assumptions, see this document.

Background of respondents

For the effectiveness of measures survey for hazardous substances, altogether 14 survey responses with 18 contributing experts were received. One of the answers was a group response with five contributing experts. For the pressure-state survey, 18 responses from 20 experts were received, from all contracting parties except Russia. Two of the responses were group answers with two contributing experts in each. For the activity-pressure survey, three responses were received with six contributing experts.

The number of experts contributing to the hazardous substance surveys is shown in Table 9, with the sub-topic division and geographic area presented in Table 10.

Table 9. Number of experts contributing to the hazardous substance surveys

Survey	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total
Effectiveness of measures	-	1	3	6	1	-	2	-	5	18
Pressure-state linkages	1	1	3	5	1	3	1	-	5	20
Activity-pressure contributions	-	1	1	4	-	-	-	-	-	6

Table 10. Number of responses to the hazardous substance surveys

Survey	Sub-topic	Geographic area	Response count
Effectiveness of measures	Mercury	Whole Baltic	11
	TBT	Whole Baltic	12
	PFOS	Whole Baltic	10
	Diclofenac	Whole Baltic	12
Pressure-state linkages	Mercury	Whole Baltic	12
	TBT	Whole Baltic	8
	PFOS	Whole Baltic	8
	Diclofenac	Whole Baltic	12

For the experts participating in the effectiveness of measures and the pressure state survey, more detailed information about their background is available (Table 11). Experts stated most often environmental research, chemistry, contamination and marine science as their respective field. About half of the experts had 10-20 years of experience in their field, while only 5-6% had 0-2 years of experience. Experts represented research institutions, environmental companies, government institutes, or ministries.

Table 11. Years of experience in the field for the litter effectiveness of measures survey

	Effectiveness of measures		**Pressure-state**	
Years	**Number of experts**	**Share of experts**	**Number of experts**	**Share of experts**
0-2 years	1	6 %	1	5 %
3-5 years	2	11 %	2	10 %
5-10 years	3	17 %	3	15 %
10-20 years	9	50 %	11	55 %
over 20 years	3	17 %	3	15 %

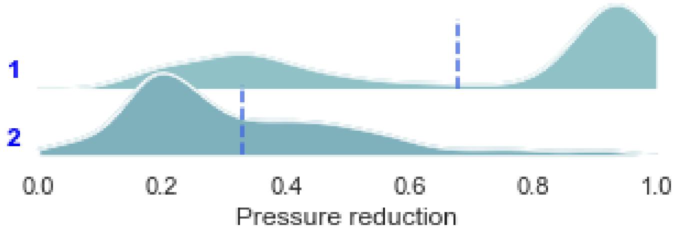
References

HELCOM (2018) Perfluorooctane sulphonate (PFOS). HELCOM core indicator report. Online. [5.8.2020], [https://helcom.fi/wp-content/uploads/2019/08/Perfluorooctane-sulphonate-PFOS-HELCOM-core-indicator-2018.pdf].

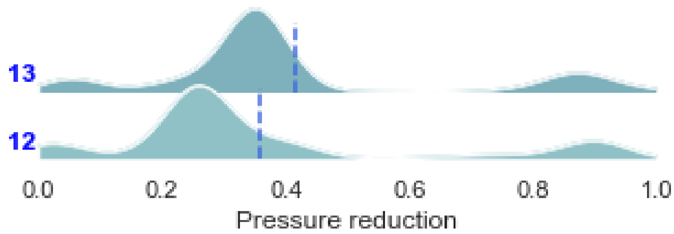
Annex 1. Supplementary results for effectiveness of measures

Table A1. Distribution of the effectiveness of measure types in controlling the *input of mercury*. The effectiveness of a measure type is the percent reduction in a pressure input resulting from a specific activity. Effectiveness values are presented as a probability distribution of effectiveness from 0% to 100% effective. The blue dotted line represents the expected value.

Pressure:	Input of mercury
Activity:	Non-renewable energy generation (fossil fuel and nuclear powerplants)
Measure type:	1: Local/state/national targets to eliminate coal fired energy production
	2: Continued application of the EU Emissions Trading System



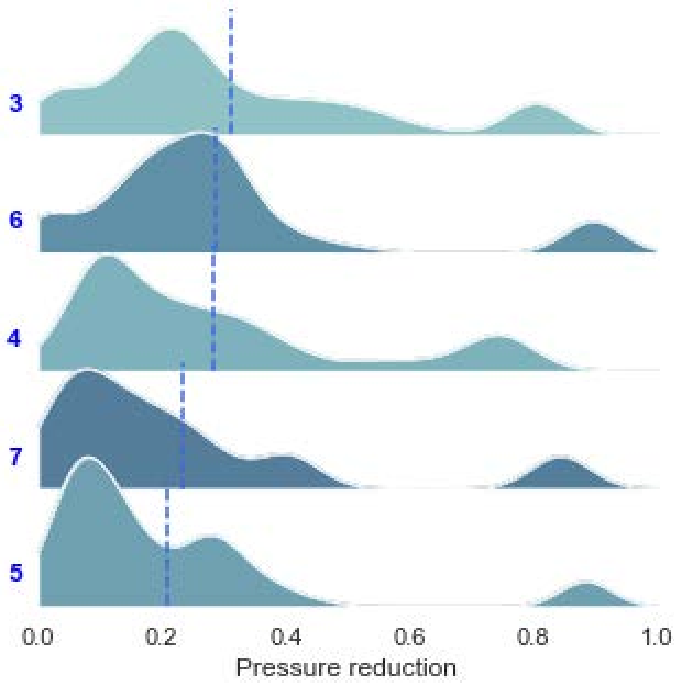
Pressure:	Input of mercury
Activity:	Transport – land (cars and trucks, trains), including infrastructure
Measure type:	13: Increased electrification of transportation fleets
	12: Increased fuel efficiency standards



Pressure:	Input of mercury
Activity:	Industrial uses (oil, gas, industrial plants)
Measure type:	3: Updated EU mercury storage regulation
	6: Ban on manufacturing processes where mercury is used as an electrode (e.g. in chlor-alkali production; Na or K methylate/ethylate production)
	4: Sand capping or removal of existing cellulose deposits

7: Ban on export of Mercury (II) sulphate ($HgSO_4$, CAS RN 7783-35-9) and Mercury (II) nitrate ($Hg(NO_3)_2$, CAS RN 10045-94-0)

5: Ban on manufacturing processes where mercury or mercury compounds are used as a catalyst (e.g. In vinyl chloride monomer production)



Pressure: Input of mercury

Activity: Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)

Measure type: 16: EU mandatory use of dental amalgam separators retaining at least 95% of amalgam particles

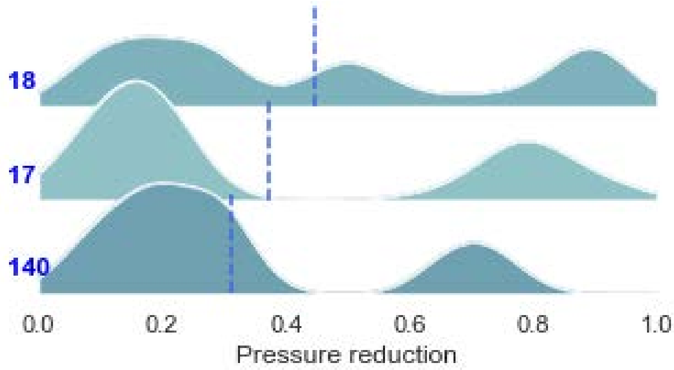
Pressure: Input of mercury

Activity: Solid waste (e.g. land-based disposal of dredged material, land-fill, solid waste streams)

Measure type: 18: Further restrictions on storage and disposal of waste/dredged material containing mercury

17: 5% increase in EU mandatory WEEE recycling levels

140: Eurasian Economic Union restrictions on hazardous substances in electrical products



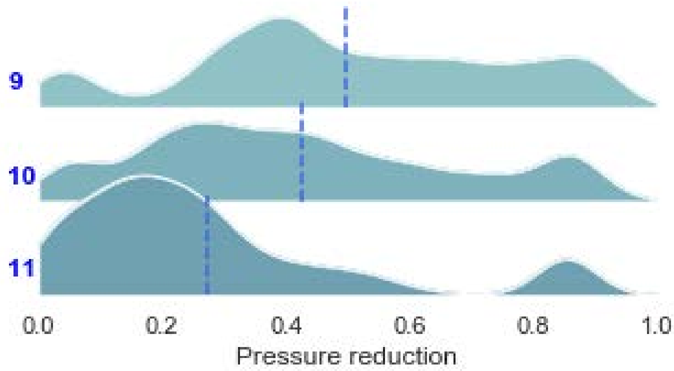
Pressure: Input of mercury

Activity: Restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)

Measure type: 9: Reduce re-suspension from sediments, by limiting restructuring of seabed to areas with low concentrations

10: Tighter allowed contamination levels during dredging activities

11: Perform dredging under conditions (low water pH and temperature) that lower desorption from sediments, i.e. Preferable during winter



Pressure: Input of mercury

Activity: Transport – shipping (incl. anchoring, mooring)

Measure type: 8: Treatment of scrubbing water from ships before disposal to reduce mercury

Pressure: Input of mercury

Activity: Activities and sources outside the Baltic Sea Region

Measure type: 14: Minamata convention

15: Paris agreement

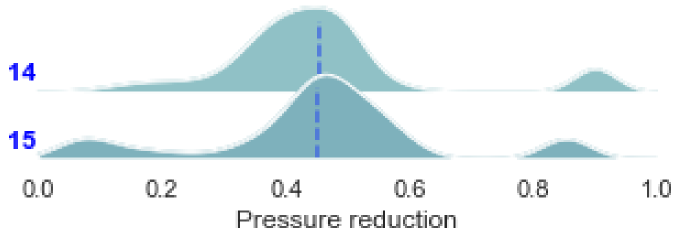


Table A2. Distribution of the effectiveness of measure types in controlling the *input of TBT*. The effectiveness of a measure type is the percent reduction in a pressure input resulting from a specific activity. Effectiveness values are presented as a probability distribution of effectiveness from 0% to 100% effective. The blue dotted line represents the expected value.

Pressure: Input of TBT

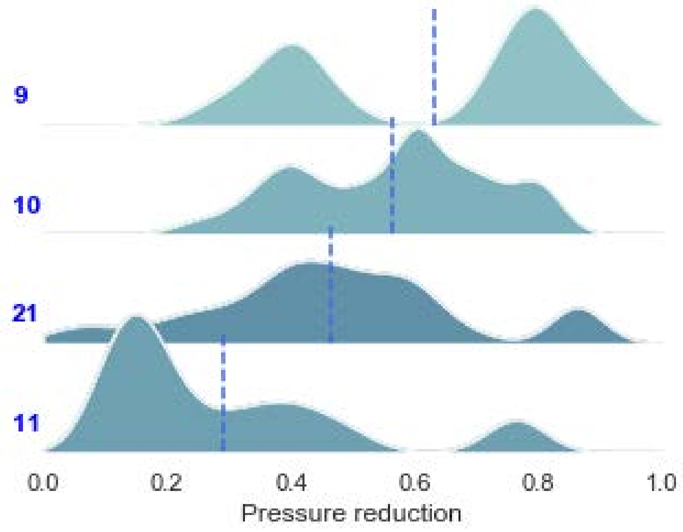
Activity: Restructuring of seabed morphology (dredging, beach replenishment, sea-based deposit of dredged material)

Measure type: 9: Reduce re-suspension from sediments, by limiting restructuring of seabed to areas with low concentrations

10: Tighter allowed contamination levels during dredging activities

21: Implement technologies for the degradation of TBT from sediment (e.g. chemical oxidation, bioremediation)

11: Perform dredging under conditions (low water pH and temperature) that lower desorption from sediments, i.e. Preferable during winter

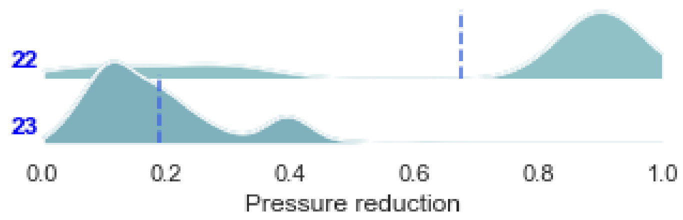


Pressure: Input of TBT

Activity: Tourism and leisure activities (boating, beach use, water sports, etc.)

Measure type: 22: Boat washing restrictions

23: Monitoring of tin in leisure boat hulls



Pressure: Input of TBT

Activity: Transport – shipping (incl. anchoring, mooring)

Measure type: 20: In water hull cleaning regulation

19: Restrictions on anchoring zones in highly contaminated areas

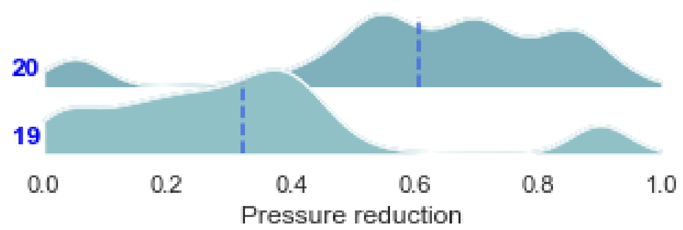
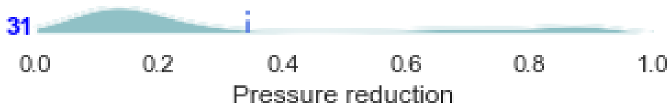


Table A3. Distribution of the effectiveness of measure types in controlling the *input of PFOS*. The effectiveness of a measure type is the percent reduction in a pressure input resulting from a specific activity. Effectiveness values are presented as a probability distribution of effectiveness from 0% to 100% effective. The blue dotted line represents the expected value.

Pressure: Input of PFOS

Activity: Transport – air, including infrastructure

Measure type: 31: Stockholm convention ban on PFOS in aviation hydraulic fluid



Pressure: Input of PFOS

Activity: Urban uses (land use), including storm water runoff

Measure type: 30: Stockholm convention ban on PFOS fire-fighting foams

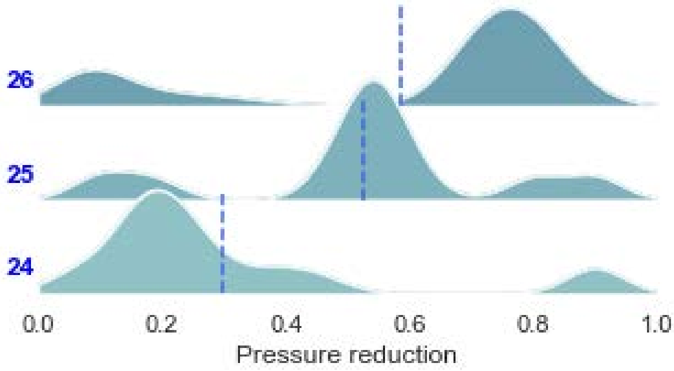
Pressure: Input of PFOS

Activity: Industrial uses (oil, gas, industrial plants)

Measure type: 26: Clean-up of contaminated sites

25: Stockholm convention PFOS lists no accepted uses or exemptions

24: Stockholm convention PFOS accepted use and specific exemptions limited to: insect baits, metal plating in a closed loop, fire-fighting foams



Pressure: Input of PFOS

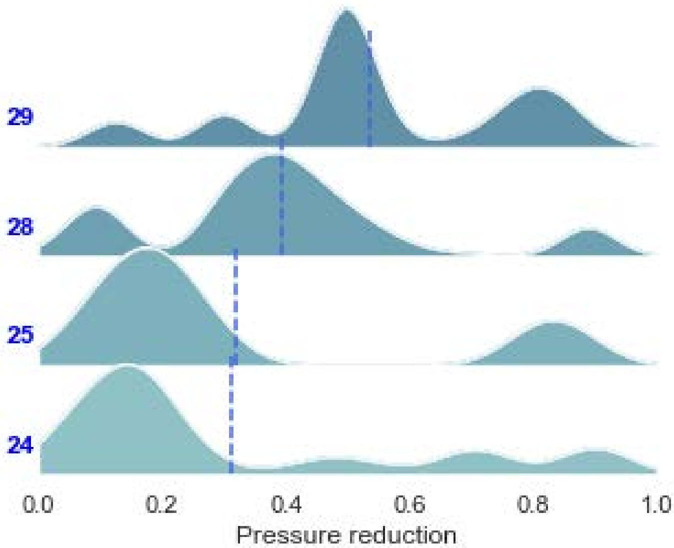
Activity: Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)

Measure type: 29: Implement technologies to remove PFOS from wastewater (e.g. activated carbon or high-pressure membrane systems)

28: Limits on PFOS concentrations in sludge used in commercial applications

25: Stockholm convention PFOS lists no accepted uses or exemptions

24: Stockholm convention PFOS accepted use and specific exemptions limited to: insect baits, metal plating in a closed loop, fire-fighting foams



Pressure: Input of PFOS

Activity: Solid waste (e.g. land-based disposal of dredged material, land-fill, solid waste streams)

Measure type: 26: Clean-up of contaminated sites

27: Restoration/upgrading of old landfill sites

25: Stockholm convention PFOS lists no accepted uses or exemptions

24: Stockholm convention PFOS accepted use and specific exemptions limited to: insect baits, metal plating in a closed loop, fire-fighting foams

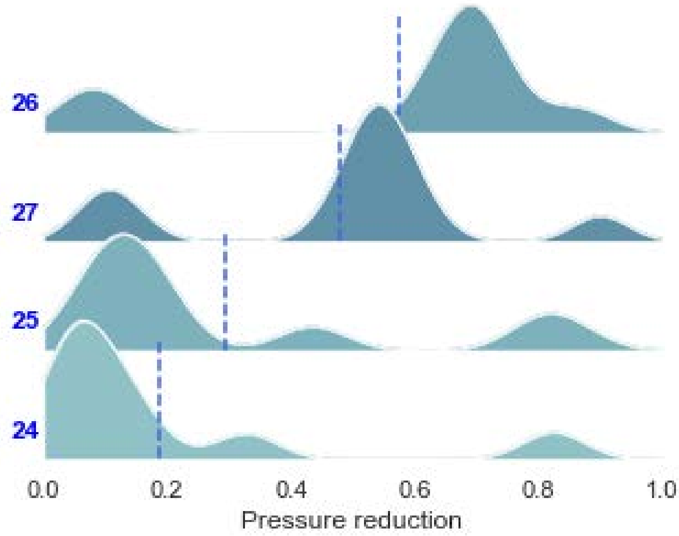


Table A4. Distribution of the effectiveness of measure types in controlling the *input of diclofenac*. The effectiveness of a measure type is the percent reduction in a pressure input resulting from a specific activity. Effectiveness values are presented as a probability distribution of effectiveness from 0% to 100% effective. The blue dotted line represents the expected value.

Pressure: Input of diclofenac

Activity: Waste waters (urban, industrial, and industrial animal farms; includes all waste streams entering wastewater systems e.g. microplastics, pharmaceuticals, etc.)

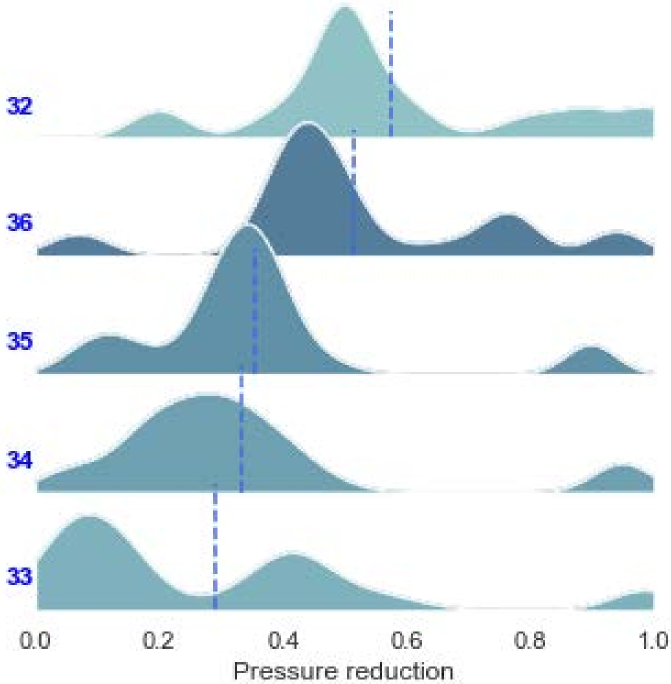
Measure type: 32: Technical upgrade of wastewater treatment plants: e.g. granular activated carbon (GAC) adsorption, ozonation, UV light, nanofiltration etc.

36: Alter prescription practices to lower consumption (drug dosage, pack size, alternative medicine, convert OTC access to prescription)

35: Increase public awareness of pharmaceutical take-back schemes

34: Improved pharmaceutical take-back schemes

33: Improved application of existing WWT technologies (e.g. increasing the sludge retention time, use of both nitrification and denitrification treatment steps)


32
36
35
34
33
0.0
0.2
0.4
0.6
0.8
1.0
Pressure reduction