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Verteilung und Biotransfer von Schwermetallen bei ausgewählten ägyptischen Böden

Distribution and bio-transfer of heavy metals in selected Egyptian soils

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E. ENGLISCHE ÜBERSETZUNG AUSGEWÄHLTER ABSCHNITTE

ENGLISH TRANSLATION OF SELECTED PARTS

Contents of the thesis „Distribution and bio-transfer of heavy metals in selected Egyptian soils“ (1.-11. in German / E. selected parts in English[1])

[1] *El Kasabi, M. N. (2001): Distribution and bio-transfer of heavy metals in selected Egyptian soils. Thesis. Friedrich Schiller University of Jena, Faculty of Biology and Pharmacy, Institute of Ecology, Department of Environmental Science, Jena, Germany: V-VII, 1-2, 5, 9, 17-18, 22, 28, 33-34, 53-57, 117-120*

E.1. INTRODUCTION

Up to now, 55 heavy metals are well-known in the ecological sphere, made by the Creator as a part of the Universe.

Most rocks and soils, which are generated from them, contain often only traces of those heavy metals. The living beings are adapted to the natural heavy metal concentrations in the lithosphere and some of the heavy metals are even of vital importance for living beings.

But heavy metals have a poisonous effect already in relatively low concentrations which exceed the tolerance concentration.

In consequence of human-caused activities, as mining, processing of minerals, industrial production and its waste, street-traffic, processes of combustion and use of refuse products (e.g. sludge), heavy metals come into the environment and eventually have been brought increasingly into the soils.

As the heavy metals are not decomposed in the environment, it comes to an accumulation, namely in upper-soils in particular. That is the consequence of natural and technological cycles. From the quantity, nature and dispersion of the heavy metals in a soil-profile may be concluded the occurrence of primary and secondary accumulations. The primary, geogenic heavy metals are found in approximately equal element relations throughout the soil profile. On the other hand pedogenetical processes can cause secondary redistributions specific to soil layers in consequence of accumulations and reverse accumulations 🕮 [62].

Heavy metals introduced by man into the soils ought to be considered with more criticism than heavy metals naturally present in the soils, since they are easier absorbed by the plants and thus enter considerably into the food chain. As a result of the accumulation by way of food chains, their action upon ecological systems and human beings may have toxicologically dangerous effects 🕮 [70].

The heavy metal contamination is a global problem and concerns many countries in different continents, especially after the second World War, due to the fast increase of industrialization. The consequences are increased cases of chronic diseases owing to permanent heavy metal contamination and acute poisoning symptoms through excessive ingestion of heavy metals.

Considering that the food chain frequently starts with the soil as substratum 🕮 [129], laws and directives have been issued in many countries in order to protect the soil and consequently avoid harm to human beings and other creatures. In Germany for example there are, among others, the federal law for soil protection, the federal directive on soil protection and dangerous waste residues and the directive on sludge (see table 68 {German tab. 11}), as well as the regulations of the law on fertilizers and plant protection, furthermore rules of the

federal law on air pollution protection and the appropriate legal directives. In addition, there is the directive on fodder and a definition of maximum contents of heavy metals in food.
STAIGER & MACHELETT (1984) as well as HELAL et al. (1995) have pointed out that irrigation water can have adverse effects on cultivated farmland by the input of heavy metals, especially when communal or industrial waste water reach the agricultural irrigation system 🕮 [109, 123]. MESHREF & FAWZI (1987) as well as RABIE et al. (1996) have proved heavy metal accumulations in the soil owing to contaminated irrigation water 🕮 [109, 123].
Cultivated farmland is also menaced by immissions of heavy metals within the precincts of traffic routes 🕮 [81]. Decreasing contents of the heavy metals Cd, Ni, Pb and Zn were found in soils at increasing distances from traffic routes 🕮 [10, 49, 65, 76, 122].
In general, it is possible to prove the negative influence of streets by increased heavy metal contents on the soil surface as far as up to 50...100 m distance 🕮 [71].

Table 68 {German tab. 11}: Soil protection levels from land administrative regulations, federal directives and guide data in Germany

	Total element content in dry substance of soil in ppm (mg/kg)						
	Background value - total content * for soil with clay quota 0 - 8% [a]	Contin-gency value for sand soil [b]	Test value - total content farmland for soil with clay quota 0 - 8% [a]	(B W I)[c] Multifunc-tional possibilities of use	Maximum permissible value in soil according to directive on sludge (AbfKlärV)	(B W II)[c] Tolerance value	(B W III)[c] toxitiy value
						for farmland, cultivation of fruit and vegetables	
Cd	0,2	0,4	1	1	(1)[d] 1,5	2	5
Cr	20	30	100	50	100	200	500
Cu	10	20	60	50	60	50	200
Ni	15	15	50	40	50	100	200
Pb	25	40	100	100	100	500	1000
Zn	35	60	150	150	(150)[d] 200	300	600
references	30	18	30	32	79	32	32

Extraction method: aqua regia
**: Background value - total content = top limit of the natural content in soil*
[a] : 3. Administrative regulation of the Ministry of Environment Bad.-Württ. for the soil protection law
[b] : Federal directive for soil protection and dangerous waste residues (BBodSchV)
( )[c] : Rule-of-thumb values relative to beneficial and protected goods for (damaging) matter in soil

E.2.5. Heavy metal transfer coefficients

E.2.5.1. Transfer coefficient

Transfer coefficients are calculated according to the following formula:

$$\text{transfer coefficient} = \frac{\text{heavy metal content in the plant}}{\text{heavy metal content of the soil}}$$

The transfer coefficient of heavy metals determines the effect of a unit of the heavy metal soil content on the heavy metal content of a plant growing in the soil and is therefore a particularly suitable parameter for the evaluation of the accumulation and/or inverse accumulation of heavy metals in the plant tissue. Since it describes the heavy metal uptake independently of the concentration, it can be used even for comparisons between different elements. It depends on the influencing factors of the plant's heavy metal uptake, therefore it varies within relatively large ranges, which are specified in table 69 {German tab. 15} for selected heavy metals.

Table 69 {German tab. 15}: Transfer coefficients according to different references

Cd	Cu	Fe	Ni	Pb	Zn	references
0,03...10,00	0,01...2,00		0,01...2,00	< 0,50	0,03...10,00	133
1,00...10,00	0,10...1,00		0,10...1,00	0,01...0,10	1,00...10,00	134
0,08... 5,55	0,06...0,33		0,05...1,18	0,01...0,13	0,16... 6,04	99
		0,01...0,05				111

E.2.5.2. Relative transfer coefficient

The relative transfer coefficient is a helpful parameter for the evaluation of the effectiveness of the soil as a sink for heavy metals (ability in fixing heavy metals), whereby it offers also a better comparability for different soils. It determines the influence of the increase of one unit of the heavy metal soil content on the increase of the heavy metal (HM) content in the plant and is calculated as follows:

$$\text{relative transfer coefficient} = \frac{(\text{HM content of the plant with HM soil addition}) - (\text{HM content of the plant without HM soil addition}}{\text{heavy metal (HM) soil addition}}$$

E.3. SETTING TASKS

On account of the imminent dangers which exist or may arise in the developing countries as a result of heavy metal contaminations the soil, water, air and victuals ought to be intensively examined and constantly controlled, in order to find out the real causes of threat.

Numerous investigations have shown that the heavy metal inputs into soil increase near roads 🕮 [49, 65, 71, 76, 81, 122], owing to street-traffic.

Heavy metal contents also raise in the soil in consequence of contaminated irrigation water 🕮 [109, 123]. That can have adverse effects on the ecological system 🕮 [70] and especially the quality of victuals and fodder plants 🕮 [4].

For these reasons investigations are prosecuted, within the scope of his thesis, relating to the distribution of heavy metals in a newly cultivated Egyptian soil[1] of a former desert region, adjoining a country road and irrigated by two irrigation systems. While doing so there is put a special emphasis on investigating the influences of the country road traffic and the different irrigation systems on the heavy metal content of the former desert soil, which is regarded as uncontaminated.

As in desert soils with little fine parts high heavy metal transfer coefficients are expected, the transfer of heavy metals from the soil to the plant is examined in the investigation area. Then the statistical relation between heavy metal contents in the Egyptian soil and the bio-transfer into the plants growing there is analysed.

The relative transfer coefficients of heavy metals of the Egyptian soil and German soils are compared in pot trials, in order to find out in which way the soil in the survey area acts as a sink for heavy metals (ability in fixing heavy metals).

E.4.4.9.5. Computer programs and statistic evaluation

The following computer programs were used:

Canoco version 4, CanoDraw version 3.1, Excel 95 and 97, Word 6,0 and 97.

For the statistic analysis see appendix to 4.4.9.5. (page 73).

[1] *The first cultivation was in in the year 1987.*

E.5.2.5.1. Lateral distribution of Pb

The soil contents of Pb in 0...30 cm depth in the survey area are normal distributed with a coefficient of variation of 27.8. In figure 2 we can see, that the Pb-contents of the sample sites are distributed relatively regular in the range of a quadrangle with higher contents of Pb. On the other hand outside the quadrangle lower Pb-contents occur in an irregular distribution. The results of chapter 5.2.3. and 5.2.4. are also recognizable in figure 2, because in general the values in the northern part are lower than in the southern part (possible influence of irrigation method), and because the occurrence of the highest Pb-contents is not restricted to the most western row besides the street (no influence of street traffic).

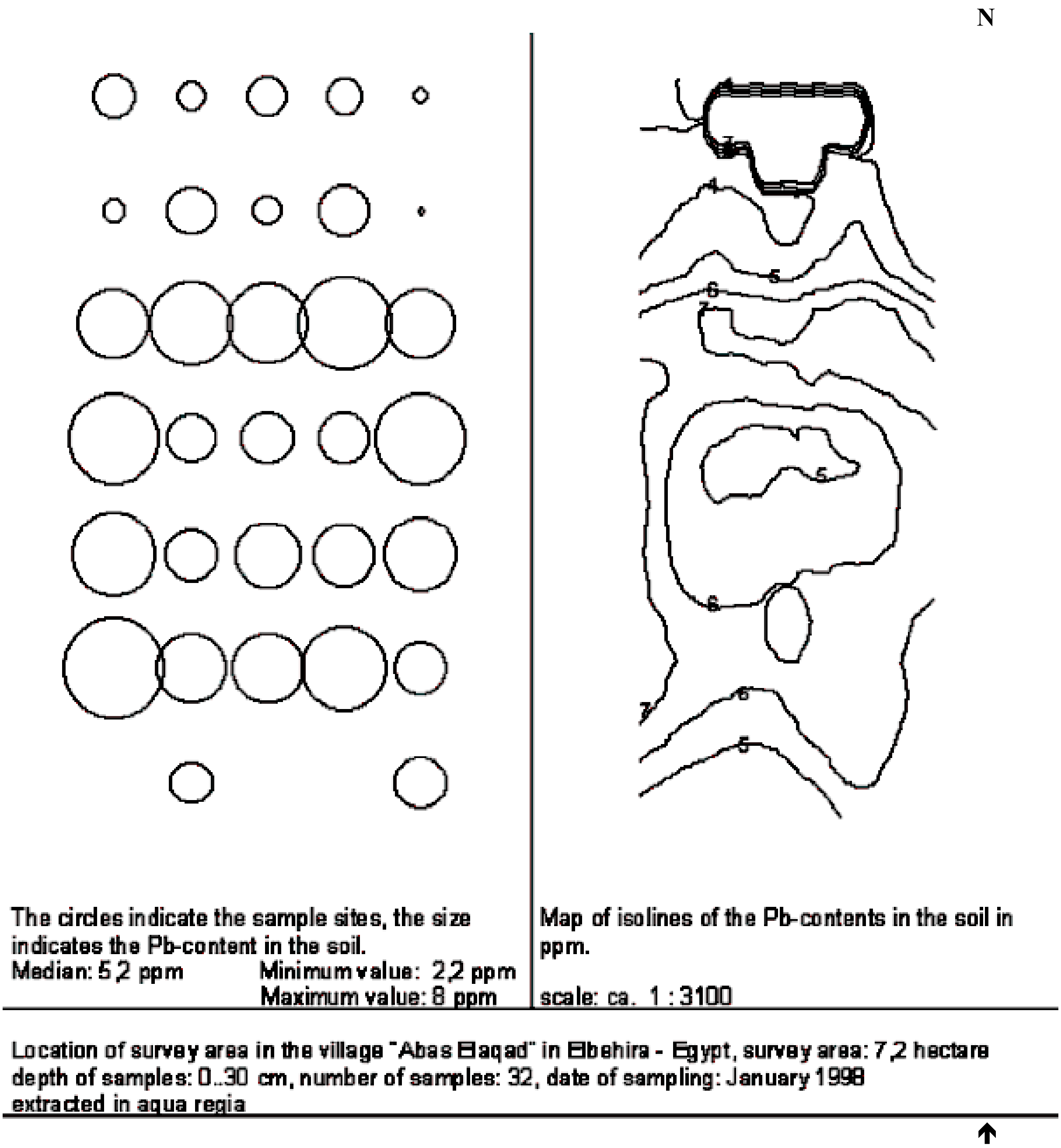

Figure 19 {German fig. 2}: Distribution of the Pb-contents in the Egyptian investigation area (produced with Canoco version 4 and CanoDraw version 3.1 programs)

E.5.2.5.2. Lateral distribution of Zn

Figure 3 shows the lateral distribution of Zn of the survey area in 0...30 cm depth with relatively high deviations of the normal distributed measured values (coefficient of variation: 33,6). High and low values are scattered over the whole area, which again confirms the results of chapter 5.2.3. and 5.2.4., showing that the soil contents of Zn are neither influenced significantly by the street traffic nor by the irrigation method.

We can see from the isolines, that the highest values are concentrated in three areas, namely in the centre of the northern part, in the the east of the southern part and in the west of the southern part.

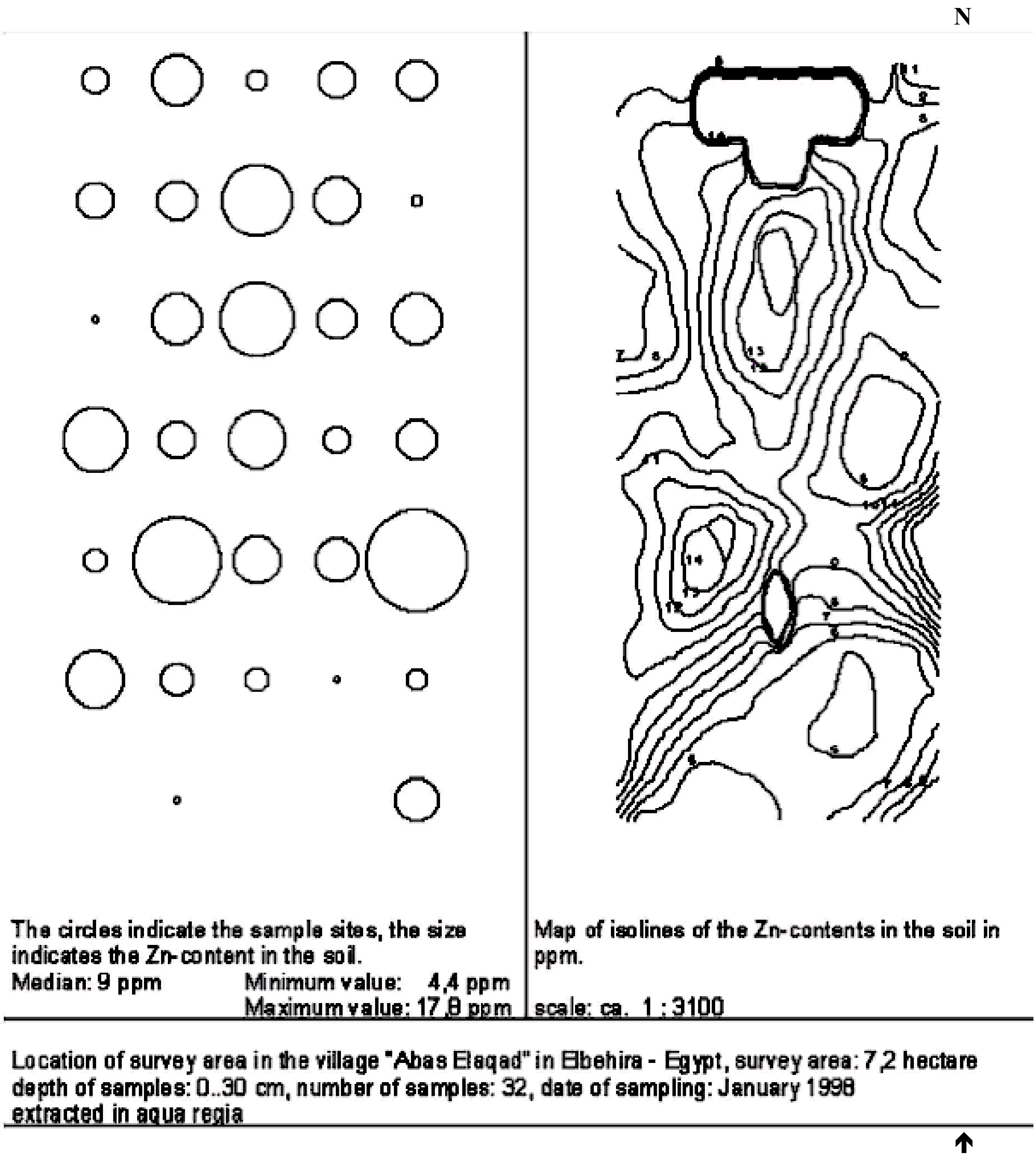

Figure 20 {German fig. 3}: Distribution of the Zn-contents in the Egyptian investigation area (produced with Canoco version 4 and CanoDraw version 3.1 programs)

E.6. GENERAL OVERVIEW AND CONCLUSIONS

All heavy metals are normal distributed in the alkaline sandy soil of the survey area, in the depth of 0...30 cm. There is no significant difference between the soil layer in 0...30 cm depth and in 55...60 cm depth. This result corresponds to the statements of BERGMANN (1998) that shiftings of heavy metals into deeper layers of soil happen more likely in acid wet soils 🕮 [8].

The **Cd** contents in soil and plants of the investigation area are below the determination limit (0,2 and respectively 0,05 mg/kg). In the pot trial with oat sprout in Egyptian sandy soil of the survey area (addition of 1 mg Cd/kg), Cd shows common transfer coefficients for Cd in sandy soil (between 0,5 and 1,025).

The **Cu** transfer coefficients show in the survey area with quite low Cu contents in the soil an exceptionally high accumulation (up to transfer coefficient 7,78), as a result of Cu deficiency of the plants. In case of a higher Cu content in the soil of the survey area, equally in the pot trial, with Egyptian soil (addition of 7 mg Cu/kg), Cu shows common transfer coefficients (< 2).

In the Egyptian soil, there can result a danger threatening the ecological system with **Ni** because of its high mobility, when Ni introduced by man (e.g. by sludge and refuse composts) spreads in the soil, as the relative transfer coefficients come up to 9,185 in the pot trial with Egyptian soil (addition of 5 mg Ni/kg).

In the soil of the survey area with a relatively low Ni content (4,3 mg Ni/kg), irrigated by the dripping system, lucerne shows a considerably increased Ni content in the sprout (35 mg/kg). The Ni transfer coefficient is very high there (8,13) owing to possible low pH-values in the rhizosphere, combined with a very low clay mineral content, as well as low contents of Fe- and Mn-oxides[1] in the soil.

In the pot trial with the soil 1A, which had also been irrigated by the dripping system in the survey area, containing 9,8 mg Ni/kg (from it 5 mg/kg were added in the form of Ni-sulphate x 7 H_2O), oat shows a considerably increased Ni content (52,3 mg/kg) in the sprout with a very high Ni transfer coefficient. That is due to the fact that Ni, brought into these soils by man, is widely available to the plants, combined with a very low clay mineral content, as well as low contents of Fe- and Mn-oxides in the soil.

The German maximum permissible values for Ni (table 68 {German tab. 11}) are not suitable for the investigated Egyptian soil, because with the above mentioned values in the pot trial the soil content comes up to about 65 % of the contingency value for sandy soils, only 19,6 % of the maximum permissible value, according to the directive on sludge, however the Ni plant

[1] *The term „oxides" includes all forms of including hydrous oxides and oxyhydroxides.*

content is considerably approached to the maximum permissible value of the directive on fodder (table 70 {German tab. 4}), reaching 92 % of that value. After all Ni has already shown a significant positive correlation between Ni soil content and Ni transfer coefficients in the investigation area with the family *Gramineae*.

These results with the Egyptain sand soil reinforce the investigation of HEIN et al. (1995), who proved that the maximum permissible value of 50 mg/kg with sandy and acid German soils ought to be even reduced by any possible means, because Ni, brought into these soils by man, is widely available to the plants 🕮 [54].

Table 70 {German tab. 4}: Selected proposed threshold values of beginning heavy metal (HM) toxicity for fodder 🕮 [3] and maximum permissible concentration of harmful substances in the plant material according to the directive on fodder (FMVO) for grassland 🕮 [82]

mg / kg air dried matter	Cd	Cu	Fe	Mn	Ni	Pb	Zn	references
proposed threshold of beginning HM toxicity	1	15	500	1000	100	25	500	3
FMVO-values for grassland	1,14	40			57	45	284	82

The **Pb** contents in the soil and plants of the survey area are relatively low, but the Pb transfer coefficients are high, though there is no accumulation yet (the highest transfer coefficient is 0,95 with leaves of the Egyptian small lime). The reason may be that the soil contents of clay minerals as well as Fe- and Mn-oxides are relatively low and at the same time the plants are subject to a deficiency in micronutrients.

There is a significant difference of Pb soil content with different methods of irrigation (sprinkling and dripping system), but there is no significant influence of street traffic emissions on Pb soil contents. That shows that up to the time of taking the samples the input of Pb into the soil is more influenced by irrigation water and other factors than by street traffic. For that reason the quality of irrigation water and fertilizers ought to be particularly examined.

The **Zn** transfer coefficients are within the common range in the investigation area and also in the pot trials of Egyptian soil (addition of 25 mg Zn/kg).

Heavy metals introduced by man into the survey area can easily come into victuals, as in the prevailing sandy soil with little fine parts, in spite of high pH-values, comparatively high (relative) transfer coefficients were ascertained.

For that reason in the event of human-caused heavy metal soil contamination man is exposed to a special danger.

E.7. SUMMARY

The dispersion of heavy metals and its bio-transfer to plants have been investigated in a lately cultivated land of a region westward of the Nile delta, on the border of the Western Sahara, in the village „Abas Elaquad“ of the region El Bustan, district Elbehira in Egypt.
Both the lateral distribution and the distribution in two different soil layers were examined. As the survey area is situated beside a country road and has two different irrigation systems, the influence of the street traffic and the different irrigation systems on the heavy metal content was investigated. Furthermore the bio-transfer of heavy metals was examined in 10 plant species and additionally the correlation of the transfer coefficient with the soil content was analysed for the family *Gramineae* on the site. Besides comparative studies on the heavy metal accumulation at the same site were conducted with regard to the different plant species and also with regard to different parts of the plant.
In addition, by means of a pot trial (according to Neubauer), the uptake of heavy metals introduced by man (in the form of Cd-acetate, Cu-, Ni- and Zn-sulfate) by plants was compared with German soils, by calculation of the relative transfer coefficients. That was done in order to find out the capacity of the soil in the survey area as a sink for heavy metals (in fixing heavy metals).

The result showed the presence of alkaline lithosole sandy soil in the investigation area with a Cd content in the soil and plants generally below the determination limit (0,2 mg/kg for soil and respectively 0,05 mg/kg for plants). The soil contents of all examined heavy metals were low, respectively normal for sandy soil.

A normal distribution of the Cr-, Cu-, Fe-, Mn-, Ni-, Pb- and Zn-soil contents was proved by the Chi-square-test in the soil (depth 0...30 cm).

By means of the t-test it was shown that there exists no significant difference between the heavy metal soil content of Cr, Cu, Fe, Mn, Ni, Pb and Zn in the soil depth 0...30 cm and 55...60 cm.
With the different irrigation methods (sprinkling and dripping system) resulted no significant difference in the Cu-, Cr-, Fe-, Mn-, Ni- and Zn-soil content.
A significant difference was ascertained by t-test only with Pb, in which case the average values of the Pb soil contents were 24 % higher in the southern part of the area, irrigated by sprinkling, than in the northern part, irrigated by the dripping system. The main reason for this may be an increased Pb content in the irrigation water. There is the imminent danger of a future human-caused Pb contamination of the soil as a result of the proved tendency of Pb accumulation in the survey area.

The application of the t-test showed that the emissions of the street traffic had no significant effect on the Cd-, Ni-, Pb- and Zn-soil contents. However, unwashed leaves of a she-oak tree in a hegde-row growing directly at the country road showed a higher content of Ni, Pb and Zn in case they grew in the direction of the road than in case they grew in the direction of the survey area (Ni ~ 25 % higher, Pb ~ 58 % higher and Zn ~ 25 % higher.) Therefore it may be supposed that the hedge of she-oak trees acts as a filter for the traffic immissions.

In general the Cu-, Fe-, Mn-, Pb- and Zn-contents in the plants of the survey area are relatively low, but the Ni contents in the plants are, on principle, in the normal range, respectively a little increased, however in the individual case of lucerne sprouts considerably increased, with a very high transfer coefficient (8,13).
The Pb transfer coefficients of the survey area are considerably increased, owing to the low soil contents of clay minerals as well as Fe- and Mn-oxides, even though there was not yet any accumulation. The transfer coefficient 0,95 in Egyptian small lime leaves was the highest.
The Cu transfer coefficients show extraordinary high accumulations (the highest Cu transfer coefficient with 7,78 was found in leaves of the date palm) with very low Cu soil content, by reason of Cu deficiency of the plants. On the other hand, reverse accumulations occurred in the same plant species (Napier grass and date palm) when the Cu soil contents were comparably higher.
The Fe, Mn and Zn transfer coefficients in the survey area were within the common ranges.

The investigation of the correlation between soil contents of heavy metals and their transfer coefficients in *Gramineae* plants at the site, by means of Pearson's coefficients of correlation and degrees of certainty showed that the correlation was significantly positive for Ni (B = 0,771), for Cu, Mn, Pb and Zn significantly negative (B = 0,801; 0,935; 0,778 and 0,732) and for Fe not significant. Deficiency of micro elements is considered as the cause of the significantly negative correlation. In order to obtain sufficient contents of micro elements, the plants react with root exudates, whereby the transfer coefficients decrease with rising soil contents.

In the pot trial the soil 1A and 4C of the examined Egyptian soils and the soil from Großbeeren of the compared German soils showed similar relative transfer coefficients of Cd, namely the highest of all compared soils, though their pH-values (7,8/ 7,9 and 6,2) and clay mineral contents (< 1 and 7 %) are different. The relative transfer coefficients of the soil 7E* of the investigated Egyptian soils and the soil from Kösnitz of the compared German soils were also similar. They were at about half of the above mentioned, whereby their pH-values (7,9 and 7,3) and clay mineral contents (< 1 and 37 %) didn´t take any increased significance,

as the organic matter and to some extend the Fe- and Mn-oxides in all soils of the pot trial were decisive for the reaction of the soils in fixing Cd.
Therefore, the soil from Fehrbellin showed a remarkably low relative transfer coefficient of Cd, as well as of Ni and Cu, owing to its high content of organic matter ($_{org}$C-content[1] 28,1 %), though its soil reaction was more acid (pH 5,4). Also for Zn it showed a great ability in fixing heavy metals, however, compared to Cd, Cu and Ni, Zn was least stronlgy fixed.
Soils with high pH-values (7,8/ 7,9), combined with low clay mineral contents (< 1 %), as well as low Fe- and Mn-oxides, don´t have a high capacity to absorb Cu and Zn and particularly Ni. They cause rather, to different degrees, a mobilization of those heavy metals, by formation of soluble and plant-available organic heavy metal complexes. Consequently, the Egyptian soils 1A, 4C and 7E* had the highest relative transfer coefficients of Cu, Ni and Zn and were fixing Cu and Zn, and especially Ni, to a smaller extent than the examined German soils.

On the whole Cd, Cu, Zn and especially Ni, which have been introduced by man, and for example may come into the examined Egyptian soil through sewage sludge and refuse-compost, ought to be considered critically.
They may represent a danger to human beings and also to animals. That stands also for similar soils in the same region El Bustan in Egypt, where the newly cultivated area is intended to reach the size of 62250 ha by the year 2017.

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[1] : C content of organic matter; it varies strongly within individual classes of substances, but on average it is usually around 50 % 🕮 [137]. For the calculation the following formula is usually used: "% org. substance = 1,67 * (%$_{org}$C)"

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