New Challenges Towards the Ecological Management of Paliastomi Lake Will Significantly Improve the Local Environment With Far-Going Positive Global Consequences

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Abstract

Background

The purpose of the research was to provide the review of the institutional and legal requirements and evaluation of the existing sanitary-biological research of the Lake Paliastomi waters; study the current state of environment, problems of pollution from agricultural sources, municipal wastewater and industry in line with the bacterial pollution caused by migratory waterfowl of the Lake Paliastomi, an internationally recognized habitat, wintery and transit area of the birds and an important tourism site.

Results

Have been prepared the analytical data on: the review of the institutional and legal requirements; evaluation of the existing sanitary-biological research of the following waters in the Lake; definition of dynamics of sanitary-microbial indicators in flowing waters; study of biological characteristics of secreted pathogenic agents and definition of their vulnerability towards bacteriophages; mathematical simulation model on different scenarios of dissemination of chemical pollutants and pathogenic bacteria in the lake Paliastomi.

The researchers identified that the pollution by nutrient-rich water causing large blooms of algae and aquatic plants that in its turn leaves little oxygen for fish and other aquatic animals, resulting in the eutrophication followed by suffocation of aquatic life.

Conclusions

The solution of problem requires complex respond: the selected spring sites, regular monitoring of nitrate contents and other basic physico-chemical water parameters; simultaneous, continuous discharge recording; monitoring and maintaining water levels in the wetlands; removing sediment and organic debris build up in wetland pond and etc.

Mathematical modeling of dissemination of the pathogenic bacteria in the Lake Paliastomi enables us to permanently monitor not only the inflowing waters of Paliastomi Lake, but seasonal sources of bacterial pollution due to the migratory birds. In line with monitoring, localized prophylactic point sources spraying of Salmonella bacteriophage cocktail (SBC) by agricultural drones will be useful to restrain bacterial contamination.

Keywords: regulations, water, waterfowl, pollution, environmental health, bacteriophages, monitoring, modeling, purification

Background

The environmental policy of Georgia is built on a sustainable, balanced development where the quality of the environment is considered equally alongside with all socio-economic challenges address following targets of the environmental protection: to avoid pressures from socio-economic activities through the careful planning of new developments, reducing the already existing pressures to acceptable levels and improving the overall state of the environment. In the long-term perspective, this shall ensure a healthy environment for the future generations.

The main law providing the legal environmental framework is the Law on Environmental Protection (1996). The ratification of the EU-Georgia AA in 2014 provides a long-term perspective for the development of the national policy in various fields, including the environment and natural resources. The AA, among other matters, defines the goals to be achieved within a clearly established timeframe for the following areas: water quality and resource management (including the marine environment); biodiversity protection; industrial pollution and industrial hazards; chemical management; and climate action [1].

The United Nations Sustainable Development Goals (SDGs) that was approved in 2015 set 169 targets to achieve by 2030. A number of those targets capture environmental aspects and countries have to adjust their policies to these global targets and in particular "ensure availability and sustainable management of water and sanitation for all (Goal 6.) [3]."

EU-Georgia AA draws attention to sustainable development and the green economy. It is expected that enhanced environment protection will bring increased economic and environmental efficiency, as well as use of modern, cleaner technologies contributing to more sustainable production patterns [1]."

The development of the National Environmental Action Programme (NEAP-3) is: To ensure good qualitative and quantitative status of surface and groundwater bodies as well as coastal waters for human health and aquatic ecosystems with accompanying targets on: development of an effective system of water resources management (Target 1); reduction of water pollution from the point and diffuse sources and ensuring sustainable use of water resources(Target 2); and improvement of the water quality and quantity monitoring and assessment systems(Target 3)[4].

Georgia is a party to the global and regional Multilateral Environmental Agreements (MEAs), including 18 conventions, a number of their protocols and agreements, to which Georgia is the Party plays a significant role in the national policy formulating process [5].

Our Publication addresses the implementation of the requirements of the International Conventions and treaties undertaken by Georgia [5];

EU-Georgia Association Agreement requires the harmonization of the European directives into National acquis.

With the EU support, Georgia working on the introduction of the basin management principles and elaborating the basins management plan. Paliastomi Lake belongs to the one of the 6 river basins of Georgia Enguri-Rioni river Basin.

The Law of Georgia on Water (16 October, 1997) Sets up the legal basis for water resource protection and management.

Main subordinate acts of the Law on Water: Regulation on the protection of Georgian surface waters from the pollution; Regulation on water protection zones; Methodology on the calculation on Maximal Admissible Discharges of pollutants in the wastewater discharged to the surface water; Regulation on the State Accounting of Water Use [6].

Paliastomi Lake was first mentioned by the Greek geographer, philosopher and historian Strabo (64 or 63 BC– c. AD 24): "The Phasisi (river Rioni) flows into the Ponto (Black Sea). At the Phasisi River, there is a city of the same name, Colchis Commercial Port facing a river on one side, a lake on the other and bordered by a Sea from the third side". Greek historian Agathias Scholasticus (ca. 532-580) gives the information about the presence of a lake in the area of the river Rioni mouth as well: "There is a lake there, which is called the small sea and which flows into the Euxene Pontos ("Póntos Áxeinos"). "Paliastomi" was also marked on the Portolan charts by Pasqualini (1408), Bianca (1436) and Freducci (1497). The meaning of this toponym derives from Greek language: Palaeo – old; Stoma – pore, hollow [7].

According to the Ramsar Convention, Paliastomi Lake is a protected area of international importance and is a part of the Kolkheti National Park. Ramsar Site N°893 "Wetlands of Central Kolkheti" are composed of three distinct peat marsh complexes (Anaklia-Churia, Nabada and Pichora-Paliastomi), Paliastomi Lake, the adjoining wet forests, the Black Sea coastal area, as well as the mouths and lowermost parts of Khobi (or Khobistskali) and Rioni Rivers, covering a total of 33,710 ha (55,500 ha including the marine part) in the central part of the Black Sea coastal alluvial plain, in the administrative regions of Khobi and Lachkhuti and the territory of the city of Poti. The site supports a wealth of relict and endemic flora and fauna species. The vegetation consists of typical bog and peat land species, with freshwater marshes supporting reedbeds and brackish areas supporting halophytic plants. Various species of waterfowls use the site for wintering [8].

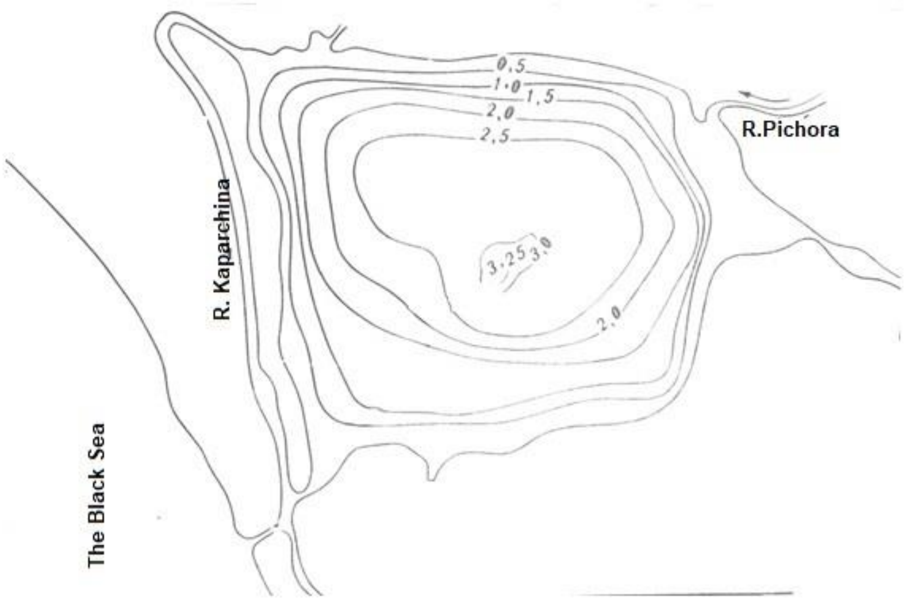
Current geological drilling data (nearly eighty 12-15-meter-deep drill holes) obtained from the bottom of Paliastomi Lake partly confirms the following mean of a vertical cross-section made under Paliastomi Lake bottom sediments:

- 0 – 3. 1 m – doughy saprobe (organic matter rich silt and salty sands) made of grey, rarely black clayey aleurites;
    - 3. 1 – 5. 3 m – peat and dark olive green peat-saprobe with sand lenses;
    - 5. 3 – 10. 3 m – grey, relatively dense clay-silt sapropel;
- 10. 3 – 15. 3 m – coastal-marine and lagoon sands and silty sands with remnants of marine mollusks.

It should be emphasized that the bed sediments of Paliastomi Lake, likewise the peat layers of coastal marshes, formed continuous horizontal layers.

Matching the results of the litho-facial analysis of Paliastomi Lake bed sediments with the sea-level regime fluctuation during the modern Black Sea phase/stage of the Black Sea basin development, later allowed making the following assumptions: during the peak of the new-Black Sea transgression (6000-4700 years ago), the Black Sea bay invaded the Paliastomi Lake area. The swamp started to form and Shavtskala, Imnati and Maltakva vast and deep peat bogs developed along the North, South and East banks of Lake Paliatomi. The time of onset of peat accumulation in these peat bogs was established by means of radiocarbon dating – 5820±210, 5950±100, 6480±90 years ago accordingly [9].

The area and its biodiversity are protected by the international conventions (Biodiversity, Ramsar, Bonn, Black Sea) and the national legislation. Its surface area is 17.3 km² and its mean depth is 2.6 m (See Picture-1 –Paliastomi Lake Bathymetry).



Picture-1 –Paliastomi Lake Bathymetry (12)

Paliastomi Lake was considered as one of the high-productive water reservoirs. The impact of ecological factors caused Lake Salination with associated changes in water hydrology, dramatic decrease in composition of the lake biodiversity (the number of fish species decreased from 40 to 24).

The Lake is fed by rain water and tributaries. High water levels are common in spring, summer and fall, while in winter the water level is low. The water is warm in July and August (25.10C) and is cold in winter (5.20C). Due to strong winds, homothermia is quite frequent on the Lake (see Chart-1).

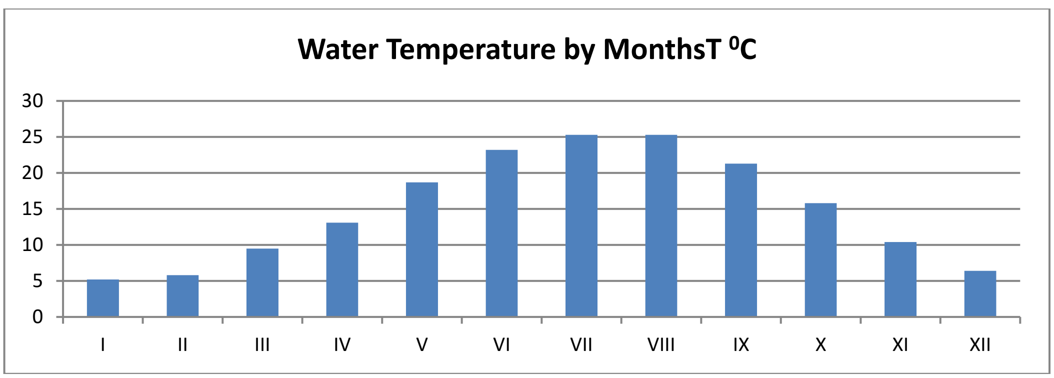


Chart-1 Water Temperature of the lake Paliastomi by Months

Paliastomi Lake is separated from the Sea by the 300-400-meter-wide and 2-meter-high sand-bar. The lake suffers from sedimentation and dense vegetation growth. In wetter areas, the rivers are controlled by flood banks. The rivers (Pichora, Tkhorika, etc) and lakes (Paliastomi, Imnati, Maltakva, etc.) receive water from a large catchment, and the water levels fluctuate between 0.2-0.7 m in marshes, 0.5-3 m in lakes and 1-21 m in rivers. Until 1924, Paliastomi Lake was a fresh-water lake: the water flowed from the lake through the River Kaparchina, which originates near the northwest bank of the Lake. Leaving the Lake, the river turns sharply to the south, runs almost parallel to the west bank and flows into the Sea 11 km from its source. Since the capacity of the River Kaparchina was too small to drain all the floodwater from the Lake effectively, the level of Paliastomi Lake rose quickly during the heavy rain and flooded about 40 km^2 of the area, including the southeastern part of the city of Poti. To protect Poti from periodic flooding, in 1924 a canal was built to connect the southwestern part of the Lake with the Sea After some time, powerful storms eroded the canal and it was replaced by a strait, 1.5 km long, 140-150 m wide and 3-4 m deep watercourse. Sea water freely enters the through this strait during the heavy storms, and this has salinized the Lake: before the strait was excavated, the salinity in the Lake was 1‰; today it is 12-13‰ [10].

The amount of annual atmospheric precipitation in the Kolkheti lowlands ranges from 1200-2800 mm, and the modulus of groundwater runoff pressure is 4 l / s from 1 km^2. See Table -1 for Paliastomi Lake Water Balance.


Photo-1 © 2020 I TV -Kolkheti National Park (r. Kaparchina)


Photo-2 © 2020 I TV -Lake Paliastomi

More than 300 different bird specimens are described. The Lake is visited more than 100 different migratory birds and their total number is more than 40 000. When the surface of the Azov Sea freezes, their number increases significantly [13].

Table1. Paliastomi Lake Water Balance [11]

Revenue elements	M^3		%	Cost elements
1	2		3	4
Y X Revenue	36x4 x10^6 581x0x10^6 617x4 x10^6		5,9 94,1 100	Y$_1$ Z Losses
M^3	% revenue		Supplement or remaining pool management unit	
5	6		7	8
- 17x8 x10^6 17x8 x10^6	- 2,9 2,9		M^3 - -	%
-	-		599,6.106	97,1

Y- Total (Summarized) water revenue from Lake watershed;
X-The amount of precipitations on the Lake surface;
Y_1 - Floods;
Z - The amount of water evaporated from the surface of Z-Lake.

The pollution with nutrient-rich water cause large blooms of algae and aquatic plants that in its turn leaves little oxygen for fish and other aquatic animals, resulting in the eutrophication followed by suffocation of aquatic life. The overloading of seas, lakes, rivers and streams with nutrients (nitrogen and phosphorus) can result in a series of adverse effects known as eutrophication. Phosphorus is the key nutrient for eutrophication in fresh waters and nitrate is the key substance for salt waters [14].

Paliastomi Lake is used as a cultural leisure zone. It also serves as an important tourist and recreational facility.

In the North-eastern part of the Lake, the Pichora River flows into the Lake crossing a large area of Western Georgia's agrarian settlements and significantly pollutes the Lake with nutrients. Another significant source of Paliastomi Lake pollution is so called "Airport Chanel" that is one of the main 'collectors' of sewage water in the city of Poti. The source is located at the North-eastern part of the Lake close to the fish factory that also pollutes the Lake, but only in November and December in anchovy fishing season when fishmeal is processed (due to lack of treatment facility).

The process of fish meal production involves the hydraulic discharge of fishes with loss of soluble proteins to the Sea [14]. Recycling the water used to unload fish from ships to factories will reduce the environmental impact [15]. These recycled fishmeal waste waters have high content of chemical oxygen demand (COD) protein and salinity (sodium, chloride, sulphate) [15, 17].

In 2015 (02.26; 08.27; 09.11) and 2016 (02.18; 05.16; 08.19; 11.22), NEA (National Environmental Agency) of Georgia provided hydrochemical analysis of the River Maltakva at the mouth of Paliastomi Lake to the Black Sea (Table- 2).

Table 2. Results of Hydrochemical Analysis of the River Maltakva

Defining ingredients		River Maltakva - Paliastomi Lake mouth to the Black Sea, Poti						
		2015			2016			
1	2	3	4	5	6	7	8	9
Sampling month, date		02.26	08.27	19.11	02.18	05.16	08.19	11.22
1	2	3	4	5	6	7	8	9
Time	Hour, Minute	14.10	11.05	13.30	14.05	18.45	16.05	12:30
Depth, M		05	05	05	05	05	05	05
Temperature, t^0C		14.2	24.2	9.2	12.0	18.4	28.8	7,2
Hardness, Mg, Eq/L		15.83	5.18	4.03	62.0	47.50		8,44
Conductivity, μsms/cm		593.0	2460.0	1791.0	2040.0	26500.0	5310.0	3190,0
Transparency, cm		3	2	2	-	3	10	2
Particulates, Mg/L		11.6	20.8	165.6	13.6	25.6	12.8	319,6
pH		8.29	7.38	7.96	8.50	8.41	8.26	7,80
Carbonate, Mg/L		1.88	-	-	3.3	3.83	1.65	-

Carbon dioxide, Mg/L	-	2.38	0.66	-	-	-	0,35
Dissolved Oxygen Mg/L	11.13	5.39	9.82	10.51	9.45	9.52	12,10
Oxygen saturation,%	111	64	85	105	101	124	99
BOD_5, Mg/L	2.87	2.74	2.91	1.32	1.41	4.10	2,45
Nitrite, Mg/L	0.009	0.047	0.021	0.005	0.000	0.003	0,000
Nitrate, Mg/L	0.053	1.004	0.726	0.192	0.000	0.000	0,287
Ammonia, Mg/L	0.107	0.182	0.062	0.013	0.026	0.021	0,467
Total Mineral Nitrogen, Mg/L	0.169	1.233	0.809	0.210	0.026	0.024	0,754
Phosphate, Mg / L	0.034	0.088	0.010	0.006	0.007	0.008	0,013
Sulfate, Mg / L	-	186.0	20.0	4.4	240.0	101.5	57,0
Chloride, Mg / L	982.2	347.4	287.2	3371.3	4292.9	756.6	855,3
Hydrocarbonate, Mg / L	151.3	80.5	107.0	125.5	202.5	140.3	147,6
Potassium, Mg / L	359.1	245.6	157.3	879.2	2047.6		482,7
Calcium, Mg / L	60.4	26.9	36.8	108.2	190.4	-	33,1
Magnesium, Mg / L	155.7	46.7	26.7	688.9	461.7	-	82,5
Mineralization, mg / L	1350.0	689.3	481.7	4298.5	5387.6	-	1176,8
Silicic acid, Mg / L	7.3	10.1	8.3	4.5	0.0	4.5	-
Iron, Mg / L	0.27	0.28	0.76	-	0.13	-	-

Source: www.nea.gov.ge

In recent years, fisheries have often been depleted, which, according to the Environmental Protection Agency of Georgia, is caused by the lack of oxygen in water that is the result of the process of eutrophication in Paliastomi Lake [19].

Migratory birds are accommodated in the areas located on migration routes for rest, food and water. During this stay, they spread the diseases they bring with them to the poultry in the region and to the poultry farms that do not take adequate biosecurity measures. This is particularly true with free-range poultry farms [20].

Wild birds may become infected through carnivorous behavior, or environmental contamination. Wild birds that are carnivorous or omnivorous are therefore most commonly infected, as they are consuming food that may be contaminated with such as intestine, consuming food that is on the ground, or feeding or living in the contaminated water [21].

Wild birds are known to be reservoirs for *Salmonella* spp. [20]. Previous studies have found that *Salmonella* is present sporadically in the intestinal flora of wild birds [23].

“..Migrating birds can become carriers of *E. coli* strains resistant to antimicrobial agents and can be responsible for the spread of R plasmids over the world [24]. Migratory waterfowl may serve as reservoirs of antimicrobial resistance of thermotolerant fecal indicator organisms [25]. *E. coli* isolates originating from Arctic birds carry antimicrobial resistance determinant.“ (May 23rd)

Wild birds are considered to be reservoirs of human enteric pathogens and vectors of antimicrobial resistance dissemination in the environment. During their annual migration, they play a potential role in the epidemiology of human associated zoonoses [26]. Furthermore, heavy stress and immunosuppression related to migration could promote the onset of infectious diseases and the spread of infectious agents. Other factors contributing to the prevalence of resistant bacterial strains in wild birds are the environmental contamination, the presence of livestock and population density [27, 28]. Several studies have shown a wide spread of antibiotic resistant enterobacteria in bird populations sympatric to areas inhabited by people and areas with a high density of livestock [29, 30, 31].

Results

Chemical and microbiological analysis of the Lake Paliastomi

On May 14-15, 2017, an expedition to conduct chemical analysis of the chemical, microbiological and seabed sediments of Paliastomi Lake was organized. We selected four analysis and sampling points near Paliastomi Lake, adjacent to Collinbari Island: 1. Rangers' Base-1. 100 meters offshore from the ranger base; 2 Rangers' Base-2, at 100 m, from the base; Rangers' Base-3, at 500 m from Ranger base; and ranger base-4 near the fish processing plant, 150 m from the factory exit channel (Map-1; Table-3; Annex-1) [14].

Map-1 Chemical pollution (14-15 May, 2017)

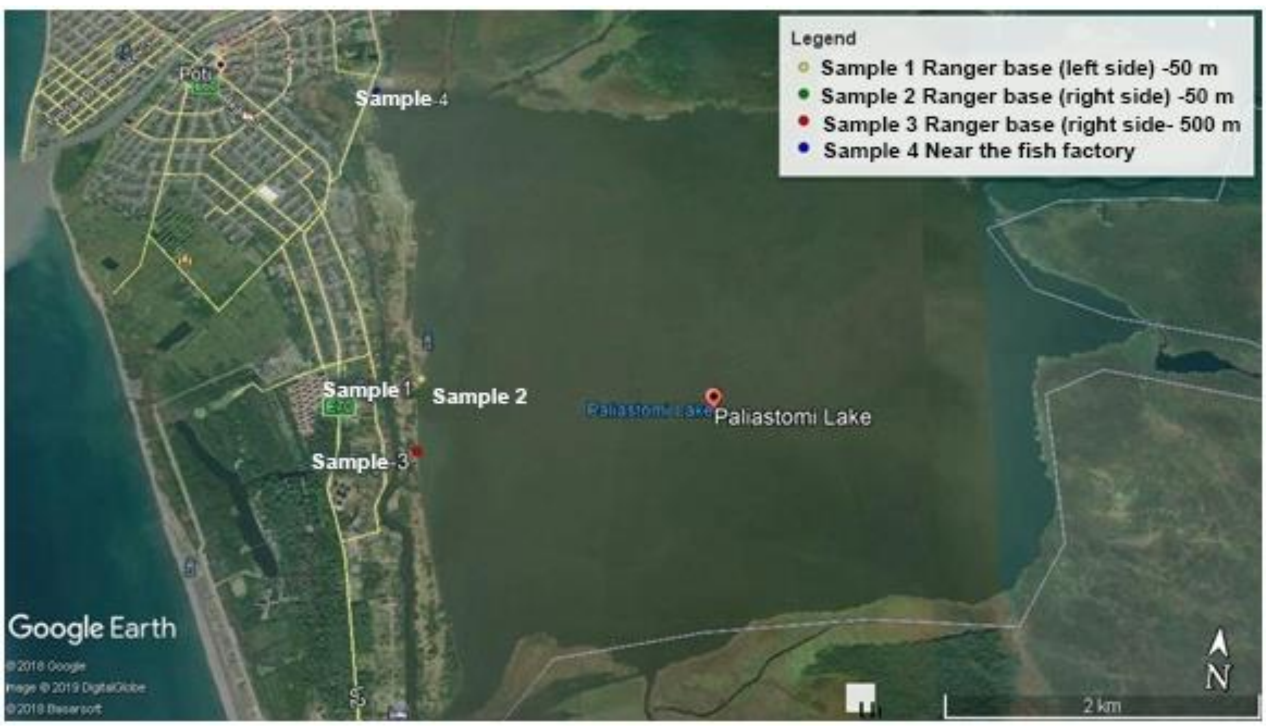


Table 3 **Results of the chemical analyses of the water of the lake Paliastomi (14-15 May, 2017)**

See full data in Annex-1 Table -3

Chemical composition	Turbulence)FTU)	pH	Dry Waste (Mg/L)	Conductivity (S/m)	Hardness	Solubility O_2	COD&(Mg/l O)	Ca Mg/l	Mg Mg/l	*Na Mg/l	K Mg/l	Fe Mg/l	Cu Mg/l	Mn Mg/l	Zn Mg/l	**Sum**
Rangers' Base -1 (42°7'2.08"N41°42'11.63"E)	150.00	8.05	5741.410	1.03350	24.564	7.800	<15.0	114.000	229.200	1694.000	57.800	0.550	0.005	0.005	0.005	2095.560
Rangers' Base -2 (42°6'58.15"N 1°42'11.79"E)	160.00	8.20	5732.795	0.98670	25.363	7.300	<15.0	6.4000	18.9630	73.8865	1.4949	0.0295	-	-	0.005	100.6766
Rangers' Base -3 (42°6'43.81"N 41°42'14.99"E)	299.00	8.30	5935.190	-	25.753	7.400	<15.0	6.0000	74.4541	-	1.4949	0.0355	-	-	-	3893.430
Near the Fish Factory (42°8'26.14"N41°41'34.76"E)	1570.00	7.20	853.611		5.168	3.600	36.000	2.6000	2.5679	9.6070	0.2256	0.3009	0.0004	0.0200	0.0005	15.3779

Paliastomi Lake water and seabed sampling, preservation, storage and transportation was done using ISO standard methods. The chemical properties of water organoleptic, chemical and microbiological indicators as well as seabed sediments were determined by field portable apparatus and stationary laboratory using ISO and GOST standard methods [36,14].

Table-3 gives the results of the chemical analysis of Paliastomi Lake. The pH value of Paliastomi Lake water is slightly more than pronounced due to the nature of the salts dissolved in it and the hydrolysis. According to samples 1, 2 and 3, the oxygen content is high at 7.3-7.8 mg / L, and the amount of oxygen dissolved according to the 4th data is relatively low and equals to 3.6 mg / L. The oxygen regime has a profound effect on the life-ability of the reservoir, the minimum dissolved oxygen content that ensures normal fish development is 5 mg / l O_2 / L, and its reduction to 2 mg / L results in massive fish mortality [5, 9, 15]. The concentration of dissolved oxygen in samples 1, 2 and 3 corresponds to class II-purified class of surface water quality, and class 4 is classified as contaminated, class 4.

Waterbed sediments are formed as a result of deterioration of catchment rocks and soil cover following the soil surface washing. The composition of waterbed sediments in the Lake basin is regularly altered by constructing rocks in accordance with lithology and grain size [34, 35]. In addition, as a result of sedimentation of minerals and organic matter in the Lake water, the water flows into the Lake and produces sediment on its bed. According to the literature, heavy metal contamination of seabed sediments is mainly caused by anthropogenic sources, residues of agriculture and enterprises working in various industries [35, 34].

Paliastomi Lake sediments were sampled and studied (by ISO methods) in May of 2017 (Table-4). Based on the geochemical background, the results of the analysis, the total copper content in the bottom sediments of Paliastomi Lake is lower than the permissible rates [12, 35, 36, 37], and exceeds the permissible values in Georgia [12, 37]. Lead and zinc content in Lake sediments may be considered as a natural background [12, 35-37]. The content of manganese and iron in the seabed is less than the MPC.

Table 4. Results of the analysis of the sediments of Paliastomi Lake (May 15, 2017)

N	Name of Sample	Registration, N	Pb.ppm	Cu.ppm	Mn%	Zn ppm	Fe%
1	Rangers' Base-1	138-S	31.0	19.5	0.14	96.5	3.60
2	Rangers' Base -2	139-S	20.5	22.0	0.17	117.0	5.60
3	Rangers' Base-3	140-S	21.5	17.5	0.11	87.0	3.90
4	Adjoining area of fish processing factory-4	141-S	17.0	47.5	0.07	95.5	2.92

Results of the microbiological analysis of Paliastomi Lake water and waterbed sediments

Since Paliastomi Lake is used for fishing, as well as for cultural recreation and swimming, it is necessary to determine the microbiological contamination of water causing various infectious diseases in order to maintain the necessary degree of the Lake water purity and ecological control.

There are very limited bacterial research data for Paliastomi Lake found in literary sources.

On May of 14-15 and August 9-10 of 2017, an expedition to collect microbiological samples of Paliastomi Lake was organized by International Center for Environmental Research (ICFER). On March 29 and April 18, 2018, the Lake water and bed samples were collected for microbiological analysis by ICFER. Besides, on January 30, 2019, the Lake water samples were taken for microbiological analysis by ICFER.

Lake water sampling, storage, transports and microbiological analysis was performed according to international ISO and GOST standards.

Tests of surface water and Lake bed sediments

The bicrobiological analysis determined the total coliforms and the number of coli-forming bacteria in the intestinal tract. In samples 1, 2 and 4, the total coliforms are sufficiently high and in 100 ml of water they are 3000, 1280, 5000 CFU, while in the third sample, their number is 920 CFU / 100 ml respectively. E-coli-grade bacteria were found in water samples 2 and 4, with a mean value of 100-40 ml per 100 ml 20-40 CFU (Table-5). Their numbers increase with the migration of migratory birds in October and May.The total water content of the open water reservoirs - mesophilic aerobes and facultative anaerobic microorganisms (MAFA) as per the permitted norm in 1 ml is no more than 1000 CFU, while in 1, 2 and 3 water samples the total amount of MAFA varies from 800 to 5000 CFU / ml, and the maximum value (3500 CFU / ml) is reached in the 4th sample (Table-5).

Table 5- **Microbiological analysis of Paliastomi Lake water (August 10, 2017)**

Microbial quality indicators of Paliastomi Lake water:	
Used Standard: ГОСТ N 18963-73	
Site: N1 R. Kaparchina-Adjacent territory to the Bridge	
Microbial quality indicators of the site water	
Outdoor reservoir water quality index MAFA actual rate by ND. Not more then	1000 CFU/ml
Total quality of MAFA/ml, MAFA actual rate	5000 CFU/ml
Indicator of water quality (coli-titer; coli-index) by ND	coli-titer < 0,4; not less -111, coli-index; not more-9
Actual indicator of the quality of open water reservoir: coli-titer and coli-index: 100 ml,10 ml,1 ml,0,1 ml (Total volume of water 111 ml);	coli-titer < 0,4 coli-index > 2380
pH	6,6
Site: N 2 Rangers Base right site	
Microbial quality indicators of the site water	
Outdoor reservoir water quality index MAFA actual rate by ND. Not more then	1000 CFU/ml
Total quality of MAFA/ml, MAFA actual rate	1000 CFU/ml
Indicator of water quality (coli-titer; coli-index) by ND	coli-titer not less -111, coli-index; not more -9
Actual indicator of the quality of open water reservoir: coli-titer and coli-index: 100 ml,10 ml,1 ml,0,1 ml (Total volume of water 111 ml);	coli-titer -4 coli-index -230
pH	6,5
Site: N 3Rangers Base left site	
Microbial quality indicators of the site water:	
Outdoor reservoir water quality index MAFA actual rate by ND. Not more then	1000 CFU/ml
Total quality of MAFA/ml, MAFA actual rate	1000 CFU/ml
Indicator of water quality (coli-titer; coli-index) by ND	coli-titer not less 111, coli-index; not more -9
Actual indicator of the quality of open water reservoir: coli-titer and coli-index: 100 ml,10 ml,1 ml,0,1 ml (Total volume of water 111 ml);	coli-titer-4 coli-index -230
pH	6,5
Site: Adjacent territory of the Island Kolimbari	
Microbial quality indicators of the site water:	
Outdoor reservoir water quality index MAFA actual rate by ND. Not more then	1000 CFU/ml
Total quality of MAFA/ml, MAFA actual rate	
Indicator of water quality (coli-titer; coli-index) by ND	1000 CFU/ml
Actual indicator of the quality of open water reservoir: coli-titer and coli-index: 100 ml,10 ml,1 ml,0,1 ml (Total volume of water 111 ml);	Coli-titer not less -111, coli-index; not more -9

Outdoor reservoir water quality index MAFA actual rate by ND. Not more then	coli-titer- 0,4 Coli-index– 2380
pH	6,8

The open water reservoir water quality index (coli titer, coli index) shall be as follows: coli - titer not less than 111 ml and coli-index not more than 9.

Coli index in water samples 1 and 4, at pH = 6.6 and pH = 6.8, was more than 2380 and coli index was less than 0.4. In the second and third samples, at pH = 6.5, the coli titre was reduced to 4 and the coli index was 230 (Table 5). Therefore, high levels of bacterial contamination of the Lake water should be caused not only by the contamination of Paliastom Lake, but also by sewage discharges (directly into the Lake, without any treatment) from internally displaced persons' shelter and open landfills adjacent to it.

In January 29 2018 has been taken water sample from the lake Paliastomi in 50 meters right from Rangers's base (latitude 42.11842; longitude 41.70293) for the purification by bacteriophages.

The microbiological analyses shown that total amount of MAFAN in the water constituted 1500 CFU/ml when the permissible norms is not more than 1000 CFU/ml.

In an open water reservoir quality indicator (coli-titer and coli-index) MAC is following: coli-titer-111, coli-index-9. During the condition when pH = 6,8 coli-titer -4 and coli-index was 230. Total amount of E-coli constituted 1x 10^3, but MAFAN equaled 1500 CFU/ml (see Table 6).

We used water sample as a model pattern for the bacterial treatment with bacteriophage cocktail (BC) (*Shigella flexneri 1, 2, 3, 4, 6 serological group; Shigella sonnei; Salmonella paratyphi A; Salmonella paratyphi B; Salmonella typhimurium; Salmonella choleraesuis; Salmonella oranienburg; Salmonella enteritidis;; enteropathogenic E. coli different serological groups; Proteus; Enterococcus; Staphylococcus; Pseudomonas aeruginosa*).

Teble 6. Results of the bacterial purification of the lake Paliastomi water by BC

Microbiological quality indicators of the water of lake Paliastomi		
Sampling location:		Lake Paliastomi Rangers Base -1 (42.11842;41.70293)
pH		6,8
MAFAN /ml by ND		Not more then 1000 CFU/ml
MAFAN /ml actual rate		1500 CFU/ml
Total MAFAN /ml after treatment with BC		600 CFU/ml
Water quality indicator (coli-titer, coli-index) by ND		Coli-titer 111, Coli-index not more then- 9.
Actual rate coli-titer, coli-index : 100ml, 10ml, 1ml, 0,1ml (total amount of water 111ml).		Coli-titer o-4 Coli-index 230.
E.coli-quantity/ml	In original water sample	1x10^3 CFU/ml
	In treated water sample	2 x10^2 CFU/ml
Used Standard:		ГОСТ-№18963-73

The BC contained viruses of the bacteria (bacteriophages) that directly affect their host bacteria, so the BC was used to treat Lake Paliastom water, reducing the amount of E-coli to 2 x10^2 CFU/ml. The amount of MAFAN/ml reduced to 600 CFU / ml. We considered the experiment successful, as during the processing of the lake water sample its bacterial contamination was reduced by 60%.

Photo 3- Lake Paliastomi water samples (original-right and after treatmen-left by BC)

Notable, that in 30.08 2004 instruction on preventive- treatment and water purification by phages preparations against salmonella bacteria worked out by International Center of Environmental Research (ICFER) was approved by the State Veterinary Department of Georgia.

The BC was tested within the WB Georgian Agriculture Development Program's Project - CGS 03-70 "Demonstration and application of achievement of environmentally friendly and efficient technology on the use of treatment-preventive veterinary biopreparation of bacteriophages against antibiotic resistant salmonella infections in poultry" implemented by ICFER(www.icfer.org).

The results of the research has been published in the Journal of Veterinary Science and Technology under the title: "Bacteriophages against Antibiotic Resistant Salmonella Bacteria for the Possible Prevention and Treatment of Birds and Clean Up of their Water Habitats" (https://www.hilarispublisher.com/open-access/bacteriophages-against-antibiotic-resistant-salmonella-bacteria-for-thepossible-prevention-and-treatment-of-birds-and-clean-up-of-2157-7579-1000395.pdf).

According to Table 7, the number of total coliforms in the sample taken in March and in the sample of April 2, is high and is 320.

Table-7 Microbiological analysis of Paliastomi Lake water (29March, 18April, 2018)

Test Name: Fish factory adjacent to Airport Channel(**42° 7'4.51"N 41°42'11.51"E**)		
Testing parameters	Evaluation criteria	
	Significance of Indicators by ND	The actual meaning of the indicator by confidence
MAFA meaning	-	37^0C-65 ;22^0C-228
Total coliforms 1000 ml	-	6000
E-coli, 1000 ml	≤ 10 000	70
(S.faecalis) 100 ml	-	29
(Cl.perfringens) per 100 ml	-	4

Pathogenic organisms, including salmonids100 ml	-	Not detected
Coliphages 1000 ml	≤ 100	Not detected
S.Aureus 100 ml	-	320
Testing sample Name: Paliastomi Lake, adjacent to the Pichora River **(42° 6'55.87"N 41°42'12.40"E);**		
Total coliforms, 1000 ml	-	7200
Testing parameters	Evaluation criteria	
	Significance of Indicators by ND	The actual meaning of the indicator by confidence
E-coli, 1000 ml	≤ 10 000	6000
Coliphages, 1000 ml-მ ლ	≤ 100	700
Ranger Base, left side (100m) **(42° 8'5.08"N41°45'2.24"E);**		
Quantity of E-coli in 1 gram	E-coli CFU/g	(*St.faecalis)*
375	**300**	**12**
Clean		
-	1-9	1-9
Polluted		
-	>10	>10
Ranger Base, right side (100m) **(42° 8'24.51"N 41°42'17.02"E)**		
Study Parameters	**ND Indicators**	**The actual value of the indicator**
Total coliforms 1000 ml	-	7200
E-coli, 1000 ml	≤ 10 000	6000
Coliphages 1000 ml	≤ 100	700

According to the data in Table 8, in line with the general microbial parameters (total microbial number at 37 ºC and 22 ºC), the water data of the test reservoir of Lake Paliastomi are within the norm. The sanitary indices of contamination (namely, total coliforms and coliphages) are relatively high. Besides, the content of salmonella is high - 35 / ml. The number of autochthonous microflora of water - vibrios and aeromonas is high enough, making 1400 CFU / 1000 ml, 1100 CFU / 1000ml, respectively.

Table8. The Results of the Microbiological analysis of Paliastomi Lake water (January 30, 2019)

Identifiable microorganisms	Permissible quantitative value of the indicator (for the 2-nd category surface	The actual meaning of the indicator by confidence
Territory adjacent to the Fish Factory		
Mesophilic aerobes and facultative anaerobes 37ºC 24h	<1000CFU/ml	42CFU/ml
Mesophilic aerobes and facultative anaerobes22ºC 48h.	<1000 CFU/ml	102CFU/ml
Total coliforms	<10000 CFU/1000ml	12000CFU/1000ml
Fecal coliforms E.coli	<5000 CFU/1000ml	700CFU/1000 ml
Fecal Streptococes	<5000CFU/1000ml	500CFU/1000 ml
Sreptophage (Enrichment Method)	<100part/1000ml	1900part/1000 ml
Total vibrio	-	1400/1000 ml
Total aeromonas	-	1100/100ml
Total Salmonella	-	35/ml

According to the data in Table 8, the general microbial parameters (total microbial number at 37 ^{o}C and 22 ^{o}C) of the site, the River Kaparchina in particular, are within the norm). The sanitary rates of contamination (namely, total coliforms, coliphages) are relatively high. Salmonella content is also high: 55 kg / ml. The autochthonous water microflora - Vibrios and aeromonas - are found in high numbers (1300 CFU / 1000 ml, 1100 CFU / 100 ml, respectively).

Table 9. Results of the Microbiological analysis of Paliastomi Lake water (January 30,2019)

Identifiable microorganisms	Permissible quantitative value of the indicator (for the 2-nd category surface water)	The actual meaning of the indicator by confidence
Site: At the bridge of the river Kaparchina		
Mesophilic aerobes and facultative anaerobes37^{0}C24h	<1000CFU/ml	68CFU/ml
Mesophilic aerobes and facultative anaerobes22^{0}C48 h	<1000 CFU/ml	320CFU/ml
Total Coliformes	<10000 CFU/1000ml	16000CFU/1000ml
Fecal coliformes/E.coli	<5000CFU/1000ml	900CFU/1000ml
Feacal Streptococes	<5000CFU/1000ml	720CFU/1000ml
Coliphages (Enrichement Method)	<100part./1000ml	3200 part/1000ml

Total vibrio	-	1300CFU/1000ml
Total aeromonas	-	1100CFU/1000 ml
Total Salmonella	-	55CFU/ml.

Water Pollution Modeling

The dissemination of pathogenic bacteria in the lake water was modeled. The following data is required to develop this model system:

- Hydrodynamic characteristics of the water depths;
- Water level;
- Wind velocity;
- Bacterial contamination points;
- Bacterial monitoring;
- Number of common coliforms.

For computational modeling of metals and coliform dissemination in Lake Paliastomi, a two-dimensional numerical model based on the system of integration by vertical integration of water motion and continuity equations was used [39, 43]. The program was compiled in Visual C ++. The model is based on the integration of the two-dimensional flow dynamics of the Lake and passive impedance in the water area using a modern high-resolution numerical scheme. In the integration process, the method of visualizing the results is applied.

The following parameter values were used in the model: Gravitational constant G=980 cm/sec^2, Coriolis setting f = 0.9510-04 sec-1, Friction strain vector at the bottom $\tau^{\rightarrow 1}$ $(\tau\frac{1}{x},\ \tau\frac{1}{y})$ calculated by formulas:

$$\tau\frac{1}{x} = b.\sqrt{u^2+v^2}.u$$

$$\tau\frac{1}{y} = b.\sqrt{u^2+v^2}.v$$

where b = 0,003

Atmospheric wind friction tension vector $\tau^{\rightarrow 0}$ $(\tau\frac{0}{x},\ \tau\frac{0}{y})$ calculated by formulas:

$$\tau\frac{0}{x} = b1.\sqrt{W\frac{2}{x} + W\frac{2}{y}}.Wx$$

$$\tau\frac{0}{y} = b1.\sqrt{W\frac{2}{x} + W\frac{2}{y}}.Wyx$$

where b_1= 3,210-06.

The occurrence of currents in Paliastomi Lake and distribution of pollutants during the northeast wind were discussed.

The modeling shows that numerical (simulation) experiments were carried out using the chemical and microbiological analysis data we obtained in the northeast wind, and the simulation experiments were carried out using the aforementioned computer model of dissemination of common of Fe particles and coliforms in Paliastomi Lake (15 May 2017 and 29 March 2018). The results are given in Figures 1, 2 and 3.

Figure 1- Dissemination of Fe particles (15 May 2017)

Figure 2- Dissemination of common coliforms (15 May 2017)

Figure 3- Dissemination of common coliforms (29 March 2018)

Figure 2 shows the dissemination of isolines of coliforms on the surface of modeled Paliastomi Lake. The figure shows the maximum concentration of coliforms in the southeastern part of the Lake where there are 3 sources of pollution (Rangers' Base 1-3). They are spread 100 meters (left and right) and 500 meters away from the Rangers' Base.

The 4th source of contamination is located northeast of Paliastomi Lake. Consequently, the spatial dissemination of isolines in the Lake water body is not a usual matter. The concentration of pathogens at base is 2-3 increases gradually to the north and reaches its maximum at base 4. Horizontal gradients of concentrations are large in the vicinity of bases and gradually decrease at some distance from bases to north and northeast.

Figure 4 shows the computer-generated currents at 10 m/s. A mathematical model to study the horizontal circulation of water flows in Paliastomi Lake, which is based on a system of two-dimensional nonlinear differential equations obtained by integrating vertical hydrothermodynamic

Figure 4 Computer-generated currents at 10 m/s north-east wind

equations in the lake was calculated. The model allows the dynamic characteristics of water masses to be calculated for atmospheric winds of different directions and powers [36]. In particular, Figure 4 gives the circulation picture of the water flows obtained by the model, which is formed under the influence of the western wind (10 m/sec).According to the presented figure, there are circles with a rather large "diameter" in the northwest and southeast of the Lake, having different directions.

A model has been developed to solve the problem of spreading the pathogenic bacteria in the Lake using numerical methods, according to which the model is based on a two-dimensional transfer-diffusion differential equation.

The spatial-temporal distribution of any passive impurities in the Lake may be estimated with known dynamic characteristics.

This model simulated the change in the values of the common coliform determined by the experiment conducted from May 15, 2017 to March 29, 2018 - April 18, 2018.

One can observe the change in total coliform concentrations in 6, 12 and 24 h. in 2 different experiments: Experiment-I 15 May 2017 (see Figure 5, 6, 7); Experiment-II 18 April 2018(see Figure 5, 6, 7). The figures show that there are two processes: the diffusion and the advective translocation of common coliforms, what result in a decreased concentration of the maximum zone and shift of total coliforms in the north-east direction, which coincides with the flow formed in Paliastomi Lake. The cyclonic flow formed in the eastern part of the Lake results in the displacement of the common coliforms in the northeast part of the Lake through the southeastern meadows, resulting in a uniform distribution with weak waveforms.

The currents formed in Paliastomi Lake result in a change in the dissemination of total coliforms, what is characterized by a decreased concentration of 40 CFU / ml for 24 hours at the

Experiment-I
(15 May 2017)

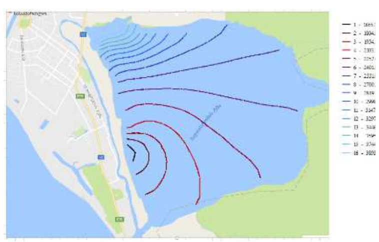


Figure 5 Dissemination of common coliforms after 6 hours

Figure 6 Dissemination of common coliforms after 12 hours

Figure 7 Dissemination of common coliforms after 24 hours

Experiment-II
(18 April 2018)

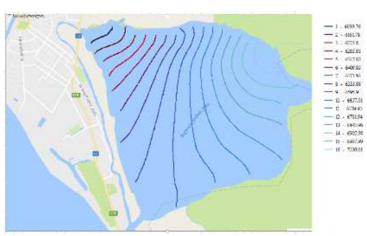


Figure 8 Dissemination of common coliforms after 6 hours

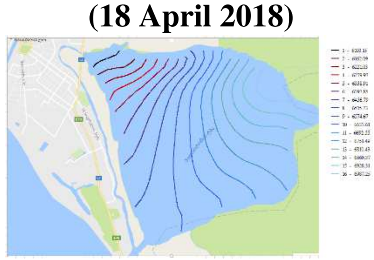


Figure 9 Dissemination of common coliforms after 12 hours

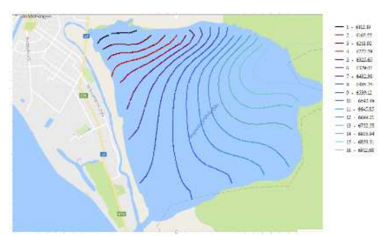


Figure 10 Dissemination of common coliforms after 24 hours

confluence of Pichora River and Paliastomi Lake, as well as by an increase of 32 ppm in the adjacent fishery areas.

This technology allows similar calculations to be made for any reservoir with a small depth. To do this, the customer will only need to change the characteristics of the reservoir (horizontal dimensions, seabed relief and atmospheric wind).

Thus, the results show that the general picture of microbiological contamination of Lake Paliastomi is inconsistent. It depends on the location of the pollutant sources, the contamination and the lake water flows formed by meteorological conditions.

The proposed model describes an actual qualitative physical process taking place in the real environment and can be successfully used to predict changes of the dynamic characteristics of the reservoirs of the same type. This model can then solve such tasks as sustainable use of water resources and environmental prognoses [38].

Natural and artificial wetlands as main tools to treat wastewater flowing into the Lake

Different sources of information evidence an increasing use of wetlands to treat wastewaters owing to its environmental benefits and relatively low operational and maintenance requirements.

The use of wetlands for wastewater treatment is not novel, but the current expertise is gathering increased momentum in water industry due to the environmental benefits and lower operational and maintenance requirements of the given systems.

There are technologies developed in various forms all over the world with their common aim of using the nature's capability to treat wastewaters by means of physical, chemical, biological and microbial processes contained within 'Natural Wetlands'.

Natural wetlands are areas where land is covered with water: either saltwater, freshwater or a mixture of both. The marshes and ponds, the edge of a lake or ocean, the delta at a river mouth or low-lying areas that frequently get flooded are all wetland areas. They contain plants and vegetation that thrive submerged or partially submerged.

The plants act as an impediment to flow and are sustained by nutrients from soils and water. Natural wetlands are named as the kidneys of the landscape because of their ability to assimilate and treat the water lost from the landscape before it flows into the waterways.

The constructed wetlands are artificial wastewater treatment systems consisting of shallow vegetated ponds with aquatic plants to treat wastewater by means of natural physical, chemical, biological and microbial processes. They are designed to control the flow direction, liquid retention time and water levels. After passing through the system, the treated effluent is allowed to discharge safely into a receiving surface water or ground water body.

There is a wide variety of different types of constructed wetlands in use throughout the world but the systems used can be categorized into two broad categories:

- Engineered Reedbed Systems; and
- Integrated Constructed Wetlands.

Engineered Reedbed Systems are a functional element in the process of treatment, with primary and/or secondary treatment process elements (depending on the particular treatment process at the plant) in front of the Reedbed wetland pond(s), which may be a surface flow and/or sub-surface flow, generally with a single plant species within a gravel media and lined with polyethylene barriers.

Integrated Constructed Wetlands (ICWs) are a sustainable wastewater treatment system constructed with natural materials and designed to integrate into the landscape with the purpose of treating wastewater by using a series of ponds with a variety of wetland plants to clean the water before allowing it return safely to the environment.

These systems generally have a primary settlement tank or primary ponds followed by a series of vegetated wetland ponds. The ICW concept may be developed to:

- integrate water flow and water quality management adapted to the landscape and with biodiversity enhancement;
- deliver enhanced treatment with emphasis on phosphorous removal;
- provide greater system robustness and sustainability.

Wetlands are adaptable and versatile systems that can be utilized for primary, secondary and/or polishing processes for the treatment of wastewater effluent. These systems have gained recognition for providing a sustainable treatment option for small rural settlements and provide opportunities for enhancing the existing wastewater treatment plants.

The management of bacterial pollution of water bodies of a global importance needs to meet international, regional and national requirements.

The benefits of wastewater treatment in wetlands range from protecting and enhancing the environment, increasing biodiversity, facilitating carbon capture and storage, extended service life when compared with conventional treatment systems and provide a robust, sustainable and aesthetically pleasing wastewater treatment plant.

The key benefit of wastewater treatment in wetlands from an operations perspective is the low cost of operation of these systems, they offer real savings in terms of energy use, demand on operations staff time and resources as well as sludge production, handling and disposal – all significant considerations when faced with managing the provision of effective wastewater treatment services within challenging budgetary constraints.

Discussion

Pollution from diffuse sources

In addition to the direct, unpurified waste water discharges, the pollution of the Lake ecosystem is also influenced by the diffuse entries from the agricultural lands in the catchment area. In addition to the proposed measures to treat the municipal wastewater, besides the land management measures are necessary what will lead to the reduction of nutrients and pesticides flowing into the catchment areas of the tributaries. To quantify this material input, on the one hand, modelings are suitable which, in accordance with the land use and the climatic and pedological conditions in the catchment area, balance the material flows. On the other hand, a realistic image of current load can be determined by means of monitoring the springs and headwater streams.

Modeling of diffuse material entries

The basic structure of modeling the diffuse inputs follows the simple load or export coefficient approach (HEATHWAITE 1993, CHENG et al. 2019). This is to be understood as an entry at the interface of the land path to the water path (still without retention in the water bed or the accompanying wetlands):

$$F_{N,P} = \sum_{i=1}^{n} a_{N,P_{i,t}} \cdot X_i$$

Whereas $F_{N,P}$ is the average nutrient input into the water body of substance N or P in [kg/a], $a_{N,Pi,t}$ are the export coefficients of N or P of land use type i [kg/(ha*a)] within time t (for simple approaches: t = 1 year – here, the export coefficient includes already the part due to atmospheric deposition (after JOHNES (1996)) and X_i represents the area of land use type i [ha].

The first extension of this model approach is that the export coefficients are calculated, for example, depending on the substance concentration:

$$a_{N,P_{i,t}} = c_{N,P_{i,t}} \cdot Q_{i,t} \cdot TD_{i,t}$$

$c_{N,Pi,t}$: substance concentration (N or P) of land use type i in time t

$Q_{i,t}$: runoff on land use type i in time t

$T_{Di,t}$: proportion of the substance (N or P) transported further into the water body in time t

TD_i describes the retention functions. In case of soil erosion, it is the sediment supply rate. Instead of land use type i, in more complex models so-called hydrological units are meant, which are defined by the same physiogeographical parameters. Interactions between the hydrological units (HRUs) are not taken into account.

When modeling the outputs from the areas, a fundamental distinction is made methodically (especially in conceptual models) between the land use types: the arable land, grassland, forest and settlement areas. The complexity of the summary calculations increases depending on the changes in the order of land use, forests and settled areas, grasslands and arable lands. due to the variability of land use.

Monitoring of springs and headwaters

The springs underline the interface from groundwater to surface water. In particular, the springs dominated by near-surface groundwater (interflow) show direct reactions to the material inputs in their catchment areas. This essentially comprises the very mobile nitrate nitrogen as well as very mobile pesticides and their transformation products. Due to its poor solubility, the phosphorus, which is likewise used in fertilization, is discharged via erosion in a particle-bound manner. In zones at risk of erosion, direct effects to prevent the phosphorus input can be achieved by simple measures in agriculture (Honecker et al., 2021).

Numerous studies have shown that the nitrate nitrogen content in spring waters is mainly determined by three factors: hydrogeology, climate/seasonality and land use (Mencio et al., 2011; Yakolov et al., 2015; Weber & Kubiniok, 2013). The land use is the dominant factor especially in semi-arid, agriculturally intensive areas (Boy-Roura et al., 2013). An integrated monitoring of spring waters representative of the land use pattern of Paliastomi Lake catchment area allows determining the actual entry into the water system. In order to capture the actual emissions from agriculture, the sub-basins of the springs to study must be free of the settlement influence. In addition, 1-2 springs without agriculture and settlement influence should be investigated in order to determine the background load.

At the selected spring sites, regular monitoring of nitrate contents and other basic physico-chemical water parameters over a minimum of two years is recommended. For sampling purposes with monthly intervals, sufficiently accurate impressions of the concentration curve in the year can be achieved. Besides, with simultaneous, continuous discharge recording, the area-specific substance loads can be reliably estimated. Recent studies have shown that this leads to similar results as complex continuous measuring devices (Weber et al., 2020).

In line with monitoring of springs and headwaters, new methods of monitoring of agricultural pollution of Paliastomi Lake by inflowing waters should be maintained.

The key benefit of wastewater treatment in wetlands from an operations perspective is the low cost of operation of these systems, they offer real savings in terms of energy use, demand on operations staff time and resources as well as sludge production, handling and disposal – all significant considerations when faced with managing the provision of effective wastewater treatment services within challenging budgetary constraints.

The majority of sediments fall into the seabed mainly from the terrestrial soil as a result of soil surface erosion, washout or soil profile leaching of organic-mineral material, as well as subsequent sedimentation of organic matter in the water. Therefore, the organic-mineral and chemical composition of the seabed is rather identical to the soil types developed in the vicinity of the basin. The laboratory study of sediments contaminated with heavy metals should mainly be carried out similar to soil studies with the method of atomic-adsorption spectroscopy [43, 44].
In order to neutralize the contaminated sediments (e.g. heavy metals), it is necessary to remove them from the surface and bury them on the safe site, unless their high pollution endangers the water ecosystem.

Conclusions

We should address this problem primarily by identifying and preventing onshore pollution by the disposal of industrial waste in a safe place, with wastewater control and purification. It will be necessary to provide monitoring of intensive agricultural processes in agricultural fields near water reservoirs and more [45,46].

Operational activities for the Integrated Constructed Wetland systems require regular periodic inspections with minimal follow up interventions to maintain surface flows within the ponds, maintain access to and from the ponds and remove sediment and organic debris that builds up over the years.

Regular operational activities for the Reedbed and ICW systems include:

- monitor and maintain water levels in the wetland;
- monitor the state of plants, minimize the need for replanting of wetland plants;
- ensure even flow across the wetland area;
- keep pipe inlets/outlets to/from the wetland free from plant and vegetation overgrowth;
- monitor discharge from the primary (and secondary treatment – especially for the reedbed system to prevent sludge carry over) into the wetland pond;
- monitor & test discharge from wetland to discharge point of system;
- remove weeds and tree saplings;
- maintain access.

Other operational activities for the ICW systems:

- desludge primary settlement tanks, as required;
- control/remove overly dominant plants and replant wetlands plants where required;
- trim and cut grass and vegetation to maintain access along the pathways and embankments around the ponds, as required by with periodic maintenance this can be on monthly frequency or more during the growing season;
- remove sediment and organic debris build up in wetland pond, 10-20 years after the establishment of an ICW. This nutrient rich material is a potential future source of phosphorous and

is expected to become a more valued resource in future when natural rock phosphorous reserves are depleted.

The initial results on the microbiological and chemical analyses combined with mathematical modeling on possible dissemination of the pathogenic bacteria in Paliastomi Lake enables us to permanently monitor not only the inflowing waters of Paliastomi Lake, but seasonal sources of bacterial pollution due to the migratory birds. In line with the monitoring, should be applied localized point sources spraying (as full treatment of the lake will not give required results) during migration seasons of waterfowl by Salmonella bacteriophage cocktail (SBC) that will help restrain bacterial contamination, as well as feeding the birds, potential carriers of pathogenic bacteria with the food supplemented by SBC will promote the elimination of the pathogens at the source that will ensure the biosecurity of the area. Furthermore, for bacterial security purposes, all procedures will be done with the agricultural drones.

Methodology

Our publication preparation team (PPT) provided interviewing of Kolkheti National Park Administration staff, rangers and other civil society members on: the current state of the environment in the area near Paliastomi Lake determined the main sources of pollution, bird migration by seasons and fall of birds and fish. PPT has provided review on: the completed data on institutional and legal requirements and documents; the accomplished sanitary-biological studies in the given waters of the Lake; definition of dynamics of sanitary-microbial indicators in the flowing waters;

An expedition was organized on May 14-15, 2017 to carry out chemical analysis of water and seabed sediments in Paliastomi Lake. We selected and fixed GPS coordinates of 4 sites.

Paliastomi Lake water and bottom sediments were sampled, preserved, stored and transported using ISO (ISO 8288-A-86; ISO 10523-2008) standard methods to determine te chemical characteristics of water, organoleptic and chemical parameters of water, as well as bottom sediments.

In order to complete the further research tasks, we organized an expedition to study the water in te Lake and waterbed sediments of Lake Paliastom in May 14-15, 2017 and August 9-10, 2017, as well as in March and April 2018 and January and March 2019. Lake water sampling, conservation, storage, transportation, as well as analysis of water organoleptic, chemical, microbiological and chemical parameters of bed sediments were determined according to international ISO standard methods andGOST:

- ISO 6222:1999 Water quality — Enumeration of culturable micro-organisms — Colony count by inoculation in a nutrient agar culture medium
- ISO 8199:2018 Water quality — General requirements and guidance for microbiological examinations by culture.
- ISO 8189:1992 Solid fertilizers — Determination of moisture content — Gravimetric method by drying under reduced pressure.
- ISO 9308-1:2014 Water quality — Enumeration of Escherichia coli and coliform bacteria — Part 1: Membrane filtration method for waters with low bacterial background flora.
- GOST 18963-73 Drinking water. Methods of sanitary and bacteriological analysis (with Amendments No. 1, 2)

The dissemination of chemicals and pathogenic bacteria in the water of the Lake was modeled. The following data were compiled to develop this model system:

- Hydrodynamic characteristics of water depths;

- Water level;
- Wind velocity;
- Bacterial contamination points;
- Bacterial monitoring;
- Number of common coliforms.

For computational modeling of metals and coliform dissemination in Paliastomi Lake, a two-dimensional numerical model based on the system of integration by vertical integration of water movement and continuity equations was used. The program is compiled in Visual C ++. The model is based on the integration of the two-dimensional flow dynamics of the lake, dynamics and passive impedance in the water area using a modern high-resolution numerical plan. During the integration, the method of visualizing the results was applied.

ABBREVIATIONS

AA –Association Agreement

AD- Anno Domini

BOD- Biological Oxygen Demand

BC– Bacteriophage Cocktail

CFU- Colony Forming Unit

EU -European Union

GPS- Global Positioning System

GOST- Russian: **го**сударственный **ст**андарт, which means **st**ate **st**andard

ICFER- International Center for Environmental Research

IBMV -Eliava Institute of Bacteriophages, Microbiology and Virology

ISO- International Standard Organization

KNP- Kolkheti National Park

MAC -Maximum Allowable Concentration

MEA- Multilateral Environmental Agreements

MAFA - Mesophilic Aerobes and Facultative Anaerobic Microorganisms

NEAP -National Environmental Action Programme

NEA- National Environmental Agency

ND- Normative Document

Ppm- part per million

tPPT- publication preparation team

SDG- Sustainable Development Goals

SBC -Salmonella Bacteriophage Cocktail

DECLARATIONS

Consent for publication

"Not applicable"

Ethics approval and consent to participate

"Not applicable"

Availability of data and materials

The data used and/or analyzed during the current research are available from the records of the projects, research and scientific publications conducted by: International Center for Environmental Research, Georgian Technical University, Iv. Javakhishvili Tbilisi State University, Kutaisi State University, Saarland University and is available from the corresponding author on reasonable request.

Competing interests

Funding Sources: International Center for Environmental Research (ICFER)

Employment: ICFER staff

Personal Financial Interests: there are no stocks or shares in or ownership of companies affected by publication of this research, consulting fees/remuneration, royalties, from organizations which may profit or lose as a result of publication, patents or patient applications whose value and integrity may be affected due to publication.

Institutional Competing Interests

There are no Institutional Competing Interests

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Please check one:

√ None declared under financial, general, and institutional competing interests

☐ I wish to disclose a competing interest(s) such as those defined above or others that may be perceived to influence the results and discussion reported in this paper.

Attestation of Investigator Independence/Accountability

I had full access to all study data, take fully responsibility for the accuracy of the data analysis, and have authority over manuscript preparation and decisions to submit the manuscript for publication.

√ Yes

☐ No, please describe below and provide additional detail in cover letter necessary

Author Signature:

Name (please type or print) - Grigol Abramia
Date: 23.04.202

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Authors' contributions

Contributions by the authors are acknowledged and they are identified by names.

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ANNEXES:

Annex-1

Table 3. Results of the chemical analyses of the water of the lake Paliastomi (Rangers' Base -1)

Type of Water	Surface	Physical-Chemical Indicator	Mg/L	Mg–eq.
Name of the Object	Lake Paliastomi	Hardness	-	24.564
Water Site	Rangers' Base-1	Alkalinity	-	N.D.
Region	Samegrelo Zemo-Svaneti	Solubility O_2	7.800	-
Turbulence (FTU)	150.00			
pH	8.05	COD&(Mg/L O)	<15.0	-
Dry Waste (Mg/L)	5741.410			
Conductivity(S/m)	1.03350			

Cations				**Anions**			
Ion	**Mg/L**	**Mg–Eq**	**Mg–Eq%**	**Ion**	**Mg/L**	**Mg–Eq**	**Mg–Eq%**
NH_4	N.D.	N.D.	N.D	*Cl	3225.950	91.0000	90.30
Ca	114.000	5.7000	5.70	HCO_3	176.9	2.9000	2.88

					00		
Mg	229.200	18.8642	18.85	CO_3	N.D.	N.D.	N.D.
*Na	1694.000	73.9738	73.94	SO_4	330.000	6.8750	6.82
K	57.800	1.4821	1.48	-	-	-	-
Fe	0.550	0.0295	0.03	-	-	-	-
Cu	0.005	0.0002	0.00	-	-	-	-
Zn	0.005	0.0002	0.00	-	-	-	-
Sum	2095.560	100.0499	100 %	**Sum**	3732.850	100.7750	100%
Toxical.Comp. **Mg/L**							
<*> - 20%–more; <N.D.> - below sensitivity;<-> - was not tested<–background meaning							
Mineralization (Mg/L): 5828.410							

Type of Water	Surface	Physical-Chemical Indicator	Mg/L	Mg–Eq
Name of the Object	Lake Paliastomi	Hardness	-	25.363
Water Site	Rangers' Base -2	Alkalinity	-	N.D.
Region	Samegrelo Zemo-Svaneti	Solubility O_2	7.300	-
Turbulence (FTU)	160.00	-	-	-
pH	8.20	COD&(Mg/L O)	<15.0	-
Dry Waste (Mg/L)	5732.795			
Conductivity(S/m)	0.98670			
Cations		**Anions**		

Mg/L	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg–Eq**	**Mg–Eq** %
Ca	128.000	6.4000	6.36	*Cl	3275.580	92.4000	91.69
Mg	230.400	18.9630	-	HCO_3	180.560	2.9600	2.94
*Na	1692.000	73.8865	73.39	CO_3	N.D.	N.D.	N.D.
K	54.500	1.3974	1.39	SO_4	260.000	5.4167	5.37
Fe	0.550	0.0295	0.03	-	-	-	-
Zn	0.005	0.0002	0.00	-	-	-	-
Sum	2105.455	100.6766	100%	Sum	3716.140	*100.7767*	*100%*
<*> - **- 20%−more; <N.D.> - below sensitivity;<-> - was not tested<−background meaning**							
Mineralization (Mg/L): 5821.595							

Type of Water	Surface	Physical-Chemical Indicator	Mg/L	Mg–Eq
Name of the Object	Lake Paliastomi	Hardness	-	25.753
Water Site	Rangers' Base -2	Alkalinity	-	0.100
Region	Samegrelo Zemo-Svaneti	Solubility. O_2	7.400	-
Turbulence (FTU)	299.00	-	-	-
pH	8.30	COD&(Mg/L O)	<15.0	-
Dry Waste (Mg/L)	5935.190			
Conductivity(S/m)	1.03870			
Cations		**Anions**		

Mg/L	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg/L**	**Mg–Eq**
Ca	120.000	6.0000	5.90	*Cl	3410.290	96.2000	91.10
Mg	1705.000	74.4541	73.18	HCO_3	167.140	2.7400	2.59
*Na	N.D.	N.D.	N.D.	CO_3	6.000	0.2000	0.19
K	58.300	1.4949	1.47	SO_4	310.000	6.4583	6.12
Fe	0.660	0.0355	0.03	-	-	-	-
Cu	N.D.	N.D.	N.D.	-	-	-	-
Sum	2123.960	101.7376	100%	**Sum**	3893.430	105.5983	100%
<*> - **- 20%–more; <N.D.> - below sensitivity;<-> - was not tested<–background meaning**							
Mineralization (Mg/L): 6017.390							

Type of Water	Surface	Physical-Chemical Indicator	Mg/l	Mg–eqv
Name of the Object	LLake Paliastomi	Hardness	-	5.168
Water Site	Fish factory-4	Alkalinity	-	N.D.
Region	Samegrelo Zemo-Svaneti	Solubility. O_2	3.600	-
Turbulence (FTU)	1570.00			
pH	7.20	COD(M/L O)	36.000	--
Dry Waste (Mg/L)	853.611			
Conductivity(S/m	0.16510			
Turbulence (FTU)	1570.00			

Cations				**Anions**			
Mg/L	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg/L**	**Mg–Eq**	**Mg/L**	**Mg–Eq**

Ca	52.000	2.6000	16.91	HCO_3	176.900	2.9000	19.30
Mg	31.200	2.5679	16.70	SO_4	56.000	1.1667	7.76
*Na	220.000	9.6070	62.47	-	-	-	-
K	8.800	0.2256	1.47	-	-	-	-
Fe	5.600	0.3009	1.96	-	-	-	-
Cu	0.014	0.0004	0.00	-	-	-	-
Mn	0.550	0.0200	0.13	-	-	-	-
Zn	0.015	0.0005	0.00	-	-	-	-
Sum	319.179	15.3779	100%	**Sum**	621.432	15.0267	100%
<*> - **- 20%–more; <N.D.> - below sensitivity;<-> - was not tested<–background meaning**							
Mineralization (Mg/L): 940.611							

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Figures

Figure 1

Dissemination of Fe particles (15 May 2017)

Figure 2

Dissemination of common coliforms (15 May 2017)

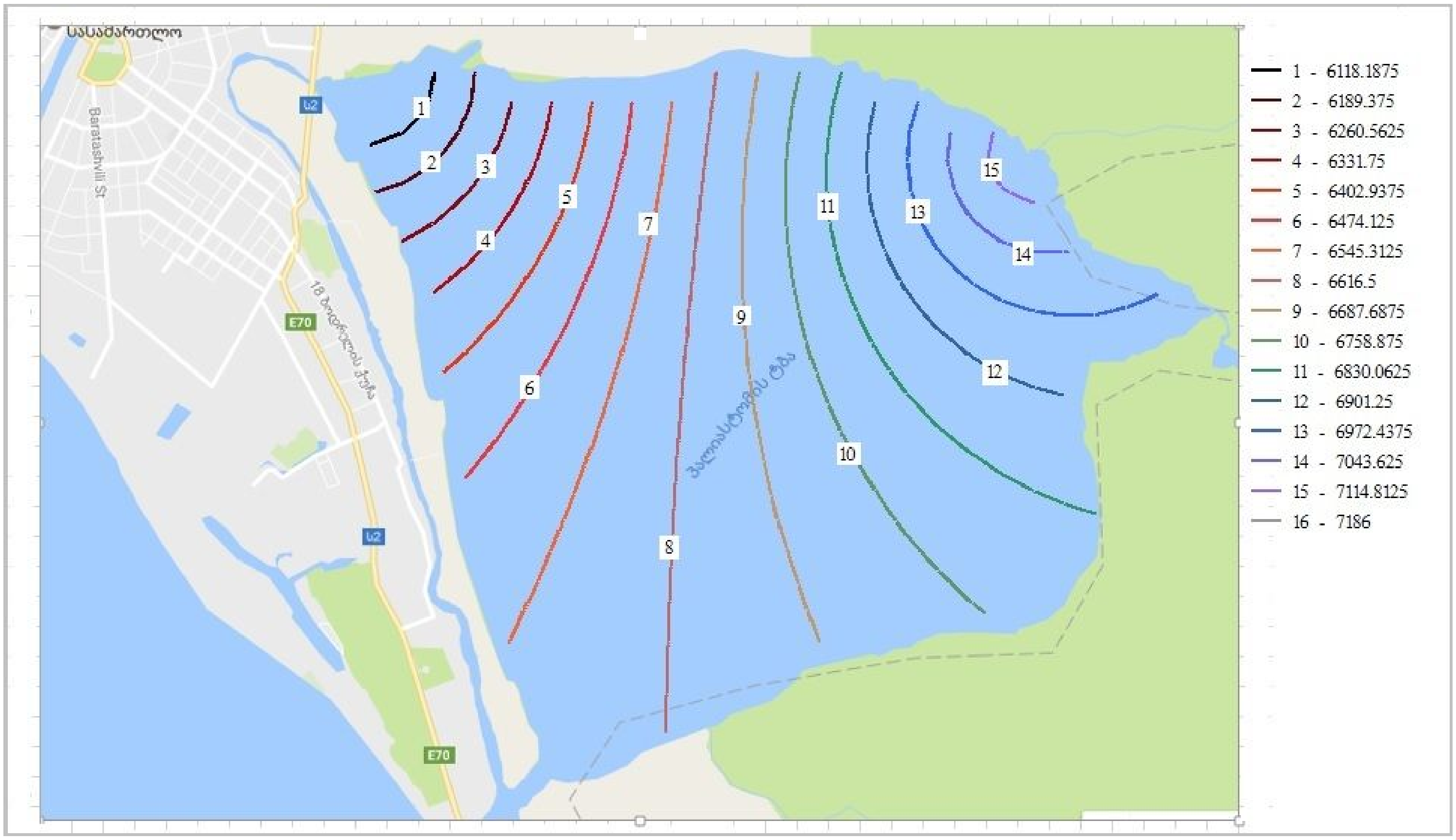

Figure 3

Dissemination of common coliforms (29 March 2018)

Figure 4

Computer-generated currents at 10 m/s north-east wind

Figure 5

Dissemination of common coliforms after 6 hours

Figure 6

Dissemination of common coliforms after 12 hours

Figure 7

Dissemination of common coliforms after 24 hours

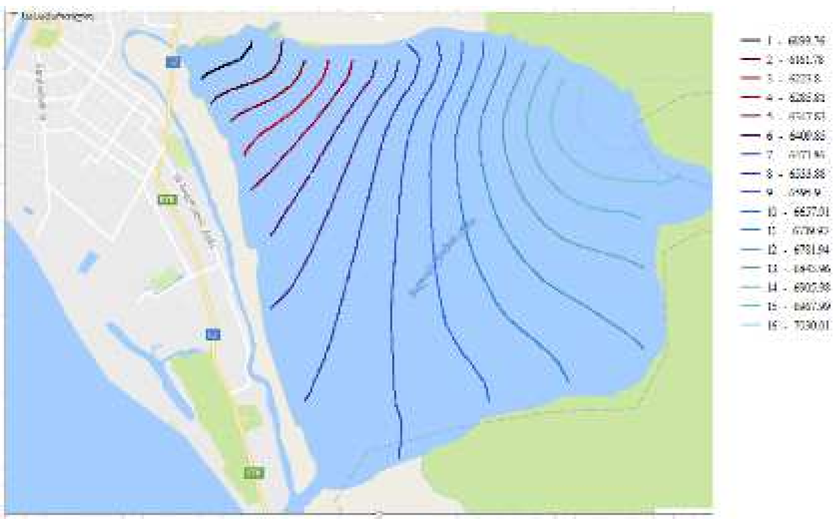

Figure 8

Dissemination of common coliforms after 6 hours

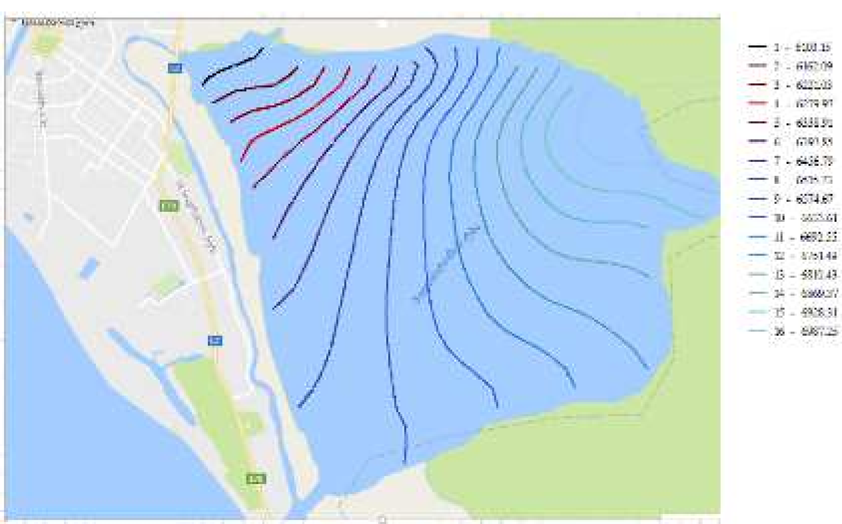

Figure 9

Dissemination of common coliforms after 12 hours

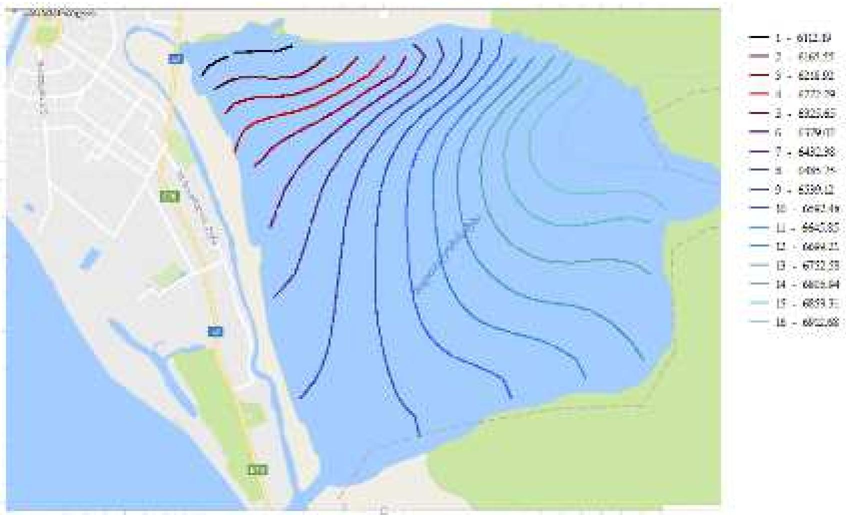

Figure 10

Dissemination of common coliforms after 24 hours

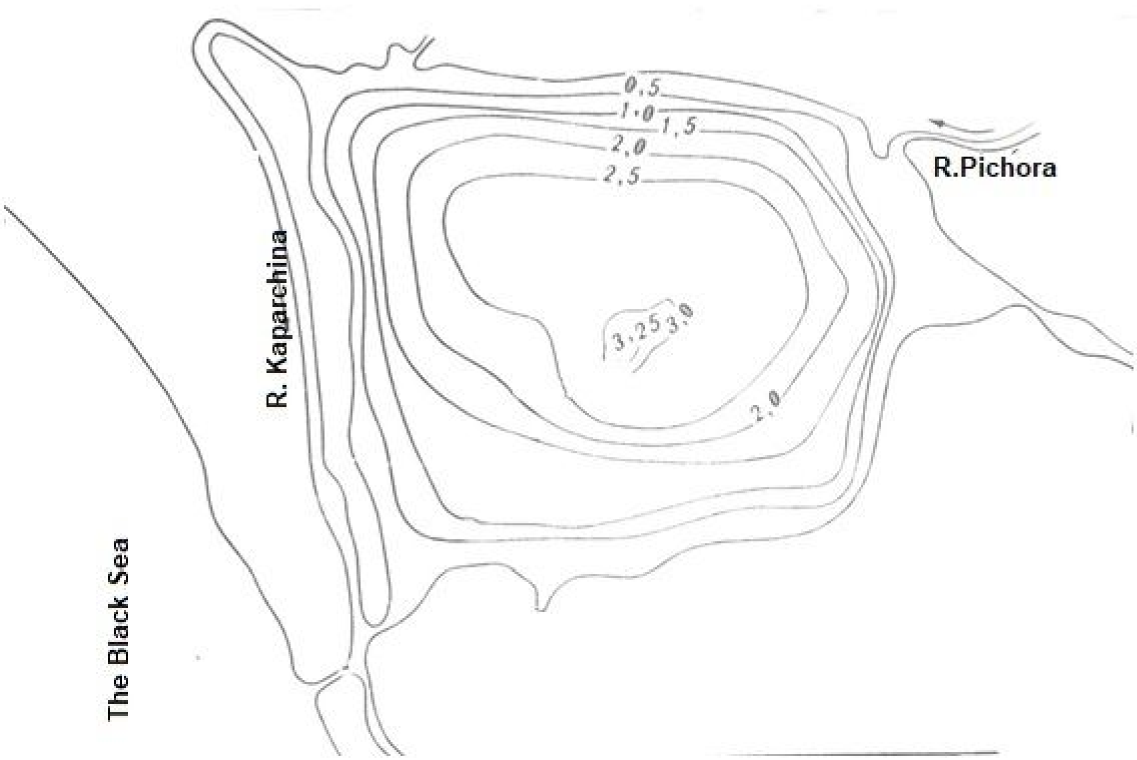

Figure 11

Paliastomi Lake Bathymetry (12)

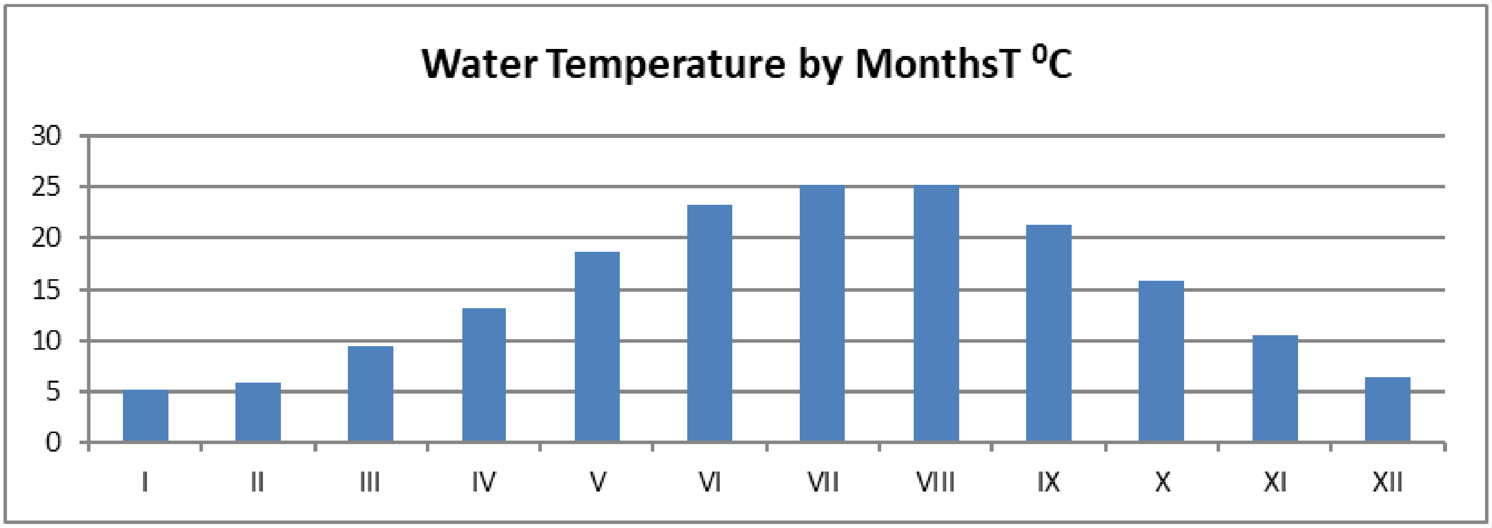

Figure 12

Water Temperature of the lake Paliastomi by Months

Figure 13

Photo-1 © 2020 I TV -Kolkheti National Park (r. Kaparchina)

Figure 14

Photo-2 © 2020 I TV -Lake Paliastomi

Figure 15

Lake Paliastomi water samples (original-right and after treatmen-left by BC)

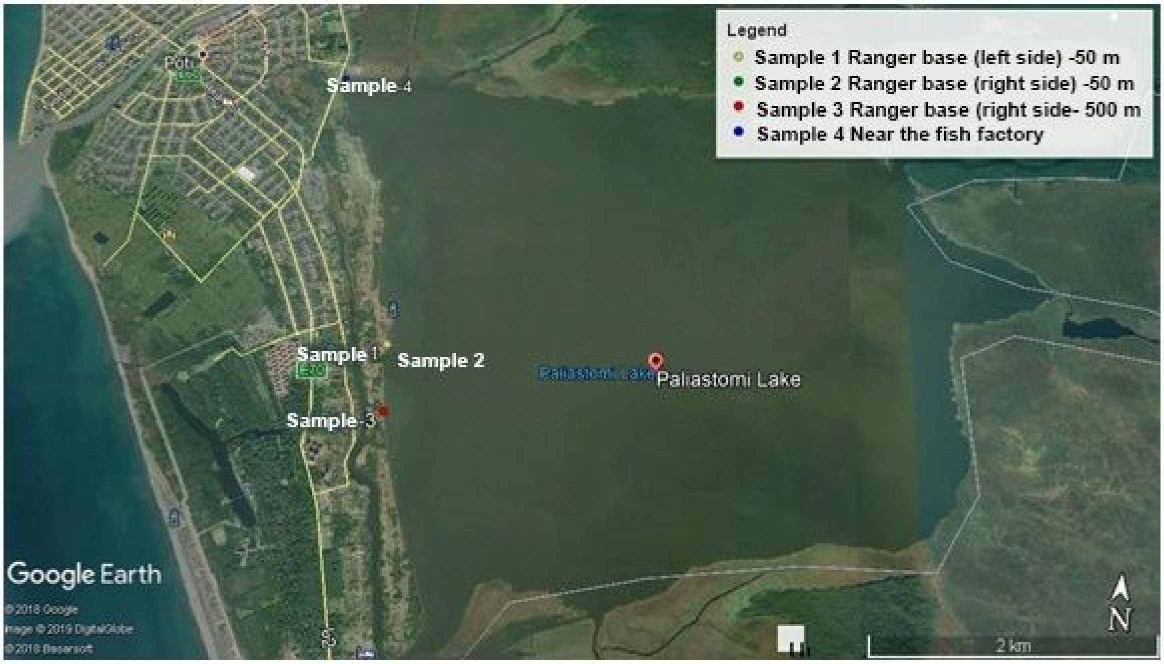

Figure 16

Map-1 Chemical pollution (14-15 May, 2017) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.