PROTE-fos

Comprehensive lakes reclamation

Inactivation of phosphorus directly in bottom sediments

The contents

1. About company

PROTE Technologies for our Environment LLC is a company that has been operating in the field of water quality enhancement and environmental protection in Poland since 1995. The company renders services at the highest level, carrying out projects related to protection of the soil and water environment. Full satisfaction of Clients is the most important aim in the course of building PROTE brand as a proven and reliable business partner. The company has implemented an Integrated Management System according to the norms of ISO 9001:2008, expanded by the requirements of AQAP 2110, ISO 14001:2004 and OHSAS 18001:2007.

We started our activity with comprehensive projects of eliminating soil and water environment contamination with the use of e.g. Intensive Bioremediation Technology (TIB). We have successfully completed over 300 projects related to site assessment and reclamation, from major catastrophes to the reclamation of petrol station areas. For the soil and water environment reclamation with the use of TIB Technology we received a Gold Medal of the International Ecological Fair POLEKO in 2001, TERAZ POLSKA Award in the best service category in 2007, as well as an honorable mention "Polish Ecology Leader" in 2009.

In the face of the deteriorating state of Polish lakes and the emerging problem related to algal blooms, as the only company in Poland, we have designed and implemented an effective method of water reservoirs reclamation – PROTE-fos, which we describe in more detail in this brochure. The PROTE-fos method has received a Gold Medal at the POLEKO Fair in 2010, an honorable mention of the TIWS Fair in 2011 as well as the title of laureate of the Polish Promotional Emblem TERAZ POLSKA in the best service category in 2011. The same year PROTE-fos became a laureate of the GreenEvo project under the patronage of the Minister of Environment as one of leading green technologies ready for export. In 2012 our PROTE-fos Lakes Reclamation Technology was recognized by the European Commission as one of five best innovative technologies in Europe.

In order to maintain the proper quality of water in the supply system on the way between the water treatment station and the end user, we introduced the comprehensive service of counteracting secondary contamination of water and water distribution network cleaning as well as maintaining the supply system in the proper sanitary condition. We cooperate with several dozen of Polish waterworks in this regard, achieving the effect of eliminating secondary contamination and enhancement of organoleptic properties of water with extending the life of the network at the same time. In 2009 we received an honorable mention in the TERAZ POLSKA contest in the best service category for the comprehensive service of water distribution network cleaning, and in 2013 we became laureates of the TERAZ POLSKA Award for this service.

Within the field of increasing water intake safety we offer SYMBIO Biomonitoring System – an early warning system against sudden contamination of potable water source. The system is based on fresh water mussels and as the only system on the market it informs about water toxicity every single second. In 2008 we received the TERAZ POLSKA Award in the best product category for the system as well as Gold Medals at the POLEKO International Ecological Fair in 2004 as well as TIWS in Kielce in 2008 and an honorable mention in the Polish Ecology Pantheon in November 2009.
You will find detailed information about our products and services in materials and brochures as well as on our website www.prote.pl.

2. Introduction

"Water is not merely an economic commodity,
as other goods, but first and foremost
it is a legacy that must be protected,
defended and treated subjectively."
(Water Framework Directive)

Despite of the important role of water both in a person's life as well as the nature around them, the expansive economy towards natural resources has led to a situation, in which we are today, that is to a constant shrinking of clear water resources, due to the unsustainable management of water resources.

One of the ecosystems which are most prone to degradation are surface water reservoirs. More and more often we face a situation where water reservoirs which used to be clean – recreational or used economically, has been deteriorated to such an extent that it is no longer possible to use them the way they had been used formerly. The most frequent visible effect of lakes degradation – algal blooms – are becoming a serious problem. Especially blue-green algae blooms are not merely an aesthetic problem, but also a toxicological problem as the blue-green algae can produce toxins that are hazardous to human health.

Nowadays in Poland surface water intakes produce about 80% of water. Such a large share of surface water in the structure of the total water produced, even though such intakes are more difficult in exploitation, is a vital question and this share will certainly be increasing in view of renewability and capacity of these intakes. Sadly the rising deterioration makes it impossible to use surface fresh water as potable water intakes.

The problem related to the degradation of water reservoirs has become a vital issue on the European scale and in the year 2000 the European Parliament established the framework for action in relation to water policy in the European Union. According to the Directive 2000/60/WE of the European Parliament and the Council of the European Union of October 23rd 2000 (the so called Water Directive), establishing the framework for common actions in the field of water policy, member countries were obliged to a rational use and protection of water resources, according to the principles of sustainable development. The main objective of this Directive is achieving a good state of all surface waters until 2015.

3. Eutrophication

Eutrophication is a natural process which is the reflection of water reservoirs aging processes. It consists in their gradual overgrowing and shallowing. Due to anthropopressure the process has been faster in many cases, especially because of an inflow of excessive quantities of nutrients (for example phosphorus and nitrogen). As a result of these processes water quality in many water reservoirs has deteriorated, which is reflected by:

- blooms – massive development of algae, especially blue-green algae,
- worsened lighting conditions, which have the influence on photosynthesis,
- gradual disappearance of aquatic plants growing in the lake bottom,
- depletion of oxygen resources.

According to the Water Directive, Poland is obliged to achieve clear water state of all waters until 2015. It might be achieved for example by carrying out restoration works in order to improve water quality and the state of ecosystems deteriorated by human activity.

Picture 1. Massive blue-green algae bloom

Unfortunately the latest report about the state of the natural environment in Poland, published by the Chief Environmental Inspectorate, says that achieving a clear water state in all reservoirs in Poland within the deadline is impossible. Bearing the negative aspects of the lakes eutrophication process in mind, we should take steps to improve surface water state, especially including the enhancement of their usability as well as recreational and tourist values. This would guarantee an increased attractiveness of many places and the safety of the people using these resources.

This state indirectly results from the fact that actions which have been taken by various subjects and institutions aiming to bring back the good state of water reservoirs, consisted mainly in attempts to weaken one element of the whole range of negative phenomena occurring in water reservoirs, and not to reestablish biological balance in the entire ecosystem, which should in fact be the main purpose of restoration activities.

In the comprehensive approach proposed by PROTE, the object of restoration works is the whole water ecosystem, and its main aim is to restore the ecological balance with the use of PROTE-fos. In the aspect of regulating complicated relationships between particular elements of an organism we can compare a lake to an ill patient. First we diagnose the source of a problem, and next on the basis of the obtained data and the knowledge about the ecosystem we construct a restoration project design. Only then we can begin reclamation works, whose aim is to bring the reservoir back to the state from before degradation – reducing or even eliminating algal blooms, especially blue-green algae blooms,

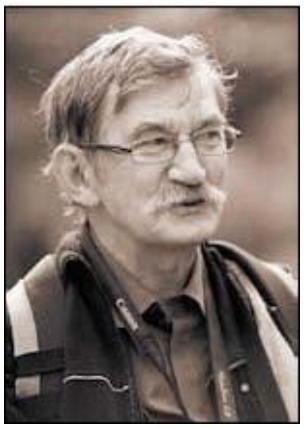
and what is related to it, enhancing water quality, which is reflected by an increase of water transparency.

4. The comprehensive reclamation schematic

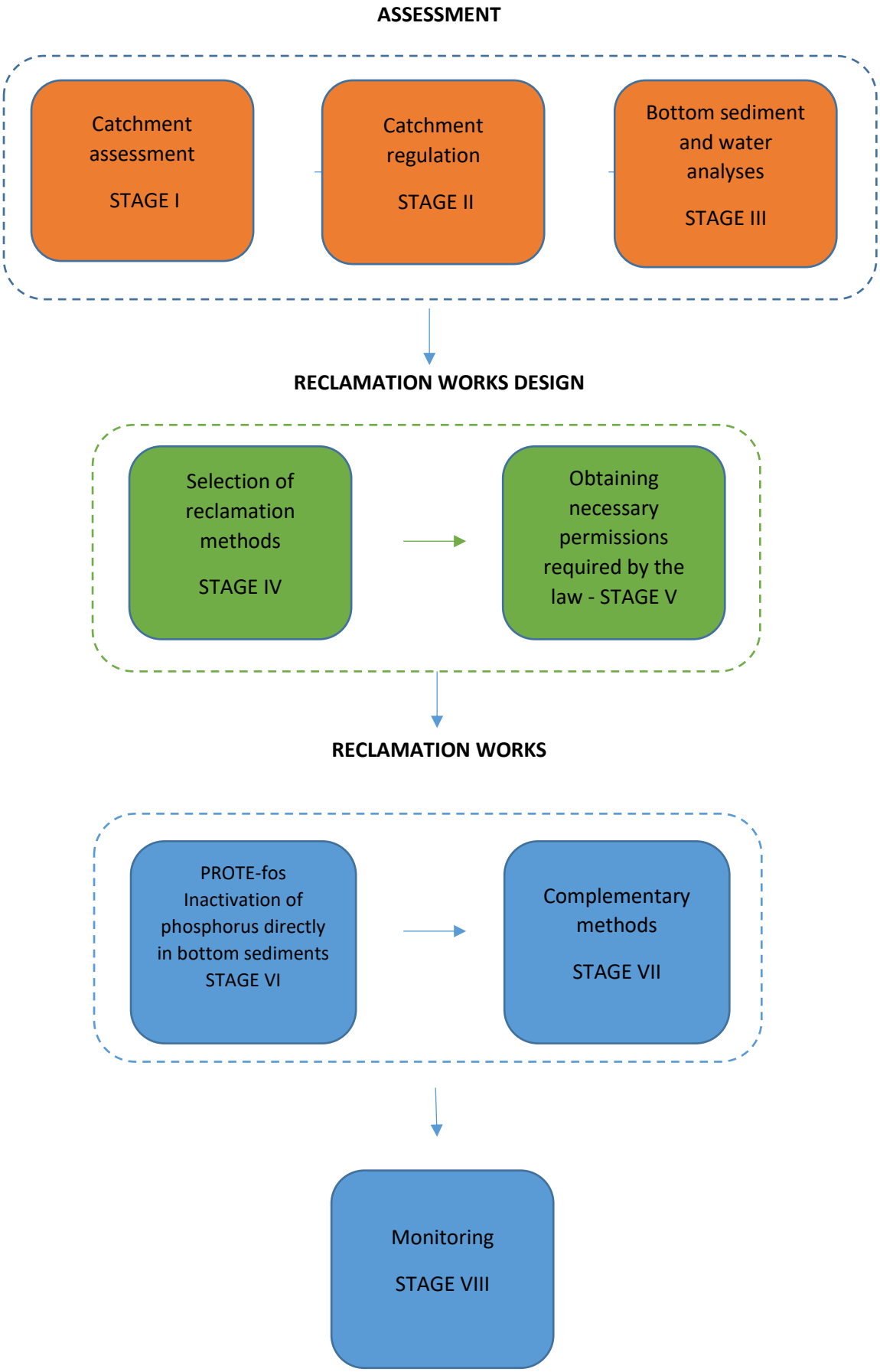
PROTE as the only company in Poland and in the world offers a comprehensive approach to lakes reclamation by means of selected complementary methods which are supportive towards the main method. The application of certain complementary methods and their proportion is strictly correlated with conclusions from the analyses of the state of water and sediments. Together with professor Ryszard Wiśniewski from the Institute of Hydrobiology in Nicolaus Copernicus University in Toruń, who provides a scientific supervision over the process, we have worked out a cooperation schematics in order to achieve ecological effect.

The schematics proposed in this brochure is related to water reservoirs with a high trophy and algal blooms.

A high trophy is not the only problem which might occur in a water reservoir, so the schematic showed below can be subject to modifications aiming to adjust to the given situation.



Picture 2. Professor Ryszard Wisniewski from the University of Nicolas Copernicus in Torun, Poland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5. Assessment

5.1. The catchment

Prior to the beginning of any reclamation works it is necessary to assess the catchment and regulate it to such an extent that the planned reclamation works are effective and its effects permanent. The next step is cutting off point contamination and maximum reduction of the inflowing nutrients.

In parallel with the diagnosis of the situation we should carry out water and bottom sediment analyses in order to be able to assess the state of the given water reservoir. Only these actions guarantee that the methods applied in the reservoir itself will be effective and their effects permanent, and that the funds spent on reclamation will not be wasted.

5.2. Water and sediment analyses

Carrying out extensive analyses of the physical, chemical and biological parameters of bottom sediments is a vital aspect. Thanks to that we can analyze the parameters which are absolutely decisive in terms of processes related to the release of phosphorus from bottom sediments (Fe, Mn, Ca concentration, the Fe : P relation) as well as the influence of pH, electrolytic conductivity, redox potential and oxygen concentration on the above mentioned processes. Crucial information for the future restoration works are the following parameters – EPC-0 and the share of mobile and immobile fractions of phosphorus in bottom sediments.

EPC-0 meaning sorption capacity of sediments in relation to phosphates allows us to assess the ability of bottom sediments to store phosphorus and not release it to water in the so called process of internal loading. The share of phosphorus fractions in bottom sediments is divided into mobile fractions and immobile fractions. Mobile fractions are directly responsible for internal loading and it is their share that needs to be reduced by means of dosing chemical substances directly to bottom sediments.

Water analysis regarding its physical and chemical parameters such as pH, conductivity, visibility is as important as biological parameters analysis, namely chlorophyll concentration, quantitative and qualitative contents of plankton (zoo- and phytoplankton).

6. Lakes reclamation project design

Obtaining the above mentioned information as well as an accurate catchment assessment, and first and foremost obtaining morphometric data of the water reservoir allows us to prepare a comprehensive reclamation project design, including the main method along with the validation of its application as well as a plan of carrying out all necessary supportive and complementary methods.

6.1. Selecting restoration methods

When deciding upon the reclamation method we should have in mind the following aspects: a degree of interference with the ecological system of the given reservoir, time needed to carry out the works, and last but not least the permanence of the expected results which the applied methodology should bring. A comprehensive approach to the process is the key. Applying only one type of treatment can bring only an unstable, temporary effect.

On the global scale there are many methods which are considered water reservoirs reclamation methods, and among them are:

- Aeration of the bottom layers of water
- Biomanipulation
- Removing water from bottom layers
- Bottom sediment dredging
- Dosing chemicals to water.

The actions, which have been taken up by various subjects and institutions aiming to restore a good state of water reservoirs boiled down merely to the weakening of a single element from the group of unfavorable phenomena existing in water ecosystems, and not to restoring ecological balance in the entire ecosystem as well the permanence of this state, which should be the main goal of restoration works.

6.1.1. Dosing chemical substances

In the aspect of dosing chemical substances blocking phosphorus in a water reservoir the most important thing is the place to which they are dosed – **most of all it is sediment**, and additionally as a supportive measures it can be dosing chemicals to water. It is important to know that **the natural repository of nutrients in each water reservoir are the bottom sediments, and not water. They have the ability to store nutrients, including phosphorus which gets into the reservoir from the catchment, but also the phosphorus already existing in the water.**

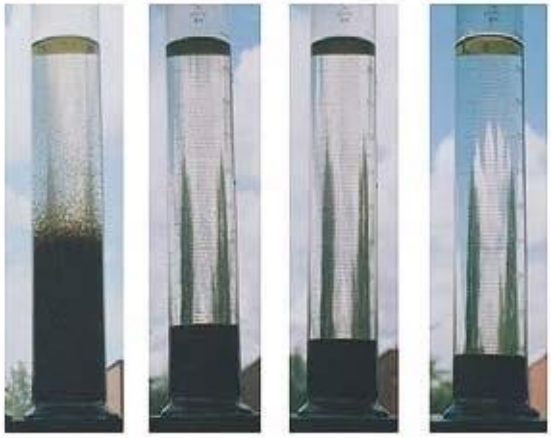
6.1.1.1. PROTE-fos the innovative method of phosphorus inactivation directly in bottom sediments

The leading reclamation method proposed by ur company is the innovative on a global scale PROTE-fos method consisting in blocking (inactivation) of phosphorus directly in bottom sediments with the use of appropriate chemical substances (coagulants), consequently leading to a reduction of phosphorus amount in water which is available for blue-green algae and phytoplankton algae that might generate blooming.

The PROTE-fos method is a modified Riplox [Ripl, 1976] method. The similarity between the two methods consists in the fact that in both cases it is both air and a coagulant that is dosed to bottom sediments of a water reservoir. The innovation in case of our method consists in triggering an intense but controlled resuspension of sediments and applying a coagulant directly to bottom sediments. The author of this method is Professor Ryszard Wiśniewski.

In the PROTE-fos method which we propose a very significant thing is the dosing place as well as the triggering of artificial but controlled resuspension of bottom sediments. Such actions allow the chemical substance to penetrate the outer layer of sediments – the most active layer in the process of internal loading, thus a layer that takes part in nutrient cycle, including phosphorus, between sediment and water.

Dosing chemicals directly to bottom sediments, apart from binding phosphorus which is already present in sediments, allows for an improvement of their condition. It means that sediments can regain or improve its ability to store phosphorus, thus leading to a decrease of its concentration in water and to controlling the concentration of this element in a longer period of time. Our method influences the dynamics of phosphorus cycle in a water reservoir. It reduces internal loading, that is releasing phosphorus accumulated in bottom sediments to water. This phosphorus is the reason for a high trophy and algae blooms. The inactivation of phosphorus directly in bottom sediments is possible thanks to using the PROTEUS vessel designed and engineered by our company, the one and only on a global scale such a vessel.



Picture 3. The course of resedimentation of bottom sediments after dosing coagulants directly to resuspended sediments within 5, 10, 30, 60 minutes. After 10 minutes you can practically see clear water and the sediments are on the bottom

6.1.1.2. Dosing chemicals from the surface

Dosing a coagulant to water usually brings a fast and unstable effect. The result is a short, temporary increase of water transparency. Such actions give an impression that the ecological effect has been achieved and a stable clear water state restored. Unfortunately this impression is wrong, as the effect achieved is only temporary. Dosing chemical substances to water we are able only t block a small part of phosphorus, which is present in water at the moment. Additionally blocking phosphorus can be difficult and not permanent as phytoplankton organisms, including blue-green algae can use it very quickly and multiply, often on a scale which is called blooms, before even the chemical substances can block phosphorus.

Dosing coagulant from the surface is accompanied by the situation when the substance creates a layer that insulates bottom sediments and allegedly blocks the migration of this nutrient from sediments to water (Picture 4). Such a layer could be created only if dosing was carried out on the entire lake area at the same time. Water in the water reservoir should not be subject to any movements, such as those resulting from waves. Hence it is quite natural that it makes us think that such a treatment is impossible to be carried out in natural conditions, and that no insulating layer can be formed on the bottom.

Additionally, a coagulant layer formed this way is unstable (Picture 5), because of:

- Activity of organisms living in the bottom sediments
- Some fish species feeding in the sediments
- The movement of water caused by the wind
- The movement of water caused by the inflowing streams
- Possible strong movement of water causing resuspension of sediments, meaning their re-elevation to water.

In the cases described in scientific literature when a coagulant is applied from water surface, the chemical substance forms a thick layer on the water surface instead of getting down to sediments. This layer floats with the wind towards the banks of the lake – such a situation can take place when the surface layer has a higher temperature by 0,5 degrees Celsius than the layers which are situated deeper.

Picture 4 – homogenous layer of a coagulant after it has dropped onto the surface of sediments – laboratory conditions (aquarium 10x10x20 cm), impossible to achieve in a natural water reservoir.

In case of deep lakes, if during an application of a coagulant there exists a thermocline, it is very probable that the coagulant which has a minimal negative floatability will stay in the so called displacement layer, changing the existing chemical conditions in this layer, and not reaching the bottom as a consequence.

The method of dosing chemicals from the surface is used by us only when there is such a necessity, as a supportive measures to the PROTE-fos method. It is used in order to bind a certain amount of phosphorus which is still present in water.

Picture 5. Fractured layer of coagulant due to the above mentioned factors (in the photo on the right you can see gas bubbles coming out of the sediments and fracturing the homogeneity of the coagulant's layer.

6.1.2. Dredging

The only alternative to the PROTE-fos method is sediment dredging, that is removing the outer layer of sediments. It is a technology that brings equally good results, but it is very expensive, long lasting and it brings two serious problems.

The first problem is storage and disposal of the extracted sediments. The place of storage cannot be located in the within the lake catchment so that the water courses along with nutrients cannot get back to the water reservoir. It would be extremely unfavorable as the amount of nutrients in the reservoir would rapidly increase while there would not be enough sediments which could bind it. Sediment disposal on the other hand is related to the necessity of finding their recipient, transportation, etc. It is also important to know that sediment dredging causes an uncontrolled resuspension, which makes the phosphorus which has been stored in sediments, get into the water.

The second problem is a rapid interference with the roles that sediment plays in a lake. Bottom sediments are an integral part of a lake ecosystem, the same as water or organisms that live in it. Depriving an ecosystem of its integral parts can have serious negative implications.

In view of these problems and the costs which are related to them, the PROTE-fos method is a lot cheaper, incomparably faster and less invasive for the ecosystem. Very often the substances dosed by us complement the natural variety of elements responsible for controlling phosphorus. They facilitate natural processes taking place in the bottom sediments of a water reservoir and, what is most important, they give the effect of binding phosphorus in sediments and reducing its concentration in water. We carry out dredging only when there is such a necessity, as a complementary measures to our PROTE-fos method, only on a limited area, in the situation when it is necessary to remove the sediments from this area so that it gets outside the catchment.

6.1.3. Other complementary methods

Depending on the characteristics of a given lake, apart from the core method, in a lakes reclamation works project design, various complementary methods can be proposed. They are strongly individualized regarding their scope and intensity, depending on: the characteristics of the water reservoir, diagnosed problems as well as a agenda of a project realization (seasons of the year). Among them are:

- Biomanipulation
- Planting macrophytes
- Biofiltration (point 7.3.)
- Seasonal cutting the excessive plants which forms reeds (point 7.3.)
- Dosing chemicals from the surface (point 6.1.1.2.)
- Dredging (point 6.1.2.)

6.2. Choosing the dosage and chemical substances blocking phosphorus

Dosing chemical substances which are to block phosphorus is inseparably connected with the way of calculating the dosage and data which is the basis for these calculations. Designing reclamation works it is necessary to aim to minimize the use of chemicals.

Dose calculation should be carried out based on the data related to the concentration of phosphorus in bottom sediments as well as water. Only calculating coagulant dosage in such a way can be effective in a time scale and the lake scale. Therefore the analyses of the water reservoir are so important, and

especially EPC-0 as well as phosphorus fractions. On the other hand the algorithm of calculating the dosage selecting measuring points, setting zones in the lake, where appropriate substances will be dosed is our know-how and is always individually established for a given water reservoir.

In case of using chemicals it is very important to select them properly. Using aluminum compounds or sulfates is related can be risky for human health.

Aluminum dosed to a lake in the form of aluminum polychloride, in contact with water dissociates into ions. In case when water pH tends in the direction of acids, ions Al^{3+} and $Al(OH)^{2+}$ become more toxic, while in the case of alkaline pH (which is the case during algae blooming) the toxicity of the ion $Al(OH)^{2+}$ increases.

Below we present bibliographic information from three scientific works regarding a decrease of effectiveness of phosphorus binding with the use of aluminum over a period of time as well as aluminum ions effects, including Alzheimer's disease:

1. Berkowitz, Jacob, Michael A. Anderson, Christopher Amrhein. 2006. Influence of aging on phosphorus sorption to alum floc in lake water. Water research, 40: 911-916.
2. Flaten, Trond Peder. 2001. Aluminum as a risk factor in Alzheimer's disease, with emphasis on drinking water. Brain research bulletin, vol. 55, No. 2, pp. 187-196.
3. Edited by Chrostopher Exley, Aluminum and Alzheimer's disease The science that describes the link, Birchall Center for Organic Chemistry and Materials Science, School of Chemistry and Physics, Keel University, ELSEVIER 2001.

Using sulfates on the other hand, carries the risk that in conditions of decreased concentration of oxygen in bottom sediments or in case of the lack of oxygen will lead to the production of hydrogen sulfide, a very toxic gas, well soluble in water. The presence of this toxic gas in sediments can lead to the formation of the so called bottom "dead zones", where practically no living organisms can live, except for some anaerobic bacteria. Another unfavorable consequence of providing "sulfur" to the lake ecosystem will be a reaction of hydrogen sulfide with the reduced to Fe(II) in anaerobic conditions ferric ion Fe(III), and as a consequence of this reaction the formation of iron sulfide – black sediment insoluble in water. This reaction causes binding ferric ions in non-active forms, which earlier

6.3. Obtaining necessary approvals

Depending on the type of proposed works in a reclamation project design it is necessary to obtain permissions, for example:

- Water permit

- Fishery plans
- Decision approving the waste management program.

In the aspect of dosing chemical substances blocking phosphorus into a water reservoir it is necessary to obtain a water permit, in which the type and maximum dosage of a chemical is mentioned based on laboratory analyses of water and sediments.

7. Reclamation works

As the only company in Poland and in the world we propose a comprehensive approach to lake reclamation. Applying appropriate methods and their proportion is strictly correlated with the conclusions from water analyses. Together with Professor Ryszard Wisniewski, who has a scientific supervision over the whole process, we worked out a cooperation schematic in order to achieve ecological effect. Regardless of the above mentioned actions before a reclamation project is started it is necessary to assess and regulate the catchment. Only such a comprehensive approach allows us to achieve the expected ecological effect.

7.1. PROTEUS – the innovative two-module vessel dedicated for restoration works with the use of PROTE-fos

In order to be able to apply our PROTE-fos method in practice we have designed and engineered a vessel used to dose chemical substances into bottom sediments. This innovative vessel called PROTEUS (Picture 8-10) consists of two modules. PROTEUS is the only available – on a global scale – patented equipment, which allows for a precise dosing of substances directly to bottom sediments during a controlled resuspension of these sediments.

The surface module is responsible for:

- Moving the whole vessel thanks to two engines installed on each of the two floaters of the surface module (catamaran). Each of the two engines can be operated individually and realize movement forward or reverse.

Picture 6. The vessel with an underwater module visible in the dock of the surface module. Due to poor water transparency during reclamation works it is impossible to present photos of the underwater module during application

- Transportation of chemical substances used in the reclamation process. The surface module can carry up to 3 tons of load, both in powder or liquid.
- Precise and controlled dosing of chemical substances. The vessel is equipped with a group of specialized pumps, with a full control of the media flow, and consequently the dosing tempo.

- Pumping air to bottom sediments. There is a compressor that is quiet enough so that it does not emit noise that would be an environmental nuisance, but has a capacity high enough to be able to pump air to an appropriate depth, oxygenating the bottom sediments and triggering their resuspension.
- Precise navigation over the reservoir and a control of its bottom. Navigation is possible thanks to two GPS systems installed on the vessel, which are coupled together. One of them cooperates with the ground reference station and thanks to that it has an accuracy of the vessel position of 1-2 cm. The other one informs about the vessel real time location, drift, and real direction it is heading. The bottom control is realized thanks to an exact, digital map of the bottom for each project and a sonar view. They enable for a precise and safe work in the sediments, avoiding collisions with sunk objects.
- Moving and steering the underwater module. In the surface module there is a place called the dock. The underwater module can be pulled out from water and placed there thanks to four winches. The winches are programmed and controlled by a computer, which allows them to work in three modes (automatic, half-automatic and manual).

Underwater module (picture 10) is responsible for:

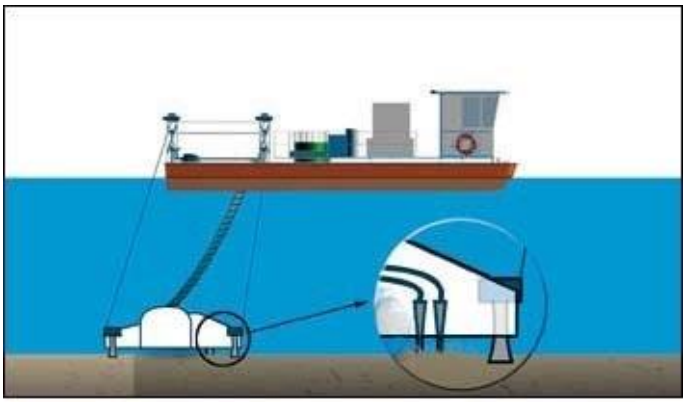
- Providing information about its location towards the sediments by means of using a system of optical multi-sensors. This information allows for an appropriate steering of the winch system and the navigation of the whole vessel.
- Triggering a controlled resuspension of sediments in its close space. The underwater module is in form of a flattened bell with vertical fins stabilizing the navigation track. Inside the space formed by this module resuspension is triggered so that the contact area between the sediments and chemical substances is increased.
- Oxygenating bottom sediments. A controlled resuspension is triggered thanks to air pumped into bottom sediments.
- Dosing appropriate chemical substances used for binding phosphorus into bottom sediments.
- Coagulation and resedimentation of sediments caused by chemical substances.

7.2. PROTE-fos – Inactivation of phosphorus directly in bottom sediments

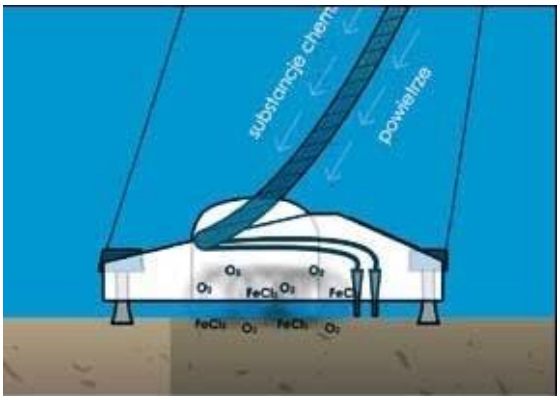
The inactivation of phosphorus is carried out with the use of the two-module vessel which applies chemical substances (coagulants) to a specified layer of sediments during their controlled resuspension and aeration (Pictures 6-7). The underwater module of the vessel is dropped over the sediments and during its work it moves over them. A set of sensors allows for the control of the vessels navigation and delving of the nozzles in the sediments, reacting to bottom depth changes, which allows for keeping the underwater module directly over the outer layer of sediments. In the closed space of the underwater module a resuspension of sediments is triggered. At the moment of triggering resuspension by means of aerating the sediments with a set of nozzles dosing of a chemical blocking phosphorus takes place. After the underwater module goes over the given area of the bottom, the mixture of bottom sediments and the coagulant sediments very quickly as the particles merge into larger flocs, not causing an uncontrolled resuspension of sediments in the water reservoir.

The application of chemical substances allows for creating a relatively hick protective layer of sediments, which insulates the deeper layers of sediments from the water. In this protective layer phosphorus is blocked, and creating appropriate oxygen conditions guarantees the permanence of the newly created structures and allows the sediments to further absorb and bind this element, including phosphorus from the water. Thus the phosphorus blocked in the sediments no longer causes trophy

of water in the water reservoir. This state creates conditions for introducing complementary methods, whose aim is to guarantee the achieved effect over time.



Picture 7. Visualization of the modules of the vessel – the surface module and the underwater module.



Picture 8. Visualization of the underwater module with sediment sensors and nozzles pumping air into bottom sediments.

7.3. Other complementary methods

When phosphorus is permanently blocked in bottom sediments thanks to PROTE-fos method it is possible to apply complementary methods in order to maintain or facilitate the achieved ecological effect.

1. Biomanipulation
2. Planting macrophytes
3. Biofiltration
4. Installing barley straw
5. Seasonal cutting excessive plants forming reeds.

- Biomanipulation. It consists in influencing trophic relations in a reservoir, most often by means of interfering with the fish species composition. This method requires a precise assessment of physical and chemical parameters of water, sediments of the reservoir as well as its biological diversity. Consequently it is necessary to limit the number of benthic and zoo-plankton eaters in order to restore the appropriate amount of zooplankton so that the zooplankton can effectively control phytoplankton feeding on it and consequently not allowing algae multiplication – algae blooms.
- Planting macrophytes. In selected parts of a reservoir we plant macroalgae as well as submerged and floating plants, effectively absorbing nutrients, for example typha. Consequently nutrients are absorbed from the water with an increased intensity, bottom sediments are consolidated, living space for other organisms is created – increased biodiversity. The richer the ecosystem in multiple species of plants and animals, the more stable and resistant to anthropogenic pressure it is.
- Biofiltration. In selected parts of the reservoir artificial bases with mussels are installed in order to multiply their population. Consequently suspended solids are more intensely filtrated from water and water transparency is increased, which is so important from the reservoir users point of view.
- Installing barley straw. In selected areas of a water reservoir, often on inflows or in the areas used for recreation barley straw bales are installed. Their decomposition causes the release of substances called algistats, which limit the development of phytoplankton algae and blue-green algae.
- Seasonal cutting the excessive plants forming reeds. This way every year a significant amount of nutrients that are in plant tissues can be driven out of the reservoir. Otherwise the plants when they die sink to the bottom and are decomposed, providing more nutrients to the ecosystem.

- Dredging – discussed in point 6.1.2.
- Dosing chemical substances from the surface – discussed in point 6.1.1.2.

8. Monitoring the effects

In cooperation with an institution who is in charge of a water reservoir we carry out monitoring, with the scope and time individually agreed for each project. Monitoring analyses should embrace sensitive points of the reservoir, qualified as such during the earlier analyses or commonly known as sensitive (for example inflows, outflows, deeper points, open bays, places used for recreation, industry in close vicinity, farming, etc.). The scope of analyses should embrace most indicators and parameters analyzed before reclamation project was started so that we are able to compare the data over a period of time. The frequency of such analyses should not be less frequent thank 4 times a year (during each of the four seasons of the year). During carrying out reclamation works as well as after these works are finished we prepare reports illustrating the course of the project tasks as well as the achieved effects. The scope and frequency of such reports is individually adjusted to a Client's needs. Monitoring is to confirm two things. First, to confirm whether the effects of works which have been initialized are permanent and whether they are going according to the plan. Second, they are to find out whether there is no interference of third parties or re-loading of the reservoir with undesirable substances.

9. The effects achieved with the use of PROTE-fos method

The effects of using PROTE-fos method of inactivation of phosphorus directly in bottom sediments:

- **Binding phosphates in bottom sediments (eliminating the so called internal loading)**
- **Reduction of phosphorus concentration in water**
- **No algae blooms**
- **Improved water transparency – mainly through limiting the amount of phytoplankton, including blue-green algae as well as through reduced amount of mineral and organic suspended solids in water**
- **Planting macroalgae and water plants in the bottom – this is possible only after water transparency is increased. The plants provide protection to sediments, which are not so often elevated by water motion. Biodiversity is increased and oxygen production enhanced in the process of photosynthesis.**
- **Improved oxygen balance in the reservoir – thanks to aerating sediments, but mainly thanks to macroalgae and water plants.**

10. Summary

The PROTE-fos method proposed by us, enables us to improve the quality of water relatively fast and cheaply. Chemical substances that we use interfere with the ecological system in a minimal way. They are safe for the ecosystem and consist of compounds naturally occurring in lakes or of natural origin.

In order to achieve a permanent ecological effect it is necessary to constantly control the reservoir itself as well as its catchment.

The first comprehensive need from the market for lake reclamation was expressed by the City of Gniezno. It is important to know that our method was awarded by the European Committee as one of five best environmental technologies in Europe co-financed from the Life+ program.

The information presented in this brochure is related to technology, our 20 years of experience which we gained carrying out projects as well as 30 years of experience and scientific expertise of Professor

Ryszard Wisniewski allow us to take up effective reclamation works on a given reservoir. The confirmation of the above mentioned is reclamation of Lake Winiary and Lake Jelonek in Gniezno, Poland. We give guarantee for the works that we carry out.

In case of any questions or doubts we offer our help. The problems which you might face often require direct consultation and therefore on your request we are ready to organize a meeting in a time convenient for you in order to discuss the legitimacy of cooperation.

In order to be able to prepare for the meeting with you we would like to kindly ask you to provide the information included in the attached questionnaire.

11. Questionnaire

PROTE-fos – BASIC DATA

Please fill in the following questionnaire. The answers you provide will help us to prepare to the meeting with you.

I. Lake – general information

1. Name……
2. Town……
3. Dominating type of lake banks:
   high banks ☐ low bank (easy access) ☐
4. Owner of the lake……
5. Lake's administrator (leaseholder, administrator, other)……
   ……
6. Area……[ha]
7. Average depth……[m]
8. Maximum depth……[m]

II. Do watercourses flow into the lake? ☐ **yes** ☐ **no**

III. Is the lake used for tourist/recreational purposes? ☐ **yes** ☐ **no**

IV. Does the problem of algal blooms occur? ☐ **yes** ☐ **no**

If yes, in which months?……

V. Have any reclamation works been carried out on the lake?

☐ yes ☐ no

VI. Do you have any investigation results for the lake (e.g. water or sediments analyses, fish species composition, composition of phytoplankton etc.)

☐ yes ☐ no

If yes, please attach such results.

VII. Contact information

Name and surname……

Post……

Name of the department that you represent……

……

Address……

……

Telephone……fax……

E-mail……

Thank you for filling in this questionnaire.
Please return the questionnaire by e-mail, fax or post at the following address:
PROTE Technologie dla Środowiska Sp. z o.o.
Ul. Dziadoszańska 10, 61-248 Poznań
Tel. +48 61 65 45 578, fax +48 61 65 45 579
E-mail: prote@prote.pl www.prote.pl