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# DYNAMICS OF SOIL AND WATER PROPERTIES OF LAND IRRIGATED WITH WASTEWATER FROM YEAST PRODUCTION Part II

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## DYNAMIKA WŁAŚCIWOŚCI GLEB I WÓD GRUNTOWYCH NAWADNIANYCH ŚCIEKAMI Z PRODUKCJI DROŻDŻY. CZ. II

Podstawowym celem przedstawionych badań było sprawdzenie tezy, czy oczyszczanie ścieków poprodukcyjnych z drożdżowni w środowisku glebowo-roślinnym jest w pełni zasadne poprzez 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 II pracy prezentuje zagadnienia związane z wpływem nawodnień ściekami podrożdżowymi na właściwości fizyczne i chemiczne gleby oraz na wielkość i jakość plonu roślin uprawnych.

Gleby nawadniane ściekami z drożdżowni wykazują przenawożenie potasem, a także zaznacza się w nich zawężenie stosunku węgla organicznego do azotu, z powodu nadmiaru azotu przy niedostatku węgla. Przeciwdziałaniem przy zmniejszaniu się zawartości substancji organicznej w nawadnianych glebach powinno być zaorywanie słomy, liści buraczanych i innych organicznych odpadów stałych.

W płodozmianie przemysłowo-zbożowym jaki stosowano na polach rolniczego wykorzystania ścieków w latach prowadzonych badań (1993–1997), odnotowano wzrost plonów większy (średnio o 13% u zbóż, u buraka cukrowego 0,5–10,7%) od plonów uzyskiwanych z pól drożdżowni nie nawadnianych i pól rolników indywidualnych, gdzie stosowano tylko dość duże nawożenie mineralne.

W porównaniu do danych literaturowych, w plonach ziarna pszenicy ozimej, jęczmienia jarego i rzepaku ozimego pod wpływem nawadniania ściekami z drożdżowni zwiększyła się nieznacznie procentowa zawartość białka, azotu, potasu, zmniejszyła natomiast wapnia i magnezu.

### Summary

The goal of the presented research works was 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 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 II presents the problems connected with the impact of irrigation with wastewater from yeast factory on soil physical and chemical properties and on the quantity and quality of arable plants yield.

Soils irrigated with process effluent from yeast factory show overfertilization with potassium. Also reduction of the organic carbon ratio to nitrogen is observed due to redundancy of potassium and deficit of organic carbon. Activities aimed at preventing reduction of organic substance consist in: straw, beet leaves and other solid organic waste ploughing.

In industrial – grain crops rotation applied in the fields used for agricultural utilization of wastewater carried out in the research years of 1993–1997, an increase of yields (average for grain – by 13% and for root beet by 0.5–10.7%) was recorded. It was higher than in the case of yields produced on yeast production facility fields not irrigated with effluent and yields obtained by individual farmers from fields intensively treated only with mineral fertilizers.

In comparison to the literature data the impact of irrigation with yeast effluent, the grain yields of winter wheat, spring barley and winter rape show slightly increased percentage contents of proteins, nitrogen, and potassium, whereas the contents of calcium and magnesium were smaller.

## INTRODUCTION

Among food processing industries, yeast production is distinguished by particularly high consumption of high quality water and generation of effluent – arduous for the environment [1–9,11].

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 simplicity of construction and operation of necessary facilities, relatively low unit costs especially due to high efficiency of both carbon compounds and eutrophic substance removal justify the attractiveness of the method. This method allows treating wastewater to $II^0$ and $III^0$ without co-reaction of chemical compounds. It also provides for utilization of it nutrition potential (which can replace artificial fertilizers) for crops 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.

## CHARACTERISTIC WASTEWATER FROM YEAST PRODUCTION

Full characteristics of wastewater from yeast production were presented in part I of article on dynamics of soil and water properties of land irrigated with wastewater from yeast production [11].

Process effluent from yeast factory in Wołczyn originates from natural materials – molasses and nutrients media for yeast propagation; it is acid (susceptible to putrefaction with release of unpleasant odors, mainly of sulfur origin) and 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, and thus they are preferred for agricultural treatment and utilization.

Wastewater from yeast production does not require either chemical or mechanical pretreatment before its application for agricultural purposes. During vegetation period the effluent is diluted with clean water in proportion 1:1 and instead of wastewater neutralization with lime, periodical soil liming is applied.

Irrigation with effluent from yeast factory should be carried out by sprinkling with reduced sprinkling doses and at the assumption of targeted soil profile wetting to the depth of 50 cm and yearly doses for individual crops based on nitrogen balance. Performance of the described procedure allows for a maximum utilization of the effluent fertilizing values by plant crops and minimum loss of fertilizing components with the runoff.

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.

## CHARACTERISTICS OF RESEARCH OBJECT

The research covered 620 ha of arable land-property of the Silesian Yeast Factory (Śląska Fabryka Drożdży SFD) in Wołczyn, which is used for treatment in soil-plant environment and agricultural 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 m from the production facility.

Soils of the fields irrigated with wastewater from Wołczyn and the adjacent areas are formed of dust clayey formations, clayey sands, not fully integrated, flat-laying on poorly clayey and loose sands. These are soil species of very good and good wheat complex with share of poor wheat complex of soil quality class III – V. Humidity relations of these soil species are close to correct, however with a considerable portion of periodically excessively dry soils.

## METHODOLOGY

To determine the impact of a long-term irrigation with effluent from yeast production on soil, three series of analyses were carried out. First series was made in 1989 after a ten years' period of irrigation with wastewater. Second series was carried out in 1994, the last one in 1998.

In the first decade the fields were overloaded with wastewater due to their limited surface and increased volume and concentration of effluent from yeast production.

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

Soil from arable layer (i.e. from the level of 0–30-cm depth) was sampled for chemical analysis by a soil-sampling bar. In the first sampling campaign a dispersed sampling point's method was used, while in the second campaign a grid method was applied for samples collection.

In the collected samples the following were determined [10]:

- organic carbon and organic substance – by Tiurin's methodology,
- total nitrogen – by Kjeldahl's methodology,
- ammonia nitrogen – by Nessler's methodology,

- nitrate nitrogen – by colorimetric method with phenoldisulphonic acid,
- total phosphorus – by colorimetric method,
- phosphorus and potassium (both accessible) – by Egner – Riehm's methodology,
- total potassium, calcium – by photometry analysis,
- total magnesium and heavy metals – by ASA methodology,
- pH in 1-n KCL – by potentiometric method.

Average plant samples for laboratory tests were taken during harvest. After drying at the temperature of 105°C and grinding, the collected samples were mineralized in a mixture of concentrated acids ($HClO_4$, $HNO_3$ and $H_2SO_4$). Determination of individual components was carried out applying the methodology used in agro-chemical stations. Total nitrogen and total phosphorus were determined by colorimetric method. ASA method was used to determine calcium, sodium, magnesium and microcomponents. Ash was determined by burning at the temperature of 550°C [10].

## IMPACT OF LONG TERM IRRIGATION WITH WASTEWATER ON SOIL

Wastewater treatment in soil-plant environment is a complicated process not even explained to the end. This process has been studied by many scientists [1–9,11] 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. In specific conditions, during the aerobic process course also nitrogen denitrification occurs. Amonification nitrogen in ammonia form is released to the atmosphere. A negative effect of nitrification is increased lability of nitrates, whereas in the case of denitrification the release of nitrogen to the atmosphere.

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

On the basis of data analysis it can be stated that within the soil layer of 0–30 cm depth irrigated with wastewater, an increase of nitrogen content and, in particular, potassium content, both total and accessible, was noted while the content of phosphorus was too small (Fig. 1, 2). Following the course of dynamics changes a significant improvement of soil pH and reduction of hydrolytic acidity resulting from magnesium lime addition to soils irrigated with yeast effluent every several years has been observed (Fig. 3).

The dynamics of changes in the abundance of the irrigated soil shows a continuous reduction of organic carbon and organic substance contents (Fig. 4). In 1997 soils irrigated with wastewater had smaller contents of organic carbon and substance in comparison to soils not irrigated with effluent. Contrary relations in arable layer were observed for nitrogen contents, whose volume in soils irrigated with wastewater increased in recent years. As a consequence an unfavorable decrease of organic carbon / nitrogen ratio (C : N) occurred as 4 : 7.

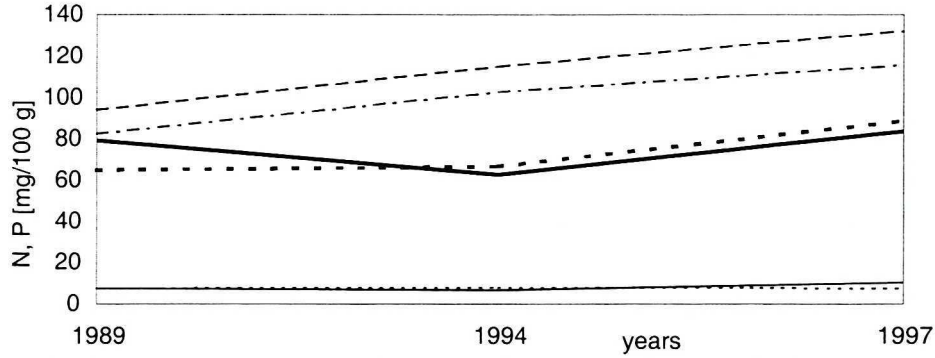


Fig. 1. Dynamics of the content of total nitrogen, total phosphorus and both accessible in arable layer of soils watered with wastewater from yeast production in comparison to non-watered soils

- Total nitrogen, watered fields
- Total nitrogen, non-watered fields
- Total phosphorus, watered fields
- Total phosphorus, non-watered fields
- Accessible phosphorus, watered fields
- Accessible phosphorus, non-watered fields

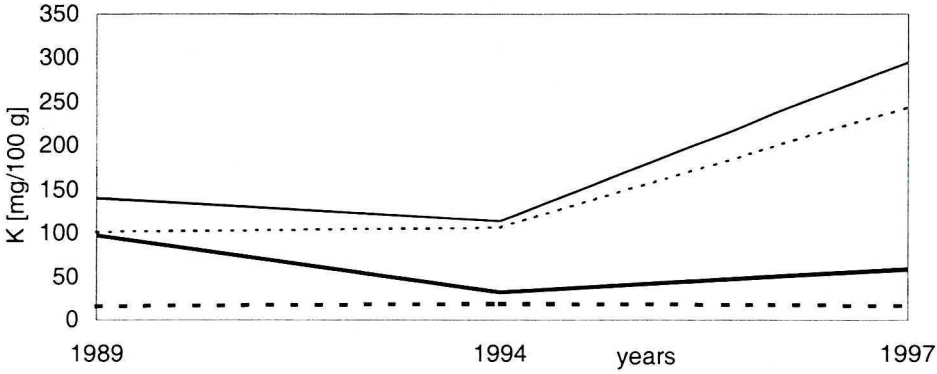


Fig. 2. Dynamics of the content of total and both accessible potassium in arable layer of soils watered with wastewater from yeast production in comparison to non-watered soils

- Total potassium, waterd fields
- Total potassium, non-waterd fields
- Accessible potassium, watered fields
- Accessible potassium, non-watered fields

Although the wastewater from yeast production contains significant volume of organic substance, its accumulation in soil irrigated with yeast effluent is very low. This fact proves that organic contaminants in the wastewater are mainly in soluble form. These are basically remains of molasses (i.e. sugars and amino-acids), yeast cells and products of their metabolic processes as well as protein compounds which easily undergo decomposition. Other reason for poor accumulation of organic substance in studied soils is most probably their liming which accelerates decomposition of organic substance and its mineralization.

Analysis of chemical composition showed migration of soluble compounds, especially potassium, calcium, magnesium and sodium in soil in soil profile.

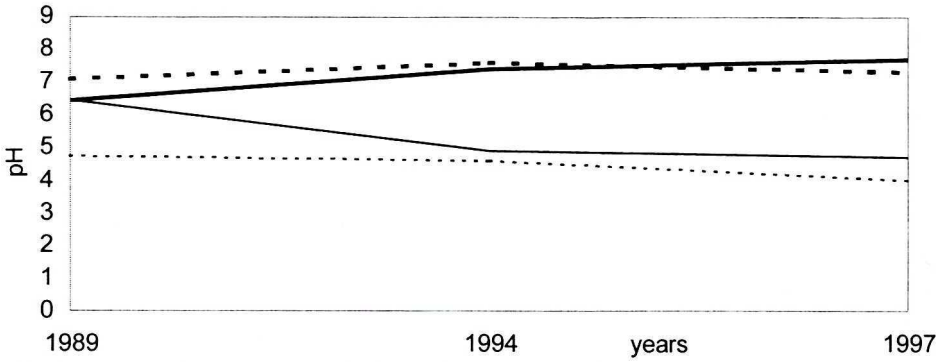


Fig. 3. Dynamics of pH changes in arable layer of soils watered with wastewater from yeast production in comparison to non-watered soils ( minimum and maximum values)

min pH, watered fields
min pH, non-watered fields
max pH, watered fields
max pH, non-watered fields

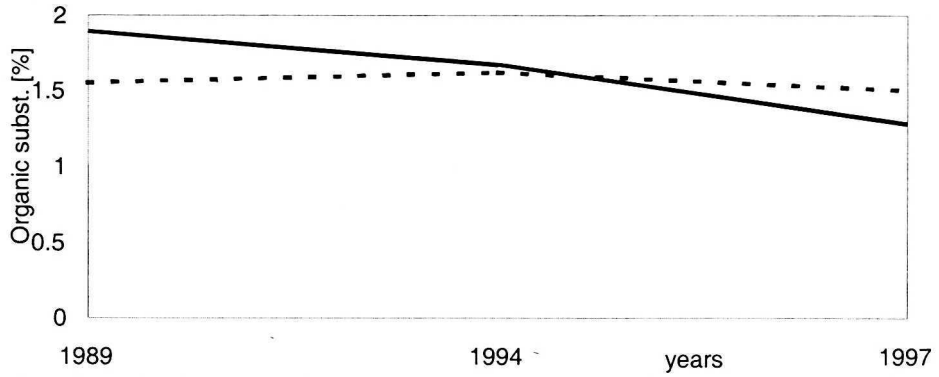


Fig. 4. Dynamics of the content of organic substance in arable layer of soils watered with wastewater from yeast production in comparison to non-watered soils.

Organic substance, watered fields
Organic substance, non-watered fields

Taking into account the abundance of the discussed soils it can be stated that nitrogen discharged with yeast effluent has a very positive effect supporting the maintenance of continuous soil fertility, provided that the content of organic carbon added to soil is increased.

Thus the up-to-date practice of straw and green remains ploughing should be continued.

The research data presented in Fig. 5 show that the contents of total metals determined in soils irrigated with wastewater as well as in adjacent to them soils not irrigated with effluent were low and close to the naturally occurring geochemical values.

## YIELDING OF CROP PLANTS UNDER THE IMPACT OF WASTEWATER IRRIGATION

In industrial – grain crops rotation applied in the fields used for agricultural utilization of wastewater carried out in the research years of 1993–1997, an increase of yields (average

for grain – by 13% and for root beet by 0.5 – 10.7%) was recorded. It was higher than in the case of yields produced on yeast production facility fields not irrigated with effluent and yields obtained by individual farmers from fields intensively treated only with mineral fertilizers (Fig. 6, 7).

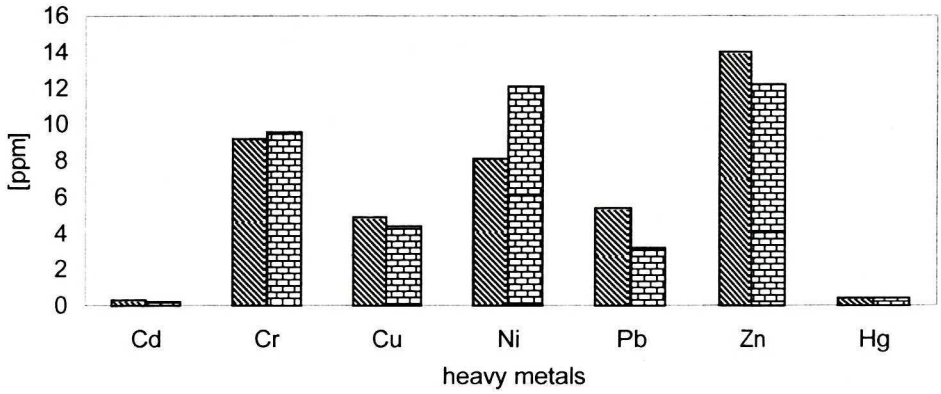


Fig. 5. Content of heavy metals Cd, Cr, Cu, Ni, Pb, Zn and Hg in arable layer of soils watered with wastewater from yeast production in comparison to non-watered soils

Watered fields

Non-watered fields

The produced yields prove appropriate cultivation of fields irrigated with wastewater from yeast production and accountancy data show that the marketed yield of crop plants covered the costs of farm operation and maintenance plus wastewater treatment costs.

## CHEMICAL COMPOSITION AND USE VALUE OF CROPS

Disturbances in plants nutrition resulting from intensive crops production can occur as a consequence of both redundancy and deficiency of one or several nutrients. Simultaneously with intensification of crops production through increase of fertilization some problems in plants nutrition can occur as a result of individual soil components equilibrium disturbance. The situation when not all nutrients are taken into a count in fertilization process despite its intensification results in the fact that the contents of nutrients available for crops in soil sorption complex are reduced. As a consequence the equilibrium of soil compounds changes what has a meaningful effect on the growth and yielding of crops and their quality.

In the process of nutrients uptake, plants use a mechanism, which allows them to selectively uptake compounds from the solum depending on plants' physiological needs. However, this principle of selection plays role mainly at low nutrients input. The higher the nutrients input in solum and the higher the domination of one compounds over the other, the weaker selectivity mechanism of the plants'. In this situation phenomena like antagonism (inhibition) and synergism (excitation) play an important role in the uptake and use of nutrients by plants. These correlations may lead to the redun-

dancy or deficiency of macro and microelements, e.g. excessive contents of potassium inhibit uptake of magnesium, calcium and sodium while redundancy of magnesium excites zinc uptake. In relation to the above at increased contents of potassium the share of calcium, magnesium, sodium and several other microelements in plants' dry mass decreases, whereas the concentration of chlorophyll and carotene increases. Redundancy of potassium delays the occurrence of larger volumes of amines, alkaloids and nitrosoamines, which are noted at more intensive nitrogen fertilization.

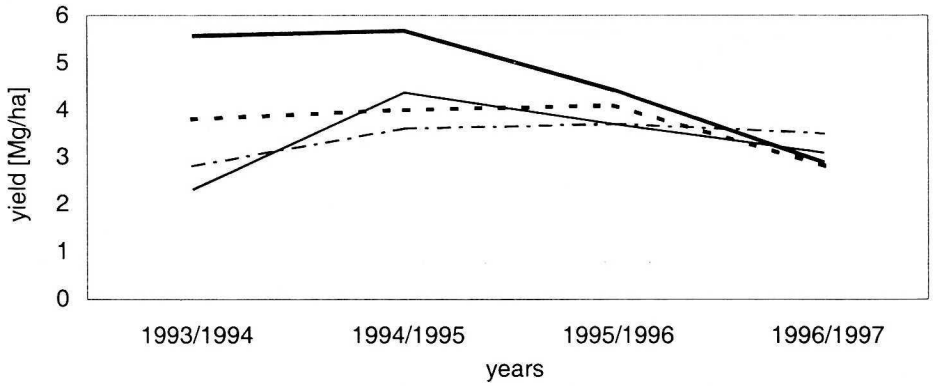


Fig. 6. Dynamics of yelding winter wheat and spring barley growing on fields watered with wastewater from yeast production in comparison to non-watered fields

Winter wheat, watered fields
Spring barley, watered fields
Winter wheat, non-watered fields
Spring barley, non-watered fields

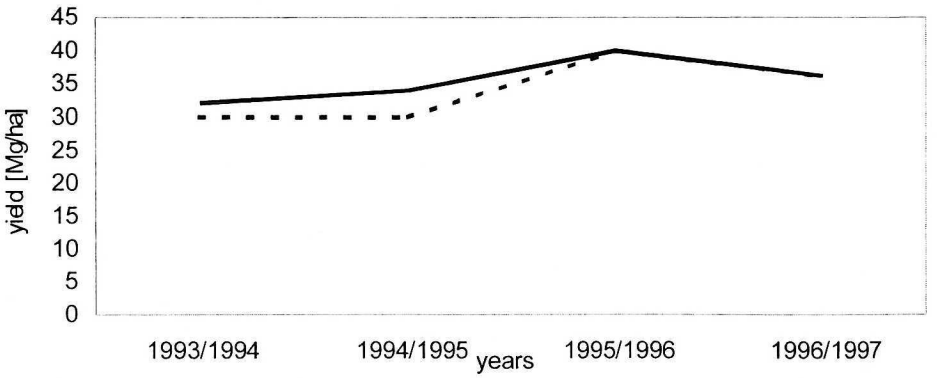


Fig. 7. Dynamics of yelding root beet growing on fields watered with wastewater from yeast production in comparison to non-watered fields

Root beet, watered fields
Root beet, non-watered fields

In comparison to the literature data, under the impact of irrigation with yeast effluent, the grain yields of winter wheat, spring barley and winter rape show slightly increased percentage contents of proteins, nitrogen, potassium, whereas the contents of calcium and magnesium were smaller (Fig. 8, 9 and table 1).

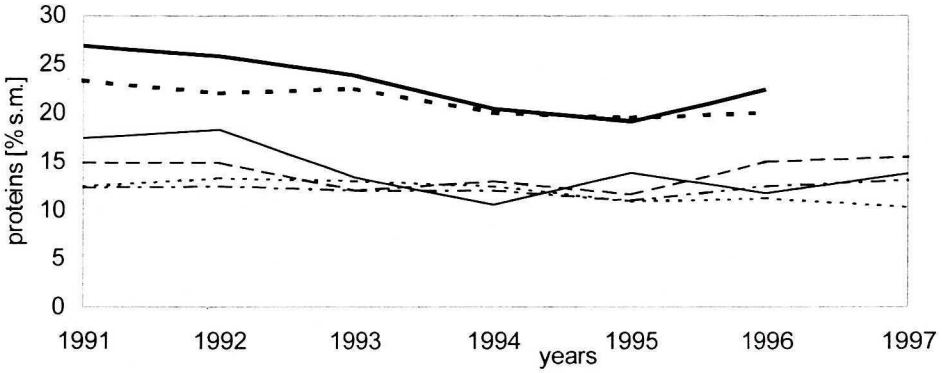


Fig. 8. Dynamics of the content of proteins in the grain of winter wheat, spring barley and winter rape growing on fields watered with wastewater from yeast production in comparison to non-watered fields

Grains of winter wheat, watered fields
Grains of winter wheat, non-watered fields
Grains of winter rape, watered fields
Grains of winter rape, non-watered fields
Grains of spring barley, watered fields
Grains of spring barley, non-watered fields

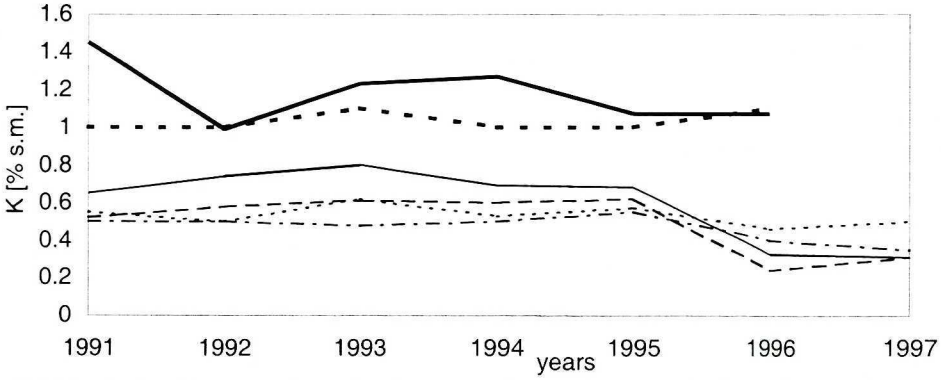


Fig. 9. Dynamics of the content of potassium in the grain of winter wheat, spring barley and in the seeds winter rape growing on fields watered with wastewater from yeast production in comparison to non-watered fields.

Grains of winter wheat, watered fields
Grains of winter wheat, non-watered fields
Grains of winter rape, watered fields
Grains of winter rape, non-watered fields
Grains of spring barley, watered fields
Grains of spring barley, non-watered fields

## CONCLUSIONS

1. Soils irrigated with process effluent from yeast factory show overfertilization with potassium. Also reduction of the organic carbon ratio to nitrogen is observed due to redundancy of potassium and deficit of organic carbon. Activities aimed at preventing reduction of organic substance consist in: straw, beet leaves and other solid organic waste ploughing.

Table 1. Chemical constitution of the grain and winter rape growing on fields watered with wastewater from yeast production

| Parameter | Winter wheat | | | Spring barley | | | Winter rape | | |
|---|---|---|---|---|---|---|---|---|---|
| % dry mass | from | to | average | from | to | average | from | to | average |
| Protein | 11.60 | 15.50 | 13.86 | 10.56 | 18.25 | 14.15 | 19.13 | 26.87 | 23.09 |
| Nitrogen total | 1.70 | 2.61 | 2.14 | 2.15 | 2.61 | 2.33 | 3.05 | 3.82 | 3.54 |
| Potassium - K | 0.20 | 0.51 | 0.41 | 0.26 | 0.68 | 0.51 | 0.82 | 1.20 | 0.88 |
| Calcium - Ca | 0.05 | 0.13 | 0.09 | 0.04 | 0.12 | 0.07 | 0.29 | 0.47 | 0.37 |
| Magnesium - Mg | 0.06 | 0.14 | 0.11 | 0.09 | 0.17 | 0.15 | 0.17 | 0.28 | 0.25 |

2. Diversified contents of phosphorus and potassium in total and available forms were observed in soil samples. Plant crop demand for phosphorus, especially available, was met even in excess at all fields watered with wastewater from yield production. Only need for a minimum additional fertilization with phosphorus amendments was noted.
3. Conducted experiments show that a significant improvement of soil reaction occurred as a result of magnesium lime addition (once every 3 – 4 years) to soils watered with wastewater from yeast production.
4. For irrigation with yeast effluent plant species of increased nitrogen and potassium demand are preferable. Root beet, rape and barley yields produced on the fields irrigated with wastewater from yeast factory in Wołczyn without application of mineral fertilizers are 1 – 13% higher than in the case of control fields fertilized only with mineral fertilizers.
5. Under the impact of irrigation with yeast effluent, the grain yields of winter wheat, spring barley and winter rape show slightly increased percentage contents of proteins, nitrogen, potassium, whereas the contents of calcium and magnesium were smaller.

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