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under grant agreement PREVEN-T – CN2 – SO2.4 – SC049

Interreg - IPA CBC

EUROPEAN UNION

Greece - Republic of North Macedonia

Preven-T

PREVEN-T DELIVERABLE 3.3 "Surface water and fragile vegetation pollution model, due to acid rain caused by air pollutants"

Authors:	Chrysoula Konteli
Status:	Final
Due Date:	31/10/2023
Version:	1.0
Dissemination Level:	PU

Interreg - IPA CBC

EUROPEAN UNION

CCI 2014 TC 16 I5CB 009

PREVEN-T Project Profile

Grant Agreement No.:	PREVEN-T – CN2 – SO2.4 – SC049
Acronym:	PREVEN-T
Title:	PREVEN-T – Modern Tools for wildfires' and Floods' Risk punctual forecast and monitoring and innovative techniques for citizens' safeguard awareness and preparedness
URL:	http://www.preven-t.eu/ - http://prevent.the.ihu.gr/ (NOT OFFICIAL - temporal)
Start Date:	03/03/2022
Duration:	18 months

Partners

INTERNATIONAL HELLENIC UNIVERSITY	International Hellenic University (IHU)	Greece
	Military Academy "General Mihailo Apostolski" (MAGMA)	RNM
	National Park Pelister	RNM

Document History

Version	Date	Author (Partner)	Remarks/Changes
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0.2	08/03/2023	Chrysoula Konteli (IHU) Panagiotis Nastos (IHU) Panteleimon Xofis (IHU)	1st Draft ready for internal review
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1.0	31/10/2023	Chrysoula Konteli (IHU) Panagiotis Nastos (IHU) Panteleimon Xofis (IHU)	FINAL VERSION TO BE SUBMITTED

Abbreviations and acronyms

Deliverable	D
Expected Outcomes	EO
International Hellenic University	IHU
Non-governmental organization	NGO

Executive Summary

PREVEN-T is a 18 month duration project funding from the Interreg IPA Cross-border Cooperation Programme: PREVEN-T – CN2 – SO2.4 – SC049.

The overarching objective of the PREVEN-T project is to examine the pollution present in fresh waters and to propose ways of dealing with it. It also aims to inform and raise public awareness on the issue of environmental protection.

The main purpose of this document is to a report the progress of the PREVEN-T project during the deliverable WP3.3 about water pollution of the according Lakes: Prespa, Kastoria's Lake, Ohrid, Vegoritida Lake and Zuka Lake and water pollution in Dragon River in March.

Table of Contents

List of Figures & Tables

1 Introduction

1.1 Purpose of the document

Natural waters include surface waters, i.e. rivers, lakes, lagoons, seas and underground waters. Natural waters contain various substances which are either dissolved or suspended and which come from the ground of the area, from the agricultural or industrial activity of the area, from the atmosphere and finally from the plant and animal organisms of the water. The purpose of this document is to analyse water pollution in a) Ohrid Lake, b) Kastoria's Lake, c) Prespa Lake d) Vegoritida Lake and to discuss the results.

In the current document the results obtained by the application of the HYSPLIT back-trajectory model and the Langrangian Particle Dispersion Model FLEXPART-WRF are also presented. The application of those models aim in explaining how the wind and rainfall patterns may affect the concentration of toxic materials in the lakes of Pelister National Parak.

Finally, an analysis is presented based on *in situ* collected data and analysis of pH on the possible implication of acid rain in massive necrosis of Blakan pine individuals or soil properties. Furthermore an analysis was undertaken based on visual interpretation of a time series of Sentinel-2 images to detect cases of extensive deaths of individuals. This analysis showed no such cases so no furtherresults are presented here.

1.2 Intended audience

The intended audience of this document consists of the following target groups:

- PREVEN-T project partners and the Project Officer at the Managing Authority

1.3 Work Package Objective

The current technical report refers to WP3.3 where it's main objective is studying and examine water pollution in order to take the appropriate measures and people to be informed about water pollution consequences.

1.4 Structure of the document

In chapter 2, this report describes the applied methodology for the current research conducted in Lakes.

In chapter 3, this report presents the results achieved from the current research.

In chapter 4, this report discusses the results in relation to water, air and soil pollution and examines the pollution factors.

2 Research aims and methodology

2.1 Research aims

The findings presented in this report are based on the chemical composition of surface waters with respect to Orhid, Kastoria, Vegoritida and Prespa lake are examined, so that to find the external forcing contributing to the water quality. The measurements concern: Ph, Temperature, Conductivity and pollution of water ecosystems by NO_3^-, SO_4^-, PO_4^-, Al, Fe, Zn, Cl_2.

2.2 Methodological framework

2.2.1. Study Areas

Prespa Lake

The Lake Prespa is located on the tripoint of North Macedonia, Albania, and Greece. It is a system of two lakes separated by an isthmus: the Great Prespa Lake, divided between the three countries, and the Little Prespa Lake, mostly within Greece. They are the highest tectonic lakes in the Balkans, standing at an elevation of 853 metres (2,799 ft).

The area contains three national parks: Prespa in Albania, Galičica in North Macedonia and Prespa in Greece. The largest town in the region is Resen in North Macedonia. In 2014, the Ohrid-Prespa Transboundary Reserve between Albania and North Macedonia was added to UNESCO's World Network of Biosphere Reserves.

The Great Prespa Lake has the total surface of 259 km2 (100.00 sq mi). The largest part of it, 176.3 km2 (68.07 sq mi) belongs to North Macedonia; 46.3 km2 (17.88 sq mi) to Albania; and 36.4 km2 (14.05 sq mi) to Greece.

Ohrid Lake

Lake Ohrid is a lake which straddles the mountainous border between the southwestern part of North Macedonia and eastern Albania. It is one of Europe's deepest and oldest lakes, with a unique aquatic ecosystem of worldwide importance, with more than 200 endemic species.

North Macedonia's side of Lake Ohrid was declared a World Heritage Site by UNESCO in 1979, with the site being extended to also include the cultural and historic area of Ohrid in 1980. In 2010, NASA named one of Titan's lakes after it. In 2014, the Ohrid-Prespa Transboundary Reserve between Albania and North Macedonia was added to UNESCO's World Network of Biosphere Reserves. Albania's side of Lake Ohrid was also designated UNESCO world heritage status in 2019. North Macedonia's portion was designated as a protected Ramsar site in 2021, passing all nine criteria for proclamation.

In Albania, the coastal portion of the lake holds Managed Nature Reserve status. In North Macedonia, a portion of the lakeside is part of the Galičica National Park.

The towns situated at the lakeside are Ohrid and Struga in North Macedonia along with Pogradec in Albania. The lake is otherwise densely surrounded by settlements in the form of villages and resorts in both basin countries.

Lake Ohrid is one of the oldest lakes in the world, and with a maximum depth of 288 metres (945 ft) and mean depth of 155 m (509 ft), it is the deepest lake in the Balkans. It covers an area of 358 square kilometres (138 sq mi) and contains an estimated 55.4 cubic kilometres (45 million acre-feet) of water. The lake is 30.4 km (18.9 mi) long and 14.8 km (9.2 mi) wide at its maximum extent, with a shoreline of 87.53 km (54.39 mi).

64% of Lake Ohrid's shoreline and 69% of its surface area are within North Macedonia, whereas 36% of the shoreline and 31% of its surface area fall within Albania.

Vegoritida Lake

Lake Vegoritida also known in the past as Lake Ostrovo , is a large natural lake in western Macedonia, northern Greece. It is situated 6 km northeast of Amyntaio and 18 km west of Edessa, at 540 m elevation. The Voras Mountains lie to the north. It belongs partly to the Florina regional unit and partly to the Pella regional unit.

The lake has an area of 54.31 sq km, a maximum length of 14.8 sq km, a maximum width of 6.9 sq km, a maximum depth of 70 m and is located at an altitude of 540 m.

Kastoria Lake

Lake Orestiada or Lake of Kastoria is a lake in the Kastoria regional unit of Macedonia, northwestern Greece. Sitting at an altitude of 630 metres, the lake covers an area of 28 square kilometres.

Nine rivulets flow into the lake, and it drains into the Haliacmon river. Its depth varies from nine to ten metres. The Orestiada was formed about 10 million years ago. The Kastoria Peninsula (with the town of Kastoria) divides the lake into two parts, the larger to the north and the smaller to the south. The lake is known to freeze in winters.

2.2.2. Methodology

In this study, the water samples were collected from Ohrid, Kastoria, Vegoritida and Prespa Lake. The water samples were collected in good quality polyethylene bottle of 500 ml/L capacity. The experimental measurements were done in the Chemistry laboratory of the Oenology department of DI.PA.E using a colorimeter and pH meter. The following parameters were considered: Ph, temperature, nitrates (NO_3^-), sulfate (SO_4^-), phosphate (PO_4^-), aluminum (Al), iron(Fe), zinc(Zn), chlorine (Cl_2).

Colorimeter

A colorimeter can measure the absorbency of light waves. During colour measurement the change in the intensity of electromagnetic radiation in the visible wavelength region of the spectrum after transmitting or reflecting by an object or solution is measured. Such a measurement can help to find the concentration of substances, since the amount and colour of the light absorbed or transmitted depends on the properties of the solution, including the concentration of particles in it. A colorimeter is an instrument that compares the amount of light getting through a solution with the amount that can get through a sample of pure solvent. A colorimeter contains a photocell which is able to detect the amount of light passing through the solution under investigation. The current produced by the photocell depends on the quantity of light hitting it after passing through the coloured solution. The higher the concentration of the colorant in the solution, the higher is the absorption of light; less light passing through the solution means less current created by the photocell. A colorimeter takes three wideband readings along the visible spectrum to obtain a rough estimate of a colour sample. Traditionally, the word ‘colorimeter’ is used for a device, having three filters, that simulates human vision.

Ph meter

A pH meter is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a "potentiometric pH meter". The difference in electrical potential relates to the acidity or pH of the solution. Testing of pH via pH meters (pH-metry) is used in many applications ranging from laboratory experimentation to quality control.

3 Results

3.1. Chemical concentration in water bodies across the wider area.

Table 1. Water quality Chemical parameters collected from various sources

Prespa Lake	*Ph*	*Temperature* (°C)	*NO_3^-* (mg/l)	*SO_4^-* (mg/l)	*Al* (mg/l)	*Fe* (mg/l)	*Zn* (mg/l)	*Cl_2* (mg/l)	*PO_4^-* (mg/l)
January	7,88	18,8	4	18	0,0	0,01	0,02	0,0	1,32
February	7,96	18,8	4,1	20	0,0	0,03	0,02	0,0	1,43
March	7,82	18,5	5,1	22	0,0	0,05	0,03	0,0	1,96
April	7,85	18,2	6	36	0,0	0,03	0,02	0,0	1,85
May	7,87	18,3	4	16	0,0	0,02	0,02	0,0	1,7
June	7,85	18,5	18	15	0,0	0,33	0,2	0,0	0,1
July	7,84	18,4	20	18	0,0	0,35	0,25	0,0	0,5
August	7,88	18,6	22	20	0,0	0,4	0,3	0,0	0,7

Table 2.Water quality Chemical parameters collected from various sources

Kastoria's Lake	*Ph*	*Temperature* (°C)	*NO_3^-* (mg/l)	*SO_4^-* (mg/l)	*Al* (mg/l)	*Fe* (mg/l)	*Zn* (mg/l)	*Cl_2* (mg/l)	*PO_4^-* (mg/l)
January	7,88	18,8	2	6	0,0	0,01	0,05	0,0	1,52
February	7,96	18,8	2,1	8	0,0	0,02	0,07	0,0	1,6
March	7,82	18,5	2,3	10	0,0	0,02	0,09	0,01	1,96
April	7,85	18,2	2	80	0,0	0,03	0,06	0,01	1,98
May	7,87	18,3	2	10	0,0	0,02	0,08	0,0	2
June	7,85	18,5	2	15	0,0	0,01	0,09	0,0	3
July	7,84	18,4	2,2	18	0,0	0,02	0,08	0,0	3.2
August	7,88	18,6	2,5	20	0,0	0,03	0,09	0,0	3.9

Table 3. Water quality Chemical parameters collected from various sources

Ohrid Lake	*Ph*	*Temperature* (°C)	*NO_3^-* (mg/l)	*SO_4^-* (mg/l)	*Al* (mg/l)	*Fe* (mg/l)	*Zn* (mg/l)	*Cl_2* (mg/l)	*PO_4^-* (mg/l)
January	7,88	18,8	1,9	1,5	0,0	0,01	0,01	0,0	1
February	7,96	18,8	2,1	2	0,0	0,02	0,01	0,0	1,2
March	7,82	18,5	2	3	0,0	0,01	0,01	0,01	1,3
April	7,85	18,2	1,5	3	0,0	0,01	0,01	0,01	1,4
May	7,87	18,3	1	3	0,0	0,02	0,01	0,0	1,5
June	7,85	18,5	1,5	3	0,0	0,04	0,1	0,0	1,3
July	7,84	18,4	1,7	3,2	0,0	0,05	0,12	0,0	1,4
August	7,88	18,6	1,8	3,5	0,0	0,05	0,15	0,0	1,4

Table 4. Water quality Chemical parameters collected from various sources

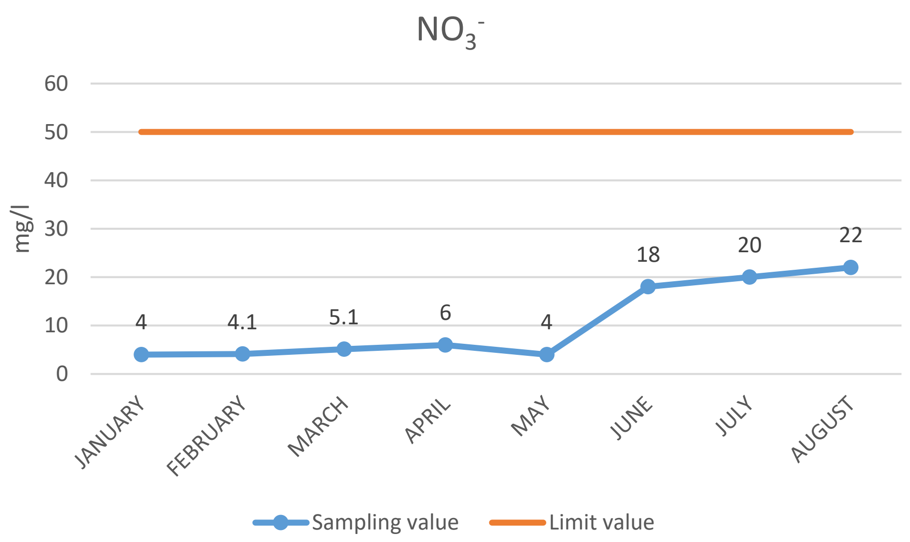
Vegoritida Lake	*Ph*	*Temperature* (°C)	*NO_3^-* (mg/l)	*SO_4^-* (mg/l)	*Al* (mg/l)	*Fe* (mg/l)	*Zn* (mg/l)	*Cl_2* (mg/l)	*PO_4^-* (mg/l)
January	7,88	18,8	2,4	80	0,0	0,01	0,01	0,01	1
February	7,96	18,8	2,8	80	0,0	0,02	0,01	0,02	1,2
March	7,82	18,5	3,8	80	0,0	0,03	0,02	0,03	0,73
April	7,85	18,2	4	80	0,0	0,05	0,01	0,03	0,83
May	7,87	18,3	5,1	80	0,0	0,06	0,13	0,04	1,13
June	7,85	18,5	3,1	80	0,0	0,06	0,07	0,03	1
July	7,84	18,4	3	80	0,0	0,05	0,09	0,04	1,1
August	7,88	18,6	3,2	80	0,0	0,06	0,1	0,04	1,2

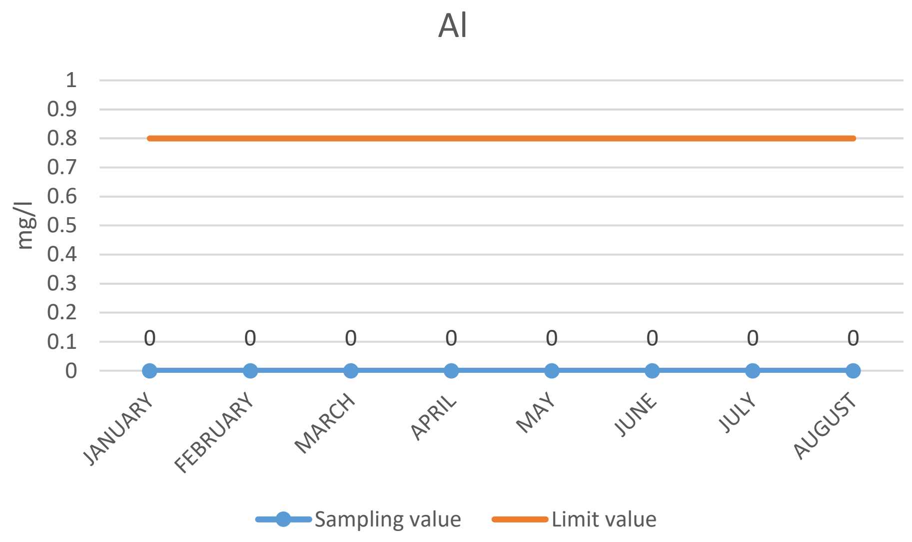
Table 5. Price ceilings

NO_3^- (mg/l)	*SO_4^-* (mg/l)	*Al* (mg/l)	*Fe* (mg/l)	*Zn* (mg/l)	*Cl_2* (mg/l)	*PO_4^-* (mg/l)
50,00	70,00	0,80	3,00	3,00	2,00	5,00

It is observed that the values obtained from the measurements are within limits and much lower than the maximum values. The most important is that the values of SO_4^- in the Lakes are higher than in the River. Also, in Vegoritida Lake is higher than the price ceilings.

Results Prespa Lake




Al
mg/l
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0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
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JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
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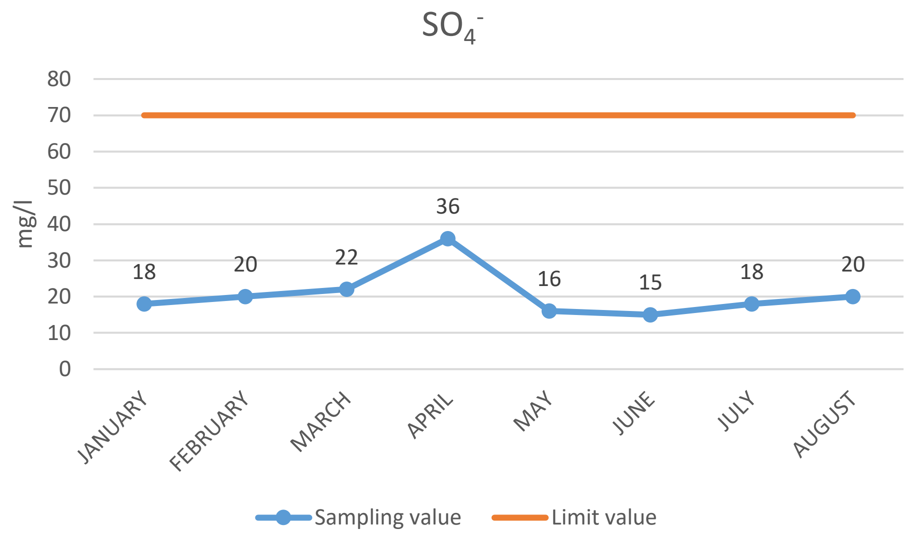
Limit value


SO_4^-
mg/l
80
70
60
50
40
30
20
10
0
18 20 22 36 16 15 18 20
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FEBRUARY
MARCH
APRIL
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JUNE
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AUGUST
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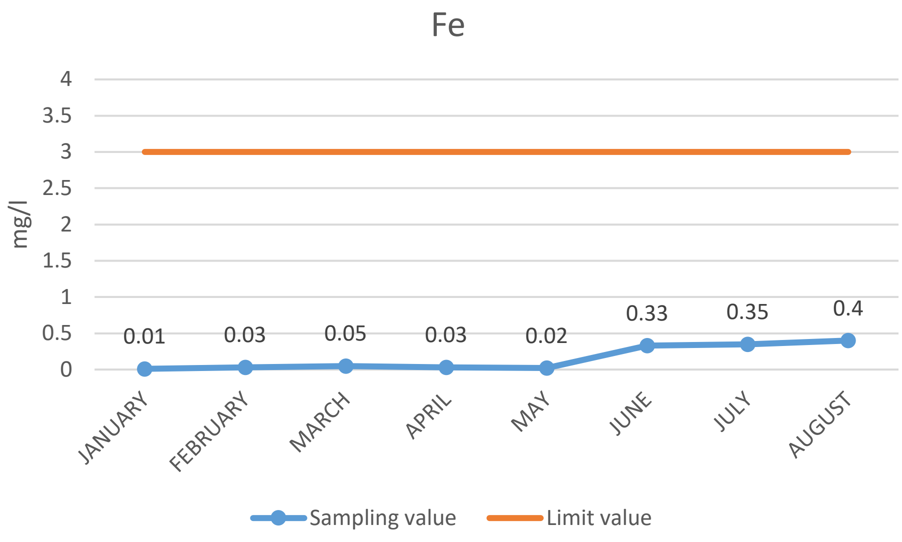
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mg/l
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3
2.5
2
1.5
1
0.5
0
0.01
0.03
0.05
0.03
0.02
0.33
0.35
0.4
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Sampling value
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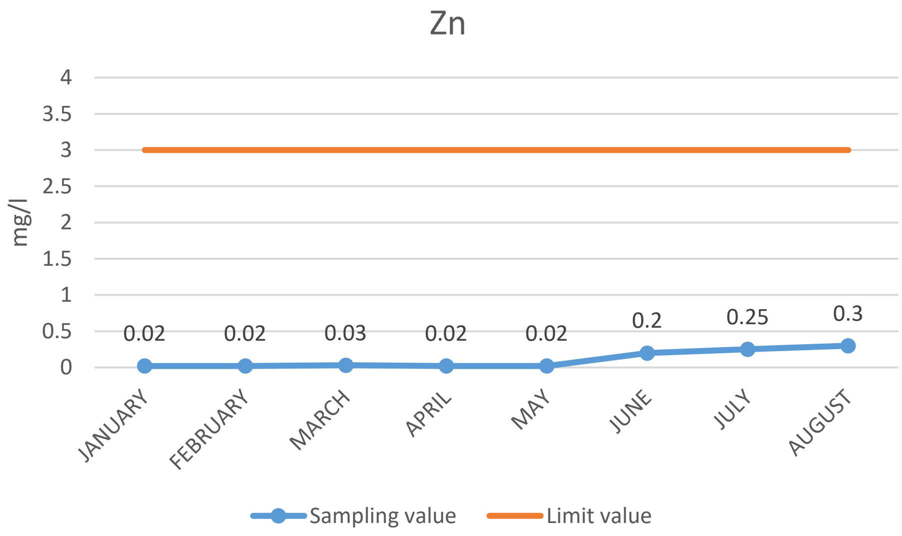
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mg/l
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2.5
2
1.5
1
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0
0.02
0.02
0.03
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0.02
0.2
0.25
0.3
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FEBRUARY
MARCH
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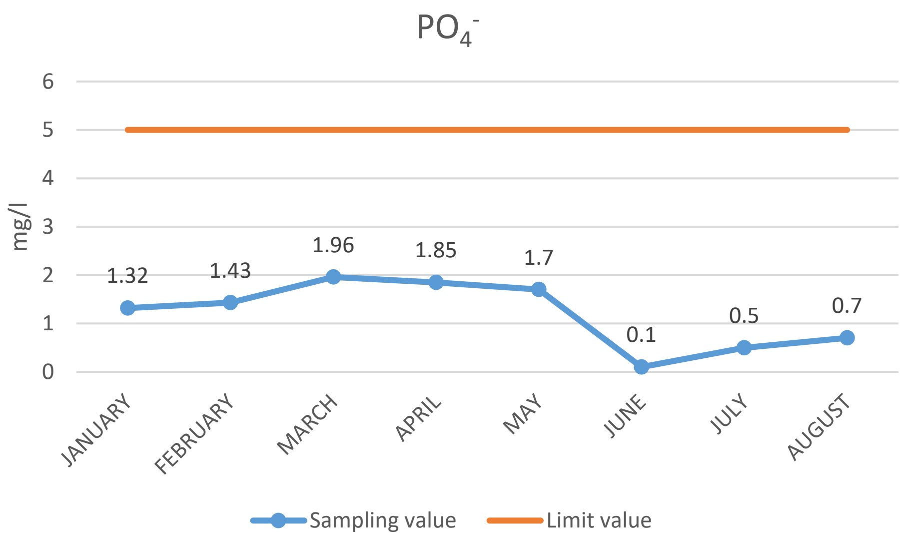
MAY
JUNE
JULY
AUGUST
Sampling value
Limit value


PO4-
mg/l
6
5
4
3
2
1
0
1.32
1.43
1.96
1.85
1.7
0.1
0.5
0.7
JANUARY
FEBRUARY
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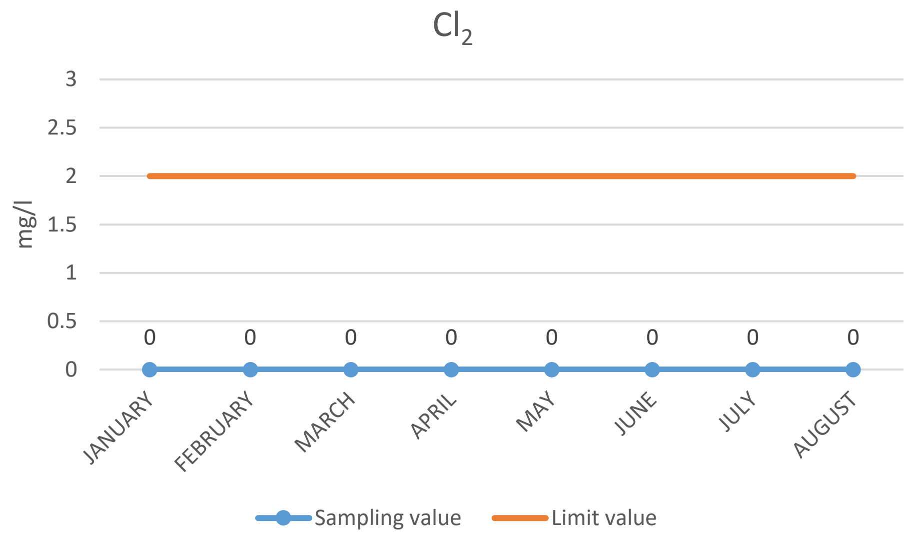
APRIL
MAY
JUNE
JULY
AUGUST
Sampling value
Limit value

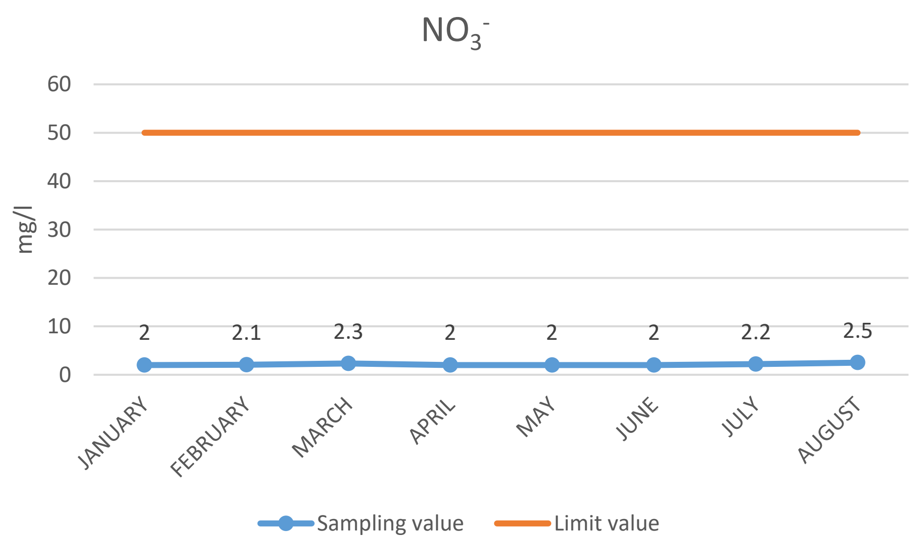


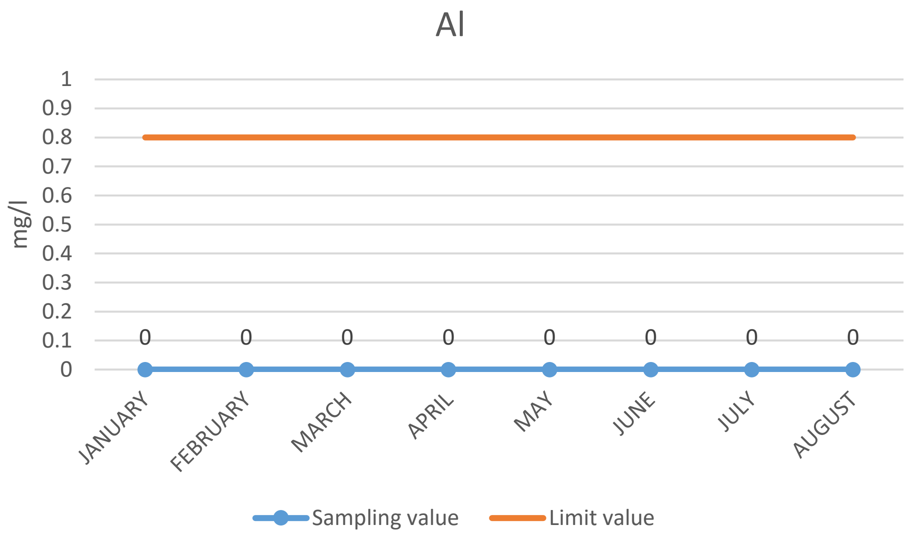
The results for Prespa Lake are that the values for NO_3^- , Zn and Fe are higher in summer,

the values for PO_4^- are lower in summer,there are no findings of Al and Cl_2, and the values of SO_4^- are similar in all sampling months except for April.

Generally, the good status that predominates in this area is due to the fact that Prespa lake is protected by strict legislation (**Greek National Woodland Park**, **Greek National Park),** that forbids many activities that can cause significant damage in the lake.

Kastoria's Lake




Al
mg/l
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
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0 0 0 0 0 0 0 0
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AUGUST
Sampling value
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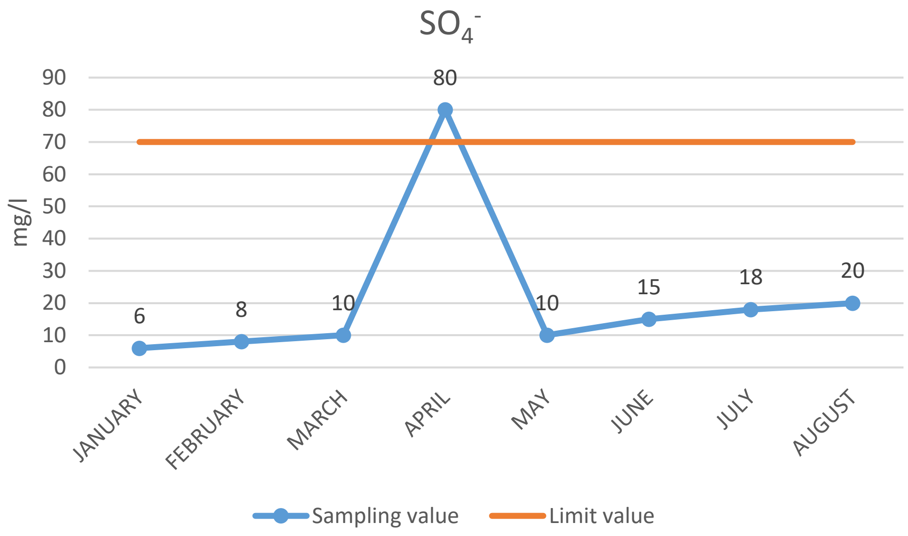
SO_4^-
mg/l
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80
70
60
50
40
30
20
10
0
6 8 10 80 10 15 18 20
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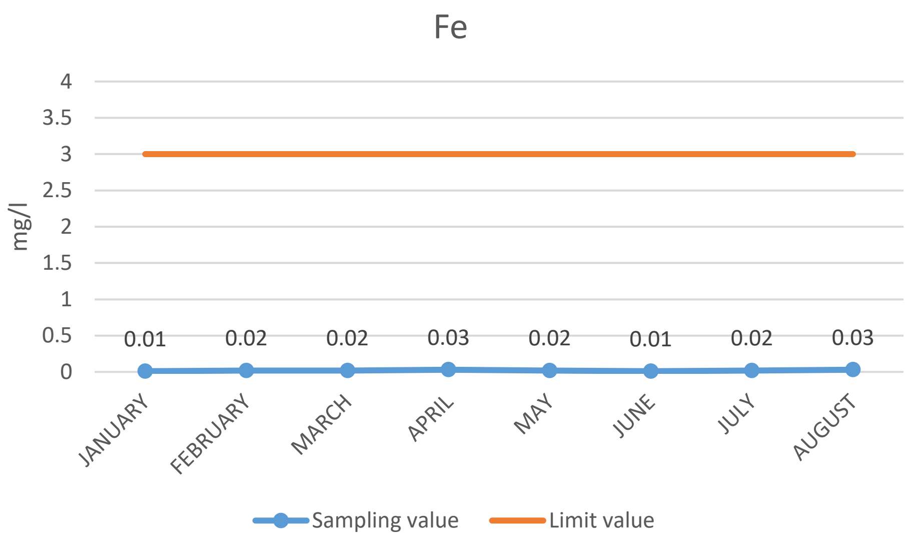
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mg/l
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3.5
3
2.5
2
1.5
1
0.5
0
0.01 0.02 0.02 0.03 0.02 0.01 0.02 0.03
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MAY
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AUGUST
Sampling value
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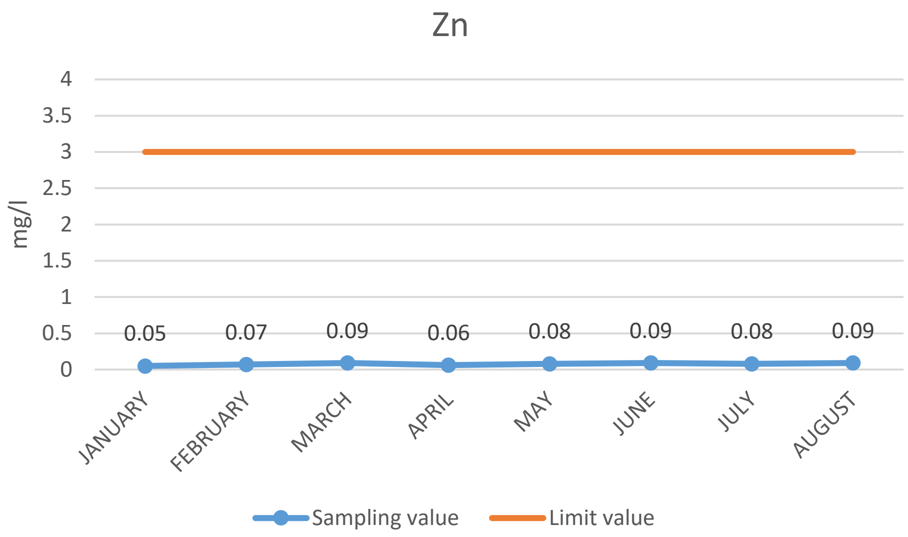
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mg/l
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3
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2
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1
0.5
0
0.05
0.07
0.09
0.06
0.08
0.09
0.08
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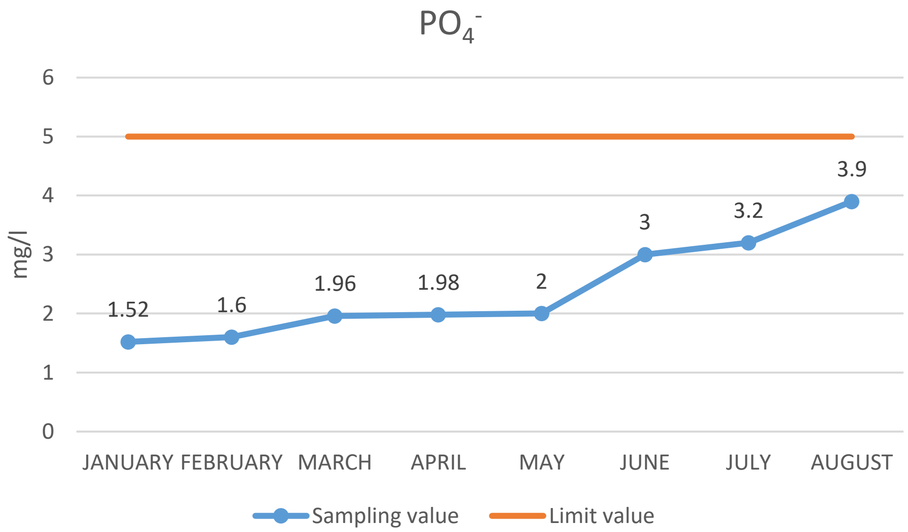
PO_4^-
mg/l
6
5
4
3
2
1
0
1.52
1.6
1.96
1.98
2
3
3.2
3.9
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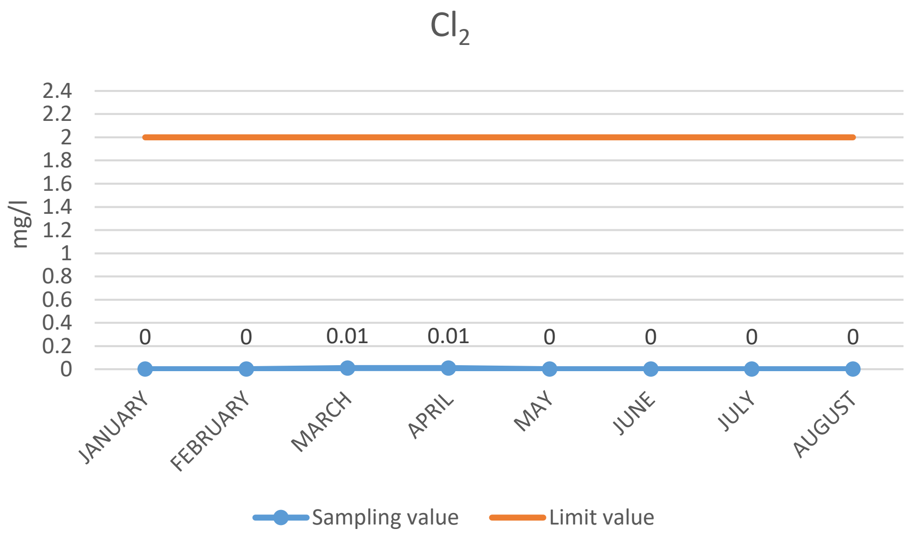
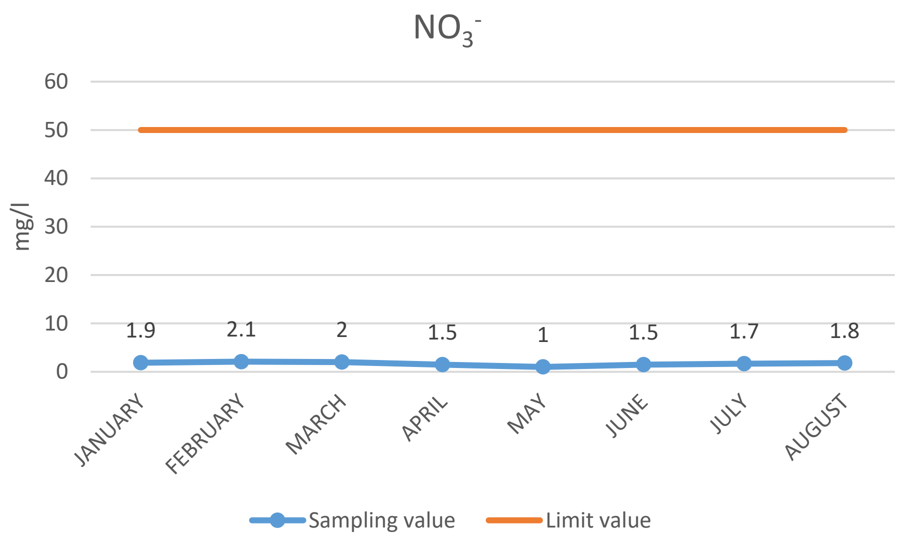

Cl_2
mg/l
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0
0.01
0.01
0
0
0
0
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
Sampling value
Limit value

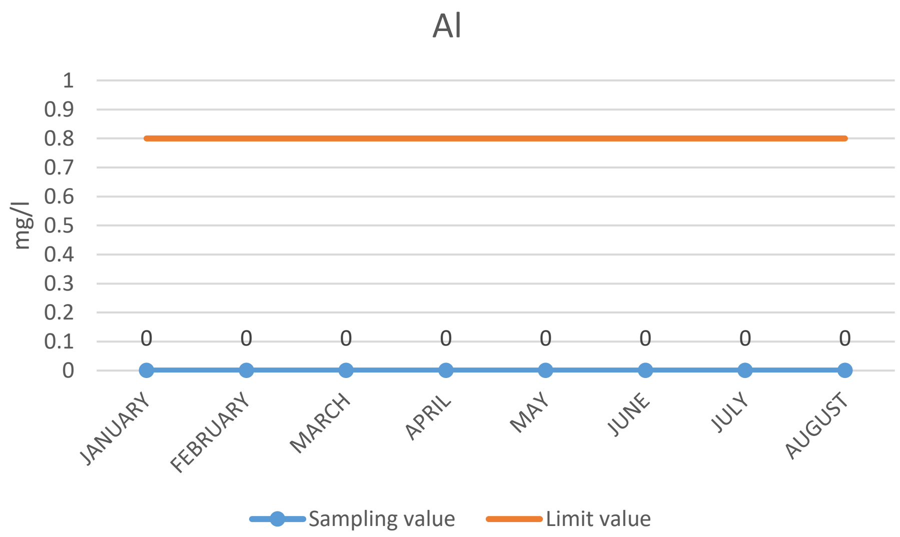
The results for Kastoria's Lake are that the values for PO_4^- are higher in summer.

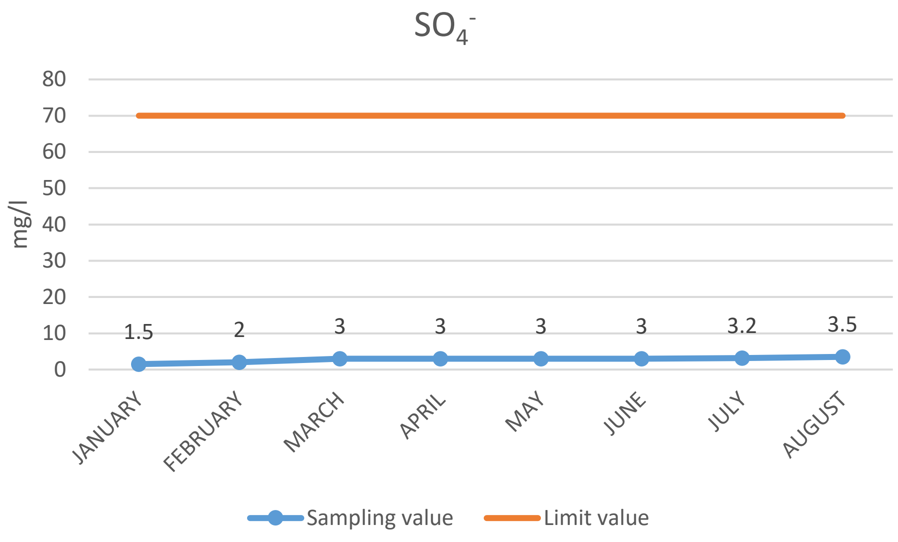
There are no findings of Al and the value of SO_4^- in April exceeds the limit value.

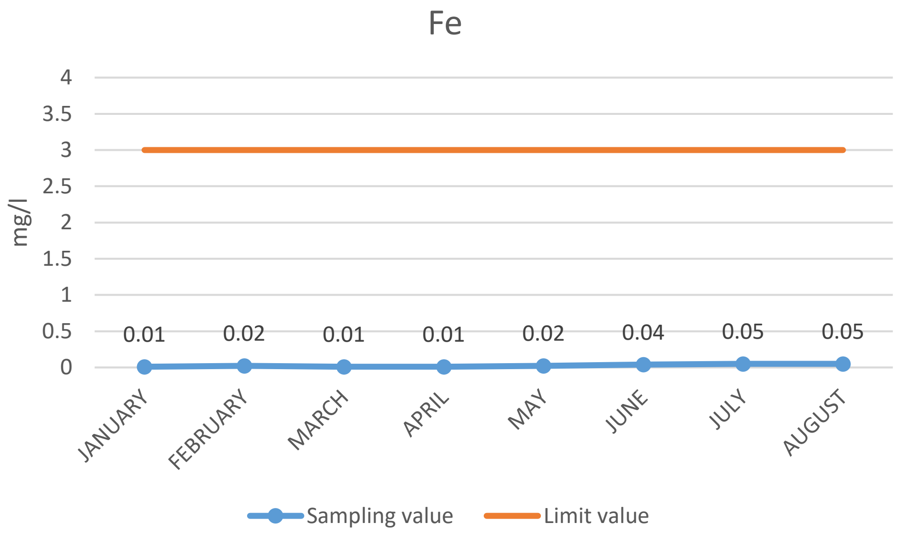
The high values of SO4 is mainly due to the existence of extensive industry (including quarries) in the broad area. The high concentration of PO4 mainly in summer months is due to fact that the broad area consists of agricultural land and due to the usage of fertilizers that runoff in the lake, the concentration of PO4 is high (source: 1st revision of catchment management plan of Western Macedonia (EL 09).

Ohrid Lake






SO_4^-
mg/l
80
70
60
50
40
30
20
10
0
1.5
2
3
3
3
3
3.2
3.5
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
Sampling value
Limit value


Fe
mg/l
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3.5
3
2.5
2
1.5
1
0.5
0
0.01
0.02
0.01
0.01
0.02
0.04
0.05
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FEBRUARY
MARCH
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MAY
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Sampling value
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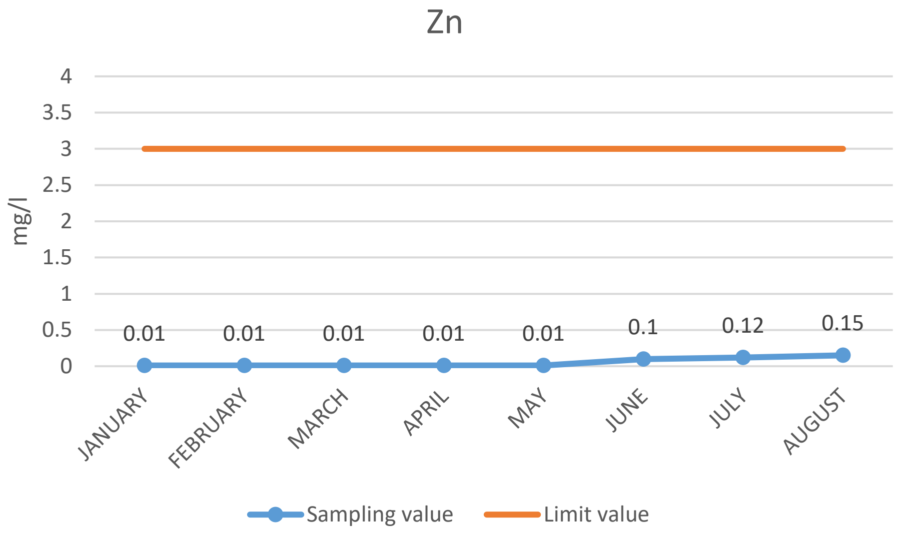
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mg/l
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3.5
3
2.5
2
1.5
1
0.5
0
0.01
0.01
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0.01
0.01
0.1
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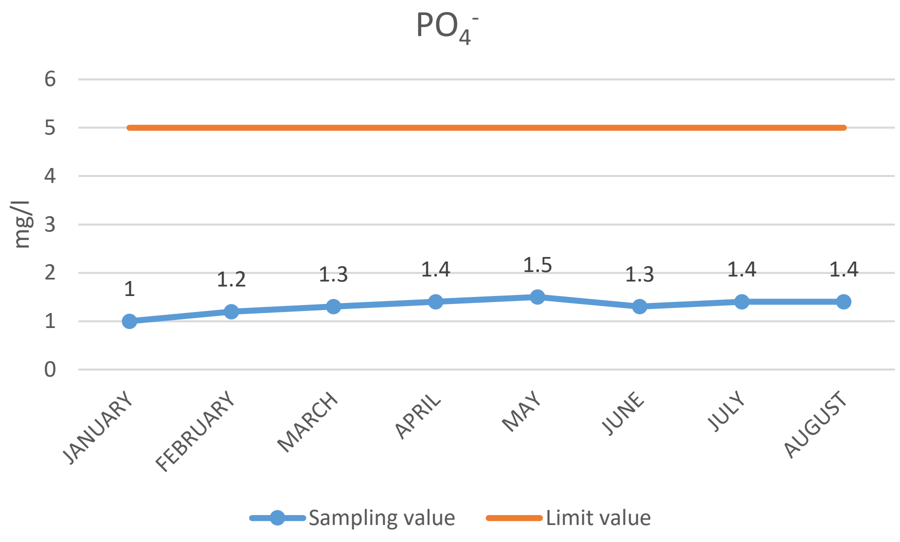
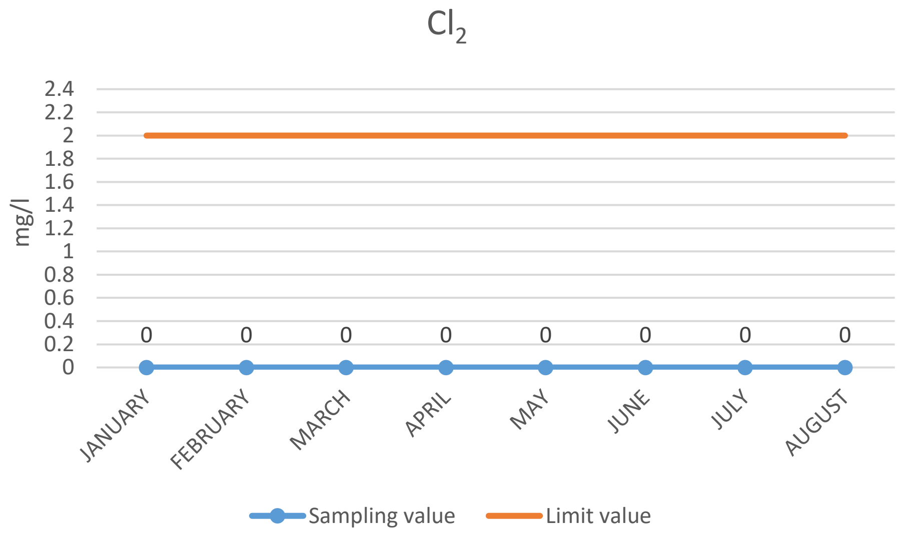




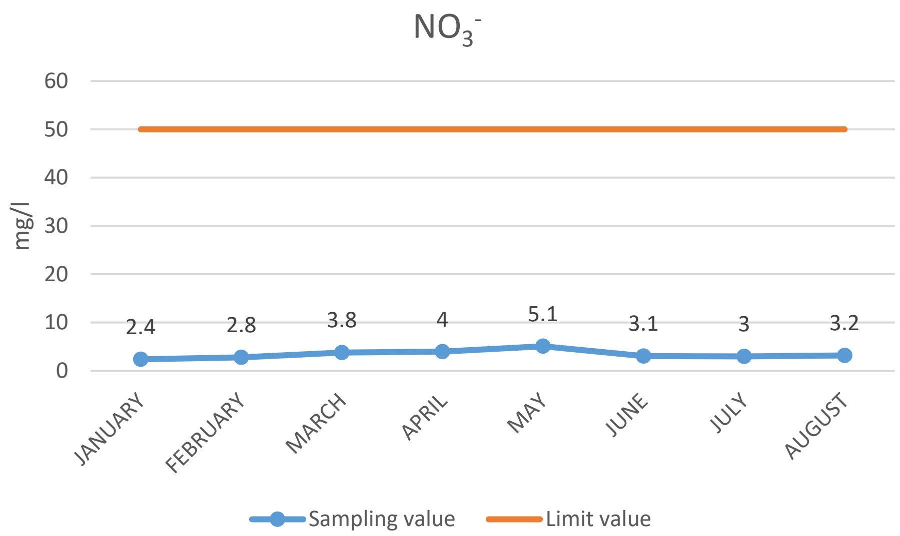
The results for Ohrid Lake are that the values for SO_4^-, Zn and Fe are higher in summer.

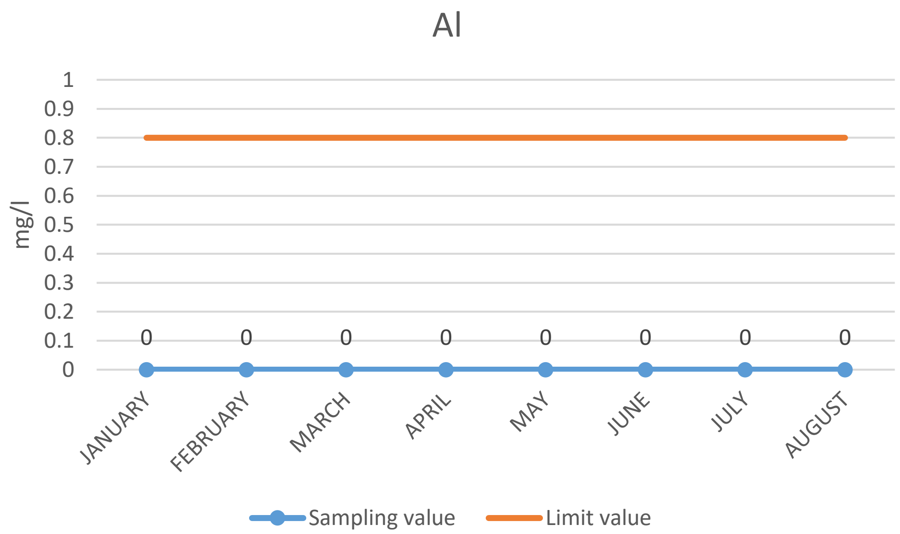
There are no findings of Al and Cl_2.

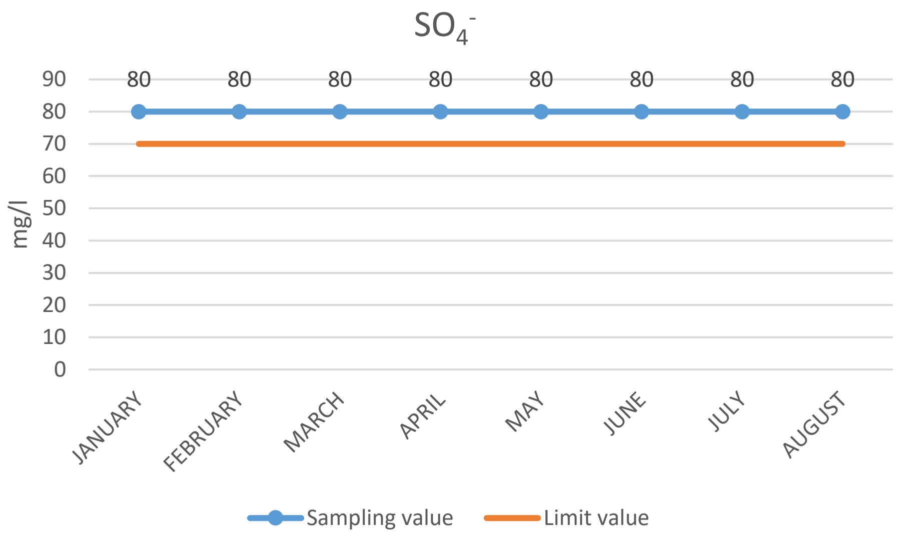
SO4 is higher in summer months due the agricultural land use.

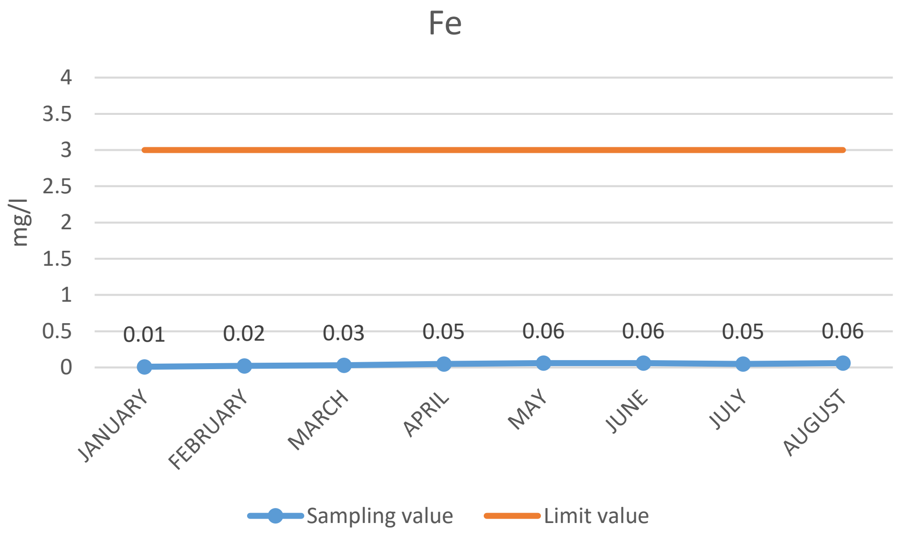
For the reason that agricultural land use is limited in North and South part of the lake and the East and West part consist of steep slopes, the situation of the lake is characterized as good.

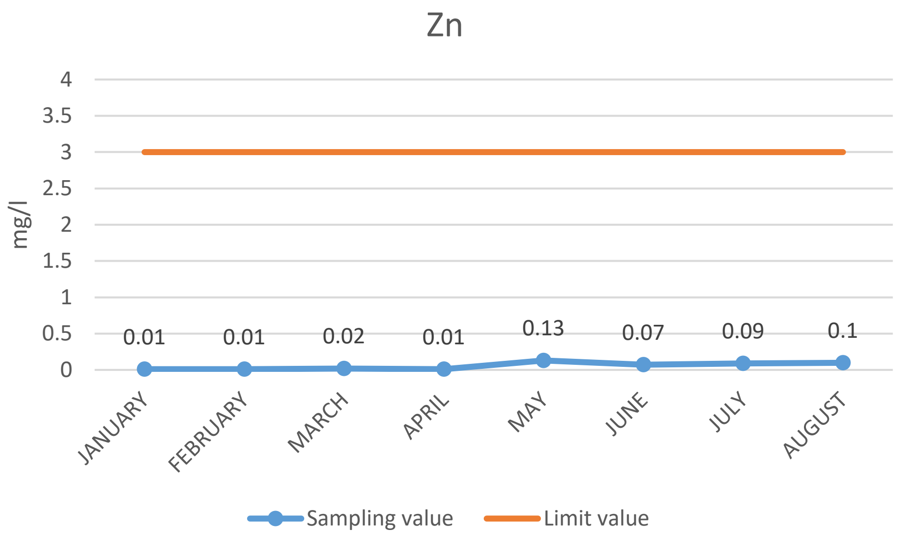
Vegoritida Lake






SO4-
90
80
70
60
50
40
30
20
10
0
mg/l
80 80 80 80 80 80 80 80
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST
Sampling value
Limit value


Fe
4
3.5
3
2.5
2
1.5
1
0.5
0
mg/l
0.01 0.02 0.03 0.05 0.06 0.06 0.05 0.06
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST
Sampling value
Limit value


Zn
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3.5
3
2.5
2
1.5
1
0.5
0
mg/l
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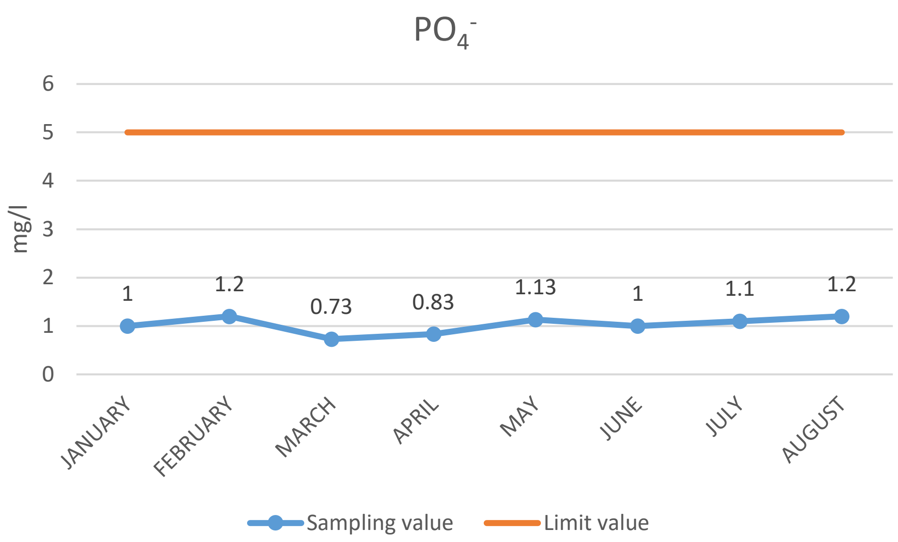
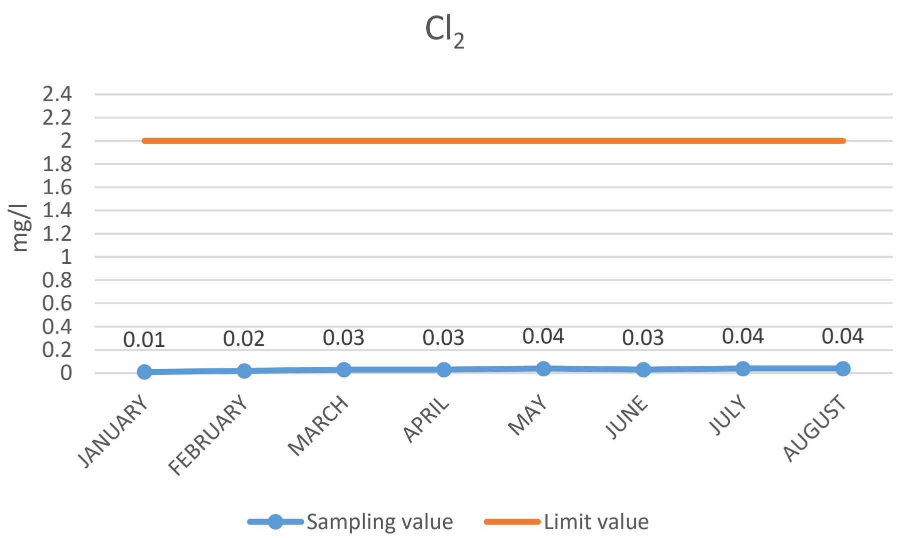
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST
Sampling value
Limit value





The results for Vegoritida Lake are that the values of NO_3^- are lower in winter months.

The values of SO_4^- exceed the limit value in all sampling months.

There are no findings of Al.

The high values of SO4 are caused by copious livestock existence in the broad area. Also the usage of fertilizers and pesticides in agriculture contribute this phenomenon. Also there are some quarries in the broad area of the lake.

3.2. Results on the application of the HYSPLIT back-trajectory model and the Langrangian Particle Dispersion Model FLEXPART-WRF

In the entire area of Pelister Park two lakes of magnificent beauty (Pelister's Eyes), are situated at an altitude of 2.200m. Moreover, in a distance STARTING from some up to several decades of km far from this park, southwards and westwards, four major lakes exist: Prespa, Ohrid, Kastoria and Veggoritis. From the other side, Pinus Peuce, a unique all over the world forest tree species, appeared in Pelister's slopes, while from the same slopes a lot of Axios (Vardar) tributaries, start their flow. Thus, taking into consideration all the above mentioned, we believe that the implementation of a model, which will explain how the lakes and the rivers, as well as the fragile vegetation of this specific area could be affected by the air pollutants that have their sources both in Greece and North Macedonia and more specifically in the Pelagonia district, as well as, in Kastoria, Florina and Kozani prefectures, when due to wind blow or to rainfall phenomena, they receive high quantities of toxic materials. For this purpose we have implemented **HYSPLIT** and **FLEXPART** models for the specific area as described in the following sections.

D1.1.HYSPLIT model runs

The long-range origin of air masses arriving at the area of interest is computed with the HYSPLIT back-trajectory model driven by the 3-hourly meteorological dataset Global Data Assimilation System (GDAS) at a resolution of 1°×1°. The HYSPLIT model is widely used to assess the air mass origin and thus the sources of the atmospheric pollutants (*Draxler and Hess 1997; Stein et al., 2015; Rolph et al., 2017*). In this regard, a full year simulation is performed for 2020 to allow the statistical description of air-mass origin on an annual basis.

Each model simulation is performed for 48-hours in backward mode. Four runs are performed for each day starting at 00:00, 06:00, 12:00 and 18:00 UTC. The complete set of output backtrajectories is shown in ***Figure 1***. The cluster analysis of the simulated back-trajectories provides the probability of air masses arriving through different atmospheric paths as described in the following model results in ***Figures 2-4***.

The cluster analysis reveals three main trajectory paths as shown in ***Figure 2***. A short-range south trajectory path suggests the origin of 69% of the air masses to be at regions located south of the station in Greece and Albania. Two long-range branches are identified for air masses arriving from NNE (28%) and N (4%) suggesting that the station is also affected by air masses arriving from North

Balkans and Central Europe. We note here that the sum of cluster percentages in HYSPLIT does not always yield 100% due to rounding.

The diurnal variation of air mass origin is shown in ***Figure 3***, indicating that the three main directions remain almost similar for all day times. A slight change is identified for the short-range south component that is reduced from about 67% for 00:00 UTC and 06:00 UTC to 57% for 12:00 UTC and 18:00 UTC.

Finally we performed a seasonal analysis to identify the origin of the air masses arriving at winter (December-January-February), spring (March, April, May), summer (June, July, August) and autumn (September, October, December). This analysis is presented in ***Figure 4*** and indicates significant variation mainly between the colder months (winter – spring) and warmer months (summer – autumn). In **winter**, the main trajectory paths are reduced to just one south (61%) and one north (39%) component. The short-range south backtrajectory in the winter origins mainly from the Northwest Greece and the Adriatic Sea. This south branch is also very often in **spring** (41%), followed by a NE backtrajectory arriving from Bulgaria (36%). The **summer** circulation suggests the arrival of air masses only from the north. The short-range branch (72%) shifts to the NW, followed by a north component (23%) and a NE component (4%). In **autumn**, 77% of the air masses originate from very close areas at the North of Greece, followed by 19% from the north and 3% from the NW.

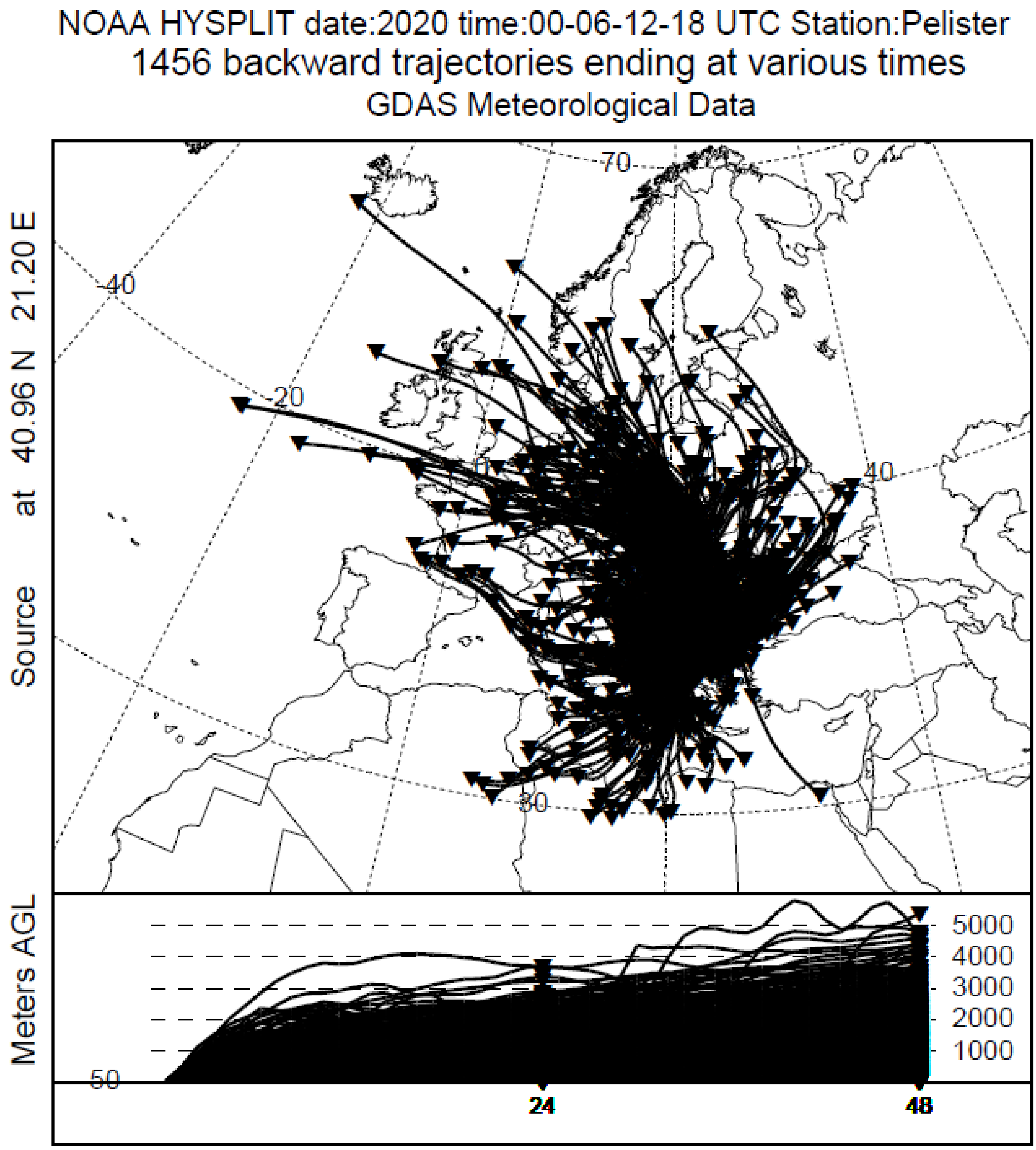


Figure 1. Daily HYSPLIT backtrajectories arriving at surface level at Pelister at 00:00, 06:00, 12:00, 18:00 UTC for the year 2020.

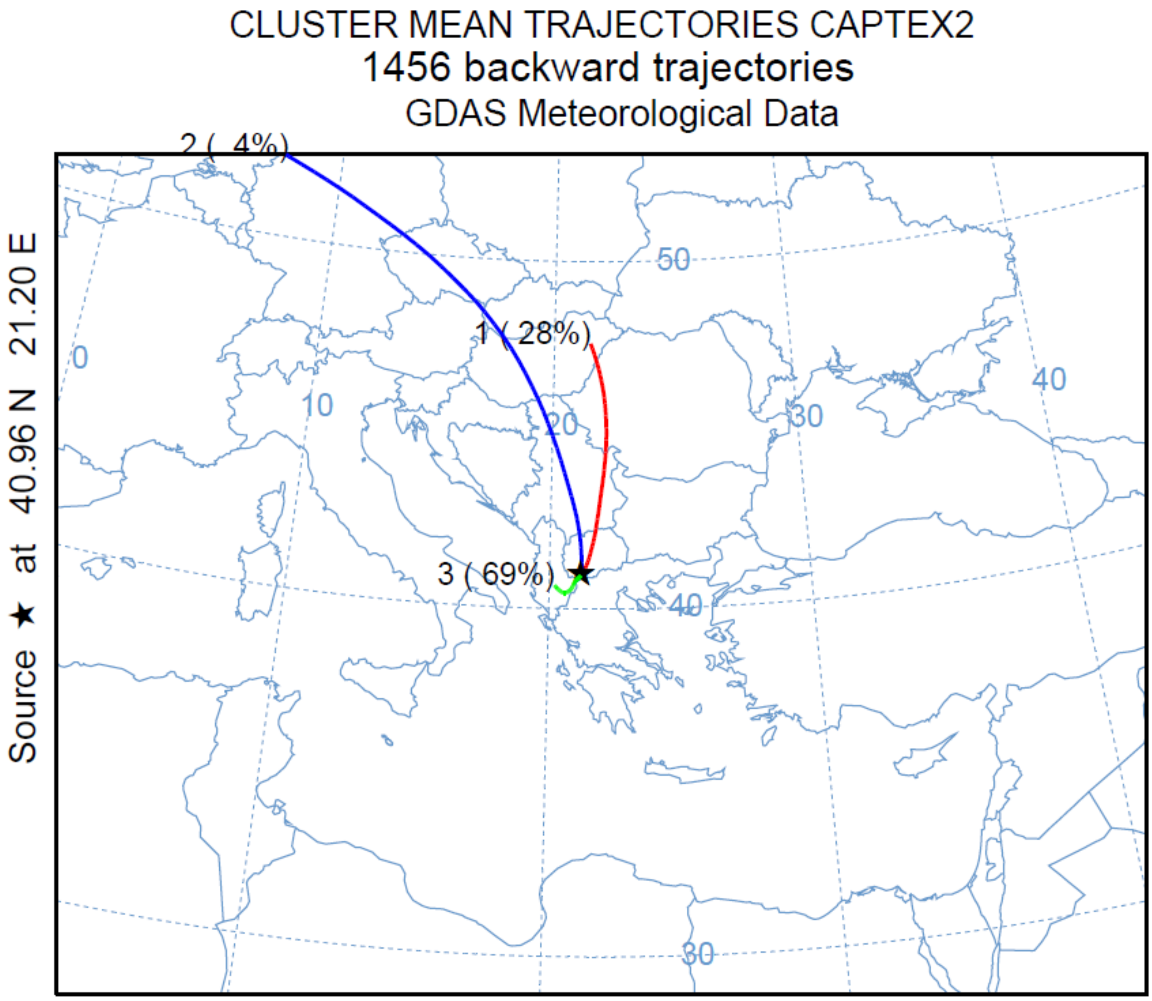


Figure 2. Cluster analysis of the daily HYSPLIT backtrajectories arriving at surface level at Pelister at 00:00, 06:00, 12:00, 18:00 UTC for the year 2020.

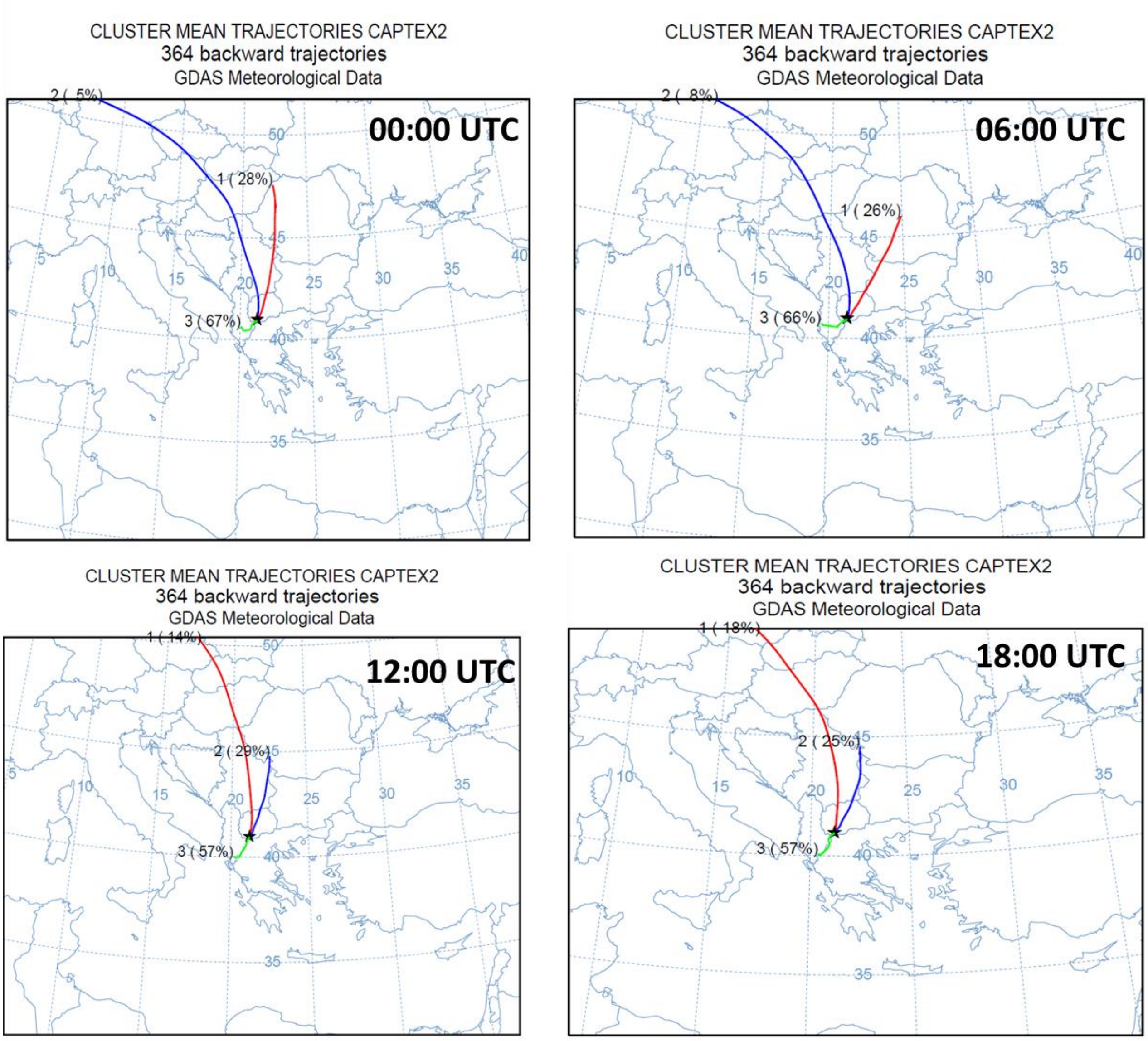


Figure 3. Cluster analysis of the daily HYSPLIT backtrajectories arriving at surface level at Pelister at different times (00:00, 06:00, 12:00, 18:00 UTC) as indicated in the plots for the year 2020.

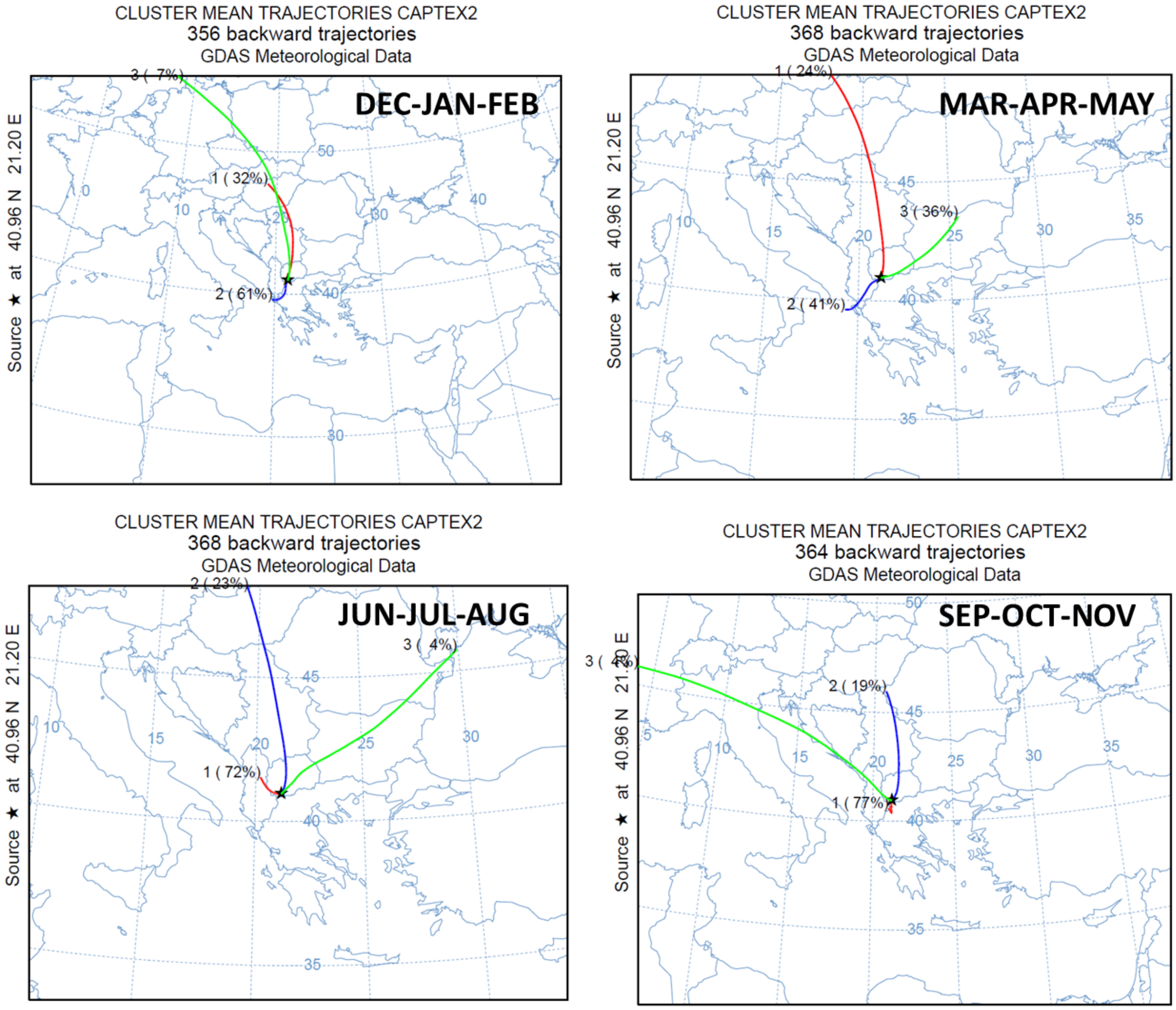


Figure 4. Cluster analysis of the daily HYSPLIT backtrajectories arriving at surface level at Pelister at different seasons (winter DEC-JAN-FEB, spring MAR-APR-MAY, summer JUN-JUL-AUG and autumn SEP-OCT-NOV) as indicated in the plots for the year 2020.

D1.2.FLEXPART-WRF model runs

A more detailed description of back-trajectories, atmospheric dispersion and source – receptor relationships at local scale is computed with the Langrangian Particle Dispersion Model FLEXPART-WRF. The current model version is offline coupled with the hourly output of WRF-CHEM atmospheric model. The hourly output of the WRF-CHEM model drives the FLEXPART dispersion simulations and a number of 40.000 releases per hour is used to describe the dispersion of different chemical species in the Lagrangian simulations. Similar forward and backward simulations with the aforementioned methodology are used to describe the local transport of pollutants at the area of interest.

FLEXPART is a particle dispersion model designed to compute the atmospheric transport, considering the diffusion and the dry and the wet deposition of particles. FLEXPART is suitable for inverse determination of emission aerosol and gas sources. The input data for the coupled FLEXPART-WRF system are the 3-D meteorological fields retrieved from the WRF model. The model solves the equations for transport, turbulent diffusions, and other relevant processes in a Lagrangian framework (*Stohl et al., 2005*). FLEXPART can run in forward mode or backward mode. In forward mode, it simulates the transport and dispersion of emissions from given sources towards receptor points, producing gridded output concentration and deposition. In backward mode, it produces the source–receptor relationship with respect to a point source or gridded sources for given receptors. An example of the emission sensitivity model runs is shown in **Figure 5** for the 48-hour backward calculation of particles arriving at Pelister between 8 April 2023 12:00 UTC and 10 April 2023 12:00 UTC**.** The arrival of the air masses is assumed to be at surface level (Receptor) and their origin is allowed to be from the 0-5 km atmospheric layer. As shown in this plot, the station on this period is mainly affected by air masses originating south of Pelister from the region of Florina. This modeling configuration allows the detailed investigation of air mass backtrajectories at different atmospheric levels.

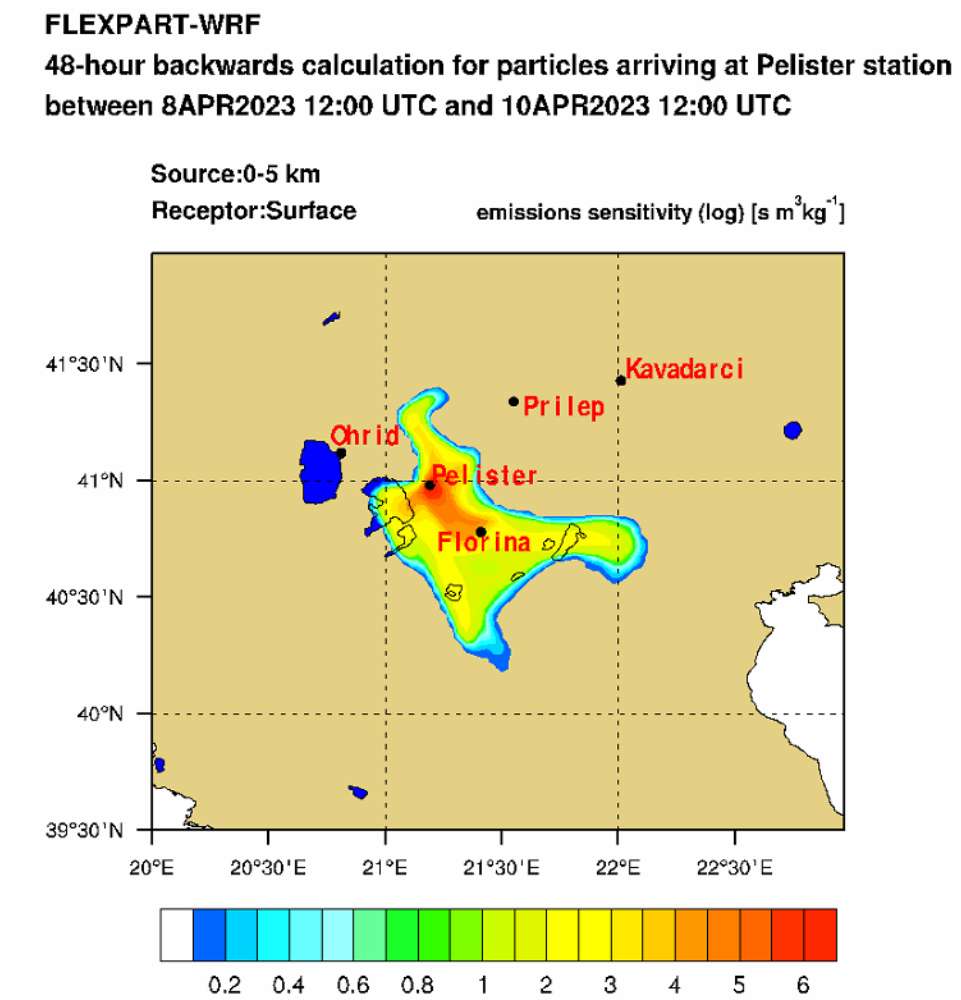


Figure 5. FLEXPART-WRF 48-hour backward calculation of particles arriving at Pelister between 8 April 2023 12:00 UTC and 10 April 2023 12:00 UTC. The arrival of the air masses is assumed to be at surface level (Receptor) and their origin (Source) is from the 0-5

3.3 Field observations on possible effects of acid rain on forest health

Acid rain, a form of precipitation with high levels of sulfuric and nitric acids, can have significant implications for forest health. These impacts are often complex and multifaceted, affecting various aspects of the forest ecosystem.

Firstly, acid rain can directly damage the leaves and needles of trees. This damage reduces the ability of trees to photosynthesize, essentially hampering their ability to produce food. Over time, this can lead to weakened trees, reduced growth, and increased susceptibility to disease and pests. Another critical aspect is the effect of acid rain on soil chemistry. When acid rain seeps into the soil, it can leach away essential nutrients like calcium and magnesium, which are vital for healthy tree growth. The increased acidity can mobilize aluminum, a toxic metal normally locked in soil minerals, making it available in a form that can be harmful to tree roots. This can further stress trees, making them less able to withstand environmental pressures. Acid rain can also affect the microbial communities in the soil. These microorganisms play a crucial role in nutrient cycling and soil health, and their disruption can have cascading effects on forest ecosystems. Finaly, acid rain can also impact water bodies within forest ecosystems, such as streams and lakes. The increased acidity in these waters can harm aquatic life, affecting food chains and possibly leading to a decrease in biodiversity.

In the broader context, these impacts can lead to changes in forest composition. Some species or individuals are more resistant to the effects of acid rain than others, leading to shifts in the dominant species within these ecosystems. Over time, this can alter the structure and function of forest ecosystems, potentially impacting wildlife, carbon storage, and even local climate conditions (Figure 6).

Figure 6. Effect of Acid rain on forest health

The effects of acid rain on forests are not always immediate or easily observable, and they can be compounded by other environmental stressors like climate change and pollution. However, ongoing research and environmental monitoring continue to shed light on these complex interactions and the long-term health of forest ecosystems in the face of acid rain. In the current study, we employed two indicators in order to access possible effects of acid rain in the area, given that no massive deaths were observed in the analysis of time series satellite data.

The first indicator was the presence of lichens in the study area. lichens are widely recognized as indicators of atmospheric pollution, including acid rain. Lichens, which are symbiotic associations between a fungus and an alga or a cyanobacterium, are particularly sensitive to environmental changes, especially air quality. This sensitivity makes them useful bioindicators for monitoring the health of ecosystems in relation to air pollution. The reasons for their usefulness in indicating air pollution and acid rain include:

Sensitivity to Pollutants: Lichens are extremely sensitive to toxic substances in the air, such as sulfur dioxide, nitrogen oxides, and other pollutants commonly associated with acid rain. These substances can directly damage lichen tissues or indirectly affect them by altering the pH of their substrate.

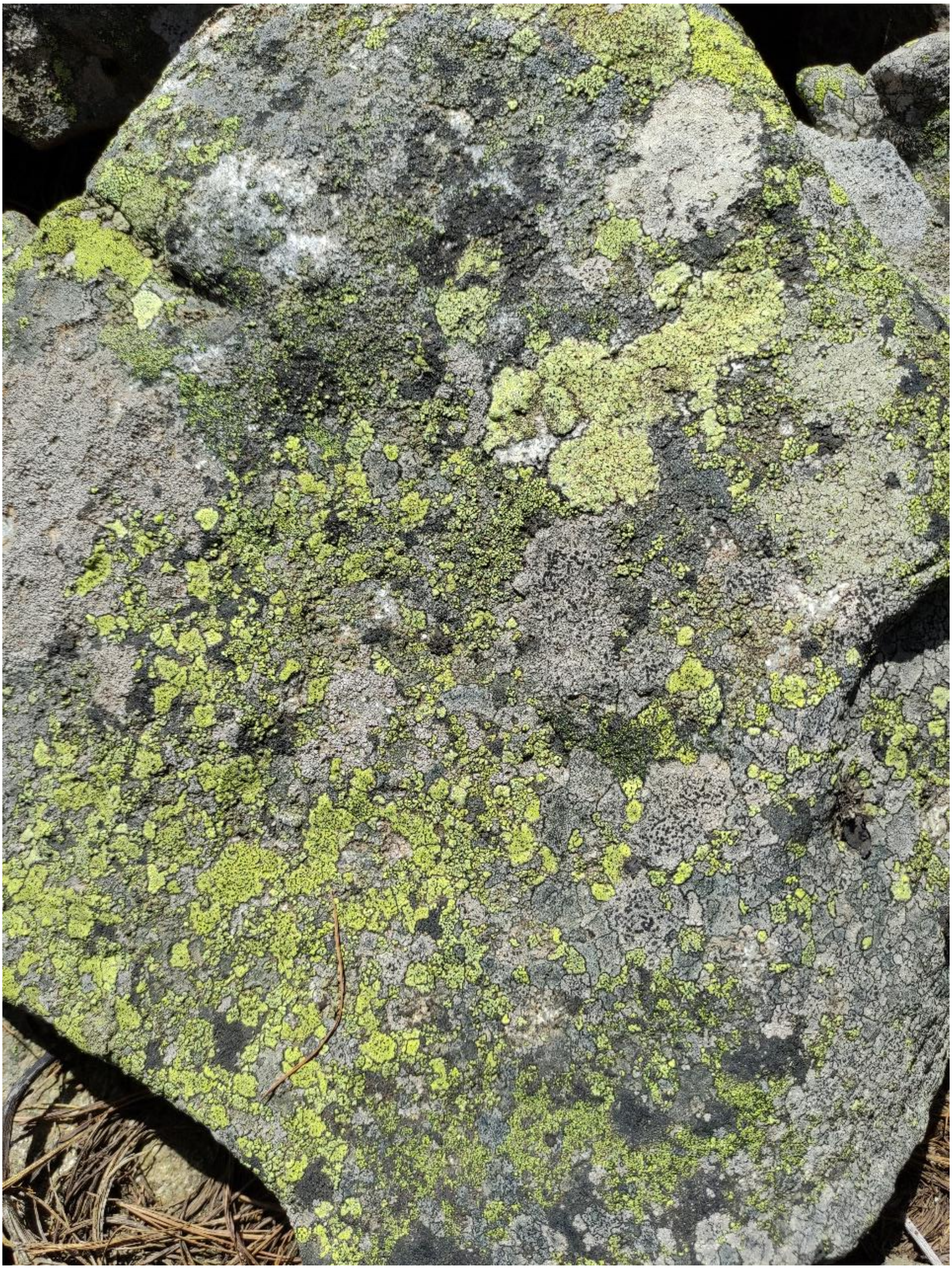
Absorption of Nutrients from the Air: Unlike most plants, lichens obtain most of their nutrients directly from the air, rather than through roots in the soil. This direct exposure means they are more susceptible to airborne pollutants.

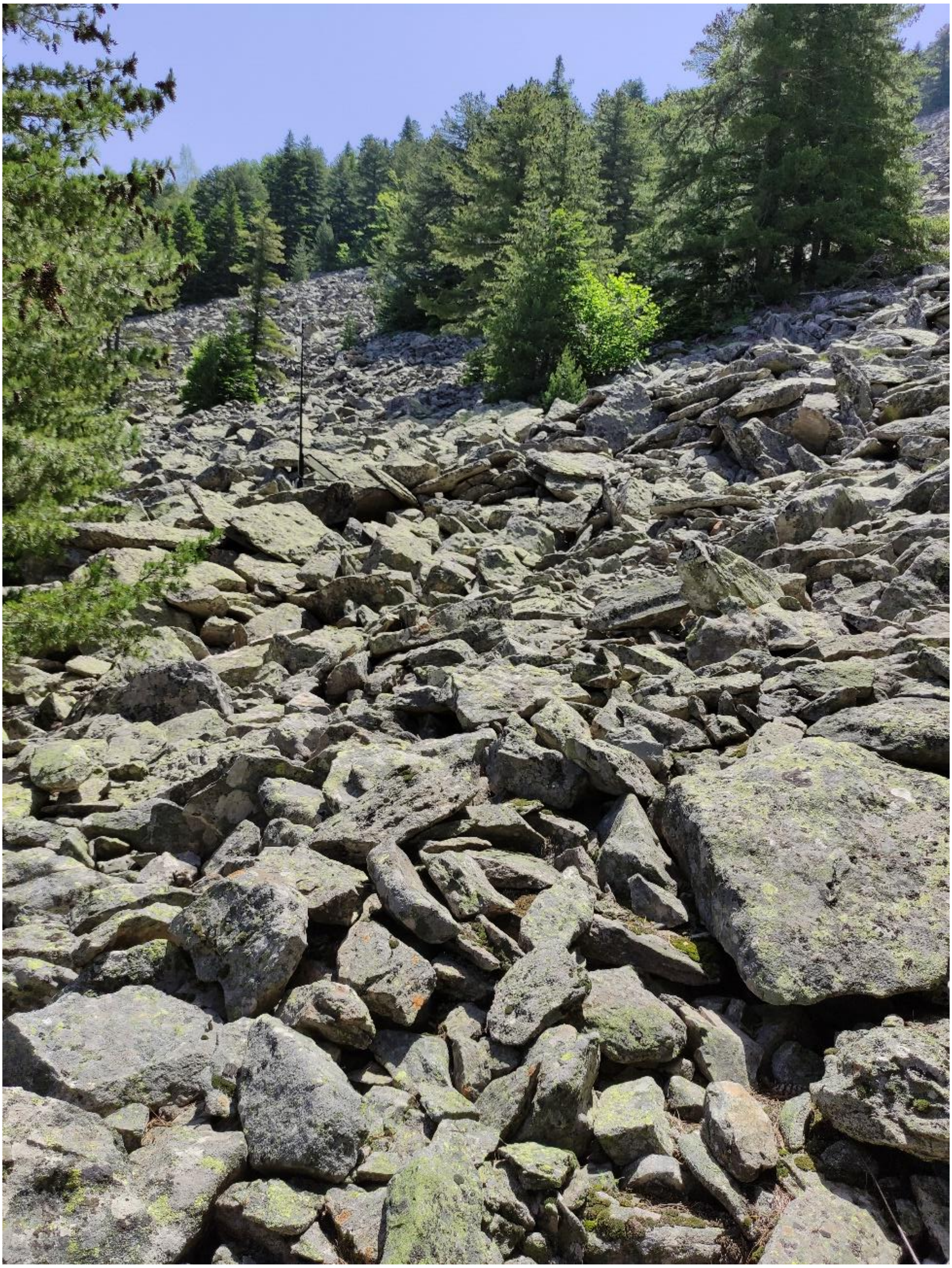
Longevity and Slow Growth: Lichens typically have long lifespans and grow slowly, which means they can accumulate pollutants over time. This makes them effective recorders of long-term pollution trends.

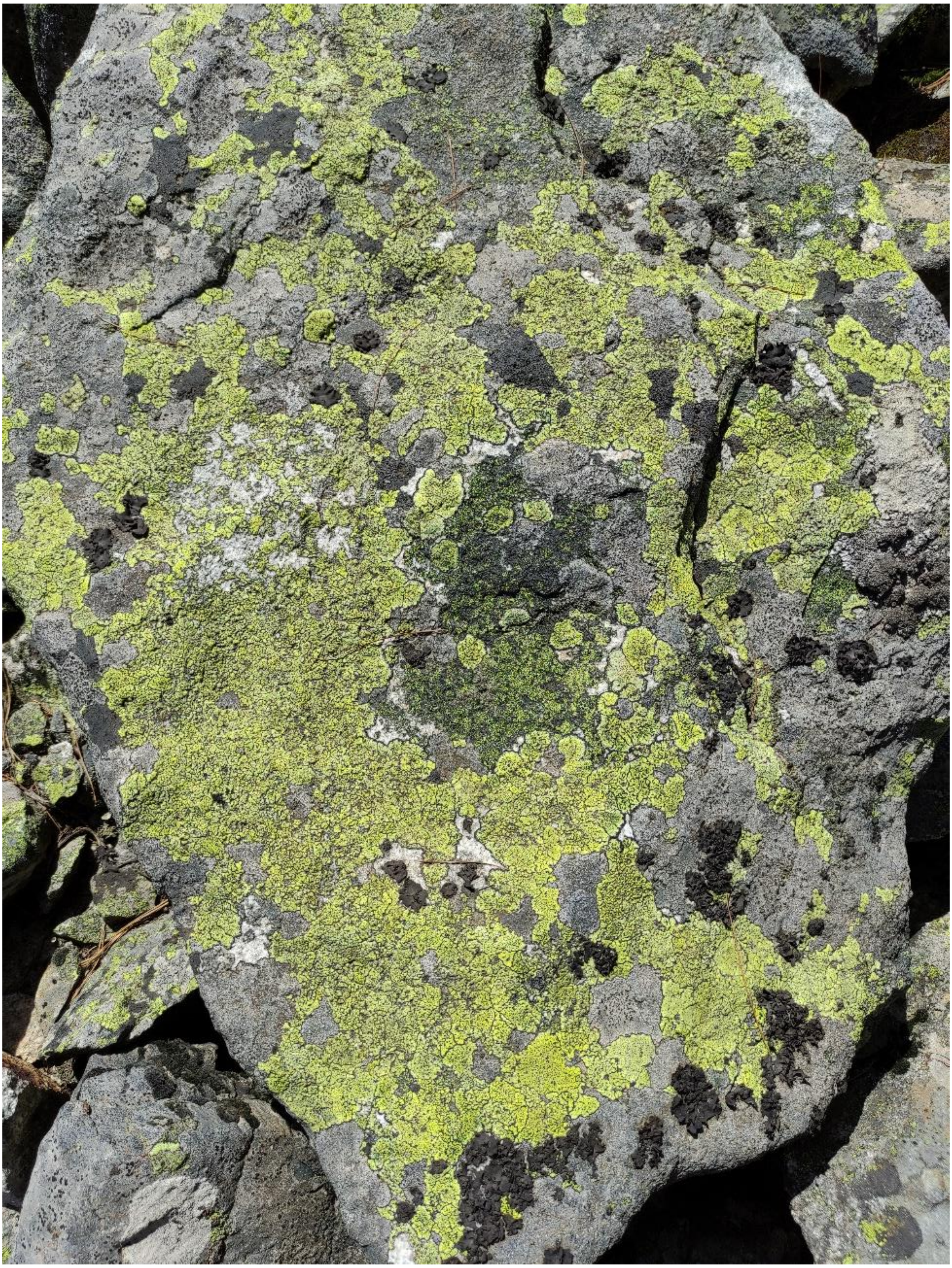
Diversity and Specificity: There is a wide variety of lichen species, each with different tolerances to pollutants. Some species are more tolerant and can survive in polluted environments, while others are highly sensitive and will decline or disappear in response to pollution. The presence or absence of specific lichen species can indicate the level of pollution in an area.

Visual Indicators: Changes in lichen communities, such as a reduction in diversity, changes in species composition, or visible damage to lichen thalli, are often visible to the naked eye and can be used as a clear indicator of increasing levels of air pollution and acid rain.

Lichen-based monitoring has been used in many parts of the world to assess the impact of air pollution, including the effects of acid rain on natural ecosystems. They are particularly valuable in tracking changes over time and in providing a low-cost, effective means of monitoring air quality and the health of the environment. In Pelister national park, as the following pictures demonstrate there are no signs of atmospheric pollution using Lichens as bioindicators.







Apart from the presence of lichens 24 soil samples were collected and ansysed for pH. The samples were distributed along the entire altitudinal range of forest national park (Figure 7). Soil pH is a key indicator of the effects of acid rain on soil. The pH level of soil is a measure of its acidity or alkalinity, and it can be significantly influenced by acid rain.

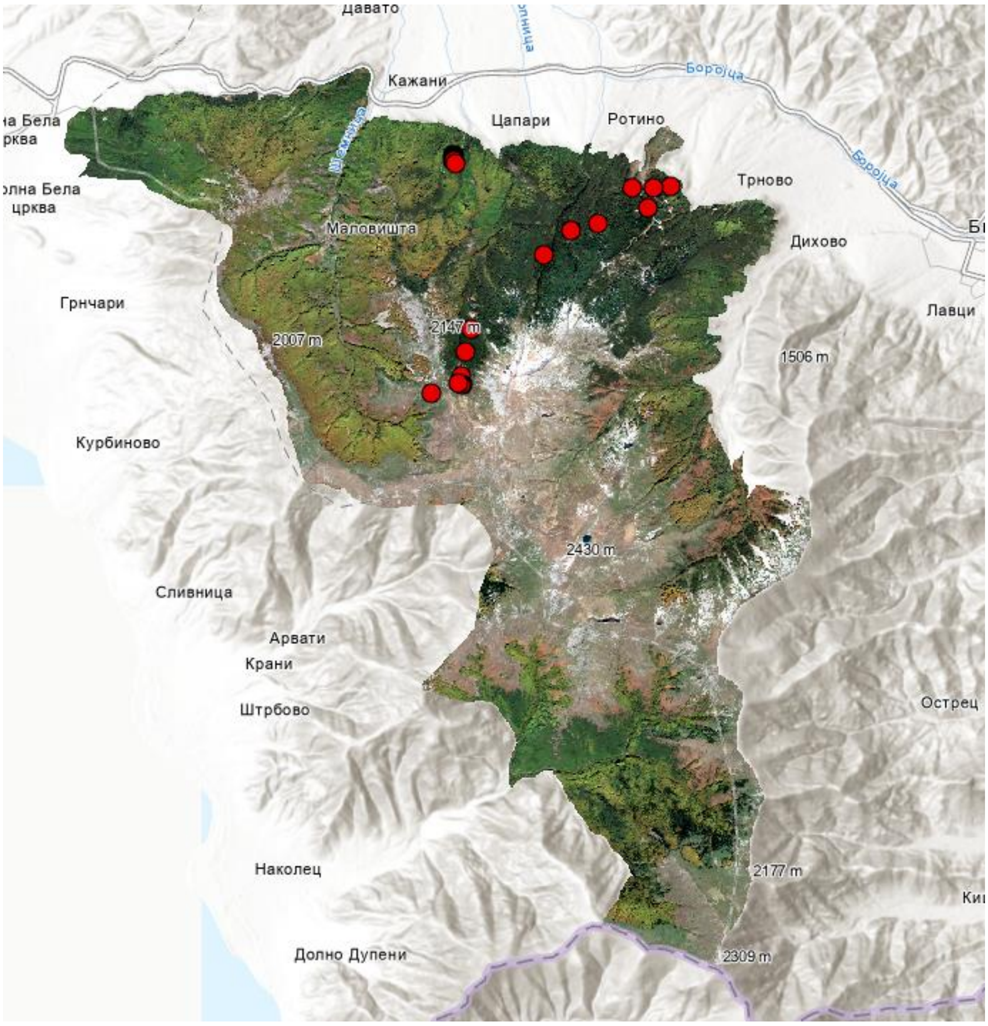


Figure 7. Distribution of soil samples across Pelister National Park

Acid rain affects soil pH in the following ways and monitoring of soil pH is important:

Acidification of Soil: Acid rain, which contains sulfuric and nitric acids, can lower the pH of soil, making it more acidic. This change in pH can happen over time, especially in areas that are consistently exposed to acid rain.

Nutrient Leaching: More acidic soil can lead to the leaching of vital nutrients, such as calcium, magnesium, and potassium. These nutrients are essential for plant growth, and their depletion can adversely affect the health of plants and the entire ecosystem.

Mobilization of Toxic Metals: Lower pH levels in soil can mobilize toxic metals like aluminum. When these metals become soluble, they can be taken up by plant roots, potentially causing toxicity in plants and, subsequently, in the animals that feed on these plants.

Microbial Activity: Soil pH can influence the activity of soil microorganisms. Many of these microorganisms play crucial roles in nutrient cycling and other essential soil processes. Acidic conditions can inhibit their activity, thereby affecting soil health and fertility.

Indicator of Long-term Changes: Monitoring soil pH over time can provide valuable information about the long-term impact of acid rain on a particular ecosystem. It can help in assessing the extent of soil acidification and in implementing measures to mitigate its effects.

The results obtained in the study area are rather interesting and presented in figure 8.

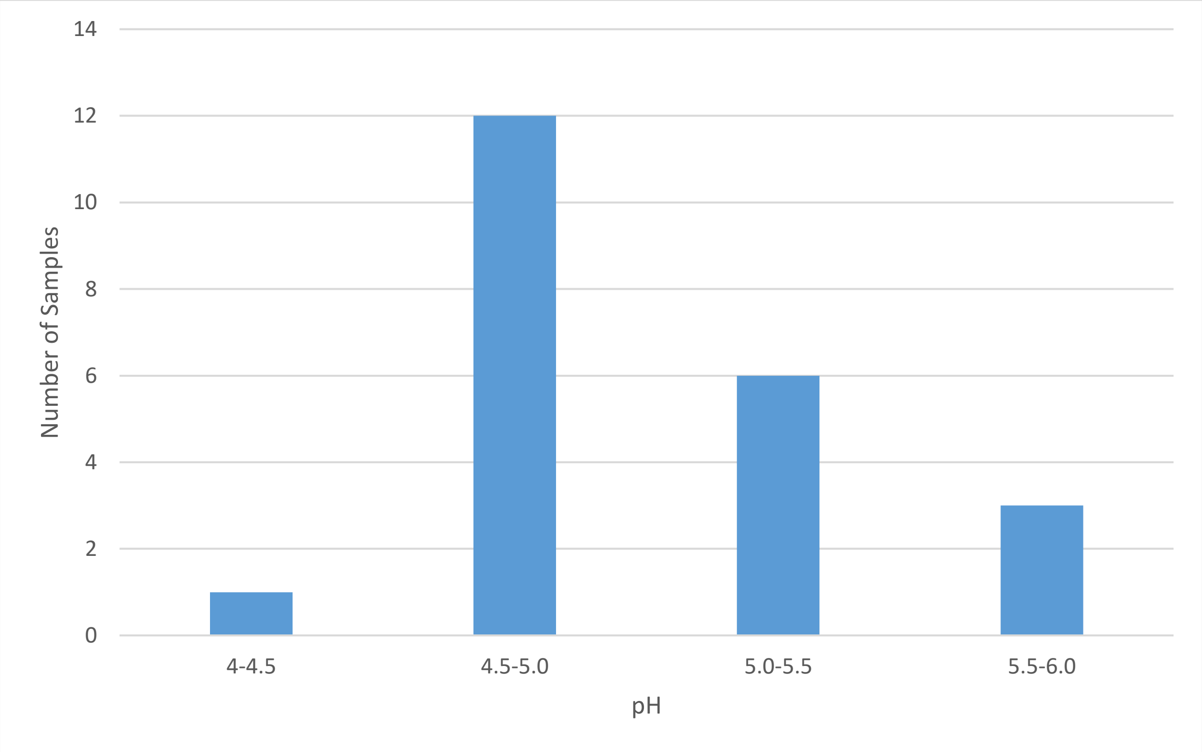


Figure 8. pH values distriution observed in Pelister National Park

Particularly low values pf pH, and acidic soils were observed in the study area. This soil acidity may create a unique environment of Balkan pine or may constitute a threat for the future. Apparently the monitoring of soil pH is a crucial aspect of understanding and managing the impact of acid rain on terrestrial ecosystems and especially unique ecosystems such as the one in Pelister National park. It helps in identifying areas that are at risk and in evaluating the effectiveness of regulatory policies aimed at reducing emissions of sulfur dioxide and nitrogen oxides, the primary contributors to acid rain.

• 4 Conclusions and recommendations

Nitrates: Nitrate is usually the most prevalent form of nitrogen in lakes. Both NO3- and NH4+ can be used by most aquatic plants and algae. If these inorganic forms of nitrogen exceed 0.3 mg/l (as N) in spring, there is sufficient nitrogen to support summer algae blooms. In this study, the nitrates values were observed between 0.0 – 7.0 mg/L.

Sulfate: Sulfate is a substance that occurs naturally in drinking water and has a secondary maximum contaminant level (SMCL) of 250mg/L, based on aesthetic effects (taste and color). In this study, the sulfate values for most of the samples were observed to be less than 5mg/L in the River and less than 80 mg/L in the Lakes. This can be used for certain industrial processes such as sugar production and concrete manufacturing.

Phosphate: Phosphates are chemicals containing the element Phosphorus and they affect water quality by causing excessive growth of algae. Phosphates enter waterways from human and animal waste, phosphorus rich bedrock, laundry, cleaning, industrial effluents, and fertilizer runoff. In this study, the phosphate values were observed between 0.0 – 2.0 mg/L.

Iron: Iron exists naturally in rivers, lakes, and underground water. Presence of iron higher concentration of iron changes color, tastes and leaving stains on clothes. Rivers usually contain approximately 0.5-1mg/L of iron. Such is observed in the given samples/springs studied.

Aluminum: Aluminum is one of the significant sources of water pollution primarily due to its abundant natural occurrence and industrial use. Aluminum is a versatile material due to its excellent properties such as lightweight, corrosion resistance, long life, and electrical conductivity. Hence aluminum finds its presence in a wide range of applications including transportation, packaging, construction, electronic hardware, and electrical transmission lines, to name a few. The release of aluminum to the aquatic environment occurs through both natural and anthropogenic forms resulting from weathering of rocks, acidic springs, and volcanic activities. The anthropogenic aluminum release is a result of human activities such as industrial processes resulting in wastewater and solid waste, fossil fuel combustion, manufacturing, aluminum production, and agriculture. Alum (potassium aluminum sulfate), a chemical used in clarification of drinking water and wastewater can also be a source of aluminum if released untreated. High levels of aluminum are observed predominantly in freshwater compared to marine water as low pH of freshwater compared to ocean water favors its solubility. Acid rain due to industrial activities is a major reason for increased aluminum levels in water as acid rain reduces water pH favoring dissolution of anthropogenic and natural forms. Hence aluminum is an inevitable source of contamination in freshwater in both urban and rural areas resulting in toxic effects on aquatic life and eventually can enter the human food chain.

Chlorine: Chlorine, on it's own, is a greenish-yellow, highly reactive and diatomic gas that is almost never found free in nature by itself. When found in freshwater, chlorine is most often found bonded to other elements and ions. Most chlorine is commercially produced and is most widely known for being used within compounds to purify water/ create cleaning products. In this study, the chlorine values were observed between 0.01 – 0.03 mg/L.

Zinc: Elevated levels of zinc in drinking water may cause the water to have a milky, chalky, or turbid appearance and a metallic/astringent taste. The symptoms of zinc poisoning include low blood pressure, urine retention, jaundice, seizures, joint pain, fever, coughing, and a metallic taste in the mouth. For drinking water, the primary source of zinc would be naturally occurring zinc in the source aquifer, zinc compounds added to water to inhibit corrosion, and/or corrosion of galvanized piping and metal fixtures. In this study, the zinc values were observed between 0.03 – 0.1 mg/L.

The general conclusions are the above:

- It is observed that the most values obtained from the measurements are within limits and much lower than the maximum values.
- It is of high importance that the values of SO_4^- in the Vegoritida Lake are higher than the upper limit values.
- Also in Kastoria's Lake the values of SO_4^- are higher than the limit value in April.
- These values are due to the pesticides , used in the area.
- Main reasons behind these are the extensive usage of fertilizers and pesticides in agriculture, the livestock farming in local area and the existence of industries.

• References

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2. Lakes at Risk of Chloride Contamination Hilary A. Dugan, Nicholas K. Skaff, Jonathan P. Doubek, Sarah L. Bartlett, Samantha M. Burke, Flora E. Krivak-Tetley, Jamie C. Summers, Paul C. Hanson, and Kathleen C. Weathers.