DOI: 10.1515/jwld-2015-0017

JOURNAL OF WATER AND LAND DEVELOPMENT
2015, No. 26 (VII–IX): 65–71
PL ISSN 1429–7426
Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 20.07.2015
Reviewed 20.08.2015
Accepted 05.09.2015

**A** – study design
**B** – data collection
**C** – statistical analysis
**D** – data interpretation
**E** – manuscript preparation
**F** – literature search

# Protection of water quality in the lake situated on the agricultural area

**Waldemar MIODUSZEWSKI** [ABCDEF]

Institute of Technology and Life Sciences, Department of Water Resources, Falenty, al. Hrabska 3, 05-090 Raszyn, Poland; tel. +48 22 735-75-59, e-mail: W.Mioduszewski@itp.edu pl

**For citation:** Mioduszewski W. 2015. Protection of water quality in the lake situated on the agricultural area. Journal of Water and Land Development. No. 26 p. 65–71.

**Abstract**

According to the Nitrate Directive it is necessary to established a protective belt (ecotones) around lakes. Inside these belts, it is forbidden to use fertilize for agricultural purposes. It is believed that it is the most imported measure to protect water quality in the lake. The analysis were conducted to estimate the sources of nitrogen entering the waters of the lake. Some analysis were conducted to estimate the sources of nitrogen entering waters of the lake. It was proved that the biggest load (more than 80%) of contamination is entering the lake with water flowing in streams and ditches. Only 10% of the chemicals are entering the lake with the groundwater filtrating to the lake. It is very important to use a proper methods of agriculture with proper methods of fertilization in the whole area of river basin flowing to the lakes.

**Key words:** *agriculture, contamination, environment, lakes, nitrogen, water quality*

## INTRODUCTION

Transport of nitrogen and phosphorous compounds to surface waters, particularly to the stagnant waters like lakes, reservoirs and ponds, causes negative environmental and economic effects. Increasingly visible eutrophication processes, particularly algae growth, hinder the rational use of natural and artificial water reservoirs [SOSZKA 2009]. Origin of the nutrient compounds can vary, ranging from the natural sources, through discharges from municipal and industrial sewage treatment plants to pollution caused by humans and animals. A particular source of pollution are nitrogen compounds of agricultural origin. Due to their disperse type they are much more difficult to locate in comparison to the point sources. Many different types of measures have been undertaken to limit the pollution inflow to surface waters. Municipal and industrial wastewater treatment plants have been constructed, special rules for use of coastal areas have been introduced, points of collection of wastes from boats and camps have been established etc.

Intensive development of vascular plants has been observed on many lakes what causes overgrowing of small reservoirs. Overgrowing process has been more intensive in recent years what is an effect of nutrients inflow from the adjacent areas, development of tourism and agriculture and input of atmospheric nitrogen [KOC 2010; SOSZKA 2009].

Undertaking measures for limiting of nutrients transport to the lakes from agricultural sources is essential for protection of lakes [KOWALEWSKI, MIODUSZEWSKI 1992].

Agricultural pollution resulting mainly from use of mineral and organic fertilizers is one of the most difficult to limit. The so called Nitrates Directive is dedicated to this problem by obliging the Member States to undertake measures for limiting the spread of pollution from agriculture.

Direct catchments of many lakes are used for agricultural purposes. Moreover, many drainage systems cover not only the arable lands but also lowland swamp areas (drainage ditches). Drainage systems rapid water outflow from agricultural lands what con-

tributes to increase of pollution transport (mainly nitrogen) to lakes.

The analysis of opportunities for use of already existing drainage infrastructure for limiting the inflow of pollution to the selected lake has been presented.

Polish lakes are particularly sensitive to eutrophication. Most of Polish lakes are of the eutrophic type what means that they are rich in organic matter. Inflow of even relatively small load of phosphorous and nitrogen can cause rapid and dangerous development of aquatic organisms. Therefore, it is essential to secure these lakes from inflow of nitrogen and phosphorous compounds [SOSZKA 2009].

Analysis of the possible impact of the planned measures resulting from the Nitrates Directive has been presented. Further needs for measures aiming at water quality protection have been presented as well.

## MATERIAL AND METHODS

**Nitrates Directive**. European Commission has confirmed the importance of the problem of protection of water quality against agricultural pollution by development of so called Nitrates Directive. The Directive is limited to implementation of regulations in scope of mineral and organic fertilizers management. The regulations are mandatory in the areas defined as vulnerable to agricultural pollution. Several areas defined as vulnerable to agricultural pollution have been selected in Poland but their total area is relatively small. The area of vulnerable zones has ranged from 1.5 to 2.5% of the area of the country and covered surface waters where nitrates concentrations were above 50 mg $NO_3 \cdot l^{-1}$. Programs of measures have been developed for these areas.

The Commission has not accepted such approach as it has been believed that areas vulnerable for pollution from agricultural sources are much more vast in Poland. Special attention has been paid to protection of water reservoirs due to the eutrophic character of the Mazury Lakes. One Program of Measures is currently under construction as it has been assumed that the area of whole country will be defined as area vulnerable to agricultural pollution. Therefore, all lakes will be covered by the new program.

As it has been mentioned before, the Nitrates Directive is limited to implementation of proper fertilizers management that will not have any negative impact on water quality. The Directive regulates the techniques of fertilization and conditions for storage of mineral and organic fertilizers.

The basic provisions of the document that is currently under development include:

- the obligation to store manure in sealed containers (slurry) or on concrete slabs (manure);
- a ban on use of fertilizers outside of vegetation period and an annual ban on use of fertilizers on wetlands and frozen soil;
- a ban on use of fertilizers on soils within the zone along the surface waters; following widths of the buffer zone have been established for lakes and water courses:
  - 5 m – in case of fertilization with manure: water courses, channels and ditches when width measures a ground level is greater than 5 m and in case of water reservoirs when the water surface is below 50 ha,
  - 10 m – in case of fertilization with slurry: water courses, channels and ditches when width measures a ground level is greater than 5 m and in case of water reservoirs when the water surface is below 50 ha,
  - 20 m – in case of fertilization with manure or slurry on areas adjacent to lakes when the water surface is above 50 ha.

The values given above result from Polish proposition on implementation of the Nitrates Directive. Apart from implementation of the Nitrates Directive other measures aiming at limiting spread of nitrates in the environment have been undertaken. The measures include the proposal of creation of buffer zone with variable width along the water courses and lakes. Their width would depend on the size of the water course or reservoir. Implementation of the Small Retention Program or so called green agriculture (preservation of natural habitats within arable lands) can also play the significant role in limiting the spread of pollution.

**Presentation of the problem.** Presented analysis of measures for protection of lake water quality has been performed on basis of existing lake. Nonetheless, this is not a formal proposal of initiating the necessary measures for water quality improvement. This publication is a preliminary analysis presenting the scope of measures that can be implemented within the analyzed lake and on other lakes threated by eutrophication. The exemplary lake has been selected due to the fact that no big river flows into the lake what might influence water quality.

The exemplary lake (Jezioro) is an ornithological reserve with high environmental value. The area of the lake is 680 ha and its capacity is 4.35 million $m^3$ with average depth of 0.6m and maximum depth of 3.0 m. Shoreline length is over 10 km. Water of the lake is subjected to strong eutrophication. Significant values of nitrogen and phosphorous concentrations result mainly from inflow of polluted water from the direct catchment. Excrements of nesting birds present in the lake also can have some influence on water quality. Periodically, over 1 000 mute swans nest in the lake. Due to presence of birds (herbivores) it can be assumed that the amount of consumed and excreted nitrogen balances out. Nutrients compounds contained in the consumed plants return to water with excrements.

**Catchment characteristics.** The area of the catchment is 48.4 $km^2$. Well developed hydrographic network (mainly artificial ditches and channels) transports water directly to the lake. Five partial catchments (sub-catchments) can be defined as it has been presented at Figure 1 and described in Table 1.

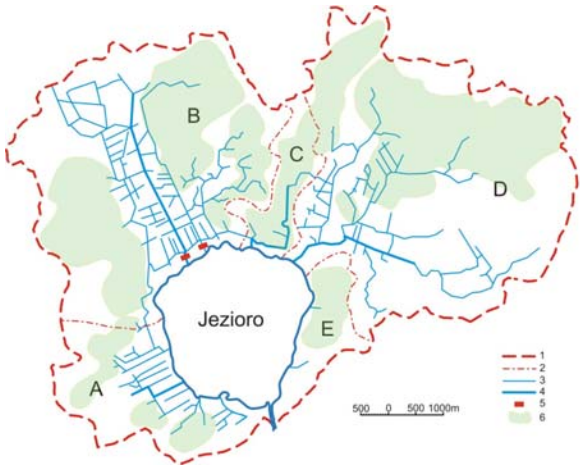


Fig. 1. Hydrographic Network within the catchment of the lake (Jezioro); *1* = border of the catchment; *2* = borders of sub-catchments; *3* = ditches with width below 5.0 m; *4* = channels (ditches) with width over 5.0 m; *5* = pump station; *6* = drainage infrastructure; source: own elaboration

**Table 1.** Characteristics of the sub-catchments

| Symbol of the sub--catchment | Area km$^2$ | Description |
|---|---|---|
| A | 5 500 | Arable lands are located in the upper part of the catchment. The valley drains a significant number of small ditches that transport water directly to the lake. |
| B | 17 375 | Almost all arable lands are drained. A channel that collects water from the smaller ditches has been constructed in the middle of the valley. The drained area is separated from the lake by a dyke and water is transported to the lake with use of pump station. |
| C | 2 063 | Almost whole area has been drained. One channel collects drainage waters from the system and delivers it to the lake. |
| D | 15 313 | Upper part of the catchment has been drained. Ca. 25% of the area is covered by water-logged forests. Valleys are drained by non-systematic network of ditches that outflow directly to the lake. |
| E | 2 125 | Small sub-catchment that has been nearly completely drained. Drainage water is delivered to the lake by two short ditches. Arable lands are located in the vicinity of the lake. |

Source: own study.

The catchment is characterized by significant terrain denivelations. Local hills with elevation exceeding 33 m in comparison to the water table level in the lake are situated next to the areas with small slopes and elevations that do not exceed 1.0 m. Geology of the area results from the last glaciations (northern Poland). The analysis of the existing dill cores allows to distinguish several layers of boulder clay separated by sands or clays. Such stratification reflects phases and sub-phases of the Scandinavian glacier. As a result of the processes connected with glaciations three basic geomorphologic units can be distinguished within the catchment: peat bog plains, ground moraine hills and frontal moraine hills. The biggest peat bog plains are located in sub-catchments B and C and they cover over 50% of its area. They are usually morphological denivelations with flat bottom that are located slightly higher than the water table level in the lake. Most of the denivelations are filled with low moor, reed or sedge peat. Average thickness of the peat is ca. 3 m and the maximum thickness is 7.5 m. Gyttja with the average thickness of 1.8 m (max 6 m) under layers the peat. Mineral bedding is composed mostly of dusty sands [KOWALEWSKI 1997].

**Hydrographic network.** Catchment of the lake is mostly drained. Drainage system consists of ditches located on plains and drainage in the upper parts of the catchment. Water from the catchment is transported to the lake mostly gravitationally. Water from sub-catchment B is pumped to the lake with use of two pump stations with efficiency ranging between 0.2 and 0.6 $m^3 \cdot s^{-1}$.

System of open ditches drains mainly valley areas (peatlands). Arable lands were equipped with ceramic tiles drainage. Drainage waters are transported to the nearest drainage ditch. Most of the drainage system has been constructed during the years 1910–1920. In 1960s' and 1970s' the system has been modernized and expanded.

Spatial management and land use. The catchment is a typical agricultural land. It has been estimated that the biggest part of the catchment is arable land – 55% of the area (most of which is equipped with drainage systems), meadows and pastures located on peatlands drained with ditches are ca. 26% of the area, forests are ca. 18% and wastelands are ca. 1%. Small part (less than 0.5%) of the catchment is covered by urban areas (Fig. 2). Meadows and pastures are mostly extensively used while arable lands are fertilized and crops and industrial plants are cultivated. Agricultural activity is,

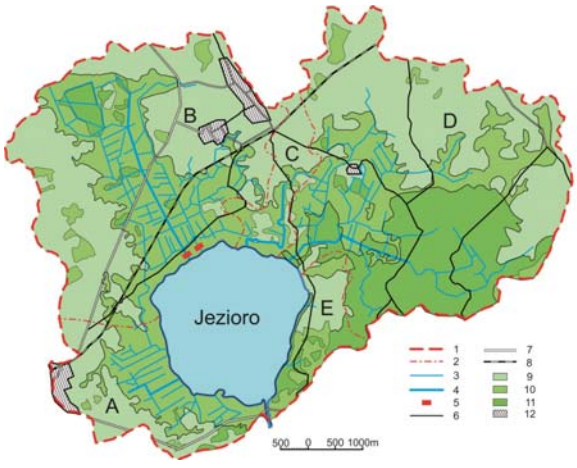


Fig. 2. Land use of the catchment; *1* = border of the catchment; *2* = borders of the sub-catchments; *3* = ditches with width below 5.0 m; *4* = channels (ditches) with width over 5.0 m; *5* = pump station; *6* = country roads; *7* = county roads; *8* = railway; *9* = arable lands; *10* = meadows and pastures; *11* = forests; *12* = urban areas; source: own elaboration

even if the rules of the proper management are followed, the source of nutrient compounds that pollute ground and surface waters [IGRAS, JADCZYSZYN 2008; PIETRZAK 2012]. Drainage network inhibits the nitrogen and phosphorous outflow [PETERSEN *et al*. 1992; RYSZKOWSKI *et al*. 1990].

Following areas can be distinguished around the lake:

- rushes and aquatic flora in the lake; width of this zone is ca. 40–50 m and in some places it expands up to 100 m;
- swamps that are periodically flooded when water table level in the lake is high; the area is covered by reed and bushes and it is connected to the aquatic flora in the lake; width of this zone is 30–80 m;
- trees – this zone is covered mainly by bushes, deciduous trees and extensively used meadows.

Arable lands and meadows are situated in a distance from the shore of the lake. It has been estimated that the shore line of the lake borders mostly with swamps (peatlands, wet meadows extensively used) – 74%, forests – 18% and meadows and pastures – 4%.

**Alimentation of the lake.** Alimentation of the lake significantly influences the plan of work for limiting the diffuse pollution transported to the lake. Assuming that the pollution present in the lake originates only from the catchment following sources of pollution can be distinguished:

- precipitation that directly aliments the lake,
- ground water infiltrating to the lake along the shore line,
- water gravitationally transported to the lake with ditches, rivers or through the pump station.

Capacity of precipitation (rain, snow) that aliments the lake has been estimated at 3.2 million cubic meters per year with average precipitation equal to 600 mm.

Volume of ground water that enters the lake as a result of infiltration has been estimated on a basis of the measurement of the ground water table level decrease and the infiltration coefficient. It has been estimated at 1.4 million cubic meters per year.

The basic alimentation of the lake occurs as a result of water inflow from the drainage ditches and drainage systems. Total volume has been estimated at 8 232 million cubic meters per year. More detailed list of water inflows from the sub-catchments has been given in Table 2.

To sum up, it can be assumed with high probability that the total alimentation of the lake that has been estimated at 13 832 million cubic meters per year origins from the surface runoff (water courses) – 67%, directly from the precipitation – 23% and infiltration – 10%.

Average values of six months and annual water inflows to the lake from each sub-catchment have been given in Table 2 [KOWALEWSKI 1997]. It can be stated that the most significant volumes of water are transported to the lake from sub-catchments D and B. The other sub-catchments are significantly smaller and the amount of inflowing water is also less significant.

Amount of nitrogen inflowing to the lake has been estimated. The results of calculations have been presented in Table 3.

**Table 2.** Average values of outflows from the sub-catchments of the lake

| Sub--catchment | Outflow during summer | Outflow during winter | Annual outflow |
|---|---|---|---|
| | thous. $m^3$ | | |
| A | 362 | 740 | 1 102 |
| B | 1 127 | 2 151 | 3 278 |
| C | 138 | 283 | 421 |
| D | 1 311 | 1 679 | 2 990 |
| E | 145 | 296 | 441 |
| Total | 3 083 | 5 149 | 8 232 |

Source: own study.

**Table 3.** Estimated load of nitrogen transported to the lake

| Source of nitrogen | Nitrogen concentration $mg \cdot l^{-1}$ | Load of nitrogen introduced to the lake | |
|---|---|---|---|
| | | kg | % |
| Precipitation | 2 | 640 | 0,3 |
| Ground water | 8 | 11 200 | 0,6 |
| Surface runoff | 20 | 180 000 | 91,0 |
| Total | – | 191 840 | 100,0 |

Source: own study.

Basing on the available literature [IGRAS, JADCZYSZYN 2008; PIETRZAK 2012] probable concentrations of nitrogen in the water alimenting the lake have been assumed. Relatively low concentrations have been assumed. The purpose of the calculation is not the evaluation of the load of pollution but the percentage share of particular waters. It is clear that mainly surface runoff influences the water quality in the lake. Relatively low concentrations of nitrogen have been assumed for the infiltrating waters. It results from the fact that bushes and trees that grow around the lake create a natural ecotone – zone that consumes the diffuse pollution [FLEISCHER, STIBE l991; NIKOLAIDIS 1993].

## RESULTS AND DISCUSSION

Polish plans of protection of the lake resulting from implementation of the Nitrates Directive include prohibition of fertilization within the 20 m width zone from the shore line. The zone has the area of 50 ha. The description of the catchment and the surroundings of the lake given above shows that the regulation has no impact on the water quality as the areas situated in the direct vicinity of the lake are not used for agricultural purposes. In most cases in Poland agricultural activity do not occur in the direct vicinity of the lakes. The shore line of the lakes are usually wet and covered by bushes and trees. If the area in the direct vicinity of the lake in Poland is used for agricultural purposes they are usually extensive meadows and pastures.

As it results from the analysis, alimentation by ground water that infiltrate from the adjacent area to the lake is relatively small (ca. 10% of total alimentation). Also, the volume of precipitation is low. The main sources of inflowing nitrogen are ditches and channels that drain the catchment. Drainage water is responsible for ca. 90% of the load of pollution introduced to the lake. Therefore, limitation of the nitrogen inflow by creation of the buffer zone along the shore line can be not effective. Nonetheless, proper agricultural management within whole catchment is recommended due to surface runoff of pollutants to the water courses.

Nitrates Directive assumes implementation of the prohibition of use of fertilizers within the buffer zone adjacent to ditches, channels and natural water courses. It should be emphasized that only in sub-catchment B mileage of ditches is over 79 km including 68 km of so-called small ditches (width lower than 5.0 m). It means that prohibition of use of fertilizers in the zone along the water course concerns only 11 km of ditches (13% the total area of all channels and ditches). Therefore, implementation of Nitrates Directive will probably not cause significant changes in scope of improvement of water quality in the lake.

More visible effects might be reached by implementation of three measures:

– annual cut of reed and aquatic flora present in shallow, coastal parts of the lake and transport of the organic mass out of the catchment;
– modernization of the drainage system in the catchment aiming at inhibition of the runoff, use of plants potential towards water purification before its entrance to the lake; in other words, implementation of technical measures including modernization of the drainage system;
– implementation of proper techniques of agricultural use of the catchment including mineral and organic fertilizers management; storage and application of fertilizers based on rules for Nitrates Vulnerable Zones (NVZs).

**Technical measures proposal.** Cutting of plants and implementation of the optimal fertilizers management methods seem to be an obvious solution. However, their effectiveness in the given case study will not be significant especially if the intensification of production and increase of fertilization rates occur in big agricultural farms. Therefore, implementation of additional measures in scope of water management within the catchment of the lake is essential. However, considering that the biggest threats for water quality origins from agricultural activities as a result of spread of pollution these measures should concern the whole catchment of the lake.

The basic accepted rule is inhibition of the fast runoff of water from the drainage system. Inhibition will allow purification of water entering the lake and the collected nitrogen will be used by plants, including cultivation plants. The basic investments should be implemented in all sub-catchments and include:

– inhibition of the outflow from drainage systems by installing of damming devices in collecting wells. Technical solutions can be found in literature [MIODUSZEWSKI 2014]; these types of measures can be used only in parts of catchments that are relatively flat;
– construction of small and shallow reservoirs on the outflow from the drainage systems to the ditches – such reservoirs will serve as biofilters;
– closing of weirs located on ditches draining peat bogs during spring.

Effectiveness of the measures given above in scope of protection of water quality can be found in numerous publications [FOLLETT 1989; MIODUSZEWSKI 2014; SKAGGS *et al*. 1990].

Due to the fact that the catchment is used for many different purposes and there are different types of drainages systems individual solutions for each of sub-catchments (A, B, C, D, E) should be given. Implementation of following measures has been suggested (Fig. 3).

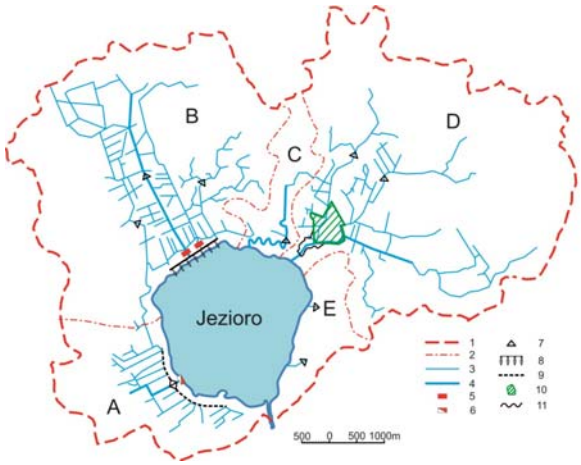


Fig. 3. Suggested technical measures for improvement of quality of water inflowing to the lake; *1* = border of the catchment; *2* = borders of the sub-catchments; *3* = ditches with width below 5.0 m; *4* = channels (ditches) with width over 5.0 m; *5* = pump station; *6* = planned pumping station; *7* = small water reservoirs (biofilters); *8* = distribution of water on the slope; *9* = collecting ditch; *10* = swamp restoration; *11* = water course meandering; source: own elaboration

A. Construction of a collecting channel (ditch) that collects water from ditches out flowing directly to the lake. This measure will prolong the flow time from the catchment to the lake. Moreover, it is recommended to install small pumping station and construction of a small reservoir (biofilter) in front of it.
B. Construction of three flow-through reservoirs on channel and ditches. Moreover, change of the water transport system from the pumping station to the lake is recommended. It is possible to construct special ditches along the dyke from the side of the lake. This ditch will collect water from the pumping stations. The ditch with flat and strength-

en bank will allow water to overflow its bank instead of flowing to the lake at the present discharge point. Moreover, water would also flow through the plants covered area (reed, bushes, grass) and the shallow part of the lake where concentration of nitrogen would decrease.

C. In the by-lake zone (within the ditch) it is recommended to construct a flow-through reservoir (biofilter). It is also possible to change the final part of the outflow into a ditch and shape it as natural meanders of the river.
D. It is recommended to construct two flow-through reservoirs (biofilters) on ditches collecting water from vast drained areas. Moreover, it is advisable to restore the swamp area (Czarne Bagno) by construction of several damming devices.
E. Construction of two small ponds (biofilters) on short ditches collecting water from drainage systems.

Solutions given above show the possibility of improvement of water quality resulting from implementation of technical measures and modernization of the existing drainage system. Confirmation of the effectiveness of these measures can be found in literature [FLEISCHER, STIBE 1991; FOLLETT 1989; MIODUSZEWSKI 2014; NIKOLAIDIS 1993; SKAGGS *et al*. 1990].

## CONCLUSION

Protection of lake water quality becomes more and more significant problem due to the observed eutrophication process. Most of pollution origins from agricultural production and as diffuse pollution they are uneasy to limit with use of the proper production techniques. Assuming that lakes are situated within the NVZs there is no doubt that implementation of the Nitrates Directive is crucial.

Proper water management is an important element of lakes protection. Vast areas of arable lands in the vicinity of lakes have been drained by drainage facilities or open ditches. Many of these devices have been constructed during the years 1910–1920. These systems are essential for conducting agricultural production but they should be modernized to limit inflow of nutrients from the arable lands. Therefore, technical measures are necessary to adjust the existing drainage systems to the degree of intensification of agriculture, state of environment and soil – climate conditions.

Technical solutions for protection of water quality in the lake endangered by eutrophication have been presented. They include:

– inhibition of rapid water runoff from agricultural lands and drainage systems;
– water damming in ditches and construction of small flow-through reservoirs covered by plants (biofilters);
– construction of meandering ditch (water course meandering) to prolong the water flow path;
– limiting water outflow from drainage systems;
– restoration of a swamp area;
– plants management – cutting of plants, transport of nutrient compounds out of the catchment area.

All the recommendations given above aim at inhibition of rapid water outflow and use of nitrogen dissolved in water for plants production out of the limits of the lake.

No measures promoted by the Nitrates Directive have been highlighted here. The Directive will force farmers to construct sealed containers or tanks for manure and it will limit use of fertilizers in the vicinity of water courses. The lake has the area of over 50 ha and the width of the buffer zone is 10 m. All these values have no meaning in the presented case study as wet areas that are not used for agricultural production surround the lake. Agricultural production occurs in distance greater than 20–50 m from the shore line of the lake.

The proposed program of measures for implementation of the Nitrates Directive includes prohibition of use of fertilizers in the 5 m-width zone along the ditches (water courses) with width greater than 5 m measured on a ground level. There are only few ditches of this size in the catchment. Most ditches are 3.5–4.5 m wide and that means that no restrictions in fertilization are present.

The conducted analysis show that restrictions resulting from the Nitrates Directive can contribute to water quality protection in the lake only to a very limited degree. Moreover, there are a lot of lakes like the one described above in Poland. Therefore, protection of lakes, particularly in the Mazurian Lakeland, demand measures exceeding the ones implemented by the Nitrates Directive.

## REFERENCES

FLEISCHER S., STIBE L. 1991. Restoration of wetlands as a mean of reducing nitrogen transport to coastal waters. Ambio. Vol. 20. No 6 p. 271–272.

FOLLETT R.F. 1989. Nitrogen management and ground water protection. Developments in Agricultural and Managed-Forest Ecology. No. 21. USDA-ARS, Northern Plains Area, 301 South Howes, USA. ISBN 978-0-444-87393-4 pp. 396.

IGRAS J., JADCZYSZYN T. 2008. Zawartość azotanów i fosforanów w płytkich wodach gruntowych w Polsce [Contents of nitrogen and phosphorus compounds in the shallow groundwaters in Poland]. Problemy Inżynierii Rolniczej. Nr 2 p. 91–102.

KOC J. (ed.) 2010. Ochrona zasobów i jakości wody w krajobrazie wiejskim [Protection of resources and quality of water in agricultural area]. Współczesne Problemy Kształtowania i Ochrony Środowiska. Monografie. Nr 1. Olsztyn. UWM. ISBN 978-83-92-94626-7 pp. 292.

KOWALEWSKI Z. 1997. Małe zbiorniki wodne elementem oceny jakości wód powierzchniowych. W: Zbiorniki wodne – rola w krajobrazie rolniczym [Small water reservoirs as an element of the improvement of surface water quality. In: Water reservoirs – their role in agricultural landscape]. Materiały Seminaryjne. No. 40. Falenty. Wydaw. IMUZ p. 30–38.

KOWALEWSKI Z., MIODUSZEWSKI W. 1992. Rola systemów melioracyjnych w ograniczeniu wpływu rolnictwa na jakość wody w jeziorze Łukajno. W: Gospodarka wodne w krajobrazie rolniczym jako element zrównoważonego rozwoju [Role of drainage systems in impast of the agricultural activities on water quality in the Łuknajno Lake. In: Water management in the agricultural landscape as an element of sustainable development]. Conference materials. Warszawa. SGGW p. 175–186.

MIODUSZEWSKI W. 2014. Stawy – małe zbiorniki wodne. Planowanie, wykonawstwo, użytkowanie [Ponds – small water reservoirs. Planning, construction and use]. Warszawa. PWRiL. ISBN 978-83-09-01159-0 pp. 150.

NIKOLAIDIS N.P. 1993. Movement of nitrogen through and agricultural riparian zone. 2. Distributed Modeling. Water Science and Technology. Vol. 28. Iss. 3/5 p. 613–623.

PETERSEN R.C., PETERSEN B.M., LACOURSICRE J. 1992. A building-block model for stream restoration. In: River conservation and management. Eds P. Boon, P. Raven. Chichester, UK. John Wiley and Sons, Ltd. p. 293–309.

PIETRZAK S. 2012. Azotany w wodach gruntowych na terenach zajmowanych przez użytki zielone w Polsce [Nitrates in ground water in grasslands in Poland]. Polish Journal of Agronomy. Nr 11 p. 34–40.

RYSZKOWSKI L., BARTOSZEWICZ A., MARCINEK J. 1990. Bariery biogeochemiczne. W: Obieg wody i bariery biogeochemiczne w krajobrazie rolniczym [Biogeochemical barriers. In: Water cycle and biogeochemical barriers in agricultural landscape]. Eds L. Ryszkowski, J. Marcinek, A. Kędziora. Poznań. Wydaw. Nauk. UAM p. 167–181.

SKAGGS R.W., CHESCHEIR G.M., GILLIAM J.W. 1990. Wetland buffer areas for treatment of pumped agricultural drainage water. Proceedings 14th International Congress on Irrigation and Drainage Rio de Janeiro, Brazil. 30 April–04 May 1990. No. 1-A p. 31–47.

SOSZKA H. 2009. Problemy metodyczne związane z oceną stopnia eutrofizacji jezior na potrzeby wyznaczania stref wrażliwych na azotany [Methodical problems associated with the assessment of lake eutrophication for designation of zones vulnerable to nitrates]. Woda-Środowisko-Obszary Wiejskie. T. 9. Z. 1 (25) p. 151–159.

**Waldemar MIODUSZEWSKI**

**Ochrona jakości wody w jeziorze położonym w terenie rolniczym**

STRESZCZENIE

**Słowa kluczowe:** *azotany, jakość wody, jeziora, rolnictwo, środowisko, zanieczyszczenia*

Zgodnie z dyrektywą azotanową wzdłuż cieków i wokół zbiorników wodnych, w tym jezior, powinny być tworzone strefy ochronne ograniczające dopływ azotanów do wód otwartych. W granicach tych stref zakazuje się prowadzenia intensywnych upraw, w tym nawożenia zarówno nawozami organicznymi, jak i mineralnymi. Uważa się, że tego typu działania znacznie ograniczą ładunek azotanów wprowadzanych do wody. Wykonane zostały analizy w celu oceny źródeł zanieczyszczeń doprowadzanych do konkretnego jeziora. Jezioro ma stosunkowo niewielką zlewnię (48 km$^2$), a większość terenu jest użytkowana rolniczo. Istniejące tu mokradła zostały odwodnione gęstą siecią rowów, a duża część mineralnych gruntów ornych jest zdrenowana. Największy dopływ zanieczyszczeń następuje poprzez liczne, niewielkie cieki i rowy odwadniające. Ocenia się, że ponad 80% azotanów dopływa do jeziora tą drogą. Natomiast zasilanie zbiornika wodami filtracyjnymi wzdłuż linii brzegowej zbiornika jest stosunkowo niewielkie. Wynika stąd wniosek, że ochrona jezior to nie tylko ochrona terenów przyległych. Na jakość wody w jeziorze wywiera wpływ cała zlewnia. W pracy zaproponowano różne rozwiązania mające na celu ograniczenie dopływu zanieczyszczeń do jeziora. Są to małe zbiorniki, piętrzenia na rowach, rozprowadzenie wody po powierzchni trawiastej. Powodują one spowolnienie dopływu wody do jeziora.