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BIOCHEMICAL OXYGEN DEMAND IN MALTA LAKE, POZNAN, POLAND

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CENTRAL OSTROBOTHNIA UNIVERSITY OF APPLIED SCIENCES		ABSTRACT
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Lots of research was done by different departments in Poznan region for many years which have been put together in this project. The departments that carried out the tests on Malta Lake were Laboratory tests of water, wastewater and air pollution in Poznan, Department of Environmental Protection Office of City Hall, Water and Soil Testing Laboratory of Voivodeship Sanitary and Epidemiological Station in Poznan.

The aim of this work was to analyse the environmental condition of Malta Lake, Poznan by comparing the biological oxygen demand (BOD), oxygen saturation and total organic carbon (TOC) over a period of time.

The results of laboratory tests done were carried out and collected from different environmental departments in Poznan. The measurement was done at three different points of the lake.

Keywords: Biological oxygen demand (BOD), oxygen saturation, total organic carbon (TOC) and refractory compounds.

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1 INTRODUCTION

Dissolved organic matter occurring in environmental waters is one of the properties of water. Dissolved in the waters of aquatic ecosystems, organic matters form a true solution, or colloidal suspension. The vast proportion of soluble organic matter is seeking up to 80% of the total occurring in the water dissolved organic matter. (Głażewski & Parszuto 2001.)

Both the organic compounds produced by plants and animals, as well as natural compounds and organic compounds produced by synthesis or by synthesis of man i.e. compounds of anthropogenic origin that are in water gradually breaks down. The biochemical processes of decomposition of organic compounds are consumed oxygen dissolved in water. The amount of oxygen needed for complete degradation of organic matter by biochemical is defined as the biochemical oxygen demand (BOD). (Elbanowska, Siepak & Zerbe 1999.)

The content of oxygen dissolved in water and the value of biochemical oxygen demand permit the determination of the quantities present in water dissolved organic matter, while indicating the degree of pollution of the aquatic environment such substances. A more reliable indicator of water pollution dissolved organic matter is an indicator of the amount of total organic carbon (TOC). (Siepak 1992.)

Determination of total organic carbon present in natural waters gives information about the quantities of all organic compounds that are easily degraded, most natural and difficult to decompose, obtained synthetically and most frequently occurring in the form of organic pollutants. Indicators of TOC, BOD and dissolved oxygen indicator can help determine the approximate nature of environmental organic compounds and thus allow you to obtain information or in waters dominated by autochthonous origin of organic compounds, or organic matter is such a difficult form of degradation of organic pollutants. (Dojlido 1987.)

Number of dissolved organic matter in surface water created by a variety of organic compounds such as amino acids, proteins, fats, organic acids, sugars, and hydrocarbons, detergents, and other humic substances, is dependent on the type and number of sources of organic material flowing into the water and weather, especially rainfall and associated surface flow. Some bodies of water such as recreational discharge, the functions may be vulnerable at certain periods in addition to the supply of organic matter in such large quantities that they can be recognized as periodic contamination.

Understanding the nature of environmental pollution in recreational water tank metropolitan agglomerations of organic substances, their quantities and the dynamics of dissolved organic matter became the main objective of this work. In particular, it was intended to make Malta Lake Water quality assessment on the basis of physical-chemical results and analysis of indicators of water oxygen saturation at the three points of control measurements from March to October 2008. The study also focused on determining spatial and temporal variability of occurrence of organic compounds in Malta Lake and the determination of the nature of environmental organic compounds present in water of Malta Lake.

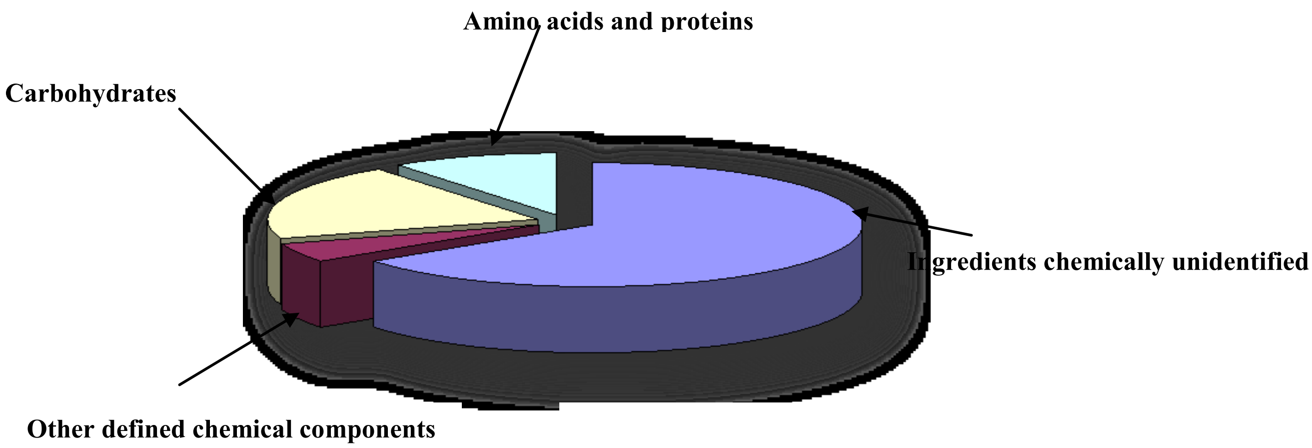
The results of laboratory tests directly extended to the results obtained by the institutions involved in the assessment of water quality in Wielkopolska region of Poland.

2 THE PRESENCE OF DISSOLVED ORGANIC MATTER IN WATER BODIES

In water bodies (surface water or ground water), numerous compounds are present. Different elements such as mercury, lead, calcium, potassium, manganese, iron and nickel inter alia, are present in small or large quantities. The elements present maybe harmful to the life of organisms in the water or harmless. The water body also contain nutrients which are mostly in dissolved form. The nutrients present undergo some transformation as a result of different processes going on in the water body. The subsequent paragraph gives a more concise detail about the dissolved organic compounds in surface water.

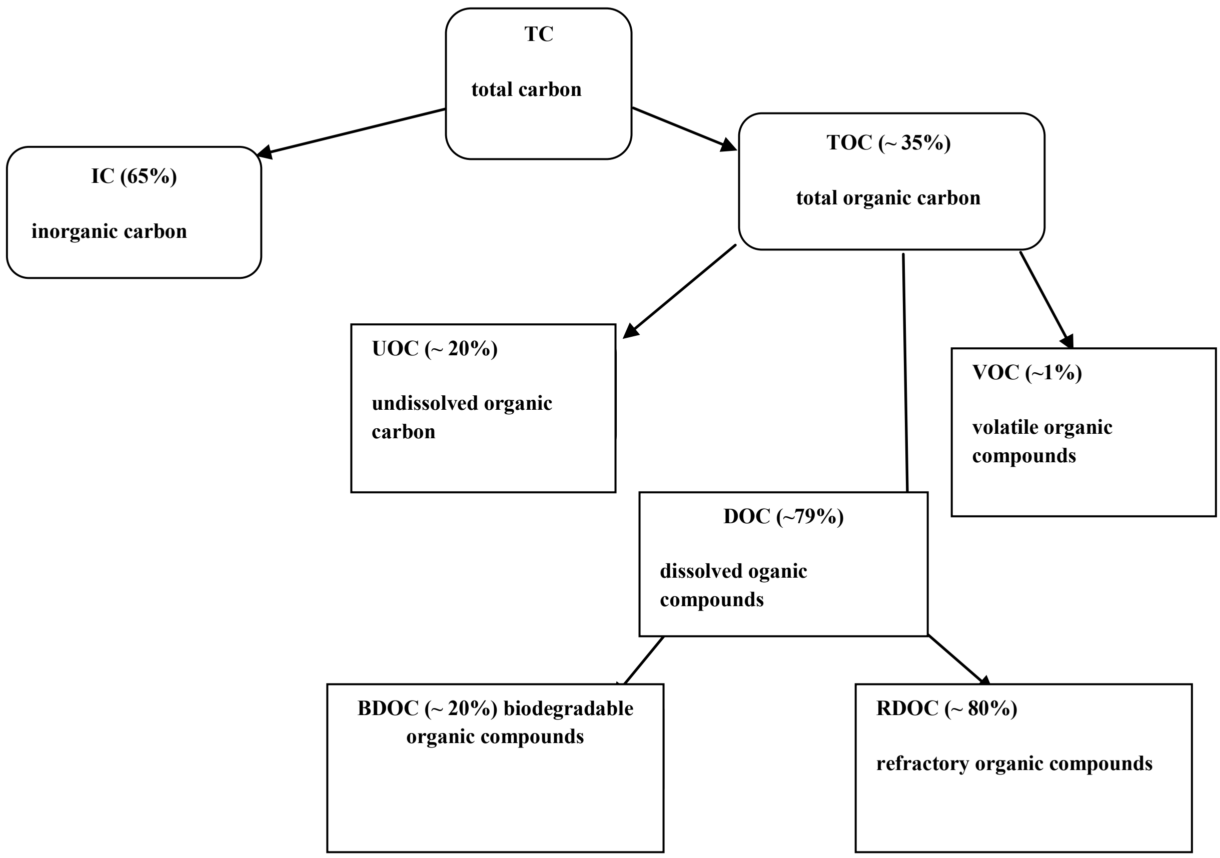
2.1 Chemical composition of dissolved organic matter

Organic substances occurring in water can be divided into the fraction of dissolved and suspended. Dissolved organic matter is the part of organic compounds, which passes through the filter of 0.45mm, while the molecular or suspended organic compounds are retained on the filter. Graph 1 shows the main classes of chemical compounds that make up the organic matter dissolved in natural waters. (Grzybowski 2006.)



GRAPH 1. The main class of compounds that make up the organic matter dissolved in natural waters

The basic element of organic compounds is coal, and the current limnological knowledge does not allow ignoring the importance of coal and its interfaces in aquatic ecosystems. Chemical analysis of the composition and structure of organic compounds is extremely difficult, time consuming and expensive because of the unique capacity of natural organic compounds to create heterogeneous systems. Breakdown due to the size of the particles leads to a general breakdown of organic carbon into different fractions; unresolved organic carbon (UOC) and dissolved organic carbon (DOC), from which the DOC is in the greatest quantities. Volatile organic compounds (VOCs) are small fractions of total organic carbon (TOC). All these fractions are of great ecological significance, a detailed breakdown of the forms of organic compounds has been presented in Graph 2. (Głażewski 2001.)



GRAPH 2. Detailed breakdown of the forms of organic compounds

Quantitative universality of DOC in the TOC due to the natural mechanism of carbon compounds in the transition phase which are biologically resistant to change reduces both energy loss and the transformation of inclement carbon dioxide. As shown in Graph 2, only a small amount of TOC is involved in the transformation of biochemical kinetics. Although it is many times higher than the geochemical cycle transformations. As a result, 80% of organic carbon accumulates in the form of humic compounds present in soil and dissolved in surfaces and at the bottom of lake. (Głażewski & Parszuto 2001.)

There are several millions of different organic compounds. Most of them are of natural origin, produced by plants and animals, and then gradually degraded to inorganic compounds. In modern times there are many new synthesized organic compounds previously not found in nature. Organic compounds are usually divided into three groups; acyclic compounds, carbocyclic compounds and heterocyclic compounds.

Acyclic compounds (aliphatic) have a straight or branched chain consisting of carbon atoms (open chain) and may include unsaturated hydrocarbons (alkanes) with the general formula C_nH_{2n+2} or unsaturated hydrocarbons i.e. alkenes (olefins) with general molecular formula of C_nH_{2n} and alkynes having its own general molecular formula as C_nH_{2n-2}.

Carbocyclic compounds have rings in their molecule composed of carbon atoms (with a closed chain of carbon atoms). It is divided into two groups (recurring and aromatic). Recurring carbocyclic compounds have similar compounds in terms of aliphatic hydrocarbons such as cyclopropane. Aromatic carbocyclic compounds have a cyclic structure containing dislocated π electrons in conjugated double bonds system. The simplest example of these compounds is benzene.

Heterocyclic compounds include rings in the molecule, which in addition to carbon atoms are present atoms of other elements such as sulphur, nitrogen, oxygen. An example of this compound is pyridine.

The surface water has a great variety of organic compounds. Among other things, they are carbohydrates, proteins, amino acids, fats, organic acids, detergents, soaps, aldehydes, ketones, alcohols, hydrocarbons, phenols, humic substances, and many others. Chemicals found in the water can be divided into groups depending on their chemical structure. They are hydrocarbons, halogenated compounds, carboxylic acids and esters and other compounds. Hydrocarbons are aliphatic saturated and unsaturated hydrocarbons, alicyclic hydrocarbons, aromatic hydrocarbons, polycyclic aromatic hydrocarbons (PAHs). Halogenated compounds are halogenated aliphatic compounds, aromatic halogen compounds, halogen ethers and other halogenated compounds. Carboxylic acids and esters include acid and esters of carboxylic acids. Other oxygen compounds found in surface water are ketones, aldehydes, ethers, alcohol and other compounds. (Dojlido 1995.)

2.2 Composition of dissolved organic matter in surface waters

Water as a very good solvent contains almost all the substances naturally occurring in the crust and the substances produced by man. These substances are present in concentrations depending on their universality, and the solubility of many different physical and chemical processes. The concentrations of organic substances occurring in surface waters on average range from several hundred ng/m^3 to mg/m^3.

In the inland part of the largest organic matter present in the dissolved, the concentration of dissolved organic matter increases with the increase trophic level. Dissolved organic substances serve as a source of energy and coal in particular for bacteria. To the seventies of last century believed that the dissolved organic matter does not undergo biological fractionation and oxidation. As a result of such thinking is a component of natural waters was considered unimportant to the aquatic environment. Widely adopted scheme of the food chain consisted of autotroph and organisms feeding on them by successive trophic levels and did not anticipate the dissolved organic matter. Clarify these inconsistencies occurred in the late seventies of the twentieth century, through the development of microscopic techniques. Identified the importance of dissolved organic matter to aquatic ecosystems, and concluded that it is an essential nutrient of bacteria, an essential component of the food chain in the aquatic environment. Bacteria cannot be reduced only to the transfer of dissolved organic matter to higher trophic levels of the pyramid, but also include the removal of aquatic ecosystem as a result of respiration.

Organic matter content is one of the major factors in determining water quality and varies in different types of water. The concentrations of organic carbon in different types of water are given in Table 1. The content of organic substances in water may also vary in different climatic zones, which is shown in Table 2. (Zabiegała 2002.)

TABLE 1. The concentrations of organic carbon in different types of water

Type of water	**total organic carbon [mg/dm^3]**	**Dissolved organic carbon [mg/dm^3]**	**Suspended organic carbon [mg/dm^3]**
Groundwater	0.7	0.7	-
Sea water	1.1	1.0	0.1
Drinking water	2.0	-	-
Surface water (lakes)	7.7	7.0	0.7
Surface water (river)	8.0	5.0	3.0
Unrefined waste water from households	200	80	120

TABLE 2. Dependence of the dissolved organic carbon in the waters of river on the type of climatic zone

Type of climatic zone	Dissolved organic carbon (DOC) (mg C/dm^3)
Arctic and Alpine	2
Taiga	10
Low temperature	3
High temperature	7
Dry	3
Tropical	6
Swamps and wet areas	25

The overall content of organic compounds in water, and indirectly on the state of purity of water affects the ratio between production and distribution, P/R. In principle, P means primary production, but also P can be input to include organic pollutants from outside. R means the team processes that reduce the organic matter content, and therefore the distribution of biochemical, sedimentation, and others. If P is greater than R, this will lead to accumulation of organic matter which can lead to significant organic pollution. On the other hand, if P is less than R, this will lead to excessive oxygen consumption, aerobic conditions may occur such as ions such as NO_3^- and SO_4^{2-} which will be reduced to N_2, NH^{4+}, HS^- and CH_4. The balance between P and R is necessary if we are to maintain pure water. (Dojlido 1987.)

2.3 Sources of dissolved organic matter in surface waters

Natural waters usually contain organic substances in addition to inorganic constituents. They are part of the living plant and animal organisms in the water or are the products of life activity and decomposition of dead organisms. Organic substances in natural waters are caused by chemosynthesis and photosynthesis.

Bacteria are capable of producing chemical synthesis of simple organic substances from inorganic compounds used for this purpose which produces energy during chemical transformation. In contrast, organisms capable of photosynthesis form organic substances used for this purpose from solar energy, but this process occurs through a special pigment (chlorophyll). Absorbed carbonic acid H_2CO_3, nutritive salts and biogenic elements (Nitrogen, Phosphorus, Potassium and Sulphur) are used to build cells. Basic primary organic matter produced by organisms producing (producer) is then consumed by other organisms (consumers) and processed into more complex forms of organic matter.

Organic substances present in natural waters may be of natural origin (plant and animal) or artificial origin. The natural and synthetic organic compounds in water depend on the origin of the water and the degree of contamination. Surface waters may contain significant quantities of organic compounds present in dissolved, colloidal and suspended. (Gomółka 1997.)

Organic substances in natural waters are created in the process of photosynthesis and chemosynthesis during life activity of aquatic organisms, but also from the decomposition of dead plant and animal organisms. Substances are thus genetically linked to the natural processes occurring within a given water body and are known as indigenous. They are the opposite of substances that are allochthonous (alluvial) i.e. originate from the outside. Autochthonous source of organic substances in the waters of phytoplankton, macromolecules and substances excreted by aquatic organisms, bio-degrade rapidly. (Szpakowska 1999.)

This is as a result of biochemical degradation of water to enter protein, amino acids, sugars, fatty acids and others. The composition of organic compounds in water depends on a considerable extent on the processes occurring in plants and animals. Part of the organic compounds occurring in the form of suspensions fell on the bottom of water reservoirs, creating bottom sediments. Particularly large accumulation of these compounds is found in bottom sediments of lakes and dam reservoirs. (Dojlido 1987.)

The main sources of organic matter are allochthonous industrial and urban waste water; they contain many natural and synthetic organic compounds. The most common synthetic substances include: aliphatic and aromatic hydrocarbons (benzene, phenols, polyclic Aromatic Hydrocarbon (PAH), aliphatic halogen compounds, acyclic, and aromatic hydrocarbons, organo-chlorine pesticides, polychlorinated biphenyls (PCBs) and phthalates. Also, drains in the fields contain pesticides. Roads in urban areas provide a variety of substances such as aliphatic and aromatic hydrocarbons, PAHs, fatty acids, etc. The sources of organic matter are also draining from mine waste and rubbish dumps (in the tanks located in areas with a large share of arable concentrations of dissolved organic matter content, the surface waters are much higher than in the tanks that are not located near cultivated fields which can leach dissolved organic matter content. (Karlik 1997.)

Another external source of organic substances in water is rainfall containing many organic substances such as PAHs, PCBs, hydrocarbons etc. It should be also added that the addition of coagulants in water treatment and waste water is also the introduction of pollutants into the water. Coagulant side may contain substances such as polyelectrolytes or acrylamide monomers. (Dojlido 1987.)

2.4 Transformation of organic compounds in surface waters

Natural water lakes, located far from human settlements and related revenues are characterized by the presence in them appropriate for the conditions of plant and animal organisms. These organisms form the teams remaining in the water balance of a biological characteristic of the climate zone and ecological conditions. Such a system outside of the seasonal change is relatively constant. The introduction of sewage into the water causes a change in living conditions, environment and thus change the composition of biological substances. (Collective Work 1969.)

Natural organic substances occurring in nature are usually easy to spread i.e. introduced into the aquatic environment decompose quickly biochemically (the process of biodegradation). Except for humic substances that are hardly biodegradable. While the organic substances produced by man in many cases are difficult to decompose. Discharged into the aquatic environment are present in it for a very long, sometimes many years. Examples of such compounds are detergents and organo-chlorine pesticides.

Organic compounds from the viewpoint of biodegradability are divided into; decompose easily (like sanitary waste-household), decompose after some time of adaptation and decompose difficultly (refractory).

In water, there are two basic processes causing transformation of organic compounds; production (assimilation) and distribution (dissimilation). Production involves the synthesis of organic compounds. It requires external energy into the system. During the decomposition of organic compounds is the separation of energy. Production and distribution are the biochemical processes involving the participation of living organisms.

These organisms can be divided into two group i.e. autotrophic organisms (producers) and heterotrophic organisms. (Dojlido 1995.)

2.5 Effect of organic compounds on surface water quality

Excess of organic pollutants in water introduces distortions to the normal metabolic processes, since the reserves of free oxygen in the water are quickly exhausted, the aerobic bacteria die. In this place appear anaerobes producing a septic process while there is higher disappearance of fauna and flora. The final result of the surface water becomes dead and stinking. In some cases, this process may be irreversible.

The organic compounds in high concentrations are undesirable. It affects the functional properties of water, its taste and smell. Large concentrations of organic compounds are also harmful to living organisms particularly dangerous compounds are difficult to decompose long-term in the aquatic environment and are subject to a strong accumulation of compounds in living organisms.

3 INDICATORS OF ORGANIC SUBSTANCES ON SURFACE WATER

In the determination of the presence of organic compounds in water, it is important to determine the overall pollution by organic substances and individual organic compounds.

Indicators of the overall pollution permit an assessment of the overall content of organic compounds in water. In this case, there is application of the following parameters: loss on ignition, dry residue, water biochemical oxygen demand (BOD), chemical oxygen demand of water (COD), organic carbon, the overall oxygen demand, absorbance in ultraviolet, carbon-chloroformic extract, coal-liquor extract. In assessing the presence of dissolved organic matter in the big urban water tank, used indicators are, biochemical oxygen demand of water, oxygen saturation of water and total organic carbon.

In the assessment of water quality, it is important to determine the content of organic matter. In addition to the specific methods used to determine the specific compounds of great practical importance, there are other methods for determining the total content of organic compounds. These methods are generally only indicative in nature. They can be divided into three groups i.e. Physical methods, biochemical methods which reduce the determination of biochemical oxygen demand and the physico-chemical methods (for the determination of the total organic carbon). (Siepak 1992.)

3.1 Biochemical oxygen demand of water (BOD)

Biochemical Oxygen Demand is one of the main indicators for assessing the organic matter content that readily decompose under aerobic conditions under the influence of enzymes secreted by microorganisms mainly by bacteria. This means they are a symbol of BOD_5. The figure at the bottom indicates the time in days, within which was in the process of biodegradation. BOD is a term contract, specifying the amount (expressed in milligrams) of oxygen required for biochemical oxidation of organic compounds to be easily oxidisable in $1dm^3$ of water under aerobic conditions and at temperature of 20^oC.

The reaction may be represented in the general form;

$$E + S \leftrightarrow ES \leftrightarrow E + P$$

Where E is enzyme, S is substrate (organic compound), ES is the relationship of the enzyme substrate transition and P is the product of oxidation. (Hermanowicz 1984.)

Biochemical decomposition of organic substrate is usually in two stages; firstly, there is oxidation of organic compounds to CO_2 and H_2O. In the second step called nitrification, bacterial ammonia is oxidized to nitrite and nitrate. Nitrification process does not occur in all waters, however, mainly due to the lack of a specific bacterial flora and fauna. The overall distribution of biochemical substances in natural waters is over 20 nights. Initially, the run is fast and then later, it is gradually slowed down. During the first 3 nights is usually mid-oxidation of organic compounds that are susceptible to biochemical decomposition. Deemed sufficient for characterization of biochemical oxygen demand in water was adopted for 5 days (BOD_5). (Elbanowska & Siepak 1999.)

In surface waters, depending on the contamination of organic compounds, BOD_5 ratio is between 2 mg O_2/dm^3 which is the first class according to Decree of the Minister of the Environment of 11.02.2004, if it is more than 12 mg O_2/dm^3, it is fifth grade according to the same regulation.

3.2 Dissolved oxygen in water

Dissolved oxygen is an important component of natural waters which comes mainly from the air and the process of photosynthesis of aquatic plants. The surface waters of dissolved oxygen is consumed in the biochemical processes of decomposition of organic compounds, and therefore the degree of saturation of water with oxygen may be less than 100%. The greater the pollution, the reduction (oxygen deficit) may be greater i.e. the degree of saturation is less than 100%. Clean surface water contains oxygen in amount corresponding almost to 100% saturation. In waters with low oxygen saturation childbearing pollution is between 80 to 95%, while the expression of polluted water falls by up to 40%. If oxygen saturation falls below 30%, abnormalities occur in the physiological activities of fish.

Dissolved oxygen in water comes mainly from air. The source of oxygen may also be photosynthesis of aquatic plants. Dissolved oxygen content is one of the most important indicators of water. Oxygen is almost always in the surface waters (the pure oxygen is usually equivalent to 100 percentage saturation). Surface waters contaminated by organic substances and dissolved oxygen are consumed on the biochemical processes of decomposition of the substance and its contents may fall below 100% saturation. Since oxygen is essential for the life of fish and other aquatic organisms, with significant reduction of its content (less than 30 to 40% saturation) abnormalities occur in the biotic community. When there is complete absence of oxygen in water, it becomes putrid. In the case of severe pollution and absence of oxygen, anaerobic bacteria grow causing anaerobic decomposition of compounds. When the contents of the compounds is not large, in the presence of oxygen passes through aerobic process in accordance with the scheme;

$$\text{Organic compounds} + O_2 \longrightarrow CO_2 + H_20$$

In standing surface water (lakes), especially deep, dissolved oxygen content is dependent on the degree of purity of water, but also from the natural stratification. In addition, the oxygen content in water may undergo large diurnal changes, particularly in the event of photosynthesis. During the day with strong sunlight, development of aquatic plant can occur with evolution of photosynthesis and free oxygen. It occurs when the water saturation oxygen saturation level may greatly exceed 100%. Night during which photosynthesis does not occur, there is a sharp drop in oxygen content and the breathing of organism is affected.

For the determination of dissolved oxygen used, Winkler titration method is one of the method used and its modifications depending on the presence of interfering substances, and methods of using the electrochemical sensor membrane. The principle of determination consists of measuring the electrochemical current resulting from oxygen reduction on electrode sensor consisting of a dish, selectively separated electrolyte membrane containing the electrolyte and two metallic electrodes. With a potential difference between electrodes caused by the reaction of cells or an applied voltage which passes through the membrane, oxygen is reduced at the cathode and the anode metal ions pass into solution. Formed in this way, the current is proportional to the speed of movement of oxygen through the membrane and electrolyte layer and to the pressure of molecular oxygen in the sample at a given temperature.

Oxygen meter is used for the determination of the electrochemical method of detection of dissolved oxygen monitoring. Under certain conditions of temperature and pressure, water can dissolve to a specified quantity of milligrams of oxygen per litre of water. This quantity gives the complete saturation of 100%. Oxygen saturation of water is an important indicator of pollution of surface waters. Oxygen saturation of pure water is approximately 100% and in bad waters, pollution decreases up to 40%. (Leith 1962.)

3.3 Total Organic Carbon (TOC)

The overall organic carbon in water comes from the presence of all kinds of organic compounds, ranging from hydrocarbon through carbohydrates and protein, ending with detergents and pesticides. The presence of organic carbon compounds in natural waters is an indicator of treated sanitary condition of surface water and their degree of contamination. The most appropriate approach to health assessment of surface water is the use of indicators of oxygen and total organic carbon. Results of TOC in terms of oxygen in conjunction with BOD and COD allow approximately to determine whether organic substances belong to the group of decomposed chemical compounds or not. If BOD_5/TOC ratio is close to unity, it means that organic compounds polluting the water are easily decomposable. Where BOD_5/TOC ratio is much smaller than unity, in the water are difficult decomposable organic compounds. (Hermanowicz 1984.)

Organic matter content is one of the major factors in determining water quality. The analysis of routine content of organic compounds are characterized by various indirect methods, loss on ignition of dry residue, chemical and biological oxygen demand, the value of absorbance under ultraviolet spectrum. Determination of total organic carbon allows for more accurate determination of water pollution with organic compounds. Organic carbon content is usually burnt organic matter to carbon dioxide. (Hermanowicz, Dojlido, Dożańska, Kozierowski & Zerbe 1999.)

Organic carbon in water and wastewater is an important indicator of environmental pollution.

Measurement of total organic carbon provides complete information about the content of all organic substances i.e. all the pollutants containing organic carbon. The parameter total organic carbon (TOC) was included in the Regulation of the Minister of Environment, Natural Resources and Forestry of 5.11.1991 on the classification of waters and the conditions to be met by waste water into waters or land.

The vast majority of organic carbons present in lake water are in dissolved form. Suspended organic carbon is on average about 10% of dissolved organic carbon. The content of dissolved organic carbon depends on the trophic status of lakes, i.e. its production capacity and the average size of between 1 mg C/dm^3 in oligotrophy (low in nutrients dissolved in water) to 50 mg C/dm^3 dissolved organic matter (DOC) in dystrophic state (characterized by large amounts of nutrients dissolved in water). The highest content of dissolved organic carbon in lakes is characterized by large amounts of humic compounds, acid reactivity, lack of oxygen and poor fauna and flora. (Zabiegała 2002.)

3.4 Indicators limit values of organic pollutants in surface waters

The limit values of indices by Decree of the Minister of Health of 11.02.2004 which should correspond to bathing water are shown in Table 3. The decree discussed the classification of the present status of surface water and groundwater, how to conduct monitoring and how to interpret the results and present status of these waters.

TABLE 3. Values for dissolved oxygen and biochemical oxygen demand of water in accordance with the Decree of the Minister of Health of 2002.10.16

Index	**Desirable value**	**Limit value**
Dissolved oxygen (% saturation)	80 to 120	Greater than 80%
BOD_5	2 mg O_2/l	6 mg O_2/l

TABLE 4. Indicator values in accordance with Regulation of the Minister of Environment of 11.02.2004 on class of surface water quality

Index	**Unit**	**Limit values in grades I to V**				
		I	**II**	**III**	**IV**	**V**
BOD_5	mg O_2/l	2	3	6	12	> 12
Dissolved oxygen	mg O_2/l	7	6	5	4	< 4
TOC	mg C/l	5	10	15	20	> 20

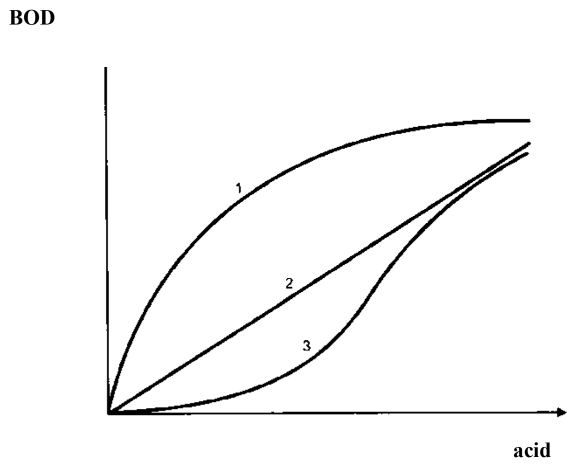
TABLE 5. Selected limits indicators of water quality in surface water quality classes based on the Decree of the Minister of Environment of 11.02.2004, Journal of Law No. 32, item. 284

No.	Indicators of water quality	unit	Breakpoints in grades I to V				
			I	II	III	IV	V
Physical Indicators							
1	Water temperature	20˚C	22	24	26	28	> 28
2	Odour	times	1	3	10	20	> 20
3	Color	mg Pt/l	5	10	20	50	> 50
5	Reaction	pH	0.5 – 8.5	6.0 - 8.5	6.0 - 9.0	5.5 - 9.0	< 5.5
Oxygen Indicators							
6	Dissolved oxygen	mg O_2/l	7	6	5	4	< 4
7	BOD_5	mg O_2/l	2	3	6	12	> 2
8	Total carbon	mg C/l	5	10	15	20	> 20
Nutrient indicator							
9	Ammonia	mg NH_4/l	0.5	1	2	4	> 4
10	Nitrate	mg NO_3/l	5	15	25	50	> 50
11	Nitrite	mg NO_2/l	0.03	0.1	0.5	1.0	> 1.0
Indicators of salinity							
12	Conductivity at 20˚C	µS/cm	500	1000	1500	2000	> 2000

3.5 Determination of the nature of organic compounds

In order to determine the nature of environmental organic compounds (easily or difficultly degradable) present in water, the method of analysis is according to respirometric analysis of BOD/time ratio. Based on the shape and course of the curves, it could be obtained to estimate the environmental characteristics of dissolved organic compounds in water, they are easily or difficultly decomposable. (Municipal Investment in Environmental Protection 1995.)

Graph 3 shows the distribution curves of typical compounds that are readily degradable in water and difficult. When the relationship is similar to curve 1, the analyzed water contains compounds readily decomposable biologically. Curve 2 in Graph 3 informs that the content of organic compounds in water is hardly degradable. Curve 3 shows the course of water content of toxic substances that inhibit the biological degradation process.



GRAPH 3. Distribution curves of typical compounds easily degradable and hard in water

Curve 1 shows BOD curve in a sample containing organic compounds that are readily biologically degradable. Curve 2 shows BOD curve in a sample containing organic compounds biologically difficult to decompose and curve 3 shows BOD curve in a sample containing toxic substances that inhibit the biological process of decomposition. There were two visible stages from the curves, the first was a very slow increase in BOD due to the strong pressure of toxic compounds to micro-organisms not adapted to their presence and a the second was faster growth of the BOD in the presence of microorganisms to toxic compounds. The time needed for adaptation affects the reduction of BOD. (Imhoff, K. 1983.)

Method of evaluating the slope of the BOD may be one way to explain the phenomenon of reduction or increase of BOD_5 determinations. Several factors influence the course of BOD test i.e. the rate of biological decomposition of organic pollutants. These are mainly pH, temperature, dissolved oxygen concentration and the concentration of toxic substances which can inhibit or even stop this process. Determination of susceptibility of organic pollutants biodegradation requires respirometric analysis. This analysis is based on measurement of oxygen consumption daily for at least five days. A graph of the oxygen consumption of time, i.e. BOD curve illustrates the susceptibility of plants to biological decomposition. This allows in assessing whether organic compounds contained in wastewater are easy or difficult to decompose. (Collective Work 1996.)

3.6 Defining the nature of organic compounds in surface waters based on the ratio of BOD/TOC

In determining the nature of environmental organic compounds found in surface water reservoirs, analysis of the relationship between TOC and BOD_5 is necessary. This relationship can be described by the following formula;

$$\frac{BOD_5}{TOC} = \frac{mass\text{ of }O_2}{mass\text{ atom. C}}\left[\frac{BOD_c}{TOD}\right]\left[\frac{BOD_5}{BOD_c}\right]$$

Where TOD is total oxygen demand.

In the literature, two values are given as described by this formula, depending on the adopted value ratio on the right side of this equation. Eckenfelder adopted the following values:

$BOD_5/BOD_c = 0.77$

Then the value of the proportion of the value BOD_5/TOC;

$$\frac{BOD_5}{TOC} = \frac{32}{12} * 0.90 * 0.77 = 1.85$$

The following values are according to Davis; (Municipal Investment in Environmental Protection 1995.)

The ratio of BOD_5/BOD_C is usually given as 0.80. Under this assumption, the calculated value is the proportion of BOD_5/TOC;

$$\frac{BOD_5}{TOC} = \frac{32}{12} * 0.95 * 0.80 = 2.03$$

The values of these proportions in the treated effluent depend on the efficiency of cleaning. As the efficiency of sewage treatment decreased, the content of degradable substances in the way of biological content of the refracting substance remains roughly unchanged. Therefore, the growth efficiency of purification BOD_5/TOC value ratio decreases. The study treated sewage from different wastewater treatment plants to indicate that in well-treated effluent BOD_5/TOC value ratio may be 0.1 to 0.2.

Table 6 compares the values of these proportions in raw industrial wastewater (Municipal Investment in Environmental Protection 1995), and Table 7 in existentially-economic effluent and urban crude and purified according to various literature data. (Municipal Investment in Environmental Protection 1995.)

TABLE 6. Value ratio of BOD_5/TOC

Description of treatment	**BOD_5/TOC**
The pulp and paper plants	0.33
Pulp mill liquors	0.83
Stationery and the slag water transportation	-
Cellulose from plants	1.18
From copper smelter	0.50

TABLE 7. Value of ratio BOD_5/TOC

Description of treatment	**Raw Sewage BOD_5/TOC**	**Waste water purified BOD_5/TOC**
Existentially-economic effluent by Wührmann	1.87	-
Existentially-economic effluent by Mohlmanna and Edwaedsa	1.35 – 2.62	-
Existentially-economic - Birmingham	1.44	-
Urban; Opole Raciborz Wroclaw	1.67 – 2.44 1.72 – 2.72 1.39	1.02 – 0.56 - -
Urban; Vienna Blumenthal	1.70 -	0.90 0.80
Urban; Malboro East	2.0	0.53
Existentially-economic efluent Rye Meads	-	0.32

In the case of typical raw sewage existentially-economic value of the proportion of;

$$\frac{BOD_5}{TOC} = 1.4 - 2.1$$

If the test value of the proportion of wastewater differs from the specified range, the results indicate that non-specific treatment. And so, if;

$$\frac{BOD_5}{TOC} > 2.1$$

Sewage are easily biologically degradable, whereas if;

$$\frac{BOD_5}{TOC} < 1.4$$

It is characterized by a large wastewater containing refractory compounds. (Municipal Investment in Environmental Protection 1995.)

Contaminants that are refractory chemical pollution are not or are only minimally biodegradable through microorganisms. These impurities are poorly removed in conventional sewage treatment processes in sewage treatment. Contaminants that are refractory chemical pollution include the following some surfactants (e.g. alkylbenzenesulphonate, ABS), insecticides, mainly from the group of organo-chlorine compounds (e.g. DDT), heavy metals (e.g. lead, cadmium, mercury, zinc, chromium), pesticides and polycyclic aromatic hydrocarbons (e.g. benzopiren). (Gomółka & Szaynok 1997.)

The values of these proportions in the treated effluent depend on the efficiency of cleaning. As the efficiency of sewage treatment decreased, the content of degradable substances in the way of biological content of the refracting substance remains roughly unchanged. Therefore, the growth efficiency of purification of BOD_5/TOC value ratio decreases. The study treated sewage from different treatment to indicate that in well treated effluent, BOD_5/TOC value ratio may be 0.1 and 0.2. (Collective Work 2000.)

4 LAND AND RESEARCH METHODOLOGY

Malta Lake is an artificial lake in Poznan. It is a recreational centre for the people of Poznan. The lake was made by damming Cybina River in 1952. Its length is about 2200m being the longest man-made lake in Poznan. There are lots of site attractions around the lake. The lake has also hosted some of rowing world competitions. A well detailed characteristic of the lake are in the subsequent paragraphs.

4.1 Characteristics of research facility

Malta Lake was formed by damming the waters of the Cybina River at height of 492km on Podwale Street between 1949 and 1953. The Lake is located within the administrative city of Poznan. It is located between the following streets; from the North - Street Warsaw, Komandoria, and Marginal, from the South - Bishop Street Baraniak, from the East - Street Wiankowa and from the west - St. John Paul.

GRAPH 4. Malta Lake

GRAPH 5. Malta Lake is one of the most modern centres in Europe for rowing competition

The geographical location of the lake is however guided by the following coordinates: 52° 23' north and 17° 49' east. Malta Lake is an artificial reservoir flow with direction from east to west flowing through Cybina River. Malta Lake flows in the area of the street in Katowice stream beds, between street Komandoria Vilnius, stream Świętojański and Szklarka Watercourse.

Parameters characterizing Malta Lake are total surface area of 67.46ha, water surface of 63.88ha, average width of 300m, length of 2200m, maximum capacity of 2,000,000m^3 and optimum ordinate of the mirror of water held back of 58.3m. The average depth of the lake is 2.80m, maximum depth of 3.70m with minimum depth of 1.80m.

The area in which Malta Lake is located is characterised by the following climatic parameters as that of Swarzędzkie Lake because of the proximity and location in the course of the same river.

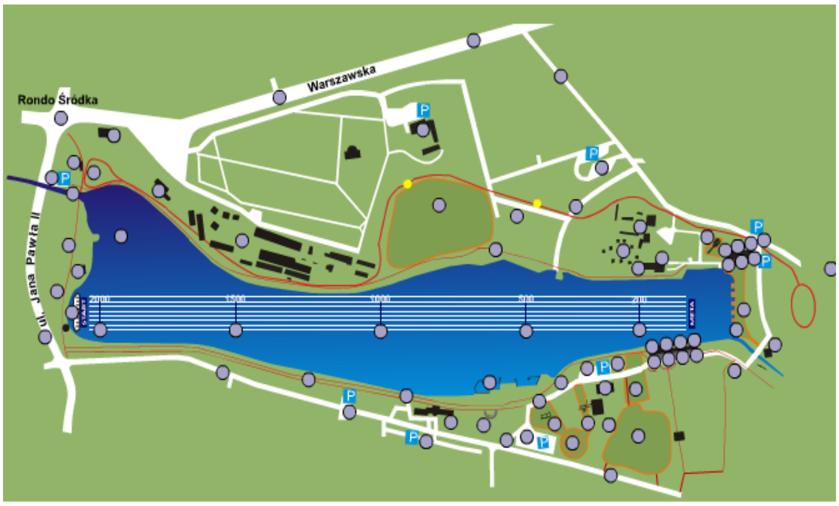
Average January temperature in Malta Lake is 0.2°C, average July temperature is 21°C, average annual temperature is 9.5°C, average annual humidity is 84% and the annual rainfall is 514mm.

4.2 Location of control points of measurement, timing and methodology of sampling and analytical work

The samples of water are taken from the following points: First control point of measurement is the impact of Cybina River to Malta Lake, second control point of measurement is located at half the length of Malta Lake and the third control point of measurement is the effluent from Cybina River to Malta Lake.

The location of the control points of measurement are presented below;

GRAPH 6. Picture of Malta Lake showing the highest fountain in Poznan



GRAPH 7. Plans around Malta Lake vicinity

GRAPH 8. Sample collection point with collection bottle

GRAPH 9. The location of the control points of measurement of Malta Lake

Sampling from all points of control measurement were made from March 2008 to October 2008, the dates of sampling are given in Table 8.

TABLE 8. Water sampling analysis made from March to October 2008.

Month	**Day**
March	09
April	01, 17
May	07, 15, 23
June	18
July	02, 11, 24
August	14, 22
September	10
October	09

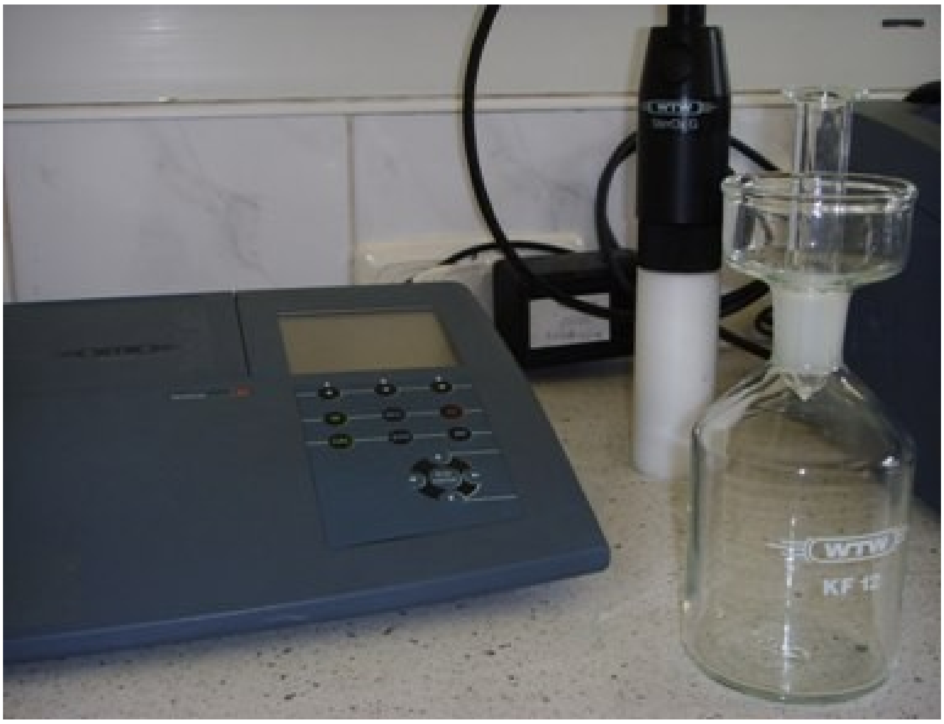
Sampling was made in accordance with the requirements of sampling for determination of the examined parameters i.e. sampling in the way that there was no oxygen in the bottle. This is usually done in a way that a sample is taken twice with the narrow-necked 250ml bottles as shown in Graph 10. After sampling, the sample was transported immediately to the laboratory for analysis.

GRAPH 10. Bottles for the collection of samples for analysis of BOD, TOC and dissolved oxygen

Analytical laboratory performed the water quality determination of dissolved oxygen according to Polish standard PN-EN 25814; 1999., determination of biochemical oxygen demand after n days (BOD_n), according to Polish standard PN-EN 1899-2; 1 December 2002. The determination of total organic carbon (TOC) and dissolved organic carbon (DOC) was done according to Polish Standard PN-EN 1484; September 1999.

Analytical studies were carried out at Research Laboratory of Water and Soil Testing Laboratory of Voivodeship Sanitary and Epidemiological Station in Poznan, Noskowskiego 21. The scope of research included water oxygen saturation, water saturation percentage of oxygen, and indicator of total organic carbon.

Measurement of oxygen saturation in water started after delivery to the laboratory tests using the electrochemical sensor on the camera's WTW inoLab terminal 740 shown in Graph 11.



GRAPH 11. Camera and electrode for measuring oxygen saturation of water

Prior to the measurement of dissolved oxygen in the water, sensor was calibrated according to manufacturer's instructions, and then measurement of oxygen saturation of water in the first attempt was made. At the end of the measurement (the camera automatically when stabilized prints the result of measurement) electrode was flushed, dried and rubbed gently.

The next sample testing started and further measurements were performed similarly. Then the samples were kept in incubator at constant temperature of 20˚C for further five nights. (Polish standard PN-EN 1899.) Subsequent measurements of oxygen saturation of water were made after five days. The difference in oxygen content was calculated for the rate of biochemical oxygen demand of water (BOD_5).

BOD_n = (c1 - c2)

where:
c1 - the dissolved oxygen concentration in the sample at time zero, in milligrams per litre
c2 - the concentration of oxygen dissolved in the same sample after n days, in milligrams per litre.

Measuring water content for total organic carbon (TOC) was made on the camera HiPerTOC Analyzer from Thermo, which is shown in Graph 10.

GRAPH 12. Camera HiPerTOC Analyzer from Thermo

Oxidation of organic carbon (C org.) in water to carbon dioxide is followed by incineration of the UV lamp or by subjecting mineralization at 1000°C. Selection of mineralization depended on the predicted concentrations of C org. in the sample. Inorganic carbon was removed from the sample by acidification and blown or is determined separately. Formed oxidation of carbon dioxide was determined directly or after reduction, for example, methane (CH_4). Final determination of CO_2 was carried out using infrared spectrometry. Feedback was given on the basis of measuring the peak area automatically by the application program for the analysis. (Polish standard PN-EN 1484; 1999.)

The study used the results obtained by the following institutions involved in the assessment of water quality; laboratory tests of water, wastewater and air pollution in Poznan, department of environmental protection office of City Hall and Water and Soil Testing Laboratory of Voivodeship Sanitary and Epidemiological Station in Poznan.

5 TEST RESULTS

The results of the analysis of selected indicators of organic pollutants carried out on Malta Lake are the biochemical oxygen demand of water, oxygen saturation of water and the total organic carbon. Works presented in the results are done in the periods of early spring, summer and early autumn.

5.1 Physico-chemical results of laboratory of soil and water

Physico-chemical analysis carried out on Malta Lake on 18.06.2008 for the thesis. Obtained results during tests results are presented in Table 9.

TABLE 9. Results of physico-chemical analysis of Malta Lake conducted in 2008

Parameter	Value	Class of water	Unit
Temperature	19	I	°C
Turbidity	20	-	NTU
Color	20	III	mg Pt/dm^3
Odour	z1R	I	-
pH	8.1	I	-
Total hardness	282.0	-	mg $CaCO_3/dm^3$
Chlorine	78.4	I	mg Cl/dm^3
Ammonium	0.3	I	mg N/dm^3
Nitrite	0.012	I	mg N/dm^3
Nitrate	0.4	I	mg N/dm^3
COD	12.2	III	mg O_2/dm^3
Sulphate	113.1	I	mg SO_4/dm^3

5.2 Physico-chemical results of other laboratories

Physical and chemical tests of Malta Lake water were carried out by three laboratories carrying out monitoring of surface water quality parameters in Poznan region of Wielkopolska. Test results of water in Malta Lake (in the bowl of lake at the measuring point were carried out on 24.05.72) (Water Research Laboratory, Plant and air at District Sanitary and Epidemiological Station in Poznan 1972) obtained by the Water Research Laboratory, Plant and air are shown in Table 10. The results obtained by the Laboratory of Hygiene Municipal District Sanitary and Epidemiological Station on 22.05.2000 are presented in Table 11 (Water and Soil Testing Laboratory of Voivodeship Sanitary and Epidemiological Station in Poznan, St. Noskowskiego 21 in Poznan and Laboratory of Water Research in Sanitary and Epidemiological Station, Sieroca 10, Poznan - Studies on the quality of water in Malta Lake (1995 to 2008). By contrast, the results of research conducted by Dr. R. Gołdyn and MSc. J. Raker for the Office of City Hall - Department of Environmental Protection Program in 1998 to protect the waters of Cybina River is summarized in Table 12. (Gołdyn & Grabia 1998.)

TABLE 10. Some parameters of water quality in Malta Lake performed by laboratory test of water, wastewater and air

Parameter	Value	Unit
Temperature	19	°C
Turbidity	10	mg SiO_2/dm^3
Odour	35	mg Pt/dm^3
Color	Z1R	-
pH	8.3	-
Total hardness	302.6	Mg $CaCO_3/dm^3$
Chlorine	48.0	mg Cl/dm^3
Ammonium	0.08	mg N/dm^3
COD	13.2	mg O_2/dm^3
Sulphate	87.46	mg SO_4/dm^3

TABLE 11. Some parameters of water quality in Malta Lake made by the Laboratory Communal Hygiene of the District Sanitary and Epidemiological Station in Poznan

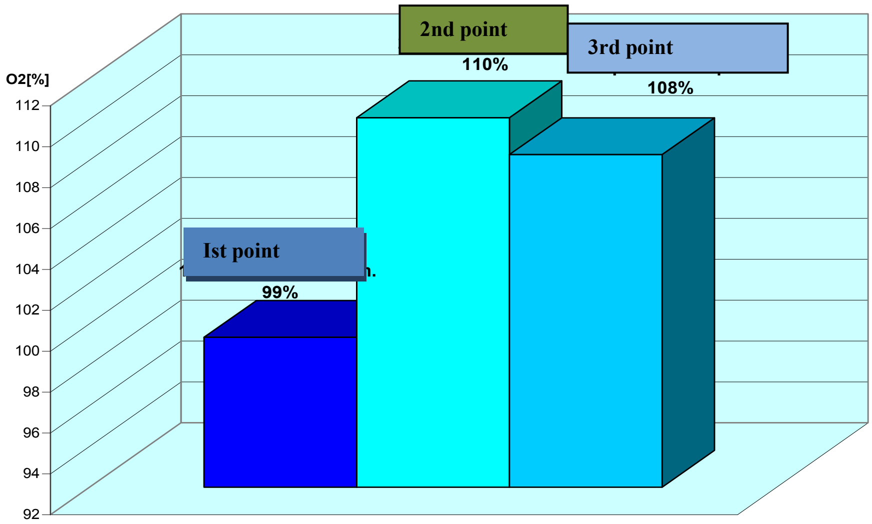
Parameter	Value	Unit
Temperature	19	°C
Turbidity	10	mg SiO_2/dm^3
Odour	35	mg Pt/dm^3
Colour	Z1R	-
pH	8.3	-
Total hardness	302.6	mg $CaCO_3/dm^3$
Chlorine	48.0	mg Cl/dm^3
Ammonium	0.08	mg N/dm^3
COD	13.2	mg O_2/dm^3
Sulphate	87.46	mg SO_4/dm^3

TABLE 12. Some of the indicators of water quality in Malta Lake made by the Department of Environmental Protection Authority City Hall in the years 1991 to 1995.

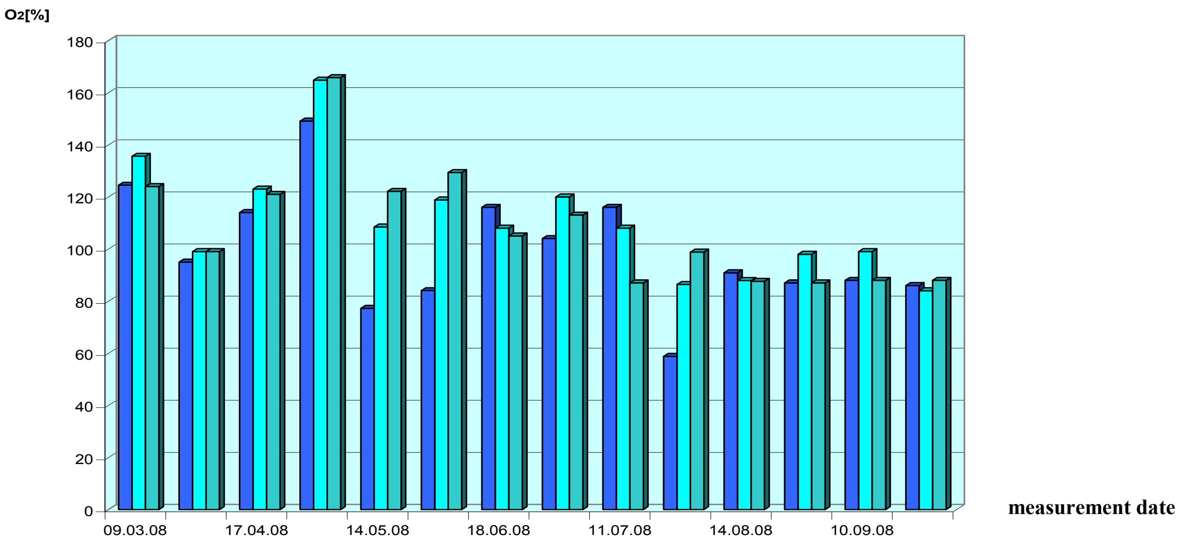
Parameter	Unit	1991	1992	1993	1994	1995
Dissolved oxygen	mg O_2/dm^3	7.6	3.0	10.2	0	0.8
COD – Cr	mg O_2/dm^3	38.5	81.7	58.5	73.5	82.0
BOD_5	mg O_2/dm^3	3.6	15.2	8.2	7.8	22.4
Phosphate	mg P/dm^3	0.131	0.082	0.029	-	-
Total phosphorus	mg P/dm^3	0.319	0.589	0.116	0.330	0.247
Mineral nitrogen	mg N/dm^3	0.47	1.18	1.41	13.84	7.64
Total nitrogen	mg N/dm^3	2.64	3.41	3.25	13.81	6.24
Transparency	M	1.02	0.57	1.30	0.70	0.70

5.3 Saturation of water with oxygen in Malta Lake

The results of the average values of water oxygen saturation measurement in 2008 are shown in Graph 13 and their values with fourteen dates at three points of control measurement is also shown graphically in Graph 14.



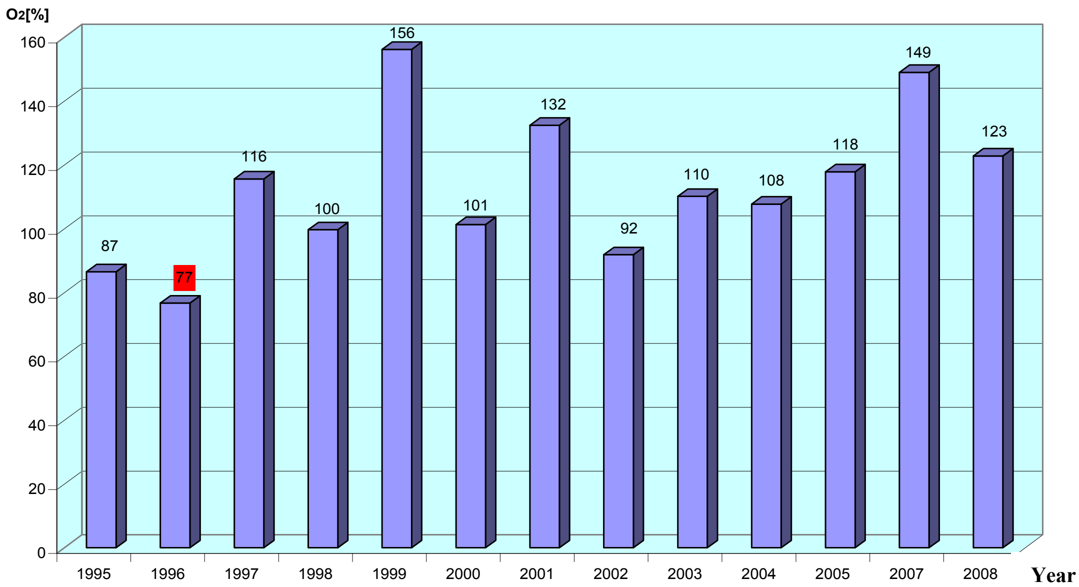
GRAPH 13. The average water saturation of oxygen in Malta Lake at the three control points measured in 2008



GRAPH 14. The average water saturation of oxygen in Malta Lake at the three control points of measurement in 2008

During the measurement from 09.03.2008 to 09.10.2008, oxygen saturation value of water in Malta Lake at the first measuring point ranged from 59% to 149%. The lowest value was recorded in August and the highest in the first decade of May. The average value of oxygen saturation of water in the first measuring point (inlet of the Cybina River) was 99%. During the measurement from 09.03.2008 to 09.10.2008, oxygen saturation value of water in Malta Lake at the second measuring point ranged from 84% to 165%. The lowest value was recorded in May and the highest in the first decade of October. The average value of oxygen saturation of water at the second measuring point was 110.1%.

During the measurement from 09.03.2008 to 09.10.2008, oxygen saturation value of water in Malta Lake at the third measuring point ranged from 87% to 166%. The lowest value were recorded in July and August and the highest in the first decade of May. The average value of oxygen saturation of water at the second measuring point was 108.3%.

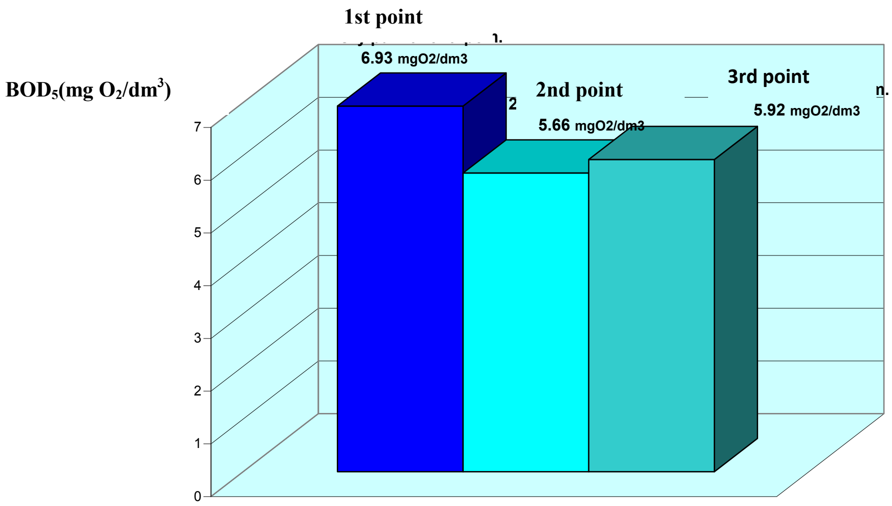


GRAPH 15. The average water saturation of oxygen in Malta Lake between 1995 and 2008

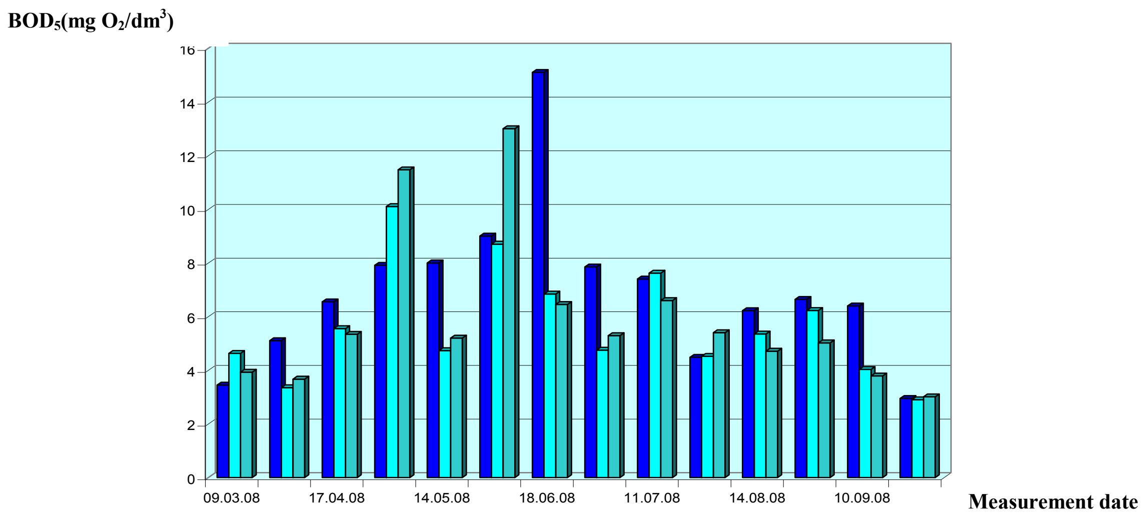
Analysing the oxygen saturation of water for 13 years, we could say that the quality of water in Malta Lake in terms of water saturation with oxygen in thirteen years from 1995 to 2008 with the exception of 2006 due to lack of research results were satisfactory. Red in Graph 15 marked a year in which the rate of water oxygen saturation was below the limit value and the lowest was 77% O_2/dm^3. (Regulation of the Minister of Health 2002.)

5.4 Biochemical oxygen demand of water

Results of the average values of biochemical oxygen demand of water in year 2008 were presented in Graph 16 and their values with fourteen dates at three points of control measurement. It is also shown graphically in Graph 17.



GRAPH 16. The average biochemical oxygen demand of water in Malta Lake at three Control points of measurement in 2008

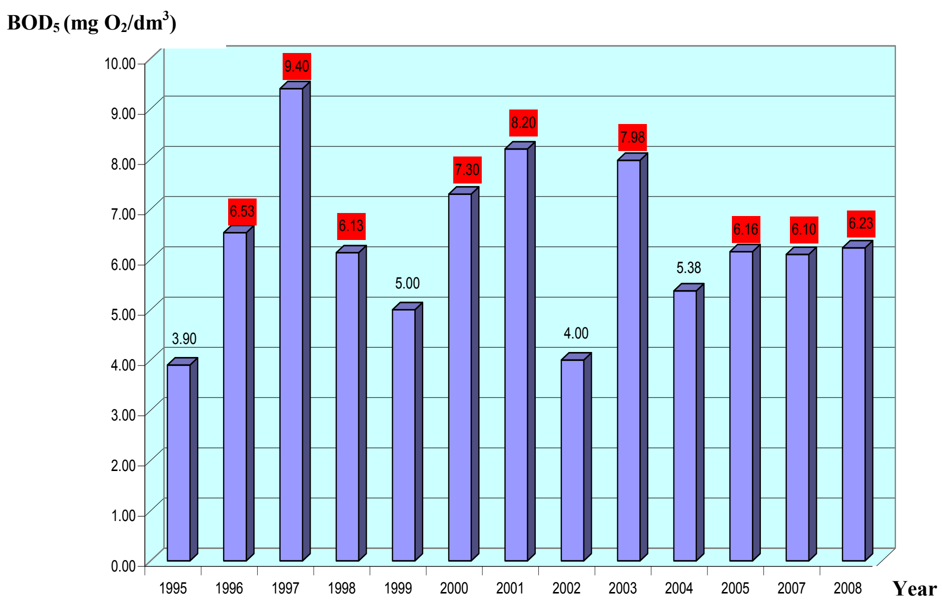


GRAPH 17. Biochemical oxygen demand of water in Malta Lake at the three control points of measurement in 2008

During the measurement from 09.03.2008 to 09.10.2008, index value for biochemical oxygen demand of water in Malta Lake at the first measuring point was from 2.95 mg O_2/dm^3 to 15.1 mg O_2/dm^3. The lowest value was recorded in October and the highest in the second decade of June. The average value of the index of biochemical oxygen demand of water at the first measuring point (Cybina River inlet) was 6.93 mg O_2/dm^3.

During the measurement from 09.03.2008 to 09.10.2008 of biochemical oxygen demand of water in Malta Lake, the second measuring point ranged from 2.9 mg O_2/dm^3 to 10.1 mg O_2/dm^3. The lowest value was recorded in October and the highest in the first decade of May. Average value of biochemical oxygen demand of water at the second measuring point was 5.66 mg O_2/dm^3.

During the measurement from 09.03.2008 to 09.10.2008 of biochemical oxygen demand of water in Malta Lake, the biological oxygen demand at the third measurement point ranged from 3.01 mg O_2/dm^3 to 13.0 mg O_2/dm^3. The lowest value was recorded in October and the highest in the third week of May. Average value of biochemical oxygen demand of water at the second point of measurement was 5.92 mg O_2/dm^3.

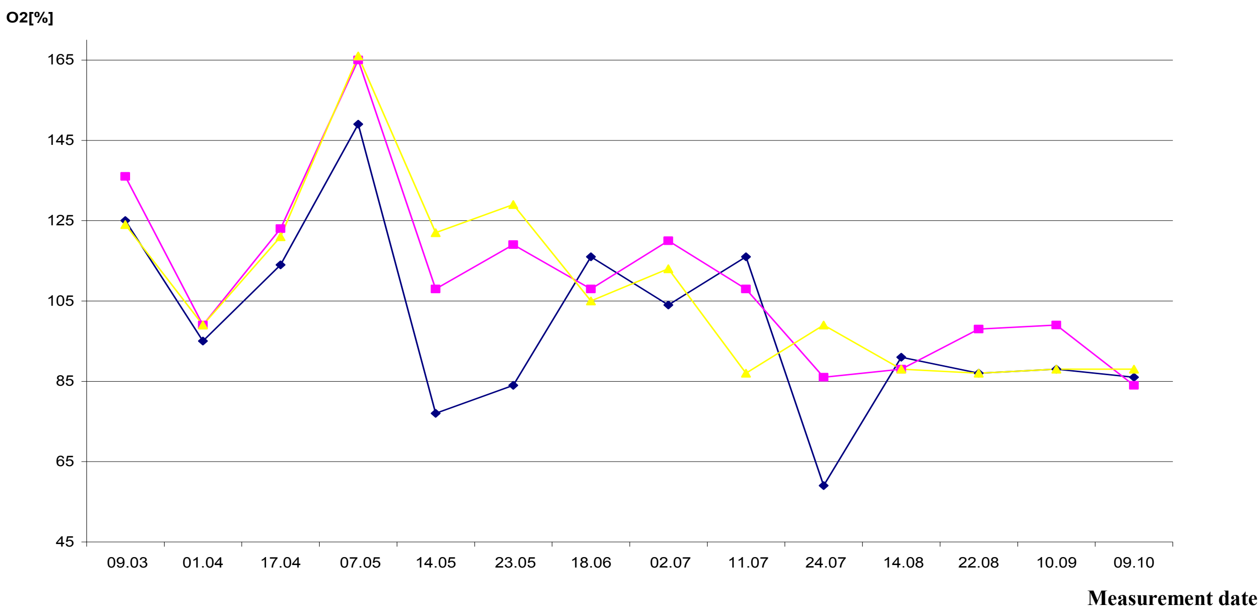


GRAPH 18. The average value of the index of the biochemical oxygen demand of water in the Malta Lake between 1995 and 2008

Analyzing Graph 18, it could be said that the quality of water in Malta Lake in terms of biochemical oxygen demand of water for thirteen years (excluding the year 2006 due to lack of research results) was unsatisfactory in nine years (shown in Graph 18 in red) out of the thirteen years examined. The value of BOD_5 ratio was exceeded, considering them in accordance with the Ordinance of the Minister of Health of 16.10.2002 where the limit value of BOD_5 is 6 mg O_2/dm^3. By contrast, according to the Decree of the Minister of Environment of 11.02.2002, only in the years 1995, 1999, 2002 and 2004 that water quality was within the limits of the acceptable level, while in the remaining years they were outside the acceptable limit level.

5.5 Saturation of water with oxygen and biochemical oxygen demand of water at three points of control measurement between March 2008 and October 2008

In this section, Graph 17 illustrates the dynamics of changes of water oxygen saturation rate at three points of measurement and testing in the period from March to October 2008. Graph 18 illustrates the dynamics of changes in rates of biochemical oxygen demand of water at three points of measurement and testing in the period from March to October 2008.



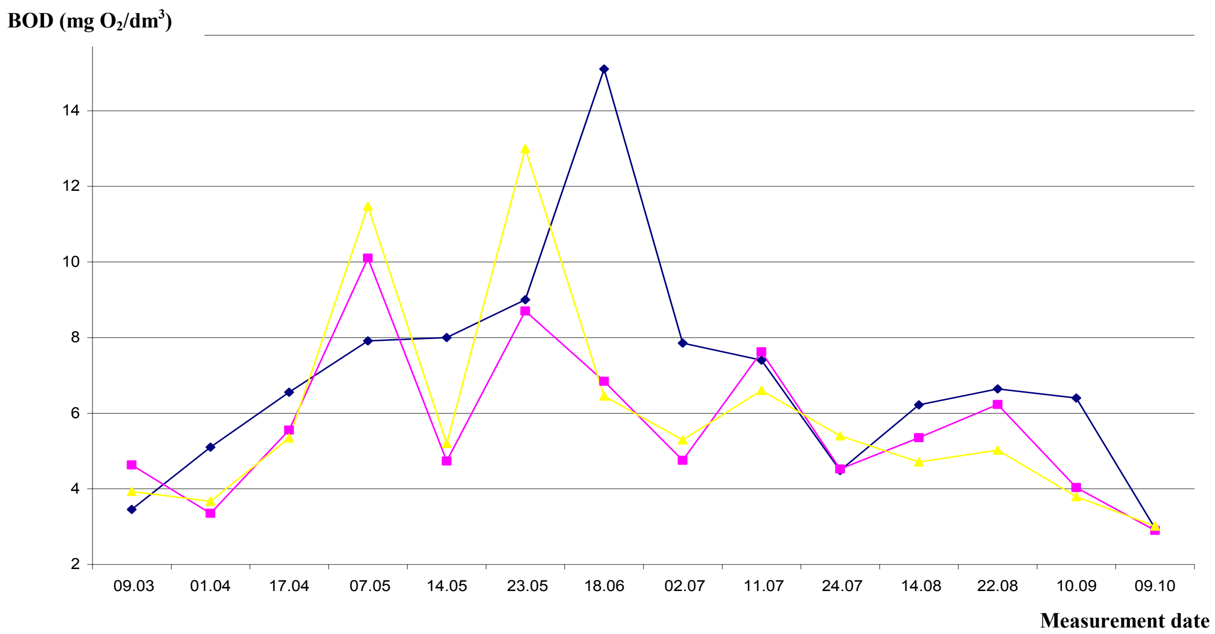
GRAPH 19. Dynamic of changes of water oxygen saturation rate at the three control points of measurement from March to October 2008

Where;

Blue curve - 1st point of measurement

Pink curve – 2nd point of measurement

Yellow curve – 3rd point of measurement



GRAPH 20. The dynamics of changes in rates of biochemical oxygen demand of water at three points of measurement in the period from March to October 2008

Table 13 compares the average index value of water saturation with oxygen and biochemical oxygen demand of water in Malta Lake in 2008 at three control measuring points. Analyzing the results obtained, it could be concluded that the worst water quality is at the first point of control measurement. This can be attributed to poor quality of waters of Cybina River that affected just around the first point. At the second point, improvements in water quality were observed, while at the third point, there was a slight deterioration.

TABLE 13. Comparison of the mean rate of oxygen saturation and biochemical oxygen demand in Malta Lake in 2008 at the three measuring points

Point of measurement	**Indicator of water quality**	
	Oxygen saturation of water [%]	**BOD_5 [mg O_2/dm^3]**
First Point of measurement	99	6.93
Second point of measurement	110	5.66
Third point of measurement	108	5.92

Table 14 compares the average of degree of water saturation values of oxygen and biochemical oxygen demand for the three points of measurement in Malta Lake in 2008, broken down by season. Analyzing the results below, we can conclude that the best in terms of water oxygen saturation occurred in the spring value of which was 120% then the average water saturation of oxygen in the summer period amounted to 97% while 86% in autumn. Analyzing the biochemical oxygen demand of water, we see that the worst average value of this ratio occurred in the spring was a little better in the summer of the lowest value of biochemical oxygen demand of water was obtained in autumn.

TABLE 14. Comparison of average (from the three points of measurement) of saturation value of oxygen and BOD_5 of Malta Lake water in 2008

Date of measurement		**The average value of dissolved oxygen [%]**	**The average value of BOD_5 [mg O_2/dm^3]**
S	09.03.08	128	4.00
P	01.04.08	98	4.04
R	17.04.08	119	5.81
I	07.05.08	160	9.83
N	14.05.08	103	5.98
G	23.05.08	111	10.23
	Average spring	**120**	**6.65**
S	18.06.08	110	9.46
U	02.07.08	112	5.96
M	11.07.08	104	7.21
M	24.07.08	81	4.80
E	14.08.08	89	5.43
R	22.08.08	91	5.96
	10.09.08	92	4.74
Average summer		**97**	**6.22**
AUTUMN 09.10.08		86	2.95
Average of all measurements		**106**	**6.17**

Table 15 compares the number of water oxygen saturation index and biochemical oxygen demand of water in Malta Lake from 1995 to 2008. The following table shows that the quality of water in the lake in terms of water oxygen saturation was satisfactory but in terms of biochemical oxygen demand of water was definitely disappointing.

TABLE 15. Oxygen saturation value index and biochemical oxygen demand in Malta Lake between 1995 and 2008

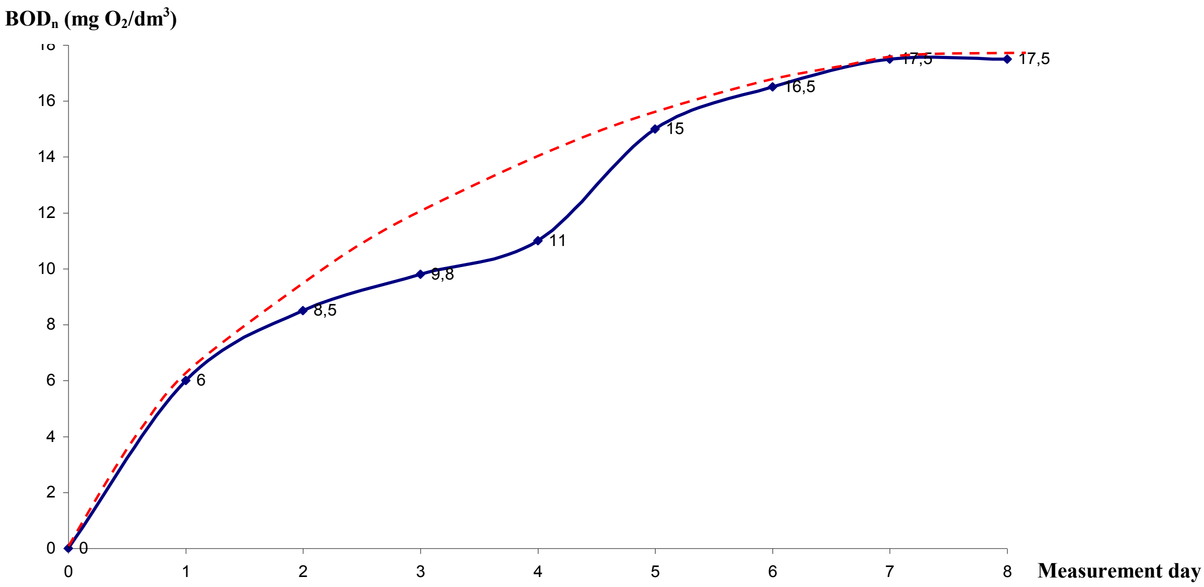
Year of measurement	**Biochemical oxygen demand of water [mg O_2/dm^3]**	**Oxygen saturation of water [%]**
1995	3.90	87
1996	6.53	77
1997	9.40	116
1998	6.13	100
1999	5.00	156
2000	7.30	101
2001	8.20	132
2002	4.00	92
2003	7.98	110
2004	5.38	108
2005	6.16	118
2007	6.10	149
2008	6.23	123

5.6 Determination of the nature of environmental organic compounds occurring in Malta Lake

In this section, the BOD_n curves of which type (contamination readily degradable or refractory) of set of organic pollutants found in Malta Lake will be discussed. From the BOD value of the experimental analysis, the course of the graph gives information about the type of organic compounds that are present.

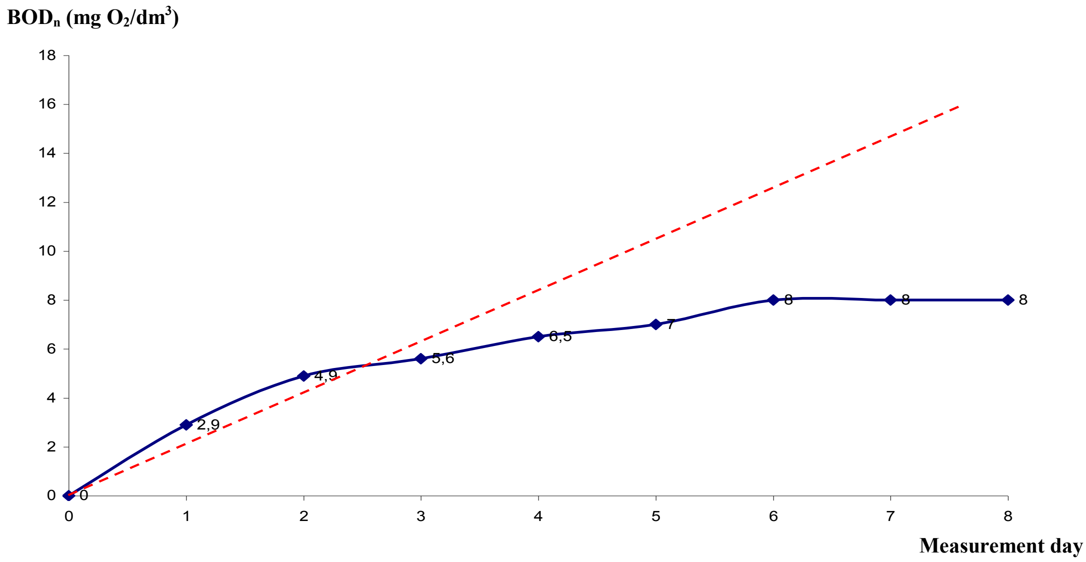
5.6.1 Nature of the organic compounds under the slope of BOD at the three control points of measurement on 22.06.08

In order to determine the nature of organic compounds entering Malta Lake and Cybina River and if the flow remains unchanged between the flow from the inlet and the outlet of Cybina River, analysis of organic compounds occurring at different points was made. The analysis was carried out on 22.06.2008 at each point of measurement and testing. BOD measurement was carried out for the next eight days.



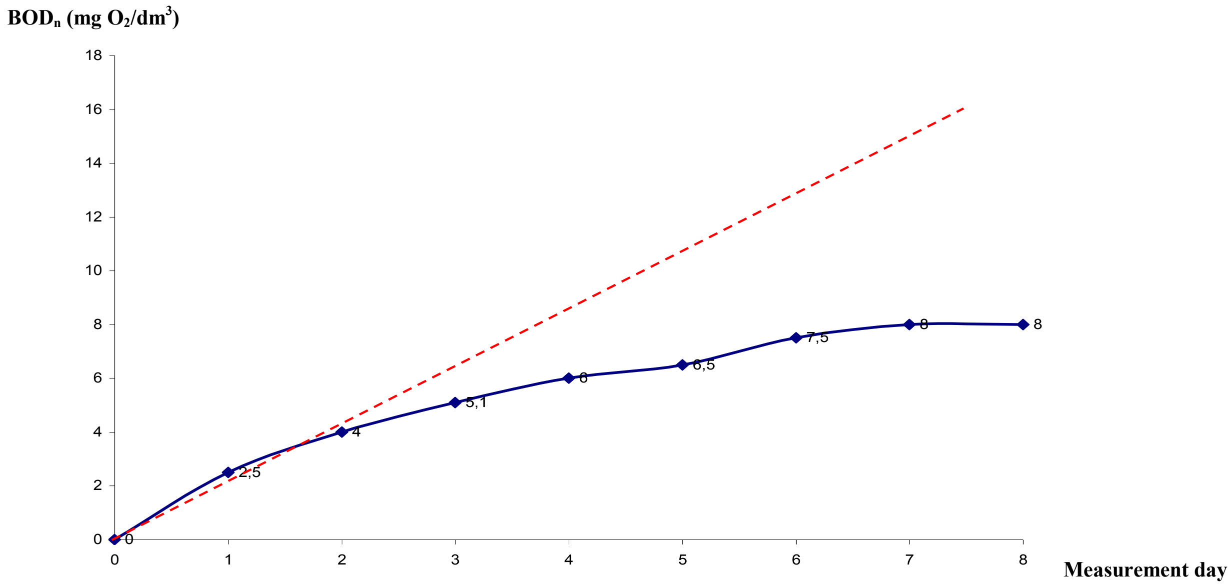
GRAPH 21. Determination of type of organic matter by measuring BOD_5 at first point of control measurement (measurement started on 22.06.2008)

From Graph 21, it shows that the organic compounds are easily decomposable biologically at the first point of measurement. The red dashed line shows the pathway of curves typical for this kind of organic pollutants which were shown in Graph 3.



GRAPH 22. Determination of the type of organic matter on the basis of measurement of BOD_5 at the second Control point of measurement (measurement started on 22.06.2008).

From Graph 22, it shows that we are dealing with organic compounds that are difficult to decompose biologically at the second measuring point. Red dashed line is the course of the curves typical for this kind of organic pollutants from Graph 3.

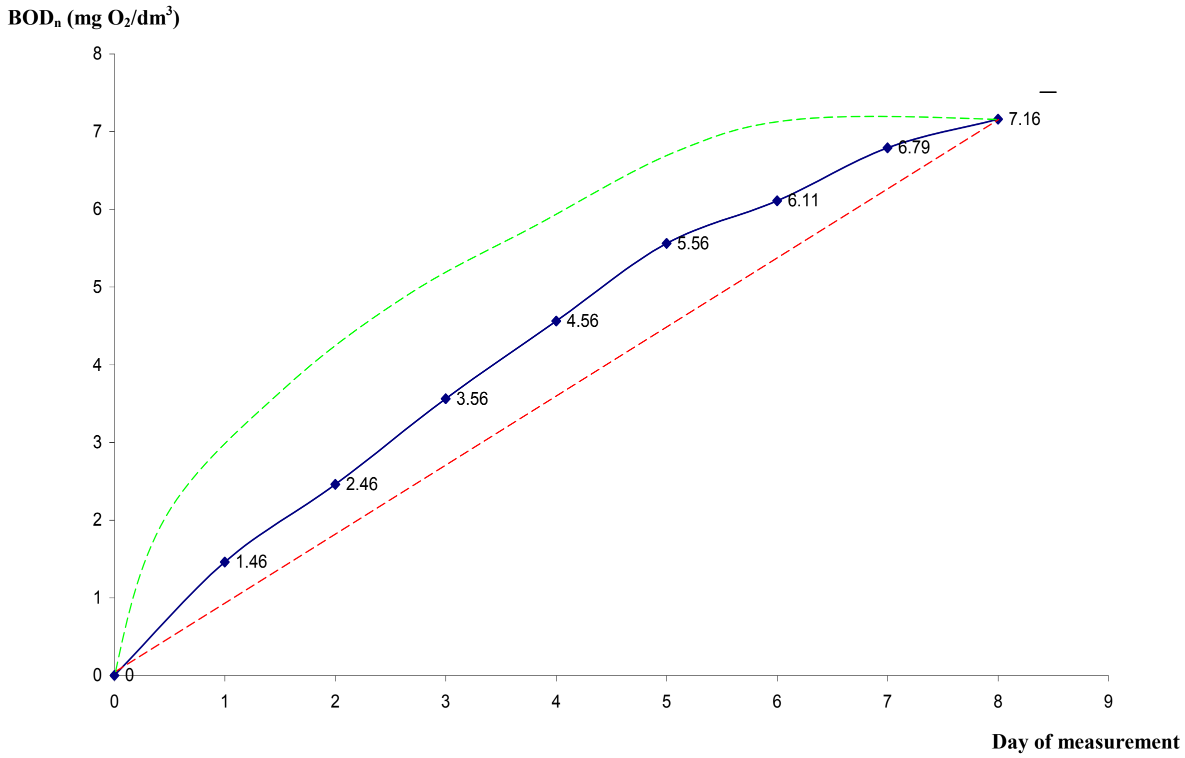


GRAPH 23. Determination of the type of organic matter on the basis of measurement of BOD_5 at the third control point of measurement (measurement started on 22.06.2008).

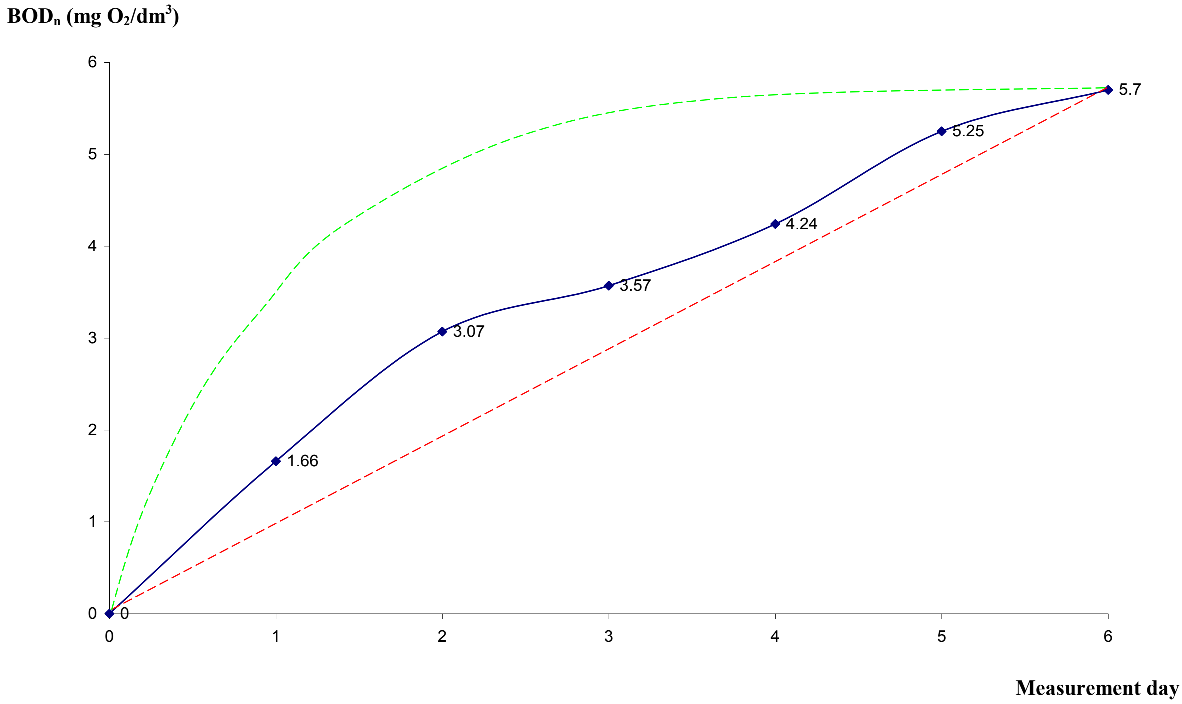
Graph 23 shows that at the third measuring point, we have to do with organic compounds that are difficult to decompose biologically. Red dashed line is the course of the curves typical for this kind of organic pollutants from Graph 3.

5.6.2 Nature of the organic compounds under the slope of BOD at the second control points of measurement

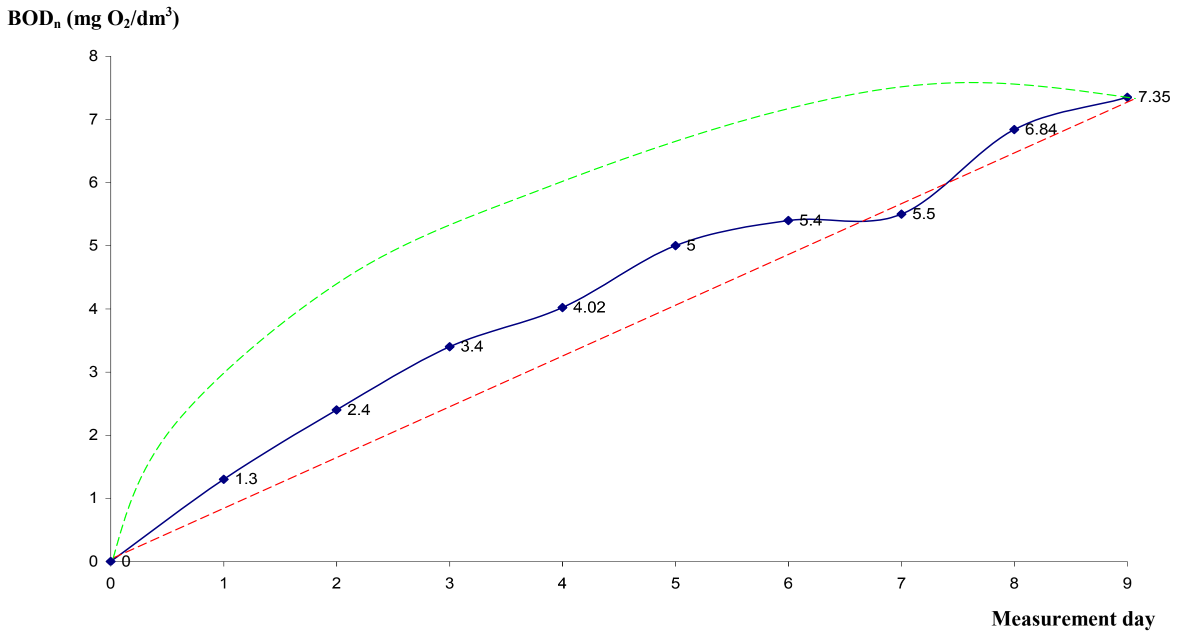
In order to determine the nature of organic compounds present at the second control point of measurement for analysis of BOD curves, samples were collected on 05.08.2008, 19.08.2008 and 02.09.2008. BOD measurement was conducted every day for eight consecutive days.



GRAPH 24. Observation of BOD_n indicator designed to determine the nature of organic pollutant (easily or difficultly degradable) from 05.08.2008 to 12.08.2008



GRAPH 25. Observation of BOD_n indicator designed to determine the nature of organic pollutant (easily or difficultly degradable) in the period from 19.08.08 to 28.08.08



GRAPH 26. Observation of BOD_n indicator designed to determine the nature of organic pollutant (easily or difficultly degradable) from 02.09.08 to 07.09.08

Graphs 24, 25 and 26 show that in the analysed water, there were both appearance of compounds that are readily and difficultly degradable (refractory). Green dashed line is the typical course of the curves easily degradable organic compounds (from Graph 3). The red dashed line is the typical course of the curves for organic compounds that are difficultly degradable (from Graph 3). Graphs of the values of biochemical oxygen demand after the readings obtained on subsequent days of measurement indicated that at the second control point of measurement, there were both refractory compounds and biologically easily degradable compounds.

5.6.3 Nature of organic compounds on the basis of BOD/TOC ratio

In order to determine the nature of organic compounds introduced into Malta Lake, together with Cybina River, analysis of the type of organic compounds present in water was made. Samples were collected on 22.06.08, 08.07.08 and 02.08.08 at the first control point of measurement. The results collected are compiled in Table 16 of test result for the comparison of BOD_5/TOC.

TABLE 16. The test result for the comparison of BOD_5/TOC

date of performance of measurement	**BOD_5 mg O_2/dm^3**	**TOC mg/l C org.**	**BOD_5/TOC**	**Conclusion**
22.06.08	15.0	10.90	1.38	The possibility of dominance of refractory compounds
08.07.08	7.85	13.53	0.57	Low probability of occurrence of refractory compounds
02.08.08	6.22	13.30	0.46	

6 DISCUSSION

Recreational Water reservoirs are necessary part of the city landscape, serving many important functions. They are places of rest for the people, meeting the needs of both recreational and aesthetic (acting on the local climate) values and in existence are the site's rich flora and fauna, influencing the growth of biodiversity in poor urban landscape. In assessing the quality of surface waters, among them recreational water reservoirs particularly the ones vulnerable to the input of pollutants, it is important to determine the total organic matter content. The pollutants of these reservoirs are natural organic compounds and compounds synthesised by man. A significant part of organic compounds found in the waters is biodegradable. In biochemical processes of decomposition of organic compounds, dissolved oxygen is consumed in water. Sometimes an indicator that indicates that the water content of organic matter is susceptible to biochemical decomposition is not only the biochemical oxygen demand (BOD), but also the amount of oxygen dissolved in water (water saturation of oxygen). To determine the content of organic compounds, the total organic carbon should also be considered.

Work presented in the results of Malta Lake water quality allowed an assessment of the degree of pollution of organic compounds. Analysis of the results of the dynamics of spatial and temporal concentrations of organic compounds and the occurrence of refractory compounds and assessment of water quality on the basis of data for many years are presented in the subsequent paragraph.

In order to determine whether the nature of organic compounds entering Malta Lake together with Cybina River is unchanged, analysis of the type of organic compounds occurring at different points was made. There was samples collection on 22.06.2008 at each point of measurement. BOD measurement was carried out daily for the next eight days. Parallel measurements were conducted with samples collected in all three points of measurement. Chapter 5.6 showed the process based on curves of BOD_n type of contaminants that were found (readily degraded or refractory) in Malta Lake. Based on the analysis of curves obtained, organic compounds found at the first point of control measurement on 22.06.08 were mainly readily degradable biological compounds which were shown on Graph 21.

However, at the second and third control point of measurement, there were organic compounds that were difficultly degradable biologically, as exemplified by Graphs 22 and 23. Entering Malta Lake are contaminants that are biodegradable, and when flowing towards the outlet of the Cybina River are only refractory compounds. This situation proves that the Cybina River introduces Malta Lake unrefined wastes which is typical for the presence of these compounds that are difficultly degradable. Compounds are usually hardly degradable longer only in the treated wastewater.

In order to determine the nature of organic compounds present at the second control point of measurement, analysis of BOD curves were made. Sample was collected on 05.08.2008 and Graph 24 showed the index of BOD measurements which was carried out for the next eight days. Another sample was collected on 19.08.2008 and Graph 25 showed the index of BOD measurements which was carried out for the next nine days. Further collection took place on 02.09.2008 and Graph 26 showed the index of BOD measurements carried out for six days.

The analysis carried out of BOD_n course curves indicated that we have to do both with organic compounds that are both easily and difficultly (refractory) degradable biologically. The second control point of measurement in all studied periods from the graphs of biological oxygen demand obtained from Graphs 24, 25 and 26 indicated that at the second point of measurement there were both refractory compounds and biologically easily decomposable compounds. Unrefined waste water flows into Malta Lake, together with Cybina River are biodegradable, which go into refractory organic compounds, but some part of the easily degradable compounds, together with the water migrates towards the second control point of measurement.

In order to determine the nature of the organic compounds introduced into Malta Lake, together with Cybina River, analysis of the type of organic compounds found in water at the first control point of measurement was made. Samples were collected on 22.06.2008, 08.07.2008 and 02.08.2008. After examining the results it could be inferred that on 22.06.2008 the BOD_5/TOC ratio equal to 1.38, oscillated within the typical urban wastewater which confirms the dominance of refractory compounds. However, during subsequent measurements, BOD_5/TOC ratios were 0.57 and 0.46. These values indicated the presence of treated urban waste water. There were few occurrences of refractory compounds.

Refractory compounds have a value of about 2, but when their number is in insignificant proportion, the value of BOD/TOC is ten times smaller. (Szpakowska 1999.)

Analysis of the results obtained for BOD/TOC shows that in June there was a possibility of significant amounts of refractory, while in July and August, the occurrence of refractory compounds was in small probability. (From Table 16).

Winkler method is one of the methods for the determination of dissolved oxygen saturation of water in salt-free surface water. Dissolved oxygen in water is an indication of its healthy nature i.e. high productivity and little pollution occurrence water. Winkler method is better performed at the point of water collection because if measurement is further delayed, there might be alteration in oxygen content in the water taken for measurement. Winkler test is done by adding excess of manganese (II) salt, iodide (I) ion and hydroxide ion to water sample to form a white precipitate of manganese (II) hydroxide. Dissolved oxygen present in the water sample oxidises the white precipitate formed into a brown manganese precipitate. Strong acid such as hydrochloric acid is then added to the brown precipitate thereby converting the iodide (I) to iodine. The solution is later titrated with sodium thiosulphate using a starch indicator and there is blue coloration after the addition of starch indicator. The amount of sodium thiosulphate used corresponds to the amount of dissolved oxygen present in the water sample.

Classification according to the Decree of Minister of Environment of 11.02.2002 on the basis for comparison of results of physico-chemical data from many years has been carried out on the basis of multi-comparisons of physico-chemical tests made on Malta Lake by various laboratories. Analysing Table 17, it could be inferred that in the water of Malta Lake, there were no radical changes. Water quality is not greatly improved or deteriorated. Water in Malta Lake can be generally regarded as the average water quality both in terms of suitability for bathing and classification. During the thirteen years of study of water quality in Malta, the average biological oxygen demand of water in nine of the thirteen years of measurements exceeded the limit value from Graph 18 and the average dissolved oxygen content from Graph 15 was too small once in 1996.

TABLE 17. Comparison of water quality in Malta Lake on the value of test of Physico-chemical indicators of water

Year of study of water quality	Class of the water. dissolved oxygen [mg O_2/dm^3]	Class by water. biochemical oxygen demand [mg O_2/dm^3]	Body that carried out research on Malta Lake
1972	I	III	*
1991	I	II	**
1992	V	V	**
1993	I	III	**
1994	V	III	**
1995	V	V	**
2000	I	IV	***
2008	I	III	****

* Represents Water Research Laboratory, Water Treatment and Air Pollution in Poznan, ** represents Department of Environmental Protection Office of City Hall, Program to protect waters of the Cybina River, Office of City Hall, Department of Environmental Protection, *** represents Water and Soil Testing Laboratory of Voivodeship Sanitary and Epidermiological station in Poznan and **** represents research work done at Laboratory of Water and Soil of Voivodeship Sanitary and Epidermiological Station, Poznan in 2008.

7 CONCLUSIONS

The analysis of the presence of dissolved organic matter in Malta Lake may be useful in assessing the recreational value of Malta Lake. From the analysis Conducted in 2008, the physico-chemical analyses of the cleanliness of Malta Lake carried out in the analysis have confirmed the view that the water in Malta Lake cannot be regarded as pure water. It was found that the quality of water colour and oxidation is associated with the occurrence of organic compounds i.e. the values correspond to class III of water purity level.

Analysis of the contents in the water of dissolved organic compounds carried out based on the indicators examined at the three measuring points analyzed - Cybina River inlet to Malta Lake, the middle part of Malta Lake and the flow of water from Malta Lake, led to the conclusion that the quality of water flowing into Malta Lake in terms of quantities of dissolved organic matter in the research was lowest at the inlet of Cybina River, the second measuring point was slightly improved and the effluent from the Lake was slightly worsen.

The nature of environmental organic compounds present in Malta Lake largely depended on incoming organic pollutants to the Lake. It was found that organic pollutants inflow to Malta Lake are mostly easily degradable compounds, while at the outlet of the Lake, the organic compounds are difficultly degradable (refractory compounds). This suggests that there is release of organic pollutants such as sewage to the Lake.

On the basis of the ratio index value of biochemical oxygen demand to total organic carbon, it was found that most of the group of compounds in June were biologically difficulty degradable (refractory). In July and August, there was low probability of the occurrence of refractory compounds.

The reasons for the continuous difference in oxygen saturation and BOD measurement for the thirteen years analysed might be due to difference in temperature or difference in photosynthesis process in Malta Lake.

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