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ORIGINAL PAPER

APPLICATION OF EFFECTIVE MICROORGANISMS TECHNOLOGY AS A LAKE RESTORATION TOOL - A CASE STUDY OF MUCHAWKA RESERVOIR*

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Abstract

This paper presents the effects of an application of Effective Microorganisms (EM) technology in line with the method developed by Sitarek, thus evaluating its effectiveness as a tool in the biological restoration of a water body. In 2012-2013, EM was applied in Muchawka Reservoir situated in the town of Siedlce (eastern Poland). Analyses of water parameters and bottom sediments were carried out in 2011, before the EM technology was implemented and again in 2013-2015 after the EM application was completed. In spring 2011, the average total nitrogen (TN) content at the surface was 3.1 mg dm^{-3} while the total mineral nitrogen content equalled 0.893 mg dm^{-3}. After the EM application was completed, in the summer of 2013, the TN content was on average 2.5 mg dm^{-3}. The content of nitrates and nitrites in the summer of 2013 reached 1.20 mg dm^{-3} at the most. Lower levels of such forms of nitrogen were observed in 2013 and also in subsequent years at the bathing beach (site 1) and the hostel (site 3) than at the inflow (site 4). Likewise, the highest content of phosphates was recorded at the inflow site (4), being four -fold lower at the other sites (1, 3). The average content of TP before the EM technology was applied was 0.205 mg dm^{-3}, whereas after the application of effective microorganisms it fell

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down to 0.189 mg dm^{-3} (2013-2015). Only slight changes of TSI_{TP} indicated that waters in Muchawka Reservoir were eutrophic. After EM was applied twice, no streaks, cyanobacterial scums or pollution at the bathing sites were visible. The bacteriological evaluation of the water samples was carried out by the County Branch of the State Sanitary Inspectorate in Siedlce. The bacteriological water quality was described as "excellent". These findings suggest that the method developed by SITAREK, combined with probiotic preparations, could be a useful tool in the restoration of water bodies, but the conclusion requires further detailed verification.

Keywords: restoration, eutrophication, remediation, EM, nutrients.

INTRODUCTION

The problem of pollution occurs in many water bodies, leading to the loss of their natural, recreational or economic values. Human intervention is required to restore the lost balance. Restoration methods vary, both in terms of the scale of intervention in the natural environment and the stability of results (e.g. SØNDERGAARD et al. 2007). Microbiological bioremediation is one of the numerous water purification methods (MINGJUN et al. 2009) involving an application of environmental probiotics, which contain microorganisms and the chemical compounds that they secrete (SIUDA, CHRÓST 2015). According to MINGJUN et al. (2009), this approach is up to 60-70% less expensive than traditional methods.

An example of the use of a probiotic microbiological product is the Technology of Effective Microorganisms, developed by Prof. T. Higa of Okinawa. EM is a composition made of two cultures of bacteria, such as lactic and phototrophic bacteria, and yeast; it is a yellow-brown liquid with pH 3-3.5, sweet-sour taste and the smell of kvass or fermenting fruit juice (HIGA 1991). The EM technology is applied in agriculture, horticulture, animal breeding and in environmental protection (JANAS 2009, ZAKARIA et al. 2010, NAMSIVAYAM et al. 2011).

Effective Microorganisms are introduced into water bodies mainly as "bokashi" balls (LÜRLING et al. 2010, PARK et al. 2016). They are manually made from clay with the addition of EM preparations, and then thrown or drowned in a lake. Both "bokashi" balls and a liquid product, containing a mixture of treacle and EM, have been used to clean or restore water bodies in Malaysia (ZAKARIA et al. 2010), with results showing the two techniques to be effective in restoring water quality in degraded water bodies.

The method developed by SITAREK describes the way microbiological liquid preparations are introduced into an aquatic environment at strategically chosen sites of a water body, depending on the conditions and expected results. It is less time-consuming than "bokashi" balls, more precise and intended to bring desired results sooner. There is a patent pending for the method (three out of the 11 applications have been granted patent numbers: P.407303, P.407304, P.407305). The method was first applied to clean water bodies near the Agricultural Advisory Centre in Piotrków Trybunalski in 2009.

The aim of this article is to present the effects of an application of EM technology according to the method developed by Sitarek and to evaluate its effectiveness as a tool in the biological restoration of a water body.

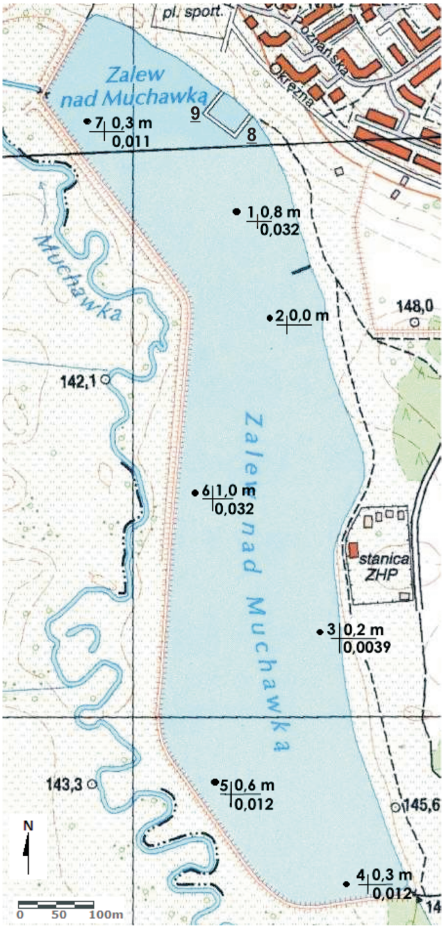
MATERIAL AND METHODS

Muchawka Reservoir is an artificial water body, situated on the western outskirts of the town of Siedlce, with an area of 40 ha and a capacity of approximately 600,000 m^3 of water supplied through a canal from the Muchawka River. The reservoir has an inlet canal, made from the regulated section of the Muchawka River and one outflow. Muchawka Reservoir is now used for leisure activities. There are several tourist facilities on its banks, including snack bars and sports grounds as well as bathing beaches, all of which add to the deteriorating quality of the water in the reservoir.

The EM technology was applied in Muchawka Reservoir in two stages at two-month intervals, from June through July 2012 and 2013. The EM Probiotyk^{TM} (Greenland Technologia EM, Poland) preparation was applied, which – according to the manufacturer's information – contains lactic acid bacteria *Lactobacillus*, yeast *Saccharomyces cerevisiae*, phototrophic bacteria *Rhodopseudomonas palustris* and sugarcane treacle as a culturing medium for the microorganisms. About 8 thousand litres of the preparation were used at each stage.

The preparation was introduced into the lake through an application system developed by Sitarek as an alternative to "bokashi" balls. The method involves a system of properly modified fuel-powered motor pumps (6.5 KM, output of 1000 l min^{-1}). The devices were used mainly in marginal zones and at sites particularly susceptible to the formation and/or accumulation of pollution. The preparation was distributed evenly across the whole surface of the reservoir, especially at the mentioned sites. The preparation was applied in the surface layer and in the water column. Certain innovative technical solutions developed in the system were submitted to patent protection. This step was necessary because no complete sets of equipment for lake restoration are currently available.

Preliminary examinations of bottom sediments and physicochemical analyses of water were carried out in March 2011, i.e. a year before the EM technology was applied. Samples of bottom sediments were taken from the depth of 1.0-1.5 m at six study sites (except site 2) (Figure 1) to carry out macroscopic determination of the type of soil. The following parameters were analysed in bottom sediments: pH, total nitrogen, organic carbon, carbonates and heavy metals (Pb, Cd, Ni, Cr). Simultaneously, water samples were col-



Legend:
The main sampling sites:
1 – the reservoir at the bathing pier
2 – the reservoir curve between the hostel and the bathing beach - a fishing pier
3 – the reservoir at the hostel - point 1
4 – water inflow to the reservoir
5 – between the inflow and the scouts' hostel
6 – the reservoir at the hostel - point 2
7 – outflow from the reservoir

The additional sampling sites:
8 – bathing area 1
9 – bathing area 2

Fig. 1. Location of sampling sites (1-9) in Muchawka Reservoir, Siedlce (eastern Poland)

lected at all the seven sites from the near-surface layer (S – surface) and the near-bottom layer (B – bottom). Both types of water samples were tested for pH, total nitrogen and its mineral forms, total phosphorus and turbidity. Additionally, the near-bottom layers were tested for total organic carbon and carbonate hardness as well as the content of heavy metals (Pb, Cd, Ni, Cr) in water.

The pH of the water extract was assessed by the potentiometric method. The total nitrogen content was determined by the Kjeldahl method, total phosphorus was assayed by the colorimetric method with ammonium molybdate and ascorbic acid, organic carbon was determined by digestion with sulphuric acid and potassium dichromate, while carbonates were assessed by titration. Absorption Atomic Spectrometry following mineralisation by strong acids was used to determine the content of heavy metals.

Subsequently, in June and July 2011 (a year before the restoration), an analysis of the selected physicochemical parameters (e.g. temperature, concentration of oxygen, concentration of total phosphorus) was repeated at 3 representative sites situated near the inflow (4), at the hostel (3) and at the bathing beach (1). Analogous measurements were made in 2013-2015 (June and July), after the restoration measures had been completed. Oxygen concentration and temperature were measured with a portable multi-parameter probe HQ 40d HACH LANGE with an INTELLICAL LDO sensor.

Bacteriological analyses (determination of *Escherichia coli* and enterococci counts by standard methods) were carried out in 2011 (June) and in 2013-2015 (June-August) at the same three sites: inflow (4), hostel (3), bathing beach (1) and at additional sites 8 and 9. Visual assessment was also performed at the same sites and on the same days for the occurrence of cyanobacteria blooms (streaks, scum, foam) and the presence of pollutants (e.g. tarry materials, glass, plastic, rubber).

Water and bottom deposit measurements in 2011 and in 2013-2015 were carried out by the Occupational Environment Protection Laboratory in Siedlce, the County Branch of the State Sanitary Inspectorate as well as by the Wastewater Analysis Laboratory in Siedlce.

The significance of biogenic substance content changes in the near-surface and near-bottom layers (sites 1-7) in Muchawka Reservoir in March 2011 was tested by the U Mann-Whitney test (to compare two independent groups). A level of significance of $p = 0.05$ was assumed. Trophic state index – TSI based only on total phosphorus – TP (Carlson 1977) and total nitrogen – TN (Kratzer, Brezonik 1981) was used to determine the trophic state of Muchawka Reservoir.

RESULTS AND DISCUSSION

Physicochemical conditions

Loamy sand, fine sand or aggregate black mud were found at six research sites (1, 3-7) in March 2011, which may be a sign of the initial stage of eutrophication. The pH of bottom sediments ranged from 5.2 to 5.4 (slightly acidic) – Table 1. The content of biogenic compounds in bottom sediments was the following: organic carbon, which had the highest share (on average 7.41% of dry matter), calcium carbonates (0.74%), total nitrogen (0.289%) and total phosphorus (0.017%). The average heavy metal content (expressed on a dry weight basis) was the following: Pb 8.0, Ni 5.9, Cr 5.5 and Cd 1.1 (in mg kg^{-1}). The results of heavy metal assays of the bottom sediments in Muchawka Reservoir showed that they were relatively clean, containing elements at trace concentrations, similarly to the geochemical background. According to the *Regulation of the Minister of Environment* (2002) on soil and

Table 1

The pH, biogenic compounds and heavy metal content in bottom sediments

Parameters	Sampling sites							
	1	3	4	5	6	7	mean	SD
pH	5.4	5.2	5.3	5.4	5.3	5.4	5.3	0.082
TN (% N d.m.)	1.100	0.031	0.085	0.180	0.240	0.095	0.289	0.404
TP (% P d.m.)	0.032	0.004	0.012	0.012	0.032	0.011	0.017	0.012
OC (% C d.m.)	24.50	0.85	2.10	5.50	8.60	2.90	7.41	8.817
$CaCO_3$ (% d.m.)	1.20	0.28	0.31	0.95	0.39	1.30	0.74	0.467
Pb (mg kg^{-1} d.m.)	10.6	4.0	7.3	6.0	9.6	10.6	8.0	2.704
Ni (mg kg^{-1} d.m.)	10.9	2.1	3.9	8.3	4.1	5.9	5.9	3.238
Cr (mg kg^{-1} d.m.)	6.8	1.6	4.6	6.8	5.7	7.3	5.5	2.129
Cd (mg kg^{-1} d.m.)	1.2	0.6	1.0	1.1	1.1	1.3	1.1	0.243

TN – total nitrogen, TP – total phosphorus, OC – organic carbon, $CaCO_3$ – calcium carbonate, Pb – lead, Ni – nickel, Cr – chromium, Cd – cadmium, the key to the sampling sites was given in Fig. 1

earth quality standards, the analysed bottom sediments can be classified as group A (typical of protected areas) in terms of the content of chromium, nickel and lead, and as group B (typical of agricultural land) regarding the cadmium content.

Prior to the application of the EM technology, the content of heavy metals, i.e. lead and nickel, in the waters of Muchawka Reservoir (Table 2) exceeded the maximum acceptable levels laid down in the environmental quality standards for priority substances and other pollutants (App. 9, *Regulation of the Minister of the Environment* (2014). The content of cadmium and chromium was below 0.025 mg dm^{-3} at all the sites, except for one sampling point (site 2), where the amount of chromium was 0.047 mg $dm^{-3.}$

The content of biogenic substances (mainly nitrogen and phosphorus) in March 2011 fluctuated within a wide range, i.e. TP 0.04-0.79 mg dm^{-3} (Figure 2*a*), TN from 2.53 to 7.59 mg dm^{-3} (Figure 2*b*). The largest concentrations of

Table 2

Heavy metal content in water samples collected near the bottom of seven sampling sites in Muchawka Reservoir

Heavy metals	Sampling sites								
	1	2	3	4	5	6	7	mean	SD
Pb (mg dm^{-3})	0.083	0.088	0.083	0.085	0.089	0.110	0.100	0.091	0.010
Ni (mg dm^{-3})	0.027	0.037	0.027	0.029	0.025	0.029	0.026	0.029	0.004
Cr (mg dm^{-3})	<0.03	0.047	<0.03	<0.03	<0.03	<0.03	<0.03	-	-
Cd (mg dm^{-3})	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-

Pb – lead, Ni – nickel, Cr – chromium, Cd – cadmium, the key to the sampling sites was given in Fig. 1

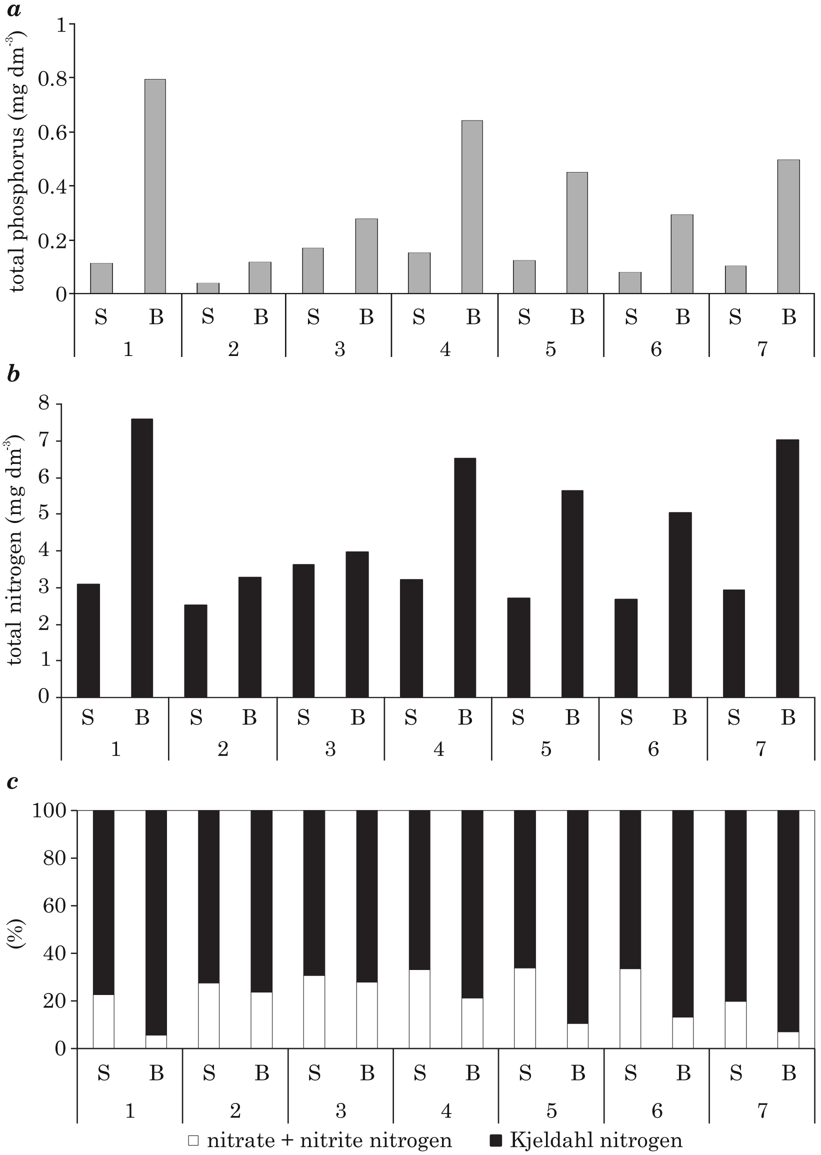


Fig. 2. The content of TP (*a*) and TN (*b*), and the share of nitrogen forms in TN (*c*) in water of Muchawka Reservoir at seven stations before EM application (March 2011); S – at surface, B – at the bottom; the key to the sampling sites was given in Fig. 1

biogenic compounds were recorded at the bottom; they were significantly different from those near the surface (*U* Mann-Whitney test, $p < 0.05$). This is consistent with the natural processes which occur in water bodies, namely the additional release of phosphorus from deposits taking place in near-bottom layers. The Kjeldahl's nitrogen (N_{org}+N-NH_4) accounted for the majority of TN, and its content ranged from 1.79 to 7.17 mg dm^{-3} (Figure 2*c*). Meanwhile, the total content of nitrates and nitrites in both water layers ranged from 0.424 (site 1 – bottom) to 1.385 mg dm^{-3} (site 4 – bottom). Nitrates reached 1.360 mg dm^{-3} at the most whereas the maximum content of nitrites was 0.033 mg dm^{-3}.

Likewise, significantly greater turbidity was observed near the bottom (*U* Mann-Whitney test, *p* = 0.002) – Figure 3, in layers in which the TOC content ranged between 6.0 and 14.8 mg dm^{-3}, carbonate hardness was near 164 mg $CaCO_3$ dm^{-3}, and water pH equalled 7.5. Increased turbidity is the most obvious sign of eutrophication (Czaplicka-Kotas et al. 2012).

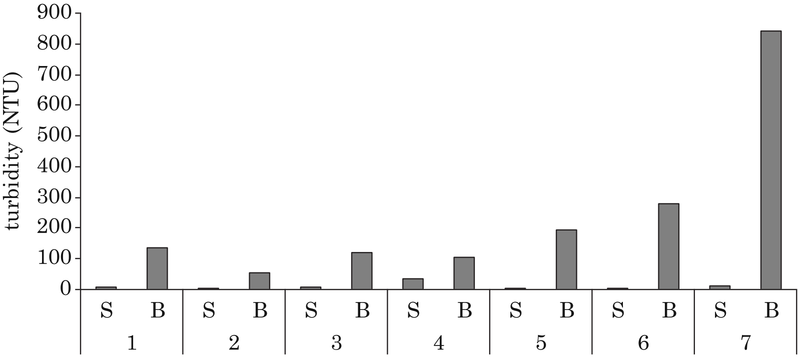


Fig. 3. The water turbidity of Muchawka Reservoir at seven sampling sites before EM application (March 2011); S – at surface, B – at the bottom; the key to the stations was given in Fig. 1

In summer, the concentration of oxygen at the sites situated near the inflow (4), the hostel (3) and the bathing beach (1) changed within the following ranges: 4.7-10.5 mg dm^{-3} in 2011, 5.7-10.2 mg dm^{-3} in 2013, 8.4-12.4 mg dm^{-3} in 2014 and 2.3-11.8 mg dm^{-3} in 2015. The water oxygenation ranged then from 57 to 138%. The temperature of near-surface water layers changed between 17.5 and 26.3°C. The water pH at that time varied from 7.1 and 9.1, similarly before and after the EM technology was applied (Figure 4). Szymanski and Patterson (2003) observed a slight effect of the EM technology on pH, alkalinity and electrical conductivity of water. On the other hand, Namsivayam et al. (2011) and Monica et al. (2011) applied EM and observed an up to 80% decrease in BOD, COD, Total Dissolved Solids and alkalinity, an increase in the amount of oxygen and a slight impact on pH. According to Chęciński and Czernaś (2012) and Czernaś et al. (2013), a higher concentration of oxygen and BOD and a lower content of chlorophyll *a* were observed, parallel to an increase in primary production up to 401.8 mg C m^{-2} h^{-1} (as a consequence of cyanobacterial blooms), following the application of the “Pro-Bio-Em” technology in an experimental part (compared to the controlled part) of a degraded pond. The pH of water in both parts of the pond was found to have decreased from 10.3 (May) to 7.1 and 7.3 (November), and the average visibility of water was comparably low (on average 0.57 m).

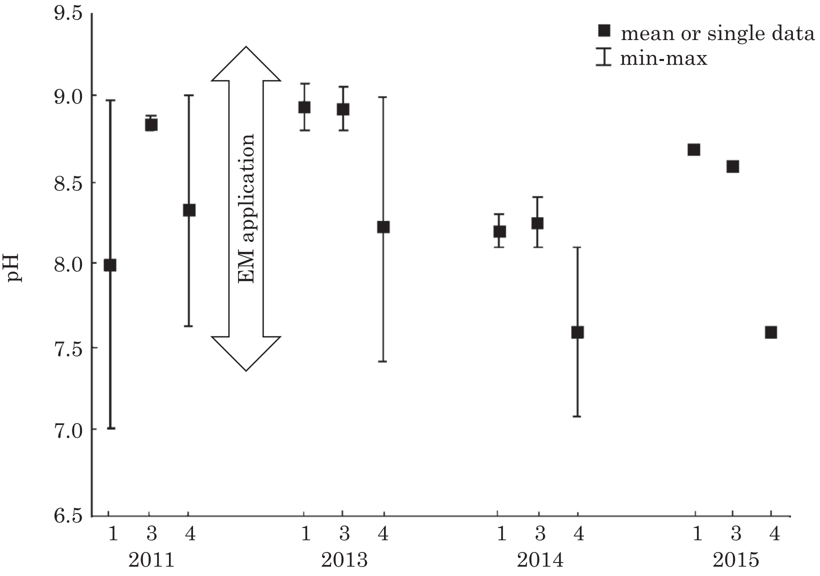


Fig. 4. Changes of water pH in summer in Muchawka Reservoir before and after EM application at selected sampling sites: 1 – bathing beach, 3 – hostel 1, 4 – inflow

In the summer 2013, after the application of EM had been completed, the content of nitrates and nitrites ranged from 0.04 to 1.20 mg dm^{-3} (Figure 5). The maximum value was observed at site 4 (inflow), where it was significantly higher than at sites 1 and 3 (up to 14 times higher). Lower levels of mine-

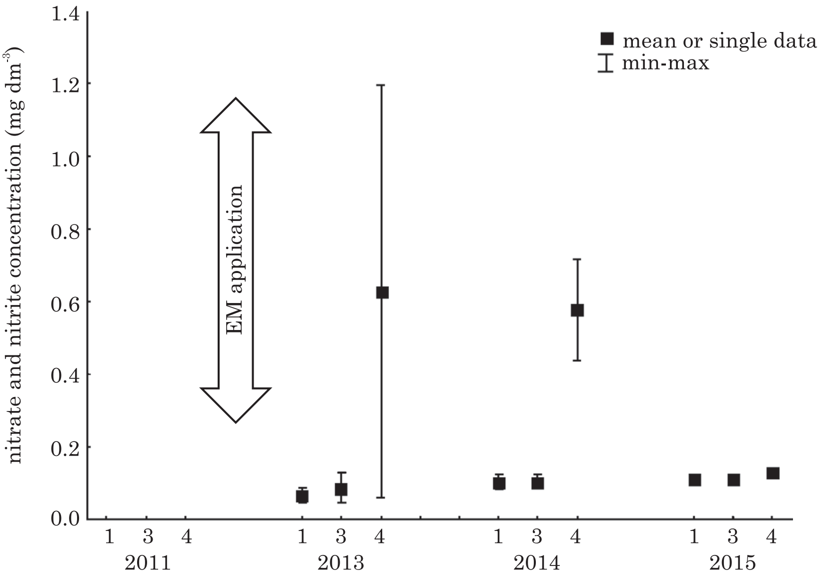


Fig. 5. The changes of mineral nitrogen concentrations in summer in Muchawka Reservoir at selected sampling sites: 1 – bathing beach, 3 – hostel 1, 4 – inflow

ral nitrogen at the hostel (3) and the bathing beach (1) than at the inflow (4) were also recorded in 2014 (up to 8 times lower). In 2015, their content was similarly low at all the three sites. Likewise, the highest content of phosphates in June and July 2013-2014 was recorded at the inflow (site 4; 0.132 mg dm^{-3} on average) and its content at the other sites (1, 3) was up to four times lower (Figure 6*a*). Similarly, a low concentration of phosphates was observed in the summer of 2015 at all the sites.

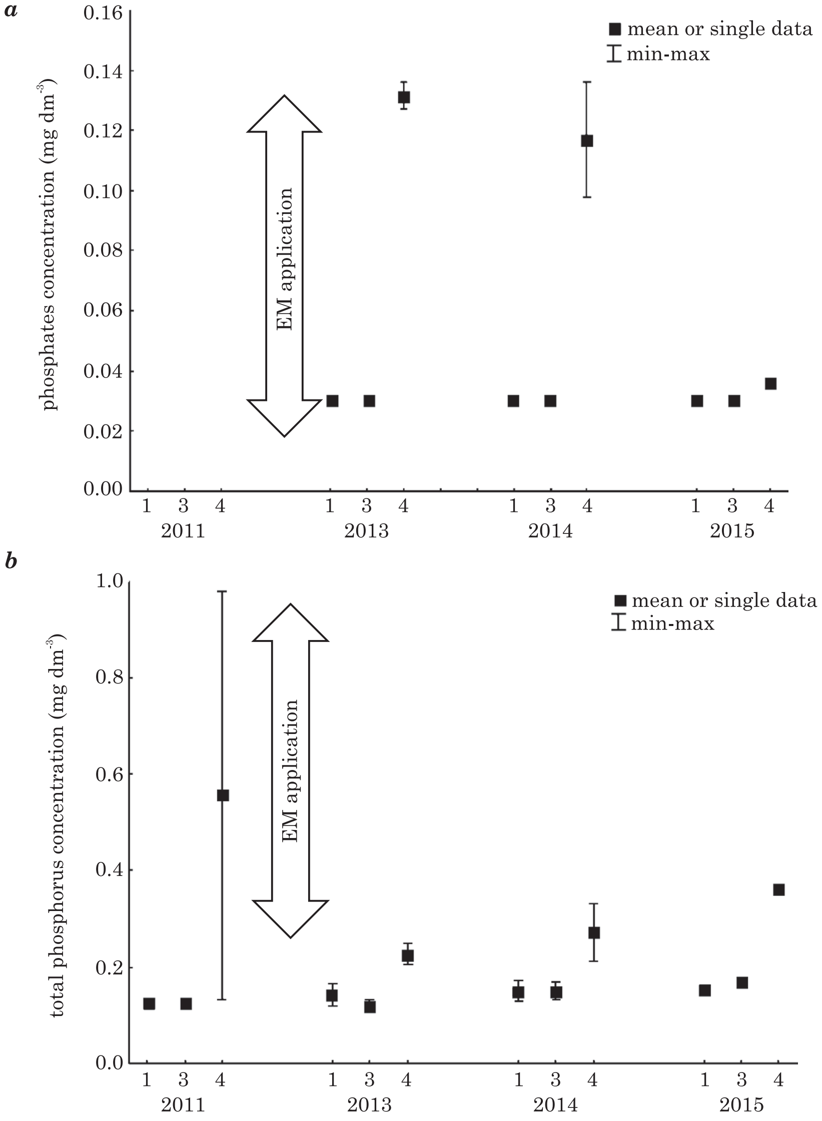


Fig. 6. Changes of mineral (*a*) and total phosphorus (*b*) concentrations in summer in Muchawka Reservoir before and after EM application at selected sampling sites: 1 – bathing beach, 3 – hostel 1, 4 – inflow

Total nitrogen is an important index which characterises the biogenic conditions in water quality assessment (App. 2, *Regulation of the Minister of Environment* (2014). The average total nitrogen content in the summer 2013, after EM had been applied, was on average 2.48 mg dm^{-3}, being comparable to the seasonal mean-based threshold of 2.5 mg dm^{-3} for classes I-II in non-stratified lakes with the Schindler ratio above 2, but higher than the threshold in non-stratified lakes with the Schindler ratio below 2. Microorganisms can help to reduce significantly ammonia, hydrogen sulphide and other gases, which are broken down by enzymes produced by microorganisms (Chen et al 2003, Jóźwiakowski et al. 2009), and therefore they can probably cause a decrease in the TN content. Total phosphorus is another important indicator of water quality. In the summer 2011, the TP content was on average 0.125 mg dm^{-3} at sites 1 and 3, being exceptionally high (0.556 mg dm^{-3}) at site 4 (Figure 6*b*). Since the total phosphorus content on 22.07.2011 was extremely high (0.981 mg dm^{-3}), it was probably caused by a one-off, uncontrolled discharge of waste with a large load of biogenic substances. Regarding all the sites (1, 3 and 4), the average content of TP in June and July 2013 was 0.163 mg dm^{-3}, increasing to 0.191 mg dm^{-3} (2014) and 0.227 mg dm^{-3} (2015). When referred to the limit values (an average of the plant growing season) established for non-stratified water bodies, the TP content in Muchawka Reservoir was below water quality class II, i.e. “good quality”, in all the years of the study. However, it should be noted that nitrogen and phosphorus are retained by bottom sediments and then released to water, especially in summer. No increase in biogenic elements was observed in Muchawka Reservoir, but their values decreased along the water flow. However, the trophic state indices: TSI_{TP} (average 80.1 in 2011 and 78.7 in 2013-2015) and TSI_{TN} (67.3 in 2013) indicated eutrophic waters (Carlson 1977, Kratzer, Brezonik 1981) in Muchawka Reservoir both before and after the application of EM. A decrease in biogenic elements following the application of EM was found by Mingjun et al. (2009) and Sekeran et al. (2005). The authors used nitrification bacteria, whereas the EM preparations used in Muchawka Reservoir contained totally different microorganisms (mainly lactic acid bacteria, phototrophic bacteria and fermenting fungi). A decrease in biogenic elements by at least 50% was confirmed by Jóźwiakowski et al. (2009).

The five different biopreparations used in the research carried out by Dunalska et al. (2015) were not shown to have caused any significant changes in the concentration of dissolved oxygen, conductivity, phosphates, total phosphorus or total nitrogen. However, those preparations contained spores rather than live bacterial cultures, as it is in EM Technology. Moreover, the preparations examined by Dunalska et al. (2015) are intended for wastewater treatment plants, although their manufacturers claim they can be used to treat water.

Bacteriological conditions

Each water body used for bathing must be subjected to bacteriological tests, following the *Regulation of the Minister of Health* (2011). Water bodies used for bathing cannot contain such impurities as bacterial contaminations in amounts exceeding the accepted levels or other microorganisms, such as cyanobacteria blooms in the form of a streak, scum or foam, or tarried impurities, glass, plastic, rubber or other waste. When a visual examination was carried out in June 2011 and in June and July 2013-2015, no intensive cyanobacteria blooms or other impurities were observed (streaks, scum or foam) before or after the microbiological preparation was applied (Table 3). Although the studies carried out by CHĘCIŃSKI and CZERNAŚ (2012) and LÜRLING et al. (2010) indicate that the application of EM can increase the biomass of cyanobacteria, effective microorganisms do not compete with cyanobacteria, and therefore they do not have a negative impact on their growth (LÜRLING et al. 2015).

Microbiological tests of water for the content of enterococci and *Escherichia coli* (Table 3) indicated that the enterococci count at the inflow site (site 4) exceeded the maximum acceptable level (≤400 MPN cm^{-3}), as laid down in the *Regulation of the Minister of Health* on supervising water quality in water bodies used for bathing and at bathing sites (2011). Likewise, a high *E. coli* count (1373 and 3600 NPL cm^{-3}, respectively) was determined in 2013 and 2015, which was above the highest acceptable level of ≤1000 NPL cm$^{-3.}$ No values exceeding the highest acceptable level were recorded (in the majority of the samples under analysis) for the enterococci or *E. coli* count, except for the bathing beach in July 2013 (2573 NPL cm^{-3} of *E. coli*). The level of bacteriological contamination of water following the application of EM was very low (up to below 15 MPN cm^{-3} of *E. coli*), especially at the bathing beach, owing to which the quality of water was described as "excellent". In comparison with the research of WROŃSKI et al. (2010) regarding the effect of EM application on indicator bacteria *Salmonella*, a similar effect was achieved, i.e. an increased elimination rate of *Salmonella*.

CONCLUSIONS

The findings suggest a downstream decrease in the total TN and TP content, especially following the application of EM (regarding TP, a decrease was also noted before EM application). Although the changes are significant, they are still below desired values. On the other hand, a considerable decrease was observed in the content of nitrates, nitrites and phosphates, i.e. available nutrients. No values exceeded the highest acceptable levels for the enterococci or *Escherichia coli* count at the hostel (site 3) or the bathing beach (site 1) (except on one occasion), and the levels were very low, especially

Table 3

The microbiological features and insoluble pollution in water of Muchawka Reservoir before (2011) and after (2013-2015) EM application at selected sampling sites

Terms	Sampling sites[*]	Number of *Escherichia coli* (NPL 100 cm^{-3})[**]	Number of Enterococci (NPL 100 cm^{-3})[***]	Cyanobacteria scum	Other pollutions[****]
A. Spatial variation					
June 9, 2011	1	150	25	not found	not found
	4	430	**900**	not found	not found
June 3, 2013	1	1	6	no data	no data
	3	14	18	no data	no data
	4	166	176	no data	no data
July 9, 2013	1	101	14	no data	no data
	3	24	40	no data	no data
	4	**1373**	**650**	no data	no data
July 19, 2013	4	180	288	no data	no data
June 24, 2014	1	15	17	no data	no data
	3	110	**866**	no data	no data
	4	45	20	no data	no data
July 29, 2014	1	40	60	no data	no data
	3	70	180	no data	no data
	4	40	**700**	no data	no data
August 12, 2015	1	40	170	no data	no data
	3	67	85	no data	no data
	4	**3600**	**1100**	no data	no data
B. Variation within bathing area (additional sampling sites)					
June 11, 2013	8	<15	<15	not found	not found
	9	<15	30	not found	not found
June 24, 2013	8	15	15	not found	not found
	9	45	61	not found	not found
July 16, 2013	8	46	46	not found	not found
	9	**2573**	46	not found	not found
July 23, 2013	8	15	15	not found	not found
	9	30	15	not found	not found
August 06, 2013	8	15	15	not found	not found
	9	46	15	not found	not found
June 11, 2015	8	30	30	not found	not found
	9	46	15	not found	not found

[*] Sampling sites: 1 – bathing beach, 3 – hostel 1, 4 – inflow, 8 – bathing area 1, 9 – bathing area 2;
[**] Permisible value ≤1000 NPL 100 cm^{-3} and [***] permisible value ≤400 NPL 100 cm^{-3} according to *Regulation of the Minister of Health on 8 April 2011 on the supervision over the quality of bathing water and the place used for swimming* (Journal of Law 2011, no 86, item 478), bold values exceeded the limit values;
[****] Other pollution include tarry materials arising from refining, distillation or any pyrolytic treatment in particular distillation residues, or glass, plastic, rubber and other waste.

at the bathing sites (8 and 9), owing to which the water quality could be described as “excellent”.

According to the findings of preliminary studies on the use of EM, the trophic state index, calculated only from the total nitrogen and total phosphorus level as TSI_{TN} and TSI_{TP} (eutrophic water) remained at the same level before and after the application of EM. The application of microbiological preparations should be further studied across a wider range of the parameters and tested multiple times to confirm their potential for changing water quality, thus confirming the effectiveness of using EM technology as a tool in the biological restoration of a lake.

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