ACTA BIOLOGICA CRACOVIENSIA *Series Zoologia* 53: 75–80, 2011

THE TRANSFER OF MACROELEMENTS IN RENATURALIZED ECOSYSTEMS

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Accepted September 12, 2011

An attempt was made to determine the role of rodents in the transmission of macroelements: calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), and sodium (Na) in reclaimed areas. The contents of these elements were determined in a group of common voles (*Microtus arvalis*) recognized as an indicator species in all the study areas. The levels of macroelements were determined in: plants growing on the experimental plots, the stomach content of rodents, whole bodies of rodents, and in their bones. The studies were carried out at the following sites: limestone quarry at Mydlniki, post-production waste sedimentation ponds of the former Cracow Soda Factory, and ash dumps of the Cracow Combined Heat and Power Plant. It has been shown that rodents living in post-industrial areas do not show any tendency to accumulate the macroelements present in the substrates in excessive quantities and that they are not a link for the transmission of these elements through the food chain.

Key words: *Microtus arvalis*, macroelements, transfer, accumulation, post-industrial areas

INTRODUCTION

The incessant development of industry brings about progressive devastation of the human environment. Degraded areas termed as soil-less, non-productive post-industrial wastelands are a permanent and ever expanding part of the industrial landscape. In the zones where the impact of extractive and processing industries has been most intense, we have to deal with a particular form of wasteland, as by-products produced by technological processes represent a burdensome problem claiming extensive areas for waste disposal.

The greatest clusters of degraded and threatened areas in Poland are concentrated in its southern and south-western zones (MACIAK, 1999). At present, the reclamation of such sites is aimed at complete or partial restitution of the area to what it was prior to the devastation and involves chiefly restoration of the vegetation cover with its protective, landscape, and ecological functions.

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PL ISSN 0001-530X

Despite the use of the most up-to-date reclamation measures it is impossible to eliminate the effects of these transformed environments on living organisms which inhabit them. In the areas modified by human activities, the natural macroelement levels in the soil and other components of the ecosystems have been changed. The macroelements in the bodies of plants and animals ensure their proper functions, although any excess may disturb their physiological processes.

The areas subject to revitalization do offer attractive habitats to plants and animals in search of vacant niches which they will colonize over time. Rodents, owing to their low level of specialization and huge adaptation potential are one of the colonizing pioneers in such areas. Their activity supports soil-formation processes, and an analysis of the macroelement contents of their bodies makes it possible to track a fragment of the macroelement cycle in renaturalized ecosystems.

MATERIAL AND METHODS

The study areas were situated in three separate sites degraded either by extraction or by post-industrial waste disposal.

1. The Limestone Quarry at Mydlniki

Two different biotopes can be distinguished within the perimeter of the abandoned limestone quarry at Mydlniki. The first has the form of a ca. 7-hectare basin created by the extraction of limestone. It has predominantly shallow, sandy soil, overgrown with ruderal and calciphilic vegetation. The second includes the upper portions of the quarry, ca. 40 hectares with characteristic brown rendzina (limestone) soil and typical calciphilic and xerothermic vegetation.

Within the Mydlniki quarry, two transects were set out in different habitat areas: I-was laid out in the aforementioned basin of the quarry, with a low-diversity plant community;

II-was laid out in the upper part of the quarry, on limestone rocks, with a compact highly-diversified plant cover.

2. The Post-production Sediment Disposal Area of the former Cracow Soda Factory (Krakowskie Zakłady Sodowe)

The Cracow Soda Factory (Solvay) which produced soda ash, caustic soda and sal soda was closed at the end of the 1980s because of the harm it caused to the environment. After operating for many years, almost 5 million metric tonnes of post-production waste accumulated in settling ponds near the plant were left behind (chiefly calcium chloride ($CaCl_2$) and calcium carbonate ($CaCO_3$)) (Proceedings Of The IIIrd Sozology [Enviromental Protection and Management] Conference, 1993).

Three transects were set out on the reclaimed sedimentation ponds of the former Cracow Soda Factory:

I-covers the area of the youngest sedimentation ponds, reclaimed in the years 1984-1994, overgrown with abundant and dense vegetation;

II-was laid down in the area of the older sedimentation ponds, where artificial experimental planting was applied in the 1970s. This transect was overgrown with very dense and compact vegetation;

III-study area situated on the youngest sedimentation ponds reclaimed in the years 1984-1994, of a typical steppe character, with not very dense but diverse vegetation.

3. The Ash Heap of the Cracow Combined Heat and Power Plant (Elektrociepłownia Kraków S.A.-Niwa)

The Cracow Combined Heat and Power Plant, which is situated in the eastern part of Cracow, fires hard coal which affects the environment through the release of combustion products. Until recently, up to 70% of combustion waste, in the form of ash and slag, were utilized to produce building materials, with the remaining 30% directed to a waste dump at Mogiła-Niwa that had been in operation since 1971. At present, the Cracow Heat and Power Plant not only uses the ash and slag from its current operations, but also eliminates the ash previously deposited on the dump (Www.Eckrakow.Pl). At the time of this study on the dump site, there were two heaps, namely: the older pile, covering an area of 8 hectares and mothballed since 1986, and the current heap, covering 12 hectares. In 1991 the Heat and Power Plant started reclamation work on the older heap (Kraków Heat and Power Plant-Report, 1997).

Two transects were set out on the reclaimed heaps of combustion waste at Mogiła-Niwa:

I-included the area of the current ash dump, in the direction of the reclaimed part;

II-was laid out through densely overgrown escarpments on the reclaimed heap.

The levels of calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), and sodium (Na) were determined in a selected group of common voles (*Microtus arvalis*) as a common species living in all the study areas. The rodents were captured in the years 1999-2001 in the autumn and spring seasons (four research cycles in total). The standard method of trap lines (ANDRZEJEWSKI *et al.* 1966; BOBEK and KOZŁOWSKI, 1987) was applied for this purpose. The macroelement content was determined in the underground and above-ground parts of plants growing in the reclaimed areas, in the stomach content of voles, and in the entire bodies and bones of voles. The vegetation was sampled in order to ensure representation of the majority of plant species in a given study area. The determination of macroelements in the raw ash was completed using nuclear spectroscopy. The parametric Student t-test was utilized to compare the mean values of the element levels in the bodies of voles in relation to the particular study area which the animals inhabited.

RESULTS AND DISCUSSION

The studies of the Ca content in the vegetation colonizing the study areas demonstrated variable levels of this element (Fig. 1). The highest level was noted at the Solvay site (21.54 mg/g wet weight), whereas the lowest-at Niwa (9.51 mg/g wet weight). These levels do not affect, however, the quantities of these elements in the whole bodies and bones of *Microtus arvalis*. LIETH (1999) reported that the average Ca content of plants ranged from 0.4 to15 mg/g, and therefore only the values found at the Solvay site exceeded the range given by this author. Calcium metabolism is of essential importance because it affects not only the growth of rodents, but their reproduction as well (GAREL, 1987; NORDIN, 1986).

Phosphorus was present chiefly in bones and there was little variability in the quantities of this element found at individual sites, as it ranged from 104.74 mg/g wet weight (Mydlniki quarry) to 120.71 mg/g wet weight (Niwa) (Fig. 2).

The analysis of the magnesium content of plants showed differences between the three sites compared (Fig. 3). The highest quantity was noted at the Niwa site (2.14 mg/g wet weight), whereas the lowest-at Solvay (1.63 mg/g wet weight), while the standard values for the content of this element in plants range from 0.7 to 9 mg/g (LIETH, 1999). It is thought that Mg and P metabolism depends on calcium metabolism (ROBERTSON, 1976). The results obtained in this study confirm this as they are in agreement with the observations of MAŁECKI (1997), according to whom the high Ca ion content blocks the assimilability of P and Mg by plants. Considering the stomach contents or the bodies, no major differences between the sites were observed.

Potassium, being one of the main constituents of all cells, participates in the maintenance of osmotic pressure and hydrogen ion concentration. In the course of this study it was not detected in bones (Fig. 4). Its quantities in plants were, however, considerably diversified (from 10.51 mg/g wet weight at the Solvay site to 20 mg/g wet weight at

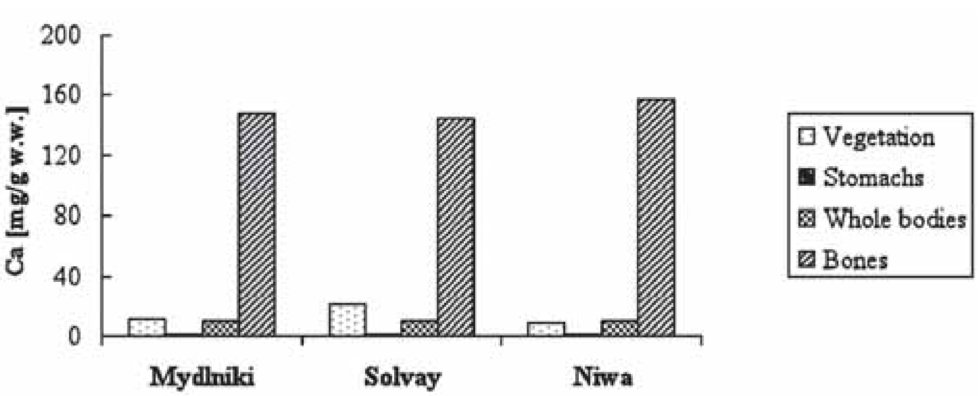

Fig. 1. Mean concentrations of calcium in the vegetation overgrowing reclaimed areas, as well as in the stomachs, whole bodies and bones of common voles (*Microtus arvalis*).

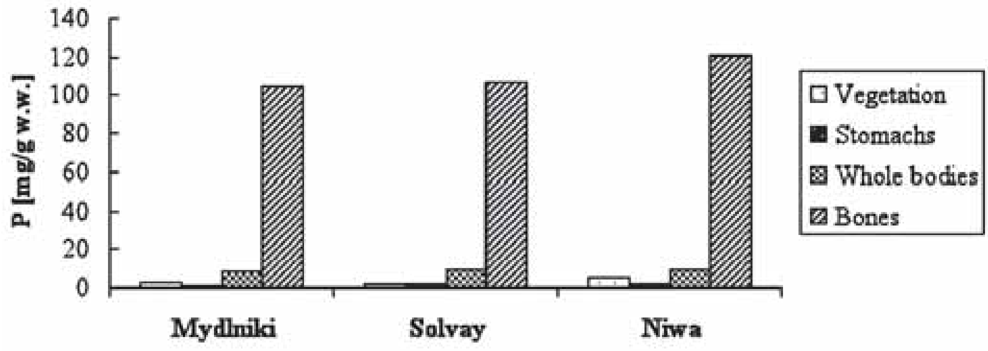

Fig. 2. Mean concentrations of phosphorus in the vegetation overgrowing reclaimed areas, as well as in the stomachs, whole bodies and bones of common voles (*Microtus arvalis*).

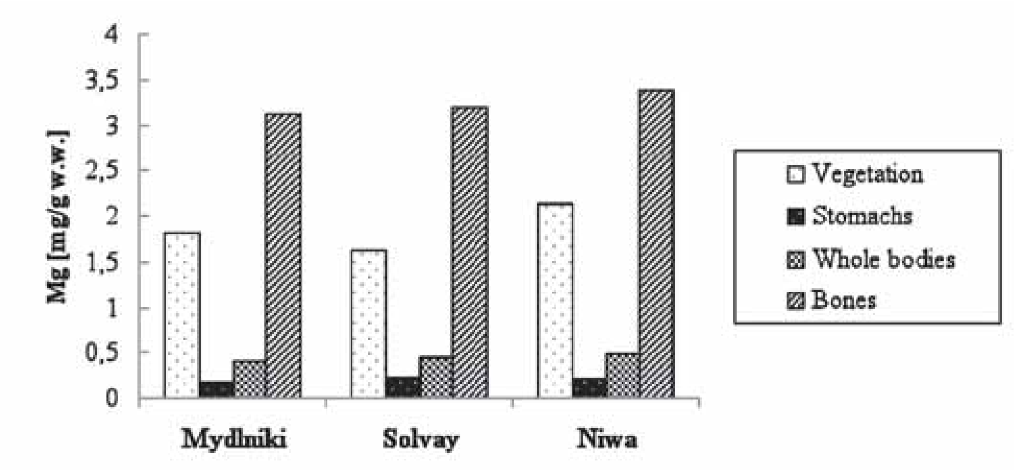

Fig. 3. Mean concentrations of magnesium in the vegetation overgrowing reclaimed areas, as well as in the stomachs, whole bodies and bones of common voles (*Microtus arvalis*).

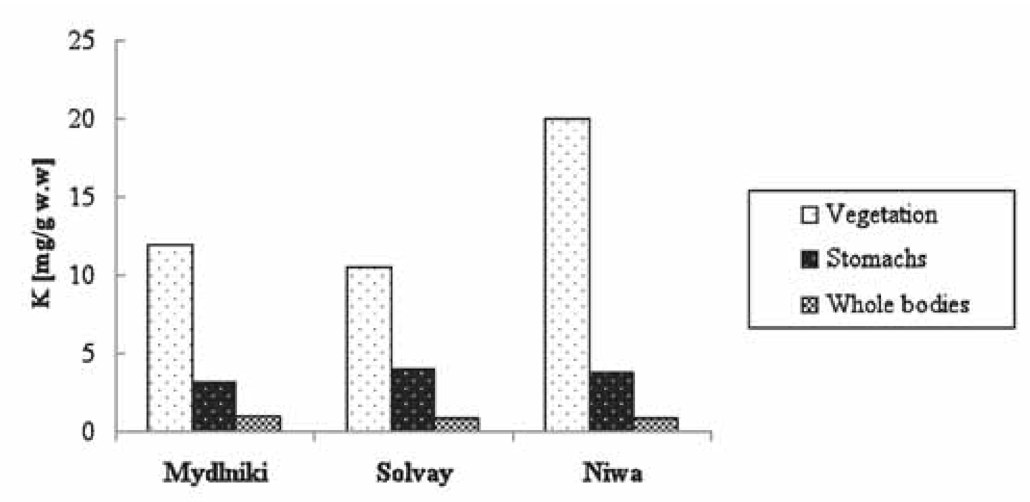

Fig. 4. Mean concentrations of potassium in the vegetation overgrowing reclaimed areas, as well as in the stomachs and whole bodies of common voles (*Microtus arvalis*).

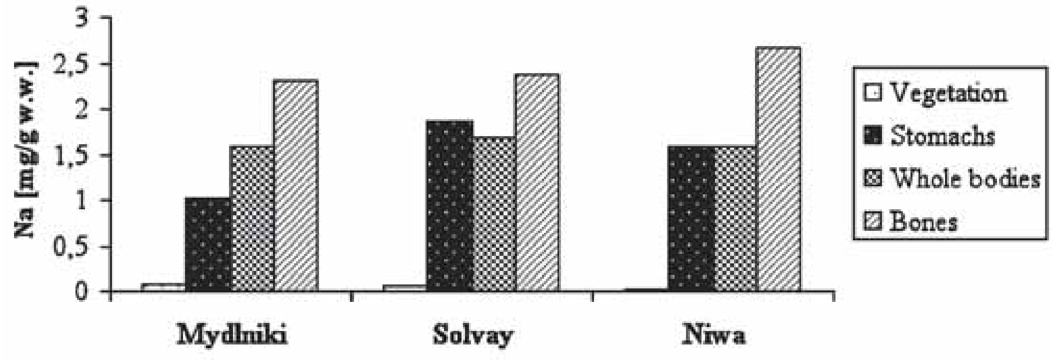

Fig. 5. Mean concentrations of sodium in the vegetation overgrowing reclaimed areas, as well as in the stomachs, whole bodies and bones of common voles (*Microtus arvalis*).

TABLE 1. Comparisons between the mean contents of various elements in the bodies of common voles (*Microtus arvalis*), in relation to individual study areas (differences are statistically significant at p<0.05 according to Student's t-test).

	Study areas		Niwa	Mydlniki
Ca	**Solvay** n= 10	x= 10.029 SD= 1.261	t= -0.170 p= 0.868	t= 0.989 p= 0.348
	Niwa n= 10	x= 10.138 SD= 1.351	/ /	t= 0.789 p= 0.449
	Mydlniki n= 10	x= 9.645 SD= 0.998	/ /	/ /
Mg	**Solvay** n= 10	x= 0.456 SD= 0.062	t= -1.933 p= 0.085	t= 2.818 p= 0.020
	Niwa n= 10	x= 0.49 SD= 0.050	/ /	t= 3.773 p= 0.004
	Mydlniki n= 10	x= 0.418 SD= 0.074	/ /	/ /
Na	**Solvay** n= 10	x= 1.699 SD= 0.178	t= 1.688 p= 0.125	t= 2.063 p= 0.069
	Niwa n= 10	x= 1.596 SD= 0.122	/ /	t= 0.422 p= 0.682
	Mydlniki n= 10	x= 1.584 SD= 0.079	/ /	/ /
K	**Solvay** n= 10	x= 0.879 SD= 0.410	t= 0.025 p= 0.980	t= - 1.221 p= 0.25
	Niwa n= 10	x= 0.875 SD= 0.510	/ /	t= - 0.788 p= 0.450
	Mydlniki n= 10	x= 0.967 SD= 0.458	/ /	/ /
P	**Solvay** n= 10	x= 55.004 SD= 47.433	t= 0.182 p= 0.859	t= 2.241 p= 0.051
	Niwa n= 10	x= 54.962 SD= 47.475	/ /	t= 2.466 p= 0.035
	Mydlniki n= 10	x= 54.505 SD= 47.956	/ /	/ /

Niwa). Still, these values did not exceed the average content found in plants living in the natural environment, which ranges from 1 to70 mg/g (LIETH, 1999).

The results pertaining to the levels of calcium, phosphorus, magnesium and potassium in plants were always higher that the respective levels in the stomachs of voles. The only exception is sodium, the concentrations of which in stomachs were higher than those in plants (Fig. 5). As reported by KRZYWY (2007), LITYŃSKI and JURKOWSKA (1982), the above-ground parts of plants usually accumulate more calcium, phosphorus, magnesium and potassium than the underground parts. Sodium demonstrates a different pattern, as the root portions accumulate higher quantities of this element (KRZYWY, 2007). The higher concentration of sodium in the contents of stomachs can therefore be explained by the feeding preferences of voles which choose chiefly the root parts of plants.

The analysis showed statistically significant differences in magnesium contents between the Mydlniki quarry and the Niwa and Solvay sites, and in phosphorus contents between the Niwa and Mydlniki quarry sites (Table 1). One of the hypotheses states that magnesium, phosphorus and sodium are important factors affecting population cycles that trigger the numerical fluctuations in rodents (TAIT and KREBS, 1985).

The results of this study indicate that common voles do not accumulate in their bodies excessive quantities of elements which occur, with variable intensity, in the post-industrial environment. In these animals it is probably accomplished already at the stage of acquiring food, considering their selective intake mechanism. This conclusion may contribute to the knowledge of the adaptive strategy of this species enabling it to function in a degraded (contaminated), post-industrial environment.

REFERENCES

ANDRZEJEWSKI R., G. BUJALSKA, L. RYSZKOWSKI, and J. USTYNIUK. 1966. On a relation between the number of traps in a point of catch and trappability of small rodents. *Acta theriol.* 11: 343-349.

BOBEK B. and J. KOZŁOWSKI. 1987. Ocena zagęszczenia zwierząt. Jagiellonian University. Kraków: 36-48.

GAREL J. M. 1987. Hormonal control of calcium metabolism during the reproductive cycle in mammals. *Physiol. Rev.* 67: 1-67.

KRAKÓW HEAT and POWER PLANT-REPORT. 1997. Kraków.

KRZYWY E. 2007. Żywienie roślin. Akademia Rolnicza w Szczecinie: 23-31.

LIETH W. C. 1999. The uilization of Mineral Elements. *Blackwell Scientific*, London.

LITYŃSKI T., and H. Jurkowska. 1982. Żyzność gleby i odżywianie się roślin. PWN, Warszawa: 180-248.

MACIAK F. 1999. Ochrona i rekultywacja środowiska. SGGW, Warszawa.

MAŁECKI Z. 1997. Problemy sozologiczne aglomeracji miejsko – przemysłowych. Restrukturyzacja – likwidacja – zagospodarowanie KZS „Solvay". Komitet Inżynierii Środowiska PAN Kraków: 1, 1-52.

NORDIN B. E. C. 1986. Calcium. J. Ford and Nutr. 42: 67-81.

Proceedings Of The IIIrd Sozology [Enviromental Protection and Management] Conference, 1993, 23-24. Kraków.

ROBERTSON W. G. 1976. Urinary excretion. In: B. E. C. Nordin. [ed.], Calcium, *phosphate and magnesium metabolism, clinical physiology and diagnostic procedures*, 113-161. Churchill Livingstone, London.

TAIT, M. J. and C. J. KREBS. 1985. Population dynamics and cycles. In: R. H. Tamarin [ed]. *Biology of New World Microtus*, 567-620, Special publication no. 8. *The American society of mammologist.*

Www.Eckrakow.Pl.