boDEREC-CE
WORKPACKAGE T4

O.T4.2 DECISION-MAKING SUPPORT TOOL FOR WATERWORKS – WWDEMAST

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1. Introduction

Output O.T4.2 Decision-making Support Tool for Waterworks - wwDEMAST was created within Work package (WP) T4 - Attenuating emerging contaminants -prospects and new approaches. WP T4 aims to provide waterworks with a tool to tackle PPCP issues by capacity building activities: a comprehensive catalogue of globally existing technical and management solutions for PPCP mitigation, demonstrating efficient and feasible solutions. Furthermore, WP T4 will reduce knowledge gaps concerning PPCP and also support decision makers in EU, since theme-related legislation is still only fragmentary in EU countries. This output resulted from joint cooperation between project partners.

Decision support system or tool (DSS or DST) is defined as a system supporting decision making and includes executive information systems, executive support systems, and on-line analytical processing. During the last few decades, several tools have been designed and/or developed to inform water resource management issues such as prevention of water shortages, surpluses (floods), and water quality and/or pollution (see, for example: Delpla et al. (2014); Visanji et al. (2018)).

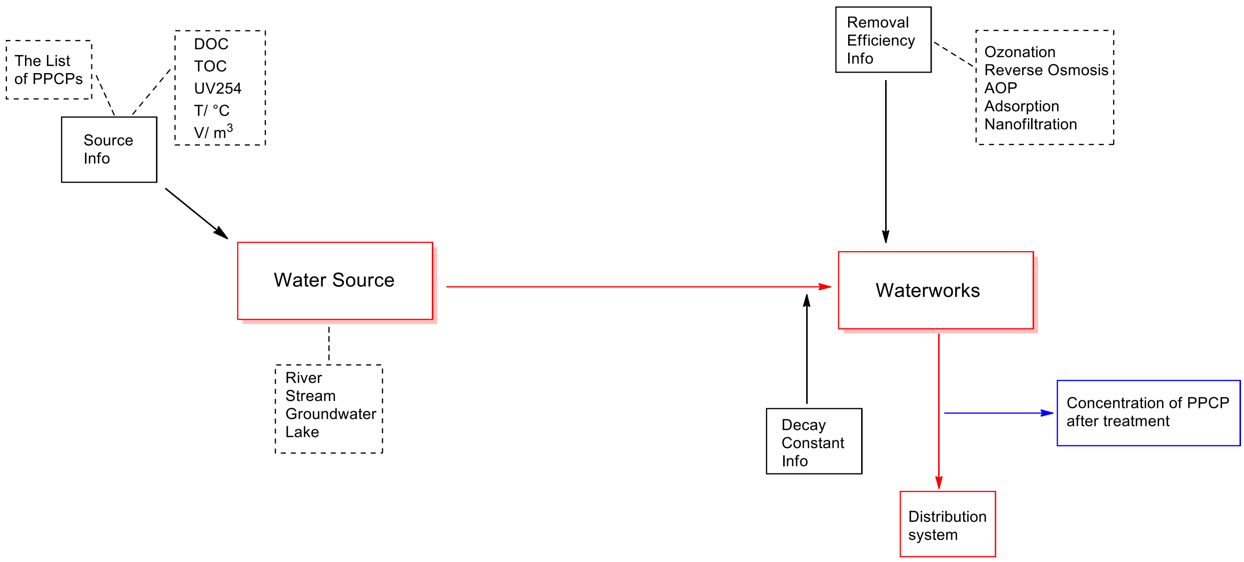
Of special importance is to develop a tool to facilitate decision makers with the complex process of selecting optimal solutions for removal of emerging contaminants - PPCPs in particular. This approach should incorporate all stages of treatment, keeping in view the end users' preferences and needs, PPCPs removal requirements, but also a total cost estimation. In addition, water leakages have to be included and considered, as requested by a revised Drinking Water Directive.

Herewith, a possible configuration with different modules is proposed. This framework is conceptual, and not intended for the immediate use. It is designed as a preliminary training set, which has orientational and, possibly, educational applications.

According to available literature (Chowdhury et al. (2018), Sard et al. (2019)) proposed models, and recommended schemes, two scenarios may be projected:

a) A simple one in which no other sources contribute to the presence of PPCPs along the water flow, i.e., between the starting water source and the final waterworks point (Scheme 1).

b) A model in which different sources contributes to the presence of PPCPs (e.g., WWTP, industry or agricultural discharges, stormwaters, animal husbandry…) (Scheme 2).



Scheme 1. A simple model with a continuous water flow between the water source and the final waterworks point. The route from water source to the distribution system depicted by red arrows, the input data depicted by black arrows, the output data depicted with a blue arrow.

2. Water source box

To build a model, one should define/select a water source from a drop-down menu (i.e., river, stream, groundwater, lake...).

3. Source info box

Additional information about the water source should be provided: general data for all water sources, and specific data for each respective water source (see below). This numerical data may be entered in a tabulated form.

3.1. The list of PPCPs

The list of PPCPs is generated from the monitoring catalo used for measurements of PPCPs in three pilot action clusters within boDEREC-CE project. Contaminant concentration at the chosen start point* (e.g., in ng/L) must be entered for a specific PPCP, or for the full set of predefined PPCPs.

3.2. General and/or Specific Data

List of general and/or specific data:

- PPCP concentration (selected from the drop-down menu),

- DOC in the source water,
- TOC in the source water,
- UV254 in the source water,
- The average temperature of water,
- Travel time/the flow rate from the chosen start point to waterworks,
- Discharge, velocity and water level and other hydrological information/data,
- The volume of the water source,
- The flow rate (minimum, maximum and mean of the time series) of the water in the river/stream,
- The river slope,
- The roughness of river/stream,
- The lake depth,
- The source of water into the lake (e.g., groundwater, river, controlled dam…),
- The surface area of the lake,
- The depth of the aquifer (relevant for groundwater),
- The volume of the aquifer (relevant for groundwater),
- Permeability of the aquifer,
- Septic tanks contamination of the aquifer or other contamination sources.

The chosen start point can be any point in the water source where the information such as distance to the WTP, concentration of contaminants, etc., is known.

UV254 is a measurement of the amount of light absorbed by organic compounds in a water sample. UV254 is an important parameter for measurement throughout the drinking water treatment process. It provides an indication of the concentration of organic matter, specifically those that contain aromatic rings or unsaturated bonds in their molecular structures. Many organic compounds occurring naturally in the environment, such as humic substances, are aromatic and exist in high concentrations in environmental water. UV254 can be measured with a portable test meter or in real-time with an online analyser.

Total Organic Carbon (TOC) is a measurement of the amount of organic carbon present in water. The method involves converting all organic carbon in a water sample to carbon dioxide by utilizing heat and oxygen, chemical oxidants, or UV radiation. The resultant carbon dioxide concentration is measured with an infrared analyzer and reported as organic carbon (mg/L). The test takes 5-10 minutes to yield results in the lab, with continuous on-line analyzers also available.

Dissolved Organic Carbon (DOC) is a measurement of the amount of organic matter in water that can be passed through a filter, commonly 0.45 µm. The procedure for analyzing DOC requires that the samples first be passed through a 0.45 µm filter. The test involves converting organic carbon to carbon dioxide through oxidation (combustion, UV promoted or persulfate oxidation).

The concentration of carbon dioxide generated is measured using an infrared analyzer and reported as organic carbon (mg/L).

UV254, TOC, DOC, and all other parameters (type and concentration of the contaminant, general and specific data) entered in the Source Info will be used to estimate a degree of attenuation of the selected PPCP before and after water treatment. Different setups/equations may be considered to estimate relevant criteria. For example, specific UV absorbance at 254 nm (SUVA) provides a general characterization of the nature of natural organic matter (NOM) in a water sample and is typically performed for the purpose of determining disinfection by-product (DBP) formation potential. SUVA is calculated by dividing the UV254 by the DOC. A high SUVA indicates a large portion of humic matter present in the water and that NOM will control coagulant dose. Since aromatic organics have a greater tendency to react with disinfectants to create DBPs, a high SUVA indicates there is a greater potential for the formation of DBP's.

4. Decay constant info box

To complete the (simple version) configuration a), additional data on decay constant of the respective PPCP and removal efficiency of selected technology should be provided. The decay constant is needed to account for PPCP decay over time in water. It corresponds to a natural attenuation (see the chapter 6 „Attenuation of emerging contaminants for the water supply purposes" in the Monograph - a deliverable D.T4.3.1 under the Work package WPT4), and depends on a number of chemical and physical processes, such as advection, dispersion, dilution… The decay rate constant (k) may derive from the first order decay equation, final concentration = initial concentration * exp. [-k t], at the average temperature of water (as set in the Source Info) where t is time, and the initial concentration of PPCP (as set in the Source Info/The List of PPCPs).

The decay constant k should be entered in the Decay Constant Info box if the value is known from the literature, or may be approximated.

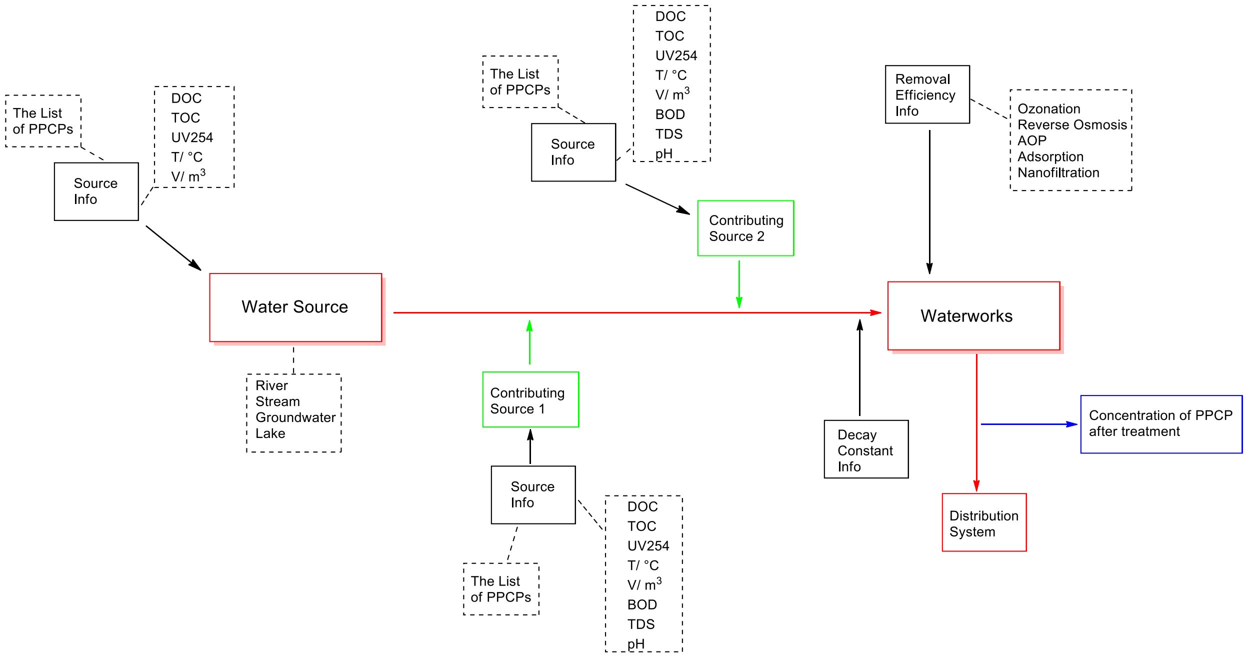
5. Waterworks box

The Waterworks box defines the final point along the water flow.

6. Removal Efficiency Info Box

Next, the model simulation (wwDEMAST) assumes that the chosen treatment technology (selected form the drop-down menu, e.g., ozonation, reverse osmosis, adsorption, etc.) will remove a certain percentage of each respective PPCP. This value (estimated or reproduced from the literature) should be entered in the Removal Efficiency Info box. A predefined set of available technologies has been displayed earlier in the Catalogue of globally existing technical solutions for PPCP mitigation - a deliverable D.T4.2.1 under the Work package WPT4 within boDEREC-CE. Of course, this list may be extended (or reduced) according to technical availability and financial costs.

When all necessary information is provided, the Decision-Making Support Tool for Waterworks may estimate a concentration of PPCP which is released to the distribution system, and may also advise on the use of specific water treatment technology.



Scheme 2. A complex model which includes different contributing sources along the water flow between the starting water source and the final waterworks point. The route from water source to the distribution system depicted by red arrows, the contributing sources depicted with green arrows, the input data depicted by black arrows, the output data depicted with a blue arrow.

The second scenario is a model in which different sources may contribute PPCPs along the water flow, i.e., between the starting water source and the final waterworks point (Scheme 2). Other sources, which increase the concentration of the respective PPCP, may be:

- stormwater discharge (surface water from heavy precipitation),

- wastewater treatment plant (WWTP, i.e., facility which removes chemicals from wastewater, but does not remove all contaminants and often introduces additional chemicals),

- agricultural or industrial discharge (runoff from farms/fields/factories),

- animal husbandry (cattle feedlot, etc.),

- tributary (stream or river flowing into another body of water).

Each contributing source should be characterized with additional parameters, if available, which will be used to calculate the concentration of PPCPs before and after water treatment. Both general and specific input data should be entered, where appropriate.

After the starting water source (river, stream, lake, etc.) has been selected (see above), the additional source info box should be loaded with a list of PPCPs, general data and specific data.

6.1. General Data

General Data list:

- PPCP concentration (selected from the drop-down menu),
- DOC in the contributing source water,
- TOC in the contributing source water,
- UV254 in the contributing source water,
- Travel time/the (discharge) flow rate,
- BOD in the contributing source water,
- TDS in the contributing source water,
- pH of the contributing source water.

BOD is a measurement of the amount of dissolved oxygen that is used by aerobic microorganisms when decomposing organic matter in water. A sample is first analysed and conditioned to ensure favourable growth conditions for bacteria, which may include adjustment for pH and neutralization of residual chlorine, if any. The sample is then diluted and the appropriate amount of seed bacteria added. The initial dissolved oxygen content is recorded and the sample is then incubated. After the certain period, the sample is removed from the incubator and the final dissolved oxygen reading is taken. BOD represents how much oxygen is needed to break down organic matter in water.

TDS represents the total concentration of all the dissolved substances in water. TDS in water comprises inorganic salts and a small amount of organic matter. Common inorganic salts that can be found in water include calcium, magnesium, sodium, and potassium, which are all cations, and carbonates, bicarbonates, chlorides, nitrates, and sulphates, which are all anions. Drinking water, with TDS levels higher than 1000mg/L, is generally considered unfit for human consumption. A high level of TDS is also a direct indicator of potential concerns and calls for a thorough analysis.

pH is the negative common logarithm of the activity of hydrogen ion in solution. Although the pH of pure water is 7, drinking water and natural water exhibits a pH range because it contains dissolved minerals and gases. Surface waters typically range from pH 6.5 to 8.5, while groundwater ranges from pH 6 to 8.5.

6.2. Specific Data

Specific Data list:

- meteorological data (stormwater discharges; the climate properties, rainfall frequency),
- water treatment used (WWTP),
- capacity of WWTP,
- the area of the contributing source (agriculture/industrial discharge, or animal husbandry),
- the frequency of discharge (agriculture discharge),
- water flow (minimum, maximum and mean of the time series) (tributary).

All other inputs, Source Info, Decay Constant Info, and Removal Efficiency Info, as described earlier, have to be included in the estimation protocol. When all necessary information is provided, the Decision-Making Support Tool for Waterworks may estimate, according to Scheme 2, a concentration of PPCP which is released to the distribution system.

7. Conclusion

In order to facilitate decision-making in the complex process on optimal solutions for the removal of emerging contaminants (EC), especially PPCPs, experts from boDEREC-CE project have developed a tool for decision-makers that provides a comprehensive approach that covers all stages of treatment. The process includes an assessment of the concentration of PPCP in the water supply system and advice on specific water treatment technologies that can be undertaken for the appropriate type of PPCP compound.

The wwDEMAST tool contains several units in which the corresponding data is entered. Within the Water source box, the water source is selected (it can be a river, stream, groundwater, lake). Additional information about the water source is entered in the Source Info box. This additional information provides general data on all water sources and general and specific data for each respected water source. Also, the necessary data on all included PPCP compounds found in three pilot action clusters within the boDEREC-CE project are entered. The process then involves entering the Decay constant in the Decay Constant info box. Decay Constant depends on physical and chemical processes such as pollution, advection and dispersion, and correspond to natural attenuation. The endpoint representing the end of the water flow is entered in the Waterworks box.

Finally, the simulation of the model within the tool provides data on which water treatment technology will remove estimated percentage of PPCP, and this value is entered in the Removal Efficiency Info box.

In conclusion, this tool, in addition to estimating the concentration of PPCPs released into the water supply system and proposing the use of water treatment technology, ensures efforts to make a big step forward in terms of biodiversity and environmental protection, and has a positive effect on human health and quality of life by conserving water resources.

8. References

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