J. Elementol. 2009, 14(1): 5-12

CONTENT OF COMPONENTS IN SOME GRASS SPECIES IRRIGATED WITH PURIFIED SEWAGE

Ryszard Baryła[1], Jolanta Sawicka[2], Mariusz Kulik[1], Halina Lipińska[1]

[1]Department of Grassland and Landscape Forming
University of Life Sciences in Lublin
[2]District Chemistry-Agriculture Station in Lublin

Abstract

Soil is a unique laboratory of transformations and energy flow, and in particular of biological sorption and synthesis of mineral components that can originate from various sources. The introduction of biomass or sewage into soil contributes to its nutrient enrichment. This can lead to periodical excess of these elements in soil and cause their migration from the soil system to underground waters, and eventually to open waters. Grass communities belong to a group of plants that make excellent use of nutrients present in soil and perform a very important role in additional purification of sewage after its mechanical purification. Grasses demonstrate resistance to the presence of large quantities of harmful compounds in sewage; they accumulate and neutralise them physiologically, thus preventing their dissemination.

The aim of this paper was to evaluate content of some macro- and microelements as well as heavy metals in chosen grass species irrigated with purified sewage. In 1997--2000, research was conducted near the Hajdów Sewage Works, using purified sewage for irrigation of grass communities. Three rates of irrigation (a – control without irrigation; b – irrigation in quantity 600 mm and c – irrigation in quantity 1200 mm) as well as two grass mixtures were tested. Content of basic macroelements (N, P, K, Ca, Mg), microelements (Cu, Zn, Mn) as well as heavy metals (Cd, Pb) in dominant grass species (*Alopecurus pratensis*, *Phalaris arundinacea*, *Festuca arundinacea*, *Festuca pratensis* and *Phleum pratense*) were determined. The content of the analyzed components in biomass was varied and depended on the grass species in the analyzing mixtures as well as on the applied rates of irrigation. *Festuca pratensis* and *Festuca arundinacea* were characterized by the largest capacity to take up calcium (Ca) and magnesium (Mg), *Phalaris arundinacea* – phosphorus (P) and zinc (Zn), while *Alopecurus pratensis* – cadmium (Cd) and lead (Pb). Biomass of *Alopecurus pratensis* was characterized by the lowest content of most of the ele-

prof. dr hab. Ryszard Baryła, Department of Grassland and Landscape Forming, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland, e-mail: mariusz.kulik@up.lublin.pl

ments, especially nitrogen, phosphorus, calcium and magnesium. The applied irrigation, especially the 1200 mm rate significantly increased potassium content and decreased manganese content in biomass of the analyzed grass species. The most useful grass species used to establish meadows irrigated with sewage are *Phalaris arundinacea*, *Festuca arundinacea* and *Festuca pratensis*.

Keywords: macro- and microelements, heavy metals, irrigation, purified sewage.

ZAWARTOŚĆ SKŁADNIKÓW W WYBRANYCH GATUNKACH TRAW NAWADNIANYCH ŚCIEKAMI OCZYSZCZONYMI

Abstrakt

Gleba jest specyficznym laboratorium przemian i przepływu energii, zwłaszcza biologicznej sorpcji i syntezy składników mineralnych, które mogą pochodzić z różnych źródeł. Wprowadzenie do gleby biomasy lub ścieków powoduje jej wzbogacenie w składniki pokarmowe. Może to być przyczyną okresowego nadmiaru tych pierwiastków w glebie i powodować ich przemieszczanie poza układ glebowy – do wód gruntowych, a w końcowym etapie do wód otwartych. Do grupy roślin doskonale wykorzystujących składniki pokarmowe z gleby oraz spełniających ważną rolę w doczyszczaniu ścieków po mechanicznym ich oczyszczeniu należą zbiorowiska trawiaste. Trawy wykazują odporność na obecność w ściekach dużych ilości związków szkodliwych, kumulują je i neutralizują na drodze fizjologicznej, zapobiegając ich rozprzestrzenianiu.

Celem badań była ocena zawartości niektórych makro- i mikroskładników oraz metali ciężkich w wybranych gatunkach traw nawadnianych ściekami oczyszczonymi. W latach 1997-2000 prowadzono badania z wykorzystaniem wód pościekowych (ścieków po mechaniczno-biologicznym oczyszczeniu) z oczyszczalni ścieków miasta Lublina do nawadniania zbiorowisk trawiastych. W badaniach uwzględniono 3 dawki nawodnień (a – kontrola bez nawadniania; b – nawodnienie w ilości 600 mm, c – nawodnienie w ilości 1200 mm) oraz dwie mieszanki trawiaste. Dominujące gatunki w runi (*Alopecurus pratensis*, *Phalaris arundinacea*, *Festuca arundinacea*, *Festuca pratensis* i *Phleum pratense*) poddano analizom chemicznym na zawartość podstawowych makroelementów (N, P, K, Ca, Mg), mikroelementów (Cu, Zn, Mn) oraz metali ciężkich (Cd, Pb). Zawartość makro- i mikroelementów oraz metali ciężkich w biomasie była zróżnicowana w zależności od gatunków w analizowanych mieszankach oraz stosowanych nawodnień. Największą zdolność do pobierania wapnia i magnezu miały *Festuca pratensis* i *Festuca arundinacea*, fosforu i cynku – *Phalaris arundinacea*, a kadmu i ołowiu – *Alopecurus pratensis*. Najniższą zawartość większości oznaczonych pierwiastków, zwłaszcza azotu, fosforu, wapnia i magnezu, stwierdzono w biomasie *Alopecurus pratensis*. Stosowane nawadniania, głównie dawka 1200 mm, wpłynęły istotnie na wzrost zawartości potasu oraz obniżenie zawartości manganu w biomasie analizowanych gatunków. Gatunkami najbardziej przydatnymi do mieszanek łąkowych nawadnianych ściekami oczyszczonymi są *Phalaris arundinacea*, *Festuca arundinacea* i *Festuca pratensis*.

Słowa kluczowe: makro- i mikroelementy, metale ciężkie, nawadnianie, ścieki oczyszczone.

INTRODUCTION

Soil is a specific laboratory of mineral components, which comes from different sources, including sewage. Introduction of biomass or sewage into soil causes its enrichment in nutrients. This may be the cause of periodic excess of these elements in soil and cause their migration outside the soil system – to groundwater and eventually to open waters (Baryła 2005, Klasa et al. 2007). Therefore, it may be necessary to grow plants of high production potential combined with high demand for water and nutrients. Grass communities belong to a group of plants that make excellent use of nutrients present in soil and perform a very important role in additional purification of sewage following its mechanical purification. Grasses demonstrate resistance to the presence of large quantities of harmful compounds in sewage; they accumulate and neutralise them physiologically, thus preventing their dissemination. The most frequent grasses in plant communities irrigated with sewage are species from humid (*Phalaris arundinacea, Alopecurus pratensis*) and moderately humid habitats (*Phleum pratense Festuca pratensis, Festuca arundinacea, Poa pratensis*). Grass species sown on land irrigated with sewage should be selected in terms of their habitat requirements and the ability to use of nutrients.

The aim of this paper has been to evaluate content of some macro- and microelements as well as heavy metals in several grass species irrigated with purified sewage.

MATERIAL AND METHODS

In 1997-2000, a study was conducted in the Bystrzyca River valley, near the Hajdów Sewage Works, in which purified sewage from Lublin was used to irrigate grass communities. The study included three rates of irrigation (a – control without irrigation; b – irrigation with 600 mm and c – irrigation with 1200 mm) as well as two grass mixtures, which were sown in summer 1996. The experiment was carried out on mineral-muck soil of neutral reaction (pH 7.1-7.2) and low content of macronutrients. Water used for irrigation was characterized by the following content of components: N – 35.5, P – 7.44; K – 30.0; Ca – 77.5; Mg – 14,0; Na – 48.3 $g \cdot m^{-3}$ and Cd – 7.23; Pb – 19,8; Cu – 21,6; Zn – 118.0 $mg \cdot m^{-3}$. Meadow sward was mowed 3 times during the growing season. Species composition of the grass mixtures, especially in the irrigated area, changed systematically. However, *Alopecurus pratensis*, *Phalaris arundinacea* and *Festuca arundinacea* were dominant species in the sward of mixture A, whereas *Alopecurus pratensis*, *Festuca pratensis* and *Phleum pratense* prevailed in mixture B (Baryła 2005). The con-

tent of basic macroelements (N, P, K, Ca, Mg), microelements (Cu, Zn, Mn) as well as heavy metals (Cd, Pb) in the dominant species was determined. Chemical analysis of plant material performed in an accredited laboratory of the District Chemistry-Agriculture Station in Lublin, according to the Poland Norm or standard procedure. The results were put to statistical analysis of variance with Tukey's test.

RESULTS AND DISCUSSION

The analyzed species of grasses were characterized by diverse content of the elements. The actual amounts of the elements determined in grasses were shaped by the biological properties of particular species, irrigation rates as well as species composition of sown grass mixtures.

Macroelements. The analyzed grass species considerably differed in their ability to accumulate most of the marked macroelements in the particular mixtures (Figure 1). *Alopecurus pratensis* had the smallest ability to take up components from soil, especially in communities with *Festuca arundinacea* and *Phalaris arundinacea*, which have a very strongly developed radicular system. In communities with these species, *A. pratensis* showed the significantly lowest content of macronutrients, with the exception of potassium. FALKOWSKI et al. (1991) report that the biomass of *A. pratensis* was characterized by low magnesium content. Moreover, these authors classify these species as nitrophilous grasses, an observation which is not confirmed by the present study. By contrast, in communities with *Festuca pratensis* and *Phleum pratense*, these species were only characterized by the significantly lowest content of calcium and significantly lower content of magnesium in relation to *F. pratensis*. It should be added that the significantly highest content of calcium and magnesium was found in the species of *Festuca* genus and that of phosphorus –in the biomass of *Phalaris arundinacea*. These results coincide with the data reported by WALCZYNA et al. (1975) and Falkowski et al. (1991), who classify *F. pratensis* and *F. arundinacea* as belonging to grasses with a high capacity for calcium accumulation. According to KOCHANOWSKA (1981), *Phleum pratense* is characterized by low magnesium content, which is confirmed by the present study. Biomass of *P. pratense* is also characterized by a low potassium content (WALCZYNA et al. 1975, BARYŁA 1992), which is not verified by the research does not conducted by FALKOWSKI et al. (1991).

The irrigation applied in our study also contributed to variations in the content of particular elements. Introduction of large quantities of macroelements with sewage waters to the soil environment resulted in increase or reduction of these ingredients in the biomass of the analyzed species. The irrigation caused a significant increase of potassium in all the grass species,

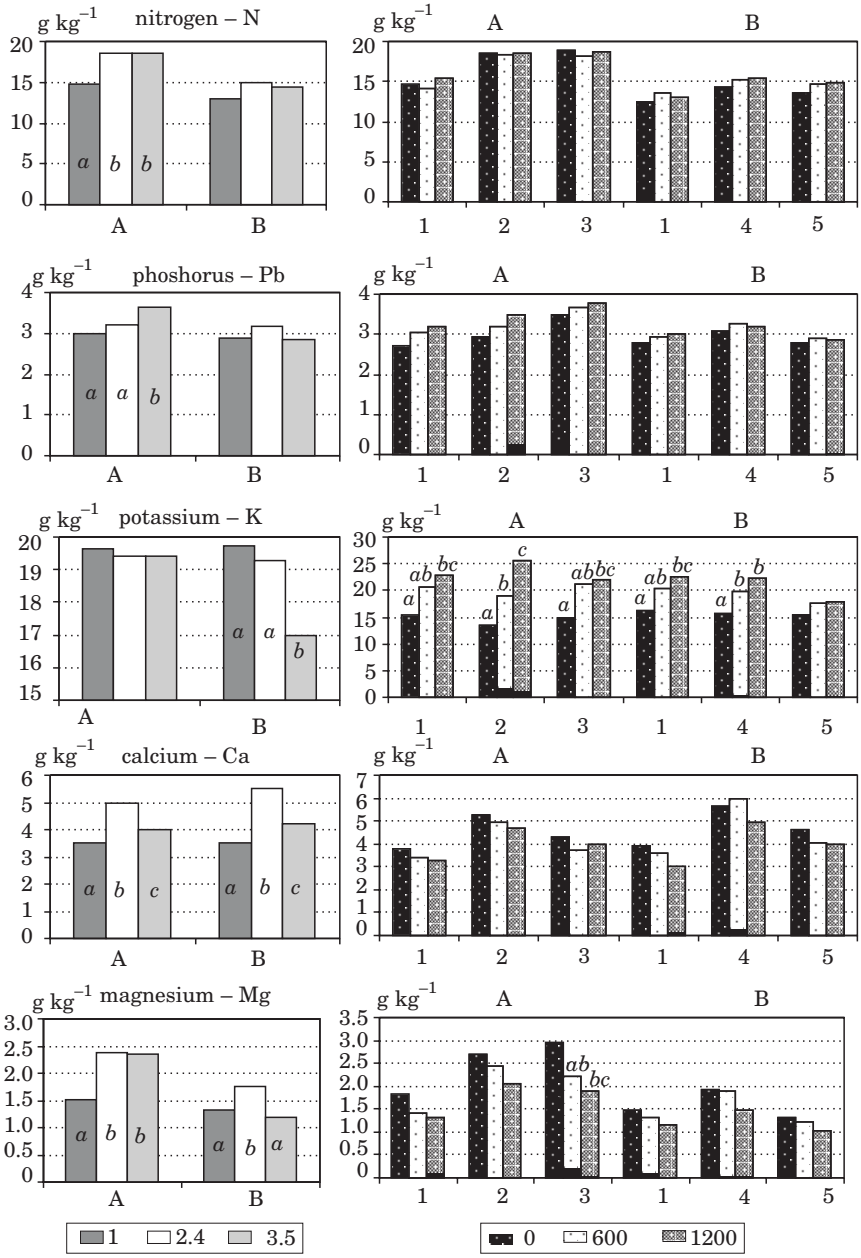

Fig. 1. Mean content of macroelements in some grass species depending on irrigation rate (mean of 4 years): A – mixture: 1 – *Alopecurus pratensis*, 2 – *Festuca arundinacea,* 3 – *Phalaris arundinacea*, B – mixture: 1 – *Alopecurus pratensis*, 4 – *Festuca pratensis*, 5 – *Phleum pratense*, irrigation rates: 0, 600 mm, 1200 mm

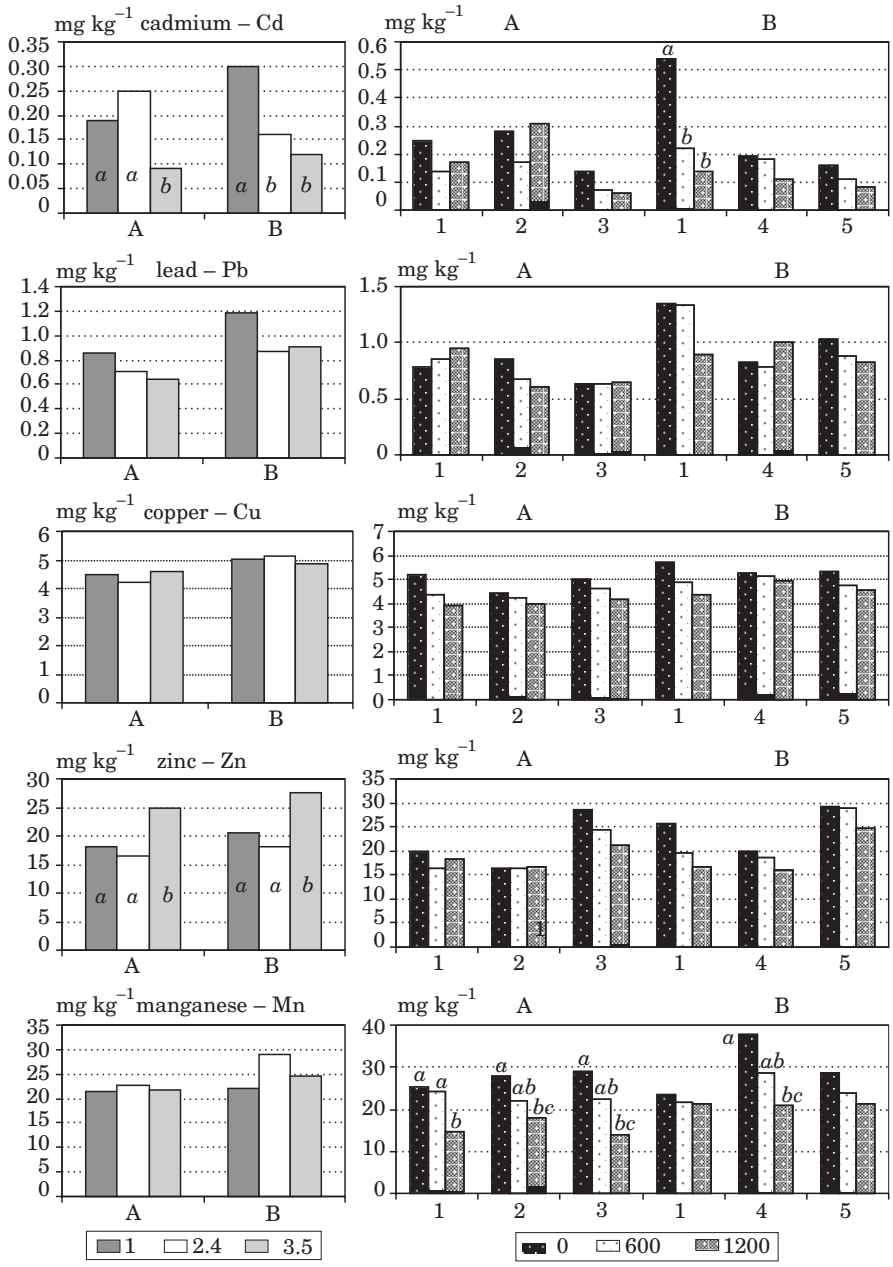

Fig. 2. Mean content of heavy metals and microelements in some grass species depending on irrigation rate (mean of 4 years). Explanations like in Fig. 1

with the exception of *Phleum pratense*. Similar correlation was observed for the content of nitrogen and phosphorus, but it was not statistically proven. In contrast, the irrigation resulted in a decrease of calcium and magnesium in the tested species, but significant differences were recorded only in the content of magnesium in the *Phalaris arundinacea* biomass. The higher irrigation rate (1200 mm) caused a significantly lower Mg content in the biomass of this species in relation to the control object (Figure 1).

Heavy metals and microelements. The biomass of the analyzed grass species was characterized by less diversity in the content of heavy metals and microelements. A relatively high content of heavy metals (cadmium and lead) was determined in *Alopecurus pratensis*. This species in the communities with *Festuca pratensis* and *Phleum pratense* had the significantly highest concentration of Cd. This is in accord with the results reported by BARYŁA and HARKOT (1997). However, our attention turned to the significantly lowest content of cadmium in *Phalaris arundinacea, F. pratensis* and *P. pratense* (Figure 2). The irrigation generally decreased the content of heavy metals in the biomass of the analyzed species, but it was only in the case of *A. pratensis* biomass in mixture B that the differences were proven statistically. According to STĘPNIEWSKA et al. (2001) irrigation with sewage waters leads to a lower concentration of heavy metals in the biomass and radicular system of grasses due to higher yields obtained under such conditions.

The content of microelements in the tested species was less variable, with the differences being statistically significant only for the content of zinc. The biomass of *Phalaris arundinacea* in mixture of A and *Phleum pratense* in mixture of B was characterized by the significantly highest content of this element (Figure 2). In a study by WALCZYNA et al. (1975), no significant modifications in the content of zinc were observed. However, the irrigation applied in our study generally decreased the content of microelements in the biomass of the analyzed species, although statistically proven modifications concerned only the content of manganese. The biomass of the analyzed grass species (with the exception of *Alopecurus pratensis* and *Phleum pratense* in mixture B) contained significantly less Mn, versus the control, when grasses were irrigated with the higher rate of sewage (1.200 mm) – Figure 2. In contrast, differences in the content of copper and zinc in the biomass of the grass species as correlated with the irrigation rates were within the limits of statistical error.

CONCLUSIONS

1. The content of macro- and microelements as well as heavy metals in the biomass was varied depending on the species and applied irrigation.

2. *Festuca pratensis* and *Festuca arundinacea* were characterized by the highest calcium and magnesium content, *Phalaris arundinacea* – by the highest phosphorus and zinc content, whereas *Alopecurus pratensis* – by the highest cadmium and lead content.

3. Biomass of *Alopecurus pratensis* had the lowest content of most of the analyzed elements, especially nitrogen, phosphorus, calcium and magnesium.

4. Adequate irrigation, mainly 1.200 mm, had a significant influence on the increase of potassium and decrease of manganese in the biomass of the tested grass species. It also caused decreased magnesium content in *Phalaris arundinacea* and cadmium content in *Alopecurus pratensis*.

5. *Phalaris arundinacea, Festuca arundinacea* and *Festuca pratensis* proved to be the most useful species in meadow mixtures sown on land irrigated with purified sewage.

REFERENCES

Baryła R. 1992. *Zawartość niektórych pierwiastków w wybranych gatunkach roślin łąkowych w zależności od zróżnicowanego nawożenia azotem*. Wiad. IMUZ, 17 (2): 309-323.

Baryła R. 2005. *Ocena przydatności oczyszczonych ścieków do nawadniania zbiorowisk trawiastych*. Ann. UMCS, sect. E, 40: 123-132.

Baryła R., Harkot W. 1997. *Zawartość kadmu w niektórych gatunkach traw nawadnianych oczyszczonymi ściekami miejskimi*. Zesz. Probl. Post. Nauk Rol., 448: 29-34.

Falkowski M., Kukułka I., Kozłowski S. 1991. *Właściwości chemiczne roślin łąkowych*. Wyd. AR Poznań, ss. 111.

Klasa A., Gotkiewicz W., Czapla J. 2007. *Modifications of physico-chemical soil properties following application of sewage sludge as soil amendment*. J. Elementol., 12 (4): 287-302.

Kochanowska R. 1981. *Dynamika rozwoju i plonowania oraz skład chemiczny niektórych gatunków traw w różnych warunkach siedliskowych*. Rocz. AR Poznań, ss. 115.

Stępniewska Z., Baryła R., Kotowska U., Kupczyk J. 2001. *Pobieranie metali ciężkich przez biomasę zbiorowisk trawiastych w warunkach zróżnicowanego nawadniania gleby ściekami po III oczyszczania*. Acta Agrophysica, 57: 113-118.

Walczyna J., Sapek A., Kuczyńska I., Smyjewski K., Sapek B. 1975. *Zawartość składników mineralnych w ważniejszych trawach i innych roślinach łąkowych z gleb torfowych*. Zesz. Probl. Post. Nauk Rol., 175: 75-83.