Co-funded by the
Erasmus+ Programme
of the European Union

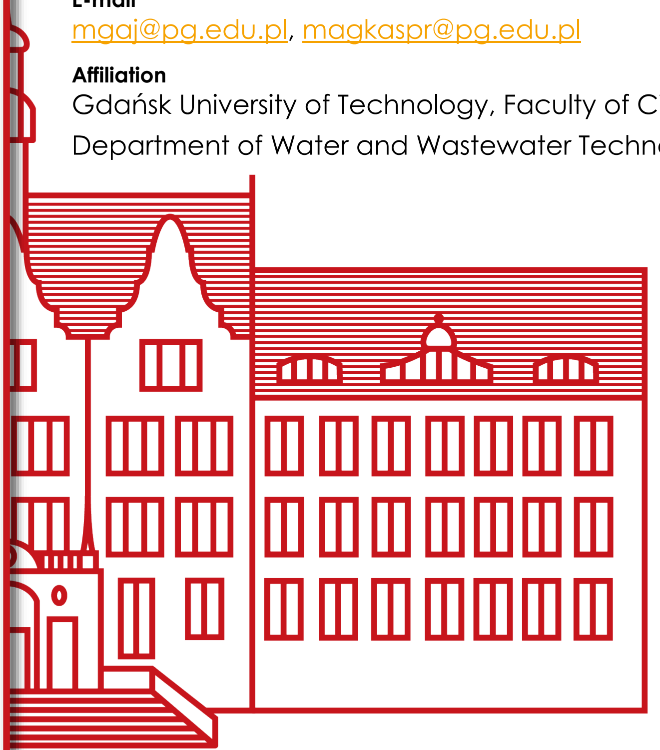
Innovative Measurement Tool towards Urban Environmental Awareness

Water Biological and Microplastic Pollution

Authors
Magdalena Gajewska, Magda Kasprzyk

E-mail
mgaj@pg.edu.pl, magkaspr@pg.edu.pl

Affiliation
Gdańsk University of Technology, Faculty of Civil and Environmental Technology, Department of Water and Wastewater Technology



This project has been funded with support from the European Commission.

This publication reflects the views only for the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Project Partners

Table of contents

1 Water biological and microplastic pollution

1.1 Introduction

The main aim of the IMPETUS IO1 MP WATER BIOLOGICAL AND MICROPLASTIC POLLUTION is to find simple measurement tools for easy classification of the water pollution index.

Currently, there is a lack of measurement instructions for citizens to evaluate the quality of the water bodies. Only qualified staff and researchers are able to measure the basic parameters of the water such as pH, conductivity, total suspended solids, color, turbidity or dissolved oxygen. On the other side, we are faced with a growing awareness of the inhabitants on environmental issues, climate changes, and surface waters such as lakes, ponds, streams, rivers pollution problems.

General knowledge on:

What is biological pollution?

Untreated domestic and industrial wastewaters discharged into water bodies. The heavily polluted water bodies can contain very high concentrations of nutrients, heavy metal and organic pollutants. The high nitrogen (N) and phosphorus (P) concentrations have a definite ecotoxicological effect on the extent of eutrophication when entered into e.g. lake water (Yin et al., 2018).

What is microplastic pollution?

Recent studies assume that microplastics fall within the range of 5 mm - 1 µm. Microplastics contamination of the environment is considered a potential threat to human health and can exist for hundreds of years in nature because they are not decomposable in any way. Despite plastic being widely used for a long time, it is only recently that its by-product microplastics have become a central topic of discussion around the world. This is not because they are good for society, but mainly because of their potential impact on the above- ground and underground environment. Therefore, a review of the potential impact of microplastics on the environment is necessary (Chia et al., 2021).

Relation between biodiversity, human health, climate changes and water pollution

Cities as well as different water bodies are becoming increasingly vulnerable to climate change. Following changes also affect biodiversity due to growing urbanisation, therefore inhabitants well-being and air quality severely decreased. More frequent flooding due to an increase in cloud bursts, or drought, forces action to be taken within already heavily urbanised areas where there is a competing demand for different land usage (Boogaard et al., 2020).

1.2 Expected results

A simple methodology for the classification of water using a defined water pollution index of any water reservoir, which can be used by nonprofessional researchers has been developed. Using this method one can:

- achieve knowledge of the impact of parameters on the surface water quality,
- gain practical knowledge how to evaluate real water during real-time monitoring,
- understand the connection with water surrounding and its influence on the condition of the basic water parameters.

For the skills achieved can be included:

- know how to measure the basic parameters of the surface water,
- know how to make a basic evaluation of the surface water condition,
- ability to do measurements with safety precautions,
- ability to use of theoretical knowledge in practical work,
- ability to find and use tools to replace laboratory equipment.

1.3 Measurement procedure

Field investigation – location of the sampling area

Open area with water reservoir (standing or flowing).

Easy and safe access for sample collection (4 possible locations for sample collection).

Prior the measurements, there is a need to:

- investigate the reservoir field,
- analyse the reservoir type (natural/artificial),
- analyse the catchment area (urban/rural),
- the reservoir bed needs to be evaluated (entrenchment),
- investigate of the potential sources of pollutants
- investigate the potential impact of human activities (discharges, solid waste).

For gathering information, the preferable method is to walk along the water body, if safety precautions are not allowed for field investigation you can use google maps and satellite photos.

Figure 1.1. Example of the sampling location – Slupia River dam (Photo: Barbara Śniatała).

Safety precautions

1. Please dress appropriately to the weather conditions.
2. Make sure that you understand the measurement procedure, *if you don't – ask your teacher before proceeding with the activity*.
3. *Perform only those experiments authorised by your teacher.*
4. Make sure that the water level is not above 30 cm (hardened bottom, safety access with galoshes).
5. Team of two persons at least is recommended.
6. Do not enter places that are not allowed.
7. ***Do not move away from the group without informing the teacher.***

Equipment

Measurements are based on simple methods and measurement equipment, which is avaible at our houses:

disposable gloves, galoshes, 4 glass beakers / jars (well washed), string, white paper, (coffee) filter, funnel, stopwatch, smartphone with camera, thermometer, (universal indicator paper, compact precision portable meter for students).

Figure 1.2. Example of equipment for measurements.

When the place is selected **describe sampling conditions.** Use Excel file:

Folder: Water biological and microplastic pollution / INDEX data sheet.xls

The following data should be added to the excel file:

1. **Season**
   a) spring
   b) summer
   c) autumn
   d) winter
2. **Time of the day**
   a) morning (8.00am – 11.00am)
   b) noon (11.00am – 2.00pm)
   c) afternoon (2.00pm – 4.00pm)
   d) evening (4.00pm – 8.00pm)

3. Air temperature (put the temperature)

____

4. Precipitation events (past 48h) (choose one dominant option)

a) what type? (rain / snow)

____

b) intensity? (drizzle / heavy rain)

____

Describe basic information about water body:

1. Type of reservoir (choose one of the options)

a) standing water
type (natural / artificial)

____

b) flowing water
type (lake, pond, sea / reservoir)

____

2. Type of the catchment

a) urban (centre of the city, close to main street)

b) semi-urban (outskirts of the city)

c) rural (close to agriculture areas)

d) semi-rural (scattered housing)

e) other

3. Type of reservoir entrenchment

a) none (natural course is maintained)

____

b) partly – what type? (fascine, gabions, concrete)

____

c) full – what type? (fascine, gabions, concrete)

____

d) other

____

4. Potential sources of the pollutants (give comments)

a) are there any discharges, connection with pipes?

____

b) are there any connections with other water bodies?

____

c) nearness of an industrial plant (what type?)

____

d) other

____

Methods for measurements

Organoleptic / Colorimetric method

Organoleptic method (sensory method) – quality assessment via senses – sight, smell, taste, and touch. The advantage of this method is its availability, the disadvantage – the subjectivity of the assessment.

Colorimetric method – a technique consisting in comparing the color of the analysed solution with the color of the reference solution. The reference solution is a solution of known concentration.

Parameters of the sample – color, turbidity, suspended solids, odour.

Results are described with words after observation / smelling of the sample.

Microplastic pollution and other suspended solids

Suspended solids are measured with simple filters (e.g. coffee filter) and funnel. Additionally, the time of filtration could be measured to define the amount of suspended solids. To evaluate the character of the suspended solids, the observation of the filter is recommended (for qualified staff – microscope observation).

Note! *Organoleptic method (sensory method) – quality assessment via senses – sight, smell, taste, and touch. The advantage of this method is its availability, the disadvantage – the subjectivity of the assessment.*

Sampling

Figure 1.3. Preparation for sampling.

Collect the samples with a glass beaker / jar. How deep: surface water or deep water, how far from edge: approx. 1 m. Preferable place for sampling is a bridge across the stream.

I. Make sure that place is safe.
II. Make sure that water level is not above 30 cm (hardened bottom, safety access with galoshes).
III. Do not take measurements alone. Team of two persons at least is recommended.
IV. Tie a string around the well washed jar.
V. Holding a string immerse the jar in water.
VI. Pull the jar out of the water and start observation. Jar should be filled to ¾ volume, next close the jar and shake for 30 s.
VII. Immediately after sample collection, carefully smell the water inside the jar and describe the following parameter.

Answer a question and put score from brackets to table in excel file (water index page).

6. Odour quantity (intensity analysis)

- no odour (1)
- perceptible (2)
- intensive (3)

7. Odour quality (description analysis)

- plant (e.g. soil, grass, cucumber, flower, aromatic) (1)
- putrid (e.g. musty, mould, faecal, hydrogen sulphide – rotten eggs) (2)
- specific (e.g. chemical, petroleum, phenol, kerosene, tar, gasoline) (3)

Note! *Water bodies which are clean should have no odour or perceptible smell all others could indicate anaerobic decay or pollution which disqualify water in terms of its quality.*

VIII. Put the jar on the white paper with text and compare your sample with images.

8. Turbidity

- no turbidity < 3 NTU (1)
- acceptable turbidity 3 – 6 NTU (1)
  (e.g. if you can read an instruction, or see fingerprints through the sample)
- turbid 6 – 15 NTU (2)
  (e.g. if you cannot read and instruction, or can see palm without fingerprints through the sample)
- very turbid / no visibility > 15 NTU (3)
  (e.g. if you cannot see anything though the sample)

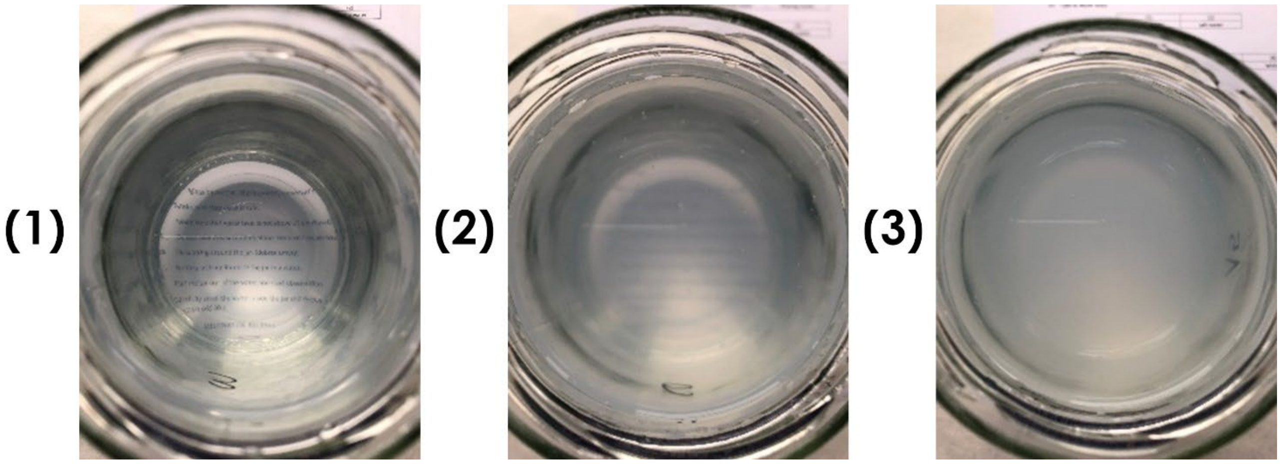


Figure 1.4. Examples of the turbidity scale.

Note! *Turbidity could be of both natural and anthropogenic origin but in both cases turbidity could be medium for the development of microorganisms and bacteria. Human eye can notice turbidity above 3 NTU (Nephelometric Turbidity Unit) level, on that basis the evaluation scale was prepared.*

IX. *Watch the sample for 15 minutes and try to observe behaviour of suspended solids.*

9. Suspended solids-presence: Do you notice suspended solids?

- yes (1)
- no (1)

10. Suspended solids-sedimentation: If yes, does it fall easy (fast)?

- yes (1)
- no (2)

11. Suspended solids-floating particles (a): Are there floating particles?

- yes (1)
- no (1)

12. Suspended solids-floating particles (b): If yes, try to evaluate the type of floating particles.

- organic / natural (e.g. leaf, pollen, stick) (0)
- specific / anthropogenic (e.g. plastic, oil) (2)

13. Suspended solids-character: Mark image similar to your sample after 15 minutes of sedimentation

- if you see two separate phases clearly (1)
  (sediment in the bottom of the vessel
- if you see three phases vaguely (2)
  (most likely there is colloidal fraction, which do not undergoes sedimentation)
- if you do not see a difference after 15 minutes (3)
  (suspended solids are not undergoes sedimentation)

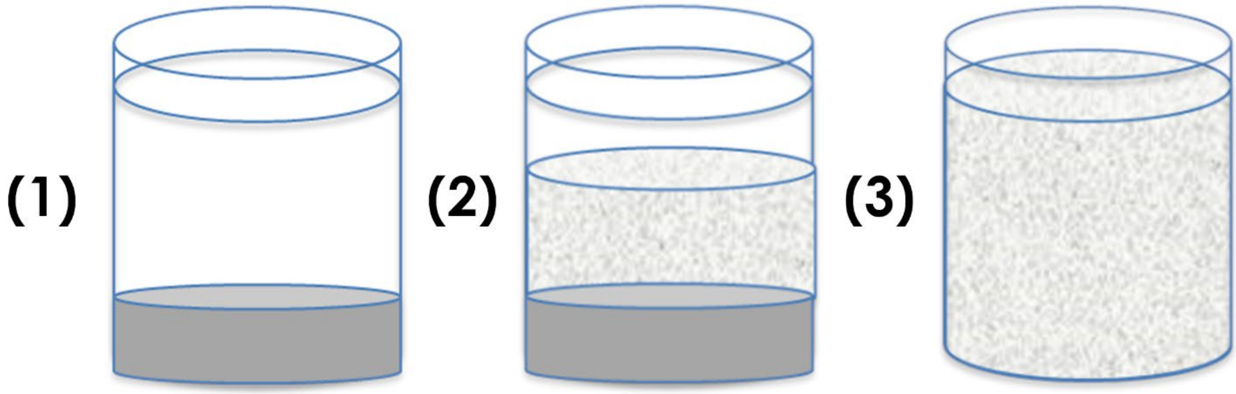


Figure 1.5. Examples of the suspended solids character.

Note! *Too high concentration of the suspended solids may reduce the access of sunlight and interfere with the photosynthesis process. Suspended solids could be both of natural and anthropogenic origin, varied from season (algae bloom) and weather condition (storm events).*

Figure 1.6. Filtration of the sample and color analysis before and after filtration.

- **X.** Prepare a second jar with a funnel inside.
- **XI.** Put the coffee filter in the funnel.
- **XII.** Prepare a stopwatch and start carefully pouring water from the first jar to a second one with the stopwatch on.
- **XIII.** Note the time of filtration and try to define the amount of suspended solids. Tip: filtration time of 1 litre of potable water is approximately 2 minutes.

14. Filtration time

- ~ 2 minutes (1)
- 3 min – 5 min (2)
- over 5 min (3)

XIV. Put the jar on the white paper and compare your sample with images.

15. Color (after filtration)

- no color < 20 mg Pt/L (1)
- 20 – 40 mg Pt/L (2)
- 40 – 60 mg Pt/L (3)
- > 60 mg Pt/L (4)

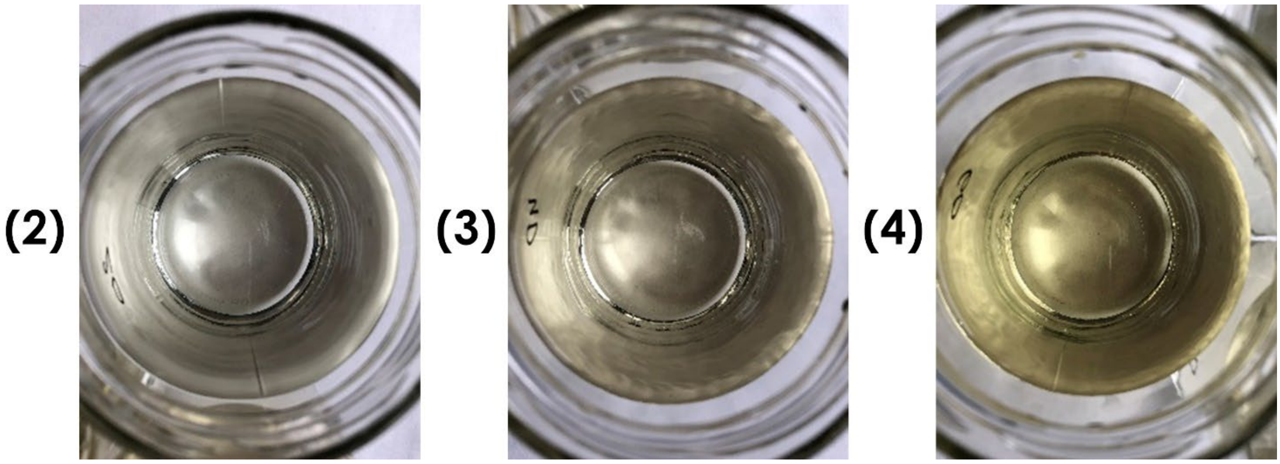


Figure 1.7. Examples of the color scale.

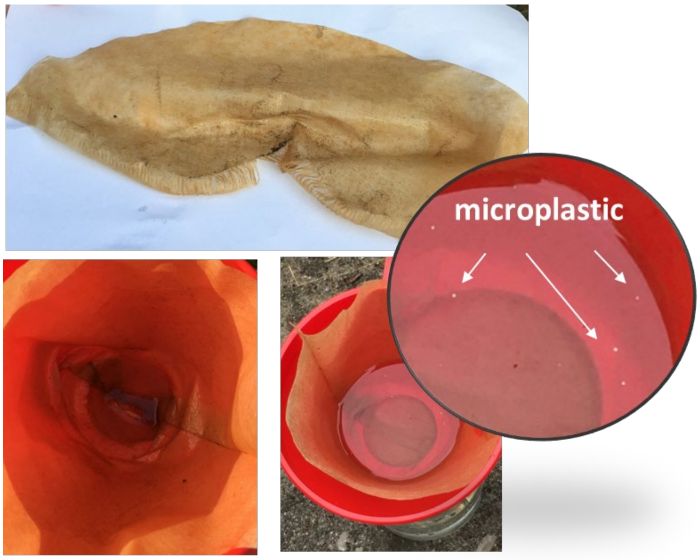


Figure 1.8. Examples of the suspended solids presence – microplastic in the form of glitter.

XV. After pouring all of the water, start observation of the filter leftovers on the white card and try to describe the following parameter:

16. Suspended solids – presence
Are there any suspended solids on the filter?

- no (0)
- yes (1)

17. Suspended solids-structure (after filtration) – assessment and origin

- mineral / sand (1)
- organic / muddy (1)
- specific (plastic, petroleum) (3)

18. Suspended solids – color (after filtration)

- sandy (1)
- brown (1)
- green (3)
- black (4)

Note! *Both color and smell of the water are assessed as acceptable or NOT acceptable. While the turbidity undergoes the quantity assessment because it is strictly linked to microbiological quality of the water body.*

Contact method

Parameters of the sample – pH, temperature, conductivity.

Samples are collected with a glass beaker / jar.

Parameters are measured with a compact precision portable meter.

Temperature could be measured with a thermometer (for non-educated).

pH could be measured with an universal indicator paper (for non-educated).

I. Put the thermometer into the water and wait until the temperature is stable. Note the results.
II. (For students) Prepare a compact precision portable meter with a pH / temperature probe and put it into the water.
III. Wait until the result is stable. Note the results.

19. Water temperature

____

Note! *Water temperature can vary during the season and day. A substantial difference in water and air temperature may indicate anthropogenic pollution (discharge of wastewater or cooling water from industry), if the water temperature is much higher than the air temperature resulting from the season and day.*

IV. Put the universal indicator paper into the water and wait until it is whole wet. Wait about 15 seconds and compare universal indicator paper color with scale color. Note the results.
V. (For students) Prepare a compact precision portable meter with pH probe and put it into the water.
VI. Wait until the result is stable. Note the results.

20. pH

a) 6.5 – 8.0 (1)
b) 8.0 – 9.0 (2)
c) < 6.5 or > 9.0 (3)

Note! *Natural water could have pH in a range of 6.5 – 8.0. Natural water is capable of buffering the pH towards alkalinity.*

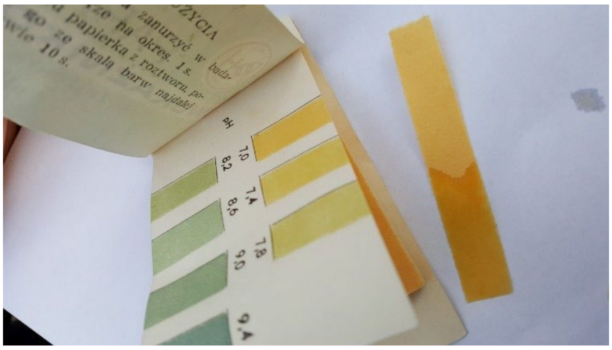


Figure 1.9. pH measurement with indicator paper scale.

VII. (For students) Prepare a compact precision portable meter with conductivity probe and put it into the water.

VIII. Wait until the result is stable. Note the results.

21. Conductivity (0.1 – 10 mS/cm)

____

Figure 1.10. Conductivity measurement with compact precision portable meter.

1.4 Data collection protocol & methodology

Table 1.1. Point evaluation scale.

LP	Name	Method	Reporting Units	Operating Range	Resolution	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (range of values)					Data Reporting
								Very low (very bad)	Low	Medium	High	Very high (very good)	
6	Odour (quantity)	organoleptic	description			1	1	3		2	1 (7=0)*		
7	Odour (quality)	organoleptic	description			1	1	3		2	1		
8	Turbidity	organoleptic	description			1	1	3		2	1	1	
9	Suspended solids-presence	organoleptic	y/n			1	1	1			1 (10-13=0)**		
10	Suspended solids-sedimentation	organoleptic	y/n			1	1	2			1		
11	Suspended solids-floating particles (a)	organoleptic	y/n			1	1	1			1		
12	Suspended solids-floating particles (b)	organoleptic	description			1	1	2			0		
13	Suspended solids-character	organoleptic	description			1	1	3		2			
14	Filtration time	time	minutes			1	1	3		2			
15	Color – after filtration	organoleptic	description			1	1	4	3	2			
16	Suspended solids-presence (after filtration)	organoleptic	y/n			1	1	1			0(17,18=0)***		
17	Suspended solids-structure	organoleptic	description			1	1	3		1	1		
18	Suspended solids-color	organoleptic	description			1	1	4	3	1	1		
20	pH	contact	-			1	1	3		2	1		
22	Dissolved oxygen concentration	chemical	description			1	1	5	4	3	2	1	

Explanations

***(7=0)** if there is **no odour** then odour (quality) = 0.

****(10-13=0)** if there are **no suspended solids** then sedimentation, floating particles (a, b), character = 0.

*****(17,18=0)** if there are **no suspended solids after filtration** then structure, color = 0.

Table 1.2. Remarks for the boundary conditions.

LP	Name	Method	Reporting Units	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (values)	Remarks
6	**Odour (quantity) – intensivity**	organoleptic	description	1	1		if there is **no odour** (1) the odour (quality) = 0
7	**Odour (quality) – description**	organoleptic	description	1	1		if odour (quality) + odour (quantity) ≥ 5 → **WBP INDEX = VERY LOW**
8	**Turbidity**	organoleptic	description	1	1		
9	**Suspended solids-presence**	organoleptic	y/n	1	1		if there is **no suspended solids** (1) then 10.sedimentation, 11,12.floating particles (a,b), 13.character = 0
10	**Suspended solids-sedimentation**	organoleptic	y/n	1	1		
11	**Suspended solids-floating particles (a)**	organoleptic	y/n	1	1		
12	**Suspended solids-floating particles (b)**	organoleptic	description	1	1		
13	**Suspended solids-character**	organoleptic	description	1	1		
14	**Filtration time**	time	minutes	1	1		
15	**Color – after filtration**	organoleptic	description	1	1		if color = 4 → **WBP INDEX = VERY LOW**
16	**Suspended solids-presence (after filtration)**	organoleptic	y/n	1	1		if there is **no suspended solids after filtration** then 17.structure, 18.color = 0
17	**Suspended solids-structure (after filtration)**	organoleptic	description	1	1		
18	**Suspended solids-color (after filtration)**	organoleptic	description	1	1		if suspended solid-color = 4 → **WBP INDEX = VERY LOW**
19	**Water temperature**	contact	°C	1	1	-	**not included for evaluation**
20	**pH**	contact	-	1	1		
21	**Conductivity**	contact	mS / cm	1	1	-	**not included for evaluation**
22	**Dissolved oxygen concentration**	chemical	description	1	1		if dissolved oxygen concentration = 5 → **WBP INDEX = VERY LOW**
			Water biological pollution INDEX			**0**	

Boundary conditions for **VERY LOW** water biological pollution (WBP) INDEX:

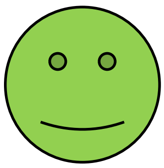
1) if odour (quality) + odour (quantity) ≥ 5
2) if color = 4
3) if suspended solid – color = 4
4) if pH = 3
5) if dissolved oxygen concentration = 5

Final results for Water biological pollution INDEX

Table 1.3. Water biological pollution INDEX evaluation point scale.

	Name	Index equations	Range of values	Quality rating (range of values)				
				Very low (very bad)	**Low**	**Medium**	**High**	**Very high (very good)**
6	Water quality INDEX	total points	40 – 7	40 – 36	35 – 30	29 – 20	19 – 14	13 – 7

Table 1.4. Water biological pollution INDEX evaluation graphical scale.

Very low (very bad) 40 – 36	Low 35 – 30	Medium 29 – 20	High 19 – 14	Very high (very good) 13 – 7
				

Example

Table 1.5. Example results for basic information about sampling condition.

Basic information about sampling conditions		
1.	**Season**	
	a)	spring
	b)	summer
	c)	autumn
	d)	winter
2.	**Time of the day**	
	a)	morning (8.00am – 11.00am)
	b)	noon (11.00am – 2.00pm)
	c)	afternoon (2.00pm – 4.00pm)
	d)	evening (4.00pm – 8.00pm)
3.	**Air temperature**	
	9 °C	
4.	**Precipitation events (past 48 h)**	
	what type? (rain / snow)	
	description	Rain
	intensity? (drizzle / heavy rain)	
	description	Light (<5 mm)

Table 1.6. Example results for basic information about water body.

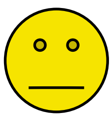
Basic information about water body		
1.	**Type of reservoir**	
	a)	standing water
		type (natural / artificial):
	description	Natural lake
		type (lake, pond, sea / reservoir):
	description	Oxbow lake by the river Labe
	b)	flowing water
		type (natural / artificial):
	description	
		type (stream, river / channel):
	description	
2.	**Type of the catchment**	
	a)	urban (centre of the city, close to main street)
	description	
	b)	semi-urban (outskirts of the city)
	description	
	c)	rural (close to agriculture areas)
	description	Located within riparian forest in countryside
	d)	semi-rural (scattered housing)
	description	
	e)	other
	description	

3.	**Type of reservoir entrenchment**	
	a)	none (natural course is maintained)
	description	Natural bed
	b)	partly – what type? (fascine, gabions, concrete)
	description	
	c)	full – what type? (fascine, gabions, concrete)
	description	
	d)	other
	description	
4.	**Potential sources of the pollutants**	
	a)	are there any discharges, connection with pipes?
	description	
	b)	are there any connection with other water bodies?
	description	During the flooding there was a possible connection with a big nearby river (Labe).
	c)	**nearness of an industrial plant (what type?)**
	description	**Large chemical factory (toxical chemicals of all types)**
	d)	other
	description	

Table 1.7. Example point results for water biological pollution INDEX.

LP	Name	Method	Reporting Units	Minimum Sample Frequency	Raw Data Collection Frequency	Quality rating (values)	Remarks
6	**Odour (quantity) – intensivity**	organoleptic	description	1	1	2	if there is **no odour** (1) the odour (quality) = 0
7	**Odour (quality) - description**	organoleptic	description	1	1	1	if odour (quality) + odour (quantity) ≥ 5 → **WBP INDEX = VERY LOW**
8	**Turbidity**	organoleptic	description	1	1	3	No visibility
9	**Suspended solids-presence**	organoleptic	y/n	1	1	1	if there is **no suspended solids** (1) then 10.sedimentation, 11,12.floating particles (a,b), 13.character = 0
10	**Suspended solids-sedimentation**	organoleptic	y/n	1	1	2	No visible sedimentation
11	**Suspended solids-floating particles (a)**	organoleptic	y/n	1	1	1	Yes
12	**Suspended solids-floating particles (b)**	organoleptic	description	1	1	0	Natural origin of particles
13	**Suspended solids-character**	organoleptic	description	1	1	3	No difference after 15 minutes
14	**Filtration time**	time	minutes	1	1	1	1.1x of drinking water filtration time
15	**Color – after filtration**	organoleptic	description	1	1	3	if color = 4 → **WBP INDEX = VERY LOW**
16	**Suspended solids-presence (after filtration)**	organoleptic	y/n	1	1	0	if there is **no suspended solids after filtration** then 17.structure, 18.color = 0
17	**Suspended solids-structure (after filtration)**	organoleptic	description	1	1	1	Organic / muddy origin
18	**Suspended solids-color (after filtration)**	organoleptic	description	1	1	3	if suspended solid-color = 4 → **WBP INDEX = VERY LOW**
19	**Water temperature**	contact	°C	1	1	-	**not included for evaluation**
20	**pH**	contact	-	1	1	-	
21	**Conductivity**	contact	mS / cm	1	1	-	**not included for evaluation**
22	**Dissolved oxygen concentration**	chemical	description	1	1		if dissolved oxygen concentration = 5 → **WBP INDEX = VERY LOW**
					Water biological pollution INDEX	**21**	MEDIUM water quality (also regarding the tests not performed)

Medium
29 – 20



1.5 Final results description

For the presentation of the methodology to your students you can use WBaMP presentation.pptx. During measurements, the results will be collected in WBaMP INDEX data sheet.xlsx manually or via app and send the results to the Climate Scan database. Students should prepare a full report of data collection and data analysis, including photo documentation of sampling and measurements conduction. Report should include analysis of weather conditions and area and reservoir description (+ photos). The last step should include conclusions and summing up regarding the result of Total water quality INDEX. For the knowledge income verification use the WBaMP pre-post test to print.doc.

1.6 External materials

See: https://impetus.aau.at/outputs/

Folder: Water biological and microplastic pollution

- WBaMP instruction.pdf
- WBaMP INDEX data sheet.xlsx
- WBaMP pre-post test to print.doc
- WBaMP pre-post test key.doc
- WBaMP presentation.pptx

1.7 References

Askarizadeh, A., Rippy, M.A., Fletcher, T.D., Feldman, D.L., Peng, J., Bowler, P., Mehring, A.S., Winfrey, B.K., Vrugt, J.A., Aghakouchak, A., Jiang, S.C., Sanders, B.F., Levin, L.A., Taylor, S., Grant, S.B., 2015. From Rain Tanks to Catchments: Use of Low-Impact Development To Address Hydrologic Symptoms of the Urban Stream Syndrome. Environ. Sci. Technol. 49, 11264-11280. https://doi.org/10.1021/acs.est.5b01635

Boogaard, F.C., Venvik, G., de Lima, R.L.P., Cassanti, A.C., Roest, A.H., Zuurman, A., 2020. ClimateCafe: An interdisciplinary educational tool for sustainable climate adaptation and lessons learned. Sustain. 12, 1–19. https://doi.org/10.3390/su12093694

Booth, D.B., Roy, A.H., Smith, B., Capps, K.A., 2016. Global perspectives on the urban stream syndrome. Freshw. Sci. 35, 412–420. https://doi.org/10.1086/684940

Chia, R.W., Lee, J.Y., Kim, H., Jang, J., 2021. Microplastic pollution in soil and groundwater: a review. Environ. Chem. Lett. https://doi.org/10.1007/s10311-021-01297-6

Digman, C., Ashley, R., Balmforth, David, Balmforth, Dominic, Stovin, V., Glerum, J., 2012. Retrofitting to Manage Surface Water. Ciria C713.

Eriksson, E., Baun, A., Scholes, L., Ledin, A., Ahlman, S., Revitt, M., Noutsopoulos, C., Mikkelsen, P.S., 2007. Selected stormwater priority pollutants - a European perspective. Sci. Total Environ. 383, 41–51. https://doi.org/10.1016/j.scitotenv.2007.05.028

Godoy, V., Martín-Lara, M.A., Almendros, A.I., Quesada, L., Calero, M., 2021. Microplastic Pollution in Water. https://doi.org/10.1007/978-3-030-52395-4_1

Hale, R.L., Scoggins, M., Smucker, N.J., Suchy, A., 2016. Effects of climate on the expression of the urban stream syndrome. Freshw. Sci. 35, 421–428. https://doi.org/10.1086/684594

Kominkova, D., 2013. The Urban Stream Syndrome – a Mini-Review. Open Environ. Biol. Monit. J. 5, 24–29. https://doi.org/10.2174/1875040001205010024

Obinnaa, I.B., Ebere, E.C., 2019. A Review: Water pollution by heavy metal and organic pol- lutants: Brief review of sources, effects and progress on remediation with aquatic plants. Anal. Methods Environ. Chem. J. 2. https://doi.org/10.24200/amecj.v2.i03.66

Oral, H.V., Radinja, M., Rizzo, A., Kearney, K., Andersen, T.R., Krzeminski, P., Buttiglieri, G., Ayral-Cinar, D., Comas, J., Gajewska, M., Hartl, M., Finger, D.C., Kazak, J.K., Mattila, H., Vieira, P., Piro, P., Palermo, S.A., Turco, M., Pirouz, B., Stefanakis, A., Regelsberger, M., Ursino, N., Carvalho, P.N., 2021. Management of urban waters with nature-based solu- tions in circular cities—exemplified through seven urban circularity challenges. Water (Switzerland) 13. https://doi.org/10.3390/w13233334

Padervand, M., Lichtfouse, E., Robert, D., Wang, C., 2020. Removal ofmicroplastics from the environment. A review. Environ. Chem. Lett. 18, 807–828. https://doi.org/10.1007/s10311-020-00983-1

Pistocchi, A., Dorati, C., Grizzetti, B., Udias, A., Vigiak, O., Zanni, M., 2019. Water Quality in Europe: Effects of the Urban Wastewater Treatment Directive. A Retrospective and Sce- nario Analysis of Dir. 91/271/EEC. https://doi.org/10.2760/303163

Rakesh, S., Davamani, V., Murugaragavan, R., Ramesh, P., Shrirangasami, S., 2021. Microplastics contamination in the environment. Pharma Innov. J. 10, 1412–1417. https://doi.org/10.33745/ijzi.2021.v07i01.019

Schwarz, N., Moretti, M., Bugalho, M.N., Davies, Z.G., Haase, D., Hack, J., Hof, A., Melero, Y., Pett, T.J., Knapp, S., 2017. Understanding biodiversity-ecosystem service relationships in urban areas: a comprehensive literature review. Ecosyst. Serv. 27, 161–171. https://doi.org/10.1016/j.ecoser.2017.08.014

Walsh, C.J., Leonard, A.W., Ladson, A.R., Fletcher, T.D., 2004. Urban Stormwater and the Ecology of Streams 44.

Walsh, C.J., Fletcher, T.D., Ladson, A.R., 2005a. Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. J. North Am. Benthol. Soc. 24, 690–705. https://doi.org/10.1899/04-020.1

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., Morgan, R.P., 2005b. The urban stream syndrome: Current knowledge and the search for a cure. J. North Am. Benthol. Soc. 24, 706–723. https://doi.org/10.1899/04-028.1

Wild, T., 2020. Nature-based Solutions: Improving Water Quality & Waterbody Conditions: Analysis of EU-funded Projects. https://doi.org/10.2777/2898

Yin, H., Zhu, J., Tang, W., 2018. Management of nitrogen and phosphorus internal loading from polluted river sediment using Phoslock® and modified zeolite with intensive tubificid oligochaetes bioturbation. Chem. Eng. J. 353, 46–55. https://doi.org/10.1016/j.cej.2018.07.112

Relation to EU law

HELCOM Recommendation 23/5-Rev.1, 2021. REDUCTION OF DISCHARGES FROM URBAN AREAS BY THE PROPER MANAGEMENT OF STORMWATER SYSTEMS.

IPCC, 2014. In: Field, C.B., Barros, V.R., Dokken, D.J. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC, 2014. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A. (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/cbo9781107415416

European Commission, 2021. Evaluating the Impact of Nature-based Solutions. A Handbook for Practitioners. https://doi.org/10.2777/2498

European Commission, 2021. Communication From the Commission to the European Economic and Social Committee and the Committee of the Regions. Pathway to a Healthy Planet for All. EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil' COM (2021) 400 final.

European Commission, 2019. Evaluation of the Urban Waste Water Treatment Directive 186. European Commission, 2019. Service Request Supporting the Evaluation of Directive 91/ 271/EEC Concerning Urban Waste Water Treatment.

European Commission, 2015. Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities. Final Report of the Horizon 2020 Expert Group on 'Nature-based Solutions and Re-naturing Cities'. https://doi.org/10.2777/765301

European Environment Agency, 2015. EEA Technical Report No 12/2015. Exploring Nature- based Solutions: The Role of Green Infrastructure in Mitigating the Impacts of Weather- and Climate Change-related Natural Hazards.

Naumann, S., Davis, M., 2020. Biodiversity and Nature-based Solutions. Publications Office of the European Union, 2020, Luxembourg. https://doi.org/10.2777/183298