



SELF-PURIFICATION OF WETLANDS

TEACHING PROTOCOL

GRADE LEVEL: Secondary-High School

DURATION: 10-15 min for the introduction ("Engage"),
20 min for indoor experiment and 60 min for outdoor field observations ("Explore")
20 min for making sense of the experience ("Explain")
25 min linking self-purification > eutrophication > Nature-based Solutions ("Elaborate")
45 min tracing the path of a pollutant ("Evaluate")

INTRODUCTION:

The topic "Self-purification" is intended to help students perceive how pollution occurs in the water environment and which processes lead to self-purification.

The protocol is comprised of a variety of activities, aiming to motivate students to be actively engaged in understanding this complex topic. In the beginning, it is foreseen to pose intriguing questions to initiate discussion guided by a teacher. Furthermore, through some simple observations and experiments, students experience some processes of self-purification that occur in native environments. According to the gained experience and supervision by a teacher, they jointly list major polluters of wetlands and draw out self-purification processes, as well as the results of their completion. Moreover, through interactive discussions, students will have an opportunity to expand their understanding by applying their knowledge to explain other related applications (e.g. Nature-based Solutions - NbS, treatment wetlands, rain gardens etc.), or to understand other related terms and processes. Finally, students trace a pollutant's path through a wetland to apply what they've learned about self-purification and water quality improvement.

LEARNING OBJECTIVES:

Students will be able to:

- 1 Perceive pollution in the water environment originating from native and anthropogenic sources
- 2 Explain ways in which nature performs self-purification
- 3 Recognize eutrophic processes in a water body
- 4 Propose Nature-based Solution (NbS) approaches to prevent eutrophication

KEYWORDS: self-purification, eutrophication, Nature-based Solutions (NbS)

TEACHING FRAMEWORK BASED ON THE 5E INSTRUCTIONAL MODEL

1. ENGAGE - Sparking curiosity (10-15 minutes)

AIMS: To stimulate curiosity about how nature cleans polluted water and to recognize the idea that wetlands act as the “liver of the landscape”. Students begin connecting pollution sources with natural purification processes.

GUIDING QUESTIONS

- How do we define pollution in water?
- Name a few examples of polluting agents in water.
- What is the self-purification ability of a water body?
- According to its origin, can we somehow classify pollution in water?
- When does fertilizer help, and when is it considered a pollutant?
- Have you ever heard that “wetlands are the liver of the landscape”?

KEYWORDS: pollution, pollutants, self-purification, natural vs. anthropogenic sources, wetland, ecosystem services, “liver of the landscape”

TEACHER SUPPORT

Ask students to identify the important pollutants that affect wetlands and to distinguish between those originating from different human activities (e.g., agriculture, industry, settlements). Students can search the internet to find examples and illustrations of these pollutants and their sources. Together, compile a list of pollutants grouped by their source type. Use the *Restore4Life interactive visualization* from Self-purification of wetlands topic.

2. EXPLORE – Hands-on learning activity

AIMS: Students actively explore and observe how pollutants behave in water and how natural processes such as filtration, sedimentation, biochemical degradation by microbes - contribute to water purification. Through these observations, they gain firsthand evidence of physical, biochemical degradation by microbes, and biological mechanisms in action.

KEYWORDS: filtration, settling, absorption, adsorption, suspension, transparency, nutrient, pollution, microbial degradation, self-purification.

STUDENT ACTIVITIES (activities of free choice), 20 minutes

In this part it is expected to actively engage students in the learning process. The tasks could be performed in a classroom or outdoors.

1 INDOOR ACTIVITIES:

The students should be split into pairs or smaller groups 3-4. Each group should do one or two tasks. Upon tasks are completed, each group explains its observations to their classmates.

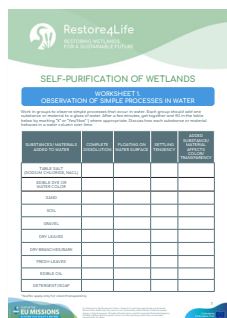
1. Observing how different compounds behave in water “What happens in the glass?”

OBJECTIVE: Observe what happens when different substances enter water and how natural materials can filter or trap them. Exercise aiming to actively engage students in the learning process. The tasks could be performed in a classroom or outdoors.

MATERIALS NEEDED:

5-6 clean transparent glasses, tap water, stirring rods, a couple of spoons of sand, a couple of spoons of soil, dried plant material (branches, leaves), a couple of spoons of washing powder, some liquid detergent and sponges.

ACTIVITY PROCEDURES:



Pour tap water into glasses and in each add one teaspoon of a different compound (e.g. soil, sand, dried plant material, washing powder or liquid detergent). Upon adding the compound, stir it well with a rod. Wait for one minute and observe what happens in each case: in which glass the substance settles; in which glass the substance is dissolved completely, and in which the substance/material does not dissolve in water, but floats on the surface, or is dispersed within the water column water. How long does the foam from detergents remain on the surface? Make a note of your observations

(use [Worksheet 1: Observation of simple processes in water](#)).

Again do the starring in all glasses and one at a time pour the content from each glass into a glass that has a sponge that is pressed by the spoon to the bottom. Wait for another minute and pour supernatant into a clean glass. What can you conclude? Has the sponge retained some impurities? Wash the sponge after pouring the content from each glass.

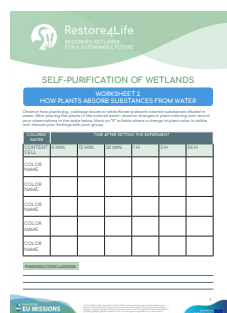
2. Observing how polluting substances from water are being absorbed by plants “Plants as purifiers”

OBJECTIVE: Explore how aquatic plants help remove pollutants or nutrients from water.

MATERIALS NEEDED:

4-5 clean transparent glasses, tap water, stirring rods, cabbage leaves or a few white flowers (of roses, lilies, or calla) and pigments or edible dyes of different colors (e.g. red, blue, green or yellow).

ACTIVITY PROCEDURES:



Pour tap water into glasses and in each glass add a few drops of pigment/edible dye of different color and mix the content with stirring rods. Cut a cabbage leaf into a few stripes or use white flowers and put each stripe/flower in a separate glass with colored water. Wait for at least 30 minutes or until the end of the lesson. Observe changes in color of the plant material and document your findings

(use [Worksheet 2: How plants absorb substances from water](#)).

Optionally, the teacher can prepare the mentioned experiment a day earlier and after the students set up their own one, to show them the results after one day.

2 INDOOR ACTIVITIES & FIELD OBSERVATIONS

MATERIALS NEEDED:

map of the area, smartphones, notebooks and pencils, transparent glasses, a Secchi disk

ACTIVITY PROCEDURES:



Visit a nearby wetland. Before the field trip, make preparations (use [Worksheet 3.1: Pre-field checklist](#)), i.e. search on the internet main features of the wetland you are going to visit, delineate the wetland on the map, explore possible sources of pollution and hydrology of the terrain, etc.

During the field trip (use [Worksheet 3.2: On field observations](#)). Visit a nearby wetland, make observations of abiotic and biotic features and fill in the Worksheet 3.2.

3. EXPLAIN – Making sense of the experiences (20 minutes)

AIMS: Students synthesize their findings and understand how physical, chemical, and biological processes interact to purify water. They connect observed phenomena to scientific terminology and draw conceptual models or mind maps.

GUIDING QUESTIONS

- Which are mechanisms/processes that enable self-purification?
- Which processes you have identified?
- Which elements are necessary for plant growth?
- Which elements are assumed by the term nutrients?

KEYWORDS: dilution, dispersion, settling, oxidation, sorption, biodegradation, absorption, evapotranspiration, photodegradation, nutrients.

During this phase, student analyze their findings, either obtained from simple experiments or from the field trip, in order to understand in which ways wetlands contribute to water purification.

TEACHER INSTRUCTION:

Begin by presenting the definition of self-purification, for example:

“The removal or transformation of pollutants from a water body through natural processes, without any artificial control, is called self-purification or natural purification.”

Encourage students to also consider the role of **abiotic factors** — such as gases from the atmosphere and ultraviolet (UV) radiation from the Sun — as well as **biotic components**, particularly microorganisms, whose activity may not have been visible during field investigations.

With the teacher’s guidance, students create a **mind map** with *“Wetland Self-purification”* in the center. From this central concept, three main branches represent the **mechanisms of self-purification**:

- Physical processes
- Chemical processes
- Biological processes

Each group can then be subdivided as follows:

KEY PROCESSES

- **Physical processes** – dilution and dispersion of pollutants; sedimentation of suspended particles; retention of particles by permeable sediments; photodegradation (UV radiation from sunlight); and evaporation of some compounds.
- **Chemical processes** – spontaneous oxidation and reduction reactions; sorption (adsorption) of pollutants onto mineral or organic particles; etc.
- **Biological processes** – subdivided into:
 - **Dissimilative (degradation) processes** – microbial decomposition of organic matter under aerobic or anaerobic conditions, driven by bacteria and fungi through extracellular and intracellular enzymes.
 - **Assimilative (uptake) processes** – absorption and incorporation of inorganic nutrients by photosynthetic organisms (plants, algae) to build new biomass, phytoaccumulation of pollutants, transfer through the food web, and evapotranspiration by plants.

Ask students to explain each process and describe when or how they observed it during the experiments or fieldwork. Encourage them to discuss **which processes were directly visible** (e.g., sedimentation) and **which ones were not observable**, even though they were **taking place invisibly** (e.g., microbial degradation, oxidation, or nutrient assimilation).

TEACHER SUPPORT

Briefly explain that a wide variety of **chemical pollutants** can reach and degrade wetland ecosystems.

Ask students to name common **pollution sources** and **pollutants**, and to think about **everyday substances** that enter wastewater and contaminate it. Emphasize that compounds containing **nitrogen** and **phosphorus** act as fertilizers, promoting excessive growth of algae and aquatic plants in rivers, wetlands, and lakes.

Nutrient inputs may come from **diffuse** or **point sources**, such as agricultural runoff or untreated and partially treated wastewater. These pollutants can occur either **dissolved in water** (as true solutions) or **attached to suspended particles**.

Once in the water, dissolved pollutants spread throughout the water column. Because dilution depends on the size of the receiving water body, **smaller wetlands experience higher concentrations** for the same input. Pollutants bound to particles will eventually **settle to the bottom**, while **organic nutrients** are released through **microbial degradation** of organic matter. **Inorganic nutrients** can be taken up (**assimilated**) by algae and aquatic plants. (Figure 1)

Under specific conditions, **nitrogen** can also be **removed** from aquatic systems through **denitrification**, a process in which bacteria convert nitrate into nitrogen gas released to the atmosphere.

Both **nutrient uptake by aquatic vegetation** and **sedimentation of particles** contribute to the self-purification of wetland habitats. However, when nutrient inputs are excessive, they cause **eutrophication**, leading to algal blooms and oxygen depletion.

Show students **photos of eutrophic water bodies** to illustrate these effects.

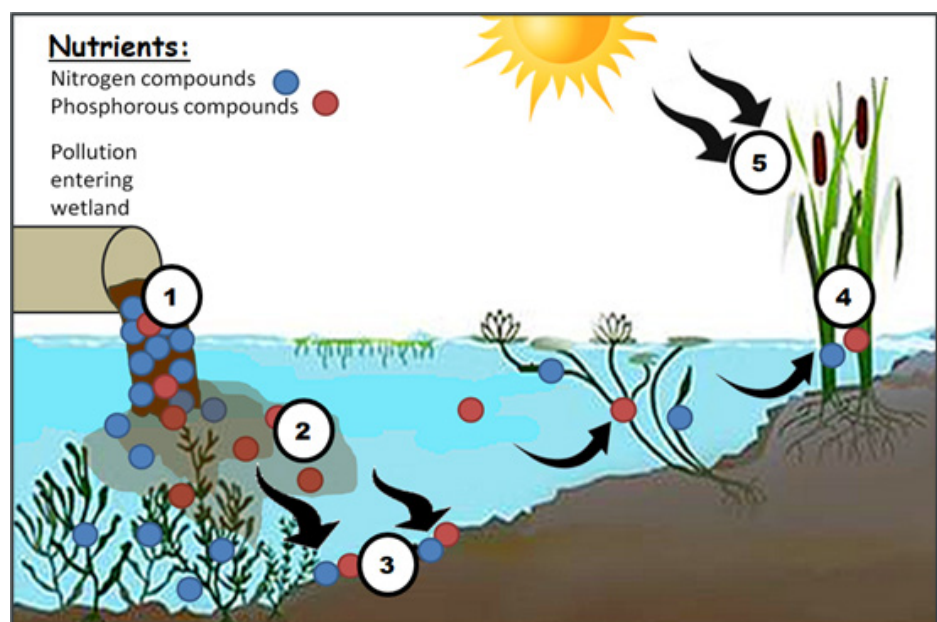


Figure 1. Processes of wetland self-purification: 1) concentrated polluted water, 2) dilution and dispersion, 3) settling, 4) nutrients uptake by aquatic plants/absorption and 5) photodegradation by UV radiation

Both described processes, uptake by aquatic vegetation or phytoplankton and settling of particles contribute to self-purification of wetland habitats. Abundance of nutrients leads to enhanced growth of photosynthetic organisms causing eutrophication. Show to student some photos of water bodies eutrophicated.

4. EXTEND / ELABORATE – Expanding understanding (25 minutes)

AIMS: Students deepen their understanding by linking self-purification to eutrophication and to Nature-based Solutions. They explore how too many nutrients can shift wetlands from purifiers to polluted systems and discuss real-world NbS applications.

GUIDING QUESTIONS

- What happens to plants (wetland vegetation) when there is few nutrients, medium amount and excess availability?
- When do eutrophic conditions occur?
- Have you heard of the term algal bloom? What is the cause of it?
- Why is swimming not recommended in surface waters with less than 50 cm vertical transparency?
- How can high diffuse nutrient inputs into surface waters be prevented by the use of plants/wetland vegetation?

KEYWORDS: eutrophication, algal bloom, organic load, nutrients, treatment wetlands, rain gardens, Nature-Based Solutions (NbS).

TEACHER SUPPORT

End this part by explaining to students that people today increasingly use natural processes and organisms to improve environment – a concept known as Nature-based Solutions. Provide some examples such as treatment wetland and rain gardens as solution intended to purify water.

Group work, during the class or as homework completing seminar papers: Ask students to split in groups of 4-5. To each group give a task to search internet and prepare presentation/seminar work related to one of the following topics:

- Natural wetlands are the livers of the landscape
- Examples of Nature-based Solutions for water purification
- Treatment wetlands: their roles and application
- Rain gardens and water purification
- How implementing and managing Nature-based Solutions leads to cleaner environment

4. EVALUATE- Assessing learning (45 minutes)

AIMS: To assess students' understanding on how nitrogen and phosphorus pollutants may enter wetlands, move through the ecosystem, and are transformed or removed through natural self-purification processes.

ACTIVITY: "TRACING THE PATH OF A POLLUTANT"

- MATERIALS:**
- "Pollutant cards": Each card describes one pollutant and its source, e.g. nitrate from fertilizer runoff, phosphate from wastewater, ammonium from livestock manure
 - Large sheet of paper, or digital drawing screen
 - Coloured pencils or markers
 - *Restore4Life interactive visualization: Self-purification of Wetlands*
 - Optional: icons or printed symbols for physical, chemical, and biological processes (sedimentation, oxidation, microbial degradation, plant uptake)
- TEACHER INSTRUCTION:**
1. Divide students into groups of 3 to 5, and provide each group with one pollutant card. There are pollutant cards on the following plant nutrient input pathways: nitrogen-based pollutants from agriculture; nitrogen-based pollutants from livestock manure; nitrogen-based pollutants from Wastewater Treatment Plants (WWTPs); nitrogen compounds from urban runoff; phosphorus-based pollutants from fertilizers; phosphorus-based pollutants from soil erosion; phosphorus-based pollutants from urban runoff; phosphorus-based pollutants from industry; phosphorus-based pollutants from WWTPs.
 1. Ask each group to create a **concept map or illustrated flow diagram** showing the "journey" of their pollutant through a wetland.
 - Start from the **source of pollution** (diffuse or point).
 - Show what happens as the pollutant enters and moves through the **wetland water column**.
 - Indicate which **self-purification processes** are interfering with the pollutant:
 - » **Physical:** dilution, sedimentation, adsorption to particles
 - » **Chemical:** oxidation/reduction, precipitation
 - » **Biochemical (dissimilative):** microbial degradation, denitrification
 - » **Biological (assimilative):** uptake by plants and algae
 - Conclude with the final fate of the pollutant, as e.g., "settled in sediments," "transformed into nitrogen gas," "assimilated into biomass".
 2. Groups present their pollutant paths in a short 2-3 minute explanation, using the interactive illustration as a visual reference.
 3. Facilitate a short class discussion comparing nitrogen vs. phosphorus behavior — where are they retained, transformed, or released?

GUIDING QUESTIONS

- From which sources (diffuse or point) does your pollutant originate?
- What pathways does it follow once it enters the wetland?
- Which natural processes are interfering with it, and where do these occur in the wetland?
- Which self-purification process occur in oxygenated micro-environments, and which ones in anoxic micro-environments?
- Which processes lead to removal (e.g., gas release, sedimentation), and which ones only transform the pollutant, or store it temporarily?
- How could human activities support or disrupt these natural processes?
- What happens if the input of your pollutant becomes too high for the system to handle?

REFLECTION POINTS

- What surprised you most about how wetlands interferes with pollutants?
- Which removal processes are most effective for nitrogen? For phosphorus?
- How are physical, chemical, and biological processes connected?
- Why do oxygenated and anoxic micro-environments occur in wetlands in close proximity?
- Which parts of the wetland act as “filters,” and which as “transformers”?
- What human activities could strengthen or weaken these natural purification functions?
- How do these natural processes inspire solutions such as treatment wetlands or buffer zones?

REFERENCES FOR TEACHERS:

<https://oceanservice.noaa.gov/facts/eutrophication.html>

<https://www.naturebasedsolutionsinitiative.org/research/examples-of-nature-based-solutions>

<https://www.youtube.com/watch?v=OKggl7WkRp4>

Nitrogen transformations in water: Some parts from this video can be used as illustration of nitrogen transformations in polluted waters, where bacteria play major role:

<https://www.youtube.com/watch?v=BosHU4ARR9w>

https://mrhuestonscience.weebly.com/uploads/5/6/9/0/56908607/reading_guide_3.4_cycle_of_matter_.pdf

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WORKSHEET 1. OBSERVATION OF SIMPLE PROCESSES IN WATER

Work in groups to observe simple processes that occur in water. Each group should add one substance or material to a glass of water. After a few minutes, get together and fill in the table below by marking "X" or "Yes/Now" ¹⁾ where appropriate. Discuss how each substance or material behaves in a water column over time.

SUBSTANCES/ MATERIALS ADDED TO WATER	COMPLETE DISSOLUTION	FLOATING ON WATER SURFACE	SETTLING TENDENCY	ADDED SUBSTANCE/ MATERIAL AFFECTS COLOR/ TRANSPARENCY
TABLE SALT (SODIUM CHLORIDE, NA _{CL})				
EDIBLE DYE OR WATER COLOR				
SAND				
SOIL				
GRAVEL				
DRY LEAVES				
DRY BRANCHES/BARK				
FRESH LEAVES				
EDIBLE OIL				
DETERGENT/SOAP				

¹⁾Yes/No apply only for color/transparency



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WORKSHEET 2 HOW PLANTS ABSORB SUBSTANCES FROM WATER

Observe how plants (e.g., cabbage leaves or white flowers) absorb colored substances diluted in water. After placing the plants in the colored water, observe changes in plant coloring and record your observations in the table below. Mark an "X" in fields where a change in plant color is visible, and discuss your findings with your group.

COLORED WATER	TIME AFTER SETTING THE EXPERIMENT					
CONTENT CELL	0 MIN.	15 MIN.	30 MIN.	1 H	3 H	24 H
COLOR NAME						
COLOR NAME						
COLOR NAME						
COLOR NAME						
COLOR NAME						

FINDINGS/CONCLUSIONS:



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WORKSHEET 3.1. PRE-FIELD CHECKLIST

Acquire a map of the wetland area you are going to visit. It would be good to have it printed in black and white, so it is possible to delineate and mark a variety of objects using different colors. When you complete a task, mark it with "x" in the box, and make some notes related to each possible source of pollution or other features in extension of the row.

TASKS TO BE COMPLETED:

- Delineate the wetland area you are going to visit.
- Identify and mark potential pollution sources using different colors on the map; for example:
 - o Settlements and roads _____
 - o Arable land and grazing areas _____
 - o Industrial or mining zones _____
 - o Tourist or recreational facilities _____
- Identify and mark potential pollution sources using different colors on the map; for example:
- Explore the hydrology of the area:
 - o Identify watercourses flowing into or out of the wetland.
 - o Search online for information about these water bodies (e.g., water quality, seasonal flow variations, sediment contribution, etc.).
- Determine the position of the wetland in relation to the potential pollution sources (e.g. is it located downstream?).
- Investigate environmental issues in the area by consulting online articles or reports. Look for mentions of pollution, erosion, overexploitation of some natural resources, or deforestation.

ADDITIONAL NOTES:

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WORKSHEET 3.2. ON FIELD OBSERVATION

Walk along the edges of the wetland and note your observations concerning the different aspects by filling in the table below:

DIFFERENT FEATURES	DESCRIPTION OF THE FEATURES		
If edges of the wetland are overgrown by vegetation, reeds, grass, trees, and scrubs (circle the most appropriate description)	DENSE VEGETATION	SPARSE VEGETATION	BARE
If plants are growing above water (e.G. Reeds), are floating (plants like water lilies), or are submerged (hornwort). (Circle which forms are dominating)	ABOVE WATER	FLOATING	SUBMERGED
Grab water from the wetland into a glass and observe its color. (Circle the color that matches your observations the most)	GREEN	BROWNICH	YELLOW
Sense its smell (Circle one that matches your sensing)	NO SMELL	NORMAL SMELL OF SOIL	UNPLEASANT SMELL OF ROTTING
Observe transparency with the bare eye or by the use of the secchi disk. (Comment your observations) Note if there are some organisms in the sampled water and in the water body.			
Find the outflow of the wetland and test/ observe its water quality in the way described above (comment your observations).			
Compare the water quality from the wetland and from its outflow. (Make comments on it)			
Ask locals about their opinions on water quality and possible sources of pollution. Entering the wetland (write down their opinion)			