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DYNAMICS OF SOIL AND WATER PROPERTIES OF LAND IRRIGATED WITH WASTEWATER FROM YEAST PRODUCTION. Part I

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DYNAMIKA WŁAŚCIWOŚCI GLEB I WÓD GRUNTOWYCH NAWADNIANYCH ŚCIEKAMI Z PRODUKCJI DROŻDŻY. Cz. I

Podstawowym celem przedstawionych badań było sprawdzenie, czy oczyszczanie ścieków poprodukcyjnych z drożdżowni w środowisku glebowo-roślinnym jest w pełni zasadne przez redukcję zanieczyszczeń wraz z jednoczesnym wykorzystaniem ich do nawożenia pól uprawnych.

Dla osiągnięcia założonego celu, badano głównie dynamikę zmian właściwości fizycznych i chemicznych wód, gleb i roślin nawadnianych ściekami z drożdżowni przez wiele lat. Cześć I pracy prezentuje zagadnienia związane z charakterystyką produkcji i gospodarki wodno-ściekowej drożdżowni, zasady i efektywność technologiczną oczyszczania ścieków z drożdżowni w środowisku glebowo-roślinnym oraz wpływ nawodnień ściekami na czystość wód.

Badania dowodzą, że na polach rolniczego wykorzystania ścieków Śląskiej Fabryki Drożdży uzyskuje się bardzo dobre wskaźniki oczyszczania biologicznego, tzn. redukcję stężeń dla BZT_5 – 99,3% i CHZT – 99,7%, a dla związków eutroficznych: N_{og} – 98,83%, P – 96,25% i K – 99,18%. Uzyskany procent redukcji zanieczyszczeń przewyższa warunki określone w pozwoleniu wodno-prawnym. Z pól nawadnianych ściekami odpływają wody drenarskie w I, II i III klasie czystości. Również wody otwarte z punktów kontrolnych na terenach nawadnianych ściekami zachowują II i III klasę czystości.

Summary

The goal of the presented research works is to prove the following thesis: Does the process of contaminants reduction and effluent application for arable land fertilization justify the treatment method of waste water from a yeast production facility in soil and plant environment.

In order to achieve the above mentioned goal, basically the dynamics of physical and chemical properties change observed for waters, soils and plants irrigated with wastewater from yeast factory has been studied for many years. Part I presented the problems characteristics of production as well as water and wastewater management in the yeast factory, principles and technological effectiveness of the treatment of process wastewater from yeast production in soil – plant environment and impact of irrigation with wastewater on water purity.

The research proved that very high biological treatment indices are achieved on the Silesian Yeast Factory fields where process wastewater is utilized i.e. concentration reduction for: BOD_5 – 99.3% and COD – 99.7%, – for eutrophic compounds: N_{total} – 98.83%, P – 96.25% and K – 99.18%. The obtained percentage of concentration reduction is higher than the standards assumed in the water supply and wastewater discharge consent issued to the factory. The drainage water from the fields irrigated with yeast effluent is of I, II and III class of purity.

INTRODUCTION

The food processing and agricultural industry is among these sectors of economy, which have a particularly destructive impact on the environment, primarily on the purity of waters. Facilities of this branch of industry consume large volumes of high quality water while at the same time discharge effluents containing large volumes of organic and biogenous contaminants. Based on the statistic data it is assumed that annually food processing and agricultural industry generates 110.3 million m^3 of wastewater of organic substance content expressed by BOD_5 index in the amount of 212 thousand tons of O_2, 18.5 thousand tons of nitrogen and 2.73 tons of phosphorus [7].

At such level of water environment contamination, a considerable share falls on yeast production industry whose basic material for processing is molasses and the technological processes require nutrition with fertilizing additives.

THESIS AND GOAL OF THE STUDY

The goal of the presented research work is to prove the following thesis: Does the process of contaminants reduction and effluent application for arable land fertilization justify the treatment method of waste water from a yeast production facility in soil and plant environment.

In order to achieve the above mentioned goal, basically the dynamics of physical and chemical properties change observed for waters, soils and plants irrigated with wastewater from yeast factory has been studied for many years. The scope of the research comprised the following problems:

1. characteristics of production as well as water and wastewater management in the yeast factory,
2. principles and technological effectiveness of the treatment of process wastewater from yeast production in soil – plant environment,
3. impact of irrigation with wastewater on water purity,
4. impact of irrigation with wastewater on soil (physical and chemical properties),

5. impact of irrigation with wastewater from yeast factory on the quantity and quality of arable plants yield,

The research covered 620 ha of arable land – property of the Silesian Yeast Factory (Śląska Fabryka Drożdży SFD) in Wołczyn, which is used for agricultural treatment and utilization of wastewater from yeast production.

The arable land irrigated and fertilized with wastewater from yeast production is located to the south west, west and north west from the town of Wołczyn, in the distance of 1500 – 4500 mn from the production facility [13].

In this part of the paper the issues 1–3 depicted in thesis and goal of the study will be discussed.

METHODOLOGY OF THE STUDY

Samples of groundwater were taken from the drainage outlets, samples of receiver water from the ditches and the Wolczanka and the Czarna Woda River. Places of sampling were located in the control sections, in accordance with the Water Law, concerning object exploitation for agricultural wastewater utilization. In investigations methods generally used for water analyses (mainly according to Hermanowicz [8] and Polish Standards) were applied to determine the physical and chemical indices. The total heavy metal content was determined using atomic absorption spectrometry (AAS).

CHARACTERISTICS OF RESEARCH OBJECT

Among branches of food processing industry, yeast production is distinguished by particularly high consumption of high quality water and generation of effluent – arduous for the environment [2, 9–12].

Basic raw materials used in yeast production are: water, beet molasses, nitrogen, phosphorous, magnesium nutrients, biostimulators (thiarnin B1 and biothyne) as well as microelements (copper and zinc salts). Beet molasses is the primary source of carbon for yeast culture. It is a by-product of sugar production process, which contains about 50% of saccharose, 30% of mineral substances and 20% of water [2, 13].

In yeast production process, water is used for the following purposes:

- to run the process in fermenters,
- to prepare liquid nutrients (molasses and phosphoric acid dilution, emulation of anti-lime agent,
- yeast milk washing,
- to supply vacuum pumps in yeast filtration process,
- to supply steam boilers (for that purpose also condensed steam is used),
- for sanitary and maintenance activities.

As a result of water use for the above mentioned purposes the following effluent sources occur:

• yeast wort hydro-extraction on centrifuges – approx. 10 – 15 m^3 of wastewater per ton of yeast,

• yeast filtration process – approx. 6 – 10 m^3 of wastewater per ton of yeast,

• from facilities washing after cycle completion – 3 – 5 m^3 per ton of yeast.

It means that production of 1 tone of yeast generates 24.3 – 33.8 m^3 of wastewater. At daily production rate on the level of 49.8 – 64.1 tons of yeast, the volume of 1555 – 1685 m^3 of wastewater is generated per day. Recalculated respectively to annual values it gives 521,000 – 564,000 m^3 of wastewater per year [2, 13].

Table 1. Chemical composition of selected food industry sewage

Parameter	Food industry plants					
	brewery	starch house	dairy	distillery	Fruits and veg. proces. plant	yeast factory
pH	5.9	5.8	7.3	6.8	6.5	4.9
BOD_5 – mg O_2/dm^3	1564	1220	587	930	494	5510
Total nitrogen – mg N/dm^3	50	142	33	59	48	541
Total phosphorus – mg P/dm^3	10	24	13	10	13	7
Potassium – mg K/dm^3	35	300	41	150	40	1306
Calcium – mg Ca/dm^3	128	69	77	61	156	356
Magnesium – mg Mg/dm^3	17	16	15	27	19	74
Sodium – mg Na/dm^3	126	13	93	33	357	301
Chlorides – mg Cl/dm^3	203	150	95	120	687	360
Sulphates – mg SO_4/dm^3	249	207	258	150	72	1215

Most of the effluent is generated in hydro-extraction process of yeast wort on centrifuges. This process consists of three stages. In the first stage – on first centrifuge, yeast milk is separated from wort. The second and third stage, on two subsequent centrifuges, consist in yeast washing to obtain yeast milk of bright, cream color. The highest contaminants load was identified in wastewater from the first centrifuge, whose dark brown color shows their high concentrations proved by chemical analyses. Effluent from the other two centrifuges is much brighter which proves a smaller load of contaminants (Table 2).

The average contents of BOD_5 on the level of 5500 COD – 7750 mg O_2/dm^3 were determined in the effluent from the Silesian Yeast Factory in Wołczyn. The load of this effluent corresponds to the equivalent number of

Table 2. Average chemical composition of wastewater from wort hydro-extraction of yeast on centrifuges

Parameter/unit	Wastewater from following centrifuges		
	I	II	III
pH	5.7	5.7	5.7
Total suspended solids – mg/dm^3	2621	487	359
BOD_5 – mg O_2/dm^3	15700	2050	944
COD – mg O_2/dm^3	27648	5939	2458
Ammonia nitrogen – mg NH_4^+/dm^3	81.2	72.8	24.0
Nitrate nitrogen – mg NO_3^-/dm^3	190.4	64.0	20.4
Total nitrogen – mg N/dm^3	1372	378	98
Total phosphorus – mg P/dm^3	10.9	8.7	8.7
Potassium – mg K/dm^3	5789	1390	357
Chlorides – mg Cl/dm^3	376	193	94
Sulphates – mg SO_4/dm^3	1218	315	195

residents (RM) higher than 150 thousand. Also basic euthrofic and mineral indices determined in wastewater from yeast production are very high i.e. above 500 mg/dm^3 of total nitrogen, 700 mg/dm^3 of potassium and 1200 mg/dm^3 of sulphates (Table 3).

Table 3. Chemical composition of wastewater from yeast production from the Silesian Yeast Factory in Wołczyn

Parameter	Years			Average values by Kutera [28]
	1995	1996	1997	
pH	5.1	4.9	5.3	4.9
Total suspended solid – mg/dm^3	734–1066	227–548	283–625	720
BOD_5 – mg O_2/dm^3	1185–4690	1110–6720	2665–6060	5510
COD – mg O_2/dm^3	6310–8684	2622–8832	4082–10731	7754
Ammonia nitrogen – mg NH_4^+/dm^3	134–496	13–296	24–165	270
Nitrate nitrogen – mg NO_3^-/dm^3	7–38	2–37	8–28	10
Total nitrogen – mg N/dm^3	51–680	11.845	37–739	541
Total phosphorus – mg P/dm^3	20	2–19	4–33	8
Potassium – mg K/dm^3	664–996	58–346	117–414	706
Calcium – mg Ca/dm^3	360–431	280–420	300–410	501
Magnesium – mg Mg/dm^3	40–80	55–75	60–85	74
Chlorides – mg Cl/dm^3	200–784	124–583	132–528	360
Sulphates – mg SO_4/dm^3	611–848	239–1490	35–1242	1215

The nutritious components of wastewater occur mainly in soluble forms thus are easily accessible to plants. More than 50% of nitrogen in wastewater falls on its organic forms (apart from others, carbohydrates, amino acids, yeast cells and products of their metabolic processes); the rest occurs in ammonium forms. In relation to the mentioned nutritious compounds, too low content of phosphorus in the studied wastewater is unfavorable [9–11, 13].

High values of BOD_5 and COD oxygen indices in the effluent prove the possibility to deoxidize it in the receiving water. The BOD_5/COD ratio shows that the organic substance of wastewater from yeast facility is easily biodegradable.

Wastewater from yeast production is acid, susceptible to putrefaction with release of unpleasant odors, mainly of sulfur origin.

Bacteriological tests made for raw wastewater showed that the effluent meets sanitary standards for wastewater utilized for agricultural purposes as no pathogenic bacteria were observed, and index of Coli of excremental type meets the standards of I class water purity [13].

The yeast production process generates also large volumes of maintenance sewage contaminated with washing and disinfecting detergents and other chemicals (caustic soda, formalin). The sewage is generated after systematic washing of facilities, fermenters, tanks, technological installations, vacuum filters and centrifuges.

The presently used traditional wastewater treatment technologies which apply mineralisation of organic substance, denitrification for nitrogen removal and biological or chemical dephosphatation for phosphorus removal are very expensive and do not prove to be efficient and cost effective for the treatment of process wastewater from the yeast production.

In the situation of stringent standards for the removal of biogenic substances i.e. nitrogen and phosphorus from sewage, the method of yeast production wastewater utilization in soil-plant environment as fertilizer for plants cultivation seems to be much more attractive. The attractiveness of the method is justified by the simplicity of construction and operation of necessary facilities, relatively low unit costs especially due to high efficiency of both carbon compounds and eutrophic substances removal. This method allows treating wastewater to II and III without co-reaction of chemical compounds. It also provides for utilization of its nutrition potential (which can replace artificial fertilizers) for crop production. Another advantage of the discussed treatment method is the fact that it is more environmentally friendly than traditional methods as it requires low consumption of energy and does not emit any toxic gases to the atmosphere [9–11].

In relation to water purity criteria, required for agricultural irrigation, the process effluent from Silesian Yeast Factory in Wołczyn shows too high oxygen indices, excessive salinity as well as potassium, sulphates and nitrogen contents, whereas the pH is too low. That is why before application, the effluent requires appropriate treatment and dilution.

The technology for yeast production wastewater treatment applied in Wołczyn does not require mechanical pretreatment and acidity correction. Instead of the effluent liming, more intensive liming of soils irrigated with it is applied. Deficiency of phosphorus in wastewater in relation to other nutritious macrocomponents is supplemented, depending on needs, with mineral fertilizers. In summer time, during the vegetation period, irrigation with effluent diluted with clean water in proportion 1:1 or 1:2 is applied.

SYSTEM FOR WASTEWATER DISTRIBUTION ON FIELD

The process effluent from production facilities is transported to the pumping station and then transferred to an intermediate tank. From there through a retention tank, two pipelines pump it to the field. In the case when there is no possibility to apply the effluent to soil, it is transported to an emergency wastewater discharge tank. From the retention tank, the averaged effluent is transported to water and wastewater collector of the main wastewater treatment plant „Wołczyn". The collector is divided into two chambers. One of them is used to discharge wastewater, the other to discharge water from the intake point at the Wołczanka River. Depending on the type of crops irrigated, during vegetation period the wastewater is diluted in appropriate proportion and pumped through pipelines to the fields.

The irrigation system, types of sprinklers and mist propagators were selected specifically for the purpose of wastewater sprinkling. The fields on which wastewater is used, intensive sprinkling with propagators of reduced stream ejection angle is applied. Mixture of water and sewage is sprinkled following an irrigation schedule developed for the fields assigned for the treatment and utilization of wastewater for every production year and adjusted to the crop structure and sprinkling dose [2, 13].

While determining yearly doses of wastewater from yeast production, fertilizing load was taken into account rather than water requirements of the cultivated plants. Especially this close was based on nitrogen balance, as it is a yield-generating nutrient, which at the same time poses the highest potential risk to the environment among the nutritious components.

In compliance to the guidelines effective for the agricultural sector, annual load of wastewater per individual crops is determined by the following formula [2, 13]:

$$D = \frac{0{,}1\ Z_N\ P_N}{C_N\ \eta\ R_N}$$

where:

D – yearly sprinkling dose of raw effluent mm/year
Z_N – nitrogen demand of the irrigated crop kg N/ha year
C_N – nitrogen concentration in effluent kg/m^3
P_N – planned supply of crops nitrogen demand
H – coefficient of nitrogen utilization depending on irrigation system for sprinkling? – 0.95, gravity system 0.90

R_N – nitrogen fertilizer equivalent, determined empirically for yeast production wastewater; for medium cohesive soils and fertilizing irrigation, mainly pre-vegetation, its assumed value is 0.60 – 0.65.

Applying crop rotation system on fields where the discussed effluent is utilized for agricultural purposes, two species of industrial plants are cultivated: rape and beet root. The sewage loads applied for these two species were approx. 100 mm/year. Additionally, two-grain species are cultivated: spring barley and spring and winter wheat for which the yearly dose was calculated on the level of 53 mm/year.

In the performed calculations the assumed nitrogen demand of industrial and cereal species was respectively: 300 kg/year and 150 kg/year at planned supply of this demand equal. The nitrogen concentration in process wastewater was assumed on the level of 0.5 kg N/m^3.

At the ratio of industrial plants cropped area to cereals cropped area 6:4, the average effluent load was 81.2 mm/year which corresponds to process wastewater dose per 1 ha of crops – 812 m^3/year.

Following the above presented data, the whole irrigated area (649 ha) can accept $812 \times 649 \sim 527\,000$ m^3/year of process wastewater [2, 13].

In order to reduce the runoff of effluent water from the irrigated area, sprinkling doses calculated for reduced targeted depth of wetting below 50 cm were applied. At technical effectiveness coefficient for sparkler and moist propagator adapted for wastewater distribution amounting 0.9, the gross sprinkling dose is 50 mm/year. At such an assumption maximum net sprinkling dose should amount:

$$d = 10\ h\ P_{Wd}$$

where:

d – net sprinkling dose, mm

h – assumed soil wetting depth, mm

P_{Wd} – planned water deficit, which for light and medium soils equals 0.09.

In practice the irrigation doses applied in the arable land of Silesian Yeast Factory are lower, usually about 30 mm [2, 13].

Sprinkled wastewater is the source of both water and nutrients for the crops. Most of effluent undergoes evapotranspiration, the remaining volume which is not used by the plants and not accumulated in soil is infiltrated to ditches and from there discharged to the Czarna Woda River through ditch no 45, monitoring and measurement weir WS-1, ditch no 46 and monitoring and measurement weir WS-2. Part of the water is also discharged to the Wołczanka River, through ditch no 4, ditch no 1 and ditch B respectively through monitoring and measurement weirs WS-4, WS-5, WS-8.

IMPACT OF WASTEWATER (FROM YEAST PRODUCTION) TREATMENT IN SOIL-PLANT ENVIRONMENT ON THE PURITY OF WATER

The abundance of wastewater from yeast production in nitrogen and potassium could be optimally used by plants representing high demand for these elements i.e. for grasslands, pasture crops, some industrial and root plants like: root and fodder beet, corn, winter rape, fodder cabbage and potatoes.

Due to the fact that the wastewater is clean from the sanitary point of view and contains only small amounts of heavy metals, the selection of species, which could be irrigated with it, could certainly be expanded by some vegetable crops.

During investigations carried out on fields irrigated with wastewater from yeast production in Wołczyn, the crops rotation was applied with grain species (spring and winter wheat, spring rape) and industrial plants (root beat and winter rape).

Wastewater treatment in soil-plant environment is a complicated process not even explained to the end. This process has been studied by many scientists [1, 6, 9 – 12] who significantly contributed to create theoretical background of wastewater treatment in natural environment. During wastewater treatment in soil environment, mainly in aerobic conditions, organic substance and nitrogen undergo mineralization and biochemical transformations of phosphorus and mineral compounds take place. Mineralized nitrogen in ammonia form is released to the atmosphere. In specific conditions, during the aerobic process course also nitrogen denitrification occurs. A negative effect of nitrification is increased lability of nitrates, whereas in the case of denitrification – release of nitrogen to the atmosphere.

Effluent phosphorus is cumulated in the soil solid phase in the form of organic compounds, absorbed ions or precipitated inorganic compounds. It is washed out from the soil only in very small amounts.

Salts soluble in wastewater, both their cations and anions are washed out from the soil to a large extent what prevents its excessive salinity.

Precise, direct determination (qualitative and quantitative) of wastewater treatment indices in natural soil-plant environment of the irrigated fields is practically not feasible. For that purpose indirect methods were used like lizymetric experiments, quantitative and qualitative analysis of wastewater runoff from the fields sampled from the drainage system and through determination of the impact of wastewater irrigated fields on water purity indices of receiving waters – ditches and rivers.

The data of lizymetric tests of the treatment of wastewater from yeast production facility in Wołczyn in the soil environment with meadow vegetation showed reduction of BOD_5 concentrations on the level of 85.0 – 99.4%, total nitrogen – 78.0 – 87.7%, phosphorus – 96.8 – 97.8% and potassium – 65.0 – 80.1% [13].

The water supply and effluent disposal consent for the treatment of wastewater from the Silesian Yeast Factory in Wołczyn specifies that the runoff of wastewater infiltrated through the soil will be 15% of the irrigating dose. Based on lizymetric tests it was assumed that the runoff from the fields where wastewater from yeast facility in Wołczyn is used for agricultural purposes is 10% of the applied effluent dose.

Most of the fields on which wastewater was applied for agricultural purposes are equipped with drainage system, which periodically transports the drainage water (runoff). The composition of the drainage water was subject to analysis and the dynamics of its changes in the period of 1995–1997 is presented in Table 4.

Chemical composition of drainage wastewater (runoff) from the fields irrigated with wastewater from the Silesian Yeast Factory is of the following purity classes: I (pH, BOD_5, COD, potassium. chlorides), II (total suspended matter, total nitrogen, NNO_3^-, NNH_4^+, sulfates), III (total phosphorus). None of the indices determined in drainage water from the system exceeds maximum values of permissible standards specified by effective legal regulations and water supply and effluent consent issued for the yeast factory.

During the course of studies the purity of water in ditches transporting the runoff from the catchment area of the fields irrigated with wastewater in Wołczyn was determined. The research on the dynamics of chemical composition changes in the years 1995–1997 in the ditches of the Wolczanka River catchment area and in five cross-sections of the river is presented in Tables 5 and 6. Table 7 shows the dynamics of chemical composition changes in the ditches of the Czarna Woda River catchment area and in two cross-sections of the river.

The presented data of the dynamics of determined indices changes shows that the water in the ditches of the Wołczanka River catchment area corresponds to the following purity classes:

I – with respect to: pH value, COD, NNO_3^-, potassium and chlorides,
II – with respect to: BOD_5, NNH_4^+,
III – with respect to: volume of suspended matter, phosphorus and sulfates.

The Wołczanka River water corresponds to the following purity classes:

I – with respect to: pH, ammonium nitrogen, potassium, chlorides and sulphates,
II – with respect to: BOD_5, COD and NNO_3^-,
III – with respect to: content of total phosphorus.

The water in ditches of the Czarna Woda River and the Czarna Woda River catchment area corresponds to the following purity classes:

I – with respect to: pH, COD, NNO_3^- and chlorides,
II – with respect to: volume of suspended matter, BOD_5, NNH_4^+, total phosphorus, sulphates,
III – with respect to: potassium content.

Table 4. Average values of chemical composition of drainage water (runoff) from the fields irrigated with wastewater

Parameter	Years				Class of purity	Values specified in the Water Law	Maximum admissible content
	1995	1996	1997	Average			
pH	6.8	6.8	6.8	6.8	I	6.5–8.5	6.5–9.0
Total suspended solids – mg/dm^3	26.2	34.2	26.8	29.1	II	50	50
BOD_5 – mg O_2/dm^3	3.9	3.2	2.7	3.3	I	15	30
COD – mg O_2/dm^3	19.7	13.3	16.1	16.4	I	70	150
Ammonia nitrogen – mg NH_4/dm^3	1.4	0.7	0.9	1.0	II	3	6
Nitrate nitrogen – mg NO_3/dm^3	5.1	3.5	1.5	3.4	II	15	30
Total nitrogen – mg N/dm^3	6.8	5.4	5.3	5.8	II	15	30
Total phosphorus – mg P/dm^3	0.20	0.26	0.47	0.30	III	3	5
Potassium – mg K/dm^3	–	4.7	6.9	5.8	I	20	80
Chlorides – mg Cl/dm^3	53.7	57.2	58.0	56.6	I	–	1000
Sulphates – mg SO_4/dm^3	186.1	186.3	166.0	179.5	II	–	500

Table 5. Chemical composition of water from the ditches of the Wolczanka River catchment area

Parameter	Place of sampling				Class of purity	Values specified in the Water Law	Maximum admissible content
	WS-4	WS-5	WS-8	Average			
pH	6.7	7.7	7.0	7.1	I	6.5 – 6.8	6.5 – 9.0
Total suspended solids – mg/dm^3	35	30	37	34	III	50	50
BOD_5 – mg O_2/dm^3	4.1	6.6	3.9	4.9	II	15	30
COD – mg O_2/dm^3	14.4	24.0	16.8	18.4	I	70	150
Ammonia nitrogen – mg NH_4/dm^3	1.1	0.6	2.4	1.4	II	3	6
Nitrate nitrogen – mg NO_3/dm^3	3.7	4.9	1.4	3.3	I	15	30
Total phosphorus – mg P/dm^3	0.4	0.4	0.3	0.4	III	3	5
Potassium – mg K/dm^3	7.8	5.5	8.4	7.2	I	20	80
Chlorides – mg Cl/dm^3	68.3	67.3	60.7	65.4	I	–	1000
Sulphates – mg SO_4/dm^3	200.8	169.3	151.0	174.0	III	–	500

Table 6. Chemical composition of water of the Wolczanka River catchment area

Parameter	Place of sampling					Class of purity	Values specified in the Water Law	Maximum admissible content
	PK-I	PK-II	PK-III	PK-IV	PK-V			
pH	6.8 – 7.5	6.8 – 7.4	6.7 – 8.4	6.6 – 7.9	6.8 – 7.1	I	6.5 – 8.5	6.5 – 9.0
Total suspended solids – mg/dm^3	29	33	37	3.0	26	III	50	50
BOD_5 – mg O_2/dm^3	4.5	5.2	1.7	1.9	3.4	II	15	30
COD – mg O_2/dm^3	11.9	26.2	12.5	9.3	23.5	II	70	150
Ammonia nitrogen – mg NH_4/dm^3	0.6	0.6	2.3	0.6	0.5	I	3	6
Nitrate nitrogen – mg NO_3/dm^3	3.2	3.7	6.0	1.1	0.9	II	15	30
Total phosphorus – mg P/dm^3	0.23	0.20	0.34	0.07	0.03	III	3	5
Potassium – mg K/dm^3	7.9	7.6	12.3	14.1	18.1	I	20	80
Chlorides – mg Cl/dm^3	50.3	50.9	57.0	29.8	29.8	I	–	1000
Sulphates – mg SO_4/dm^3	105.7	107.3	102.0	68.1	69.0	I	–	500

Table 7. Chemical composition of water of the Czarna Woda River catchment area

Parameter	Place of sampling				Class of purity	Values specified in the Water Law	Maximum admissible content
	Drainage ditches		Czarna Woda River				
	WS-1	WS-2	PK-1	PK-2			
pH	7.4	6.7	7.1	7.2	I	6.5–8.5	6.5–9.0
Total suspended solids – mg/dm^3	24.5	34.0	23.0	20.0	II	50	50
BOD_5 – mg O_2/dm^3	2.3	2.5	4.7	3.9	II	15	30
COD – mg O_2/dm^3	13.7	12.4	15.9	12.3	I	70	150
Ammonia nitrogen – mg NH_4/dm^3	1.2	1.5	1.1	2.1	II	3	6
Nitrate nitrogen – mg NO_3/dm^3	1.7	4.3	1.4	1.3	I	15	30
Total phosphorus – mg P/dm^3	0.02	0.2	0.03	0.1	II	3	5
Potassium – mg K/dm^3	11.6	8.2	15.2	13.5	III	20	80
Chlorides – mg Cl/dm^3	46.5	66.4	34.3	36.9	I	–	1000
Sulphates – mg SO_4/dm^3	107.0	197.6	93.0	75.0	II	–	500

CONCLUSIONS

1. The process effluent from the yeast factory in Wołczyn originates from natural materials – molasses and nutrients media for yeast propagation; it is acid arid abundant in organic substance, eutrophic compounds especially in nitrogen and potassium. The wastewater contains also small, harmless amount of heavy metals, however it is sanitarily clean, thus they are preferred for agricultural treatment and utilization.

2. On the basis of the data obtained during the research period very good indices of biological treatment were noted on the fields irrigated with the effluent from Wołczyn yeast factory: reduction of concentrations– BOD_5 – 99.3% and COD – 99.7% and for eutrophic compounds: N_{total} – 98.83%, P – 96.25% and K – 99.18%. The obtained concentration reduction percentage exceeds the values specified in the water supply and effluent discharge consent. The drainage water from the fields irrigated with the yeast effluent is of I, II and III class of purity.

3. In all of the analyzed waters i.e. open water, ditches and rivers located within the impact of fields irrigated with wastewater from yeast production facility in Wołczyn, no exceedances of any if the analyzed chemical indices were observed in the period 1995–1997.

Thus, the above presented results prove the effectiveness of the method applied to treat the effluent from Silesian Yeast Factory in Wołczyn which is based on the utilization of wastewater for agricultural purposes. Proven effectiveness of yeast production wastewater treatment in soil-plant environment is very high and difficult to achieve using traditional systems of treatment plants.

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