PhD THESIS

Sustainable management and rehabilitation of degraded urban land

(PhD THESSYS SUMMARY)

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INTRODUCTION

Despite the uncertainties, inevitable in any research regarding future trends, it is increasingly clear that urbanization will continue to affect the soil, the environment, biodiversity and ecosystems, with most of the effects manifesting in the developing world which has limited means to approach each urbanization challenge. Erosion and pollution are current problems that can be reduced or prevented by improving soil cover with vegetation, maintaining biodiversity and using good soil and land management practices.

The main purpose of this research is to point the attention to children's playgrounds, since play and socialization are fundamental for their development, from all points of view. Professionals in the field believe that the development of children's social skills occurs on the playground and can become lifelong skills, these places being, outside the home, the most important environments, because free and spontaneous play is an essential activity and beneficial. Children's playgrounds can be contaminated with toxic substances that pose risks to human health, because heavy metals have become widespread urban pollutants, and the fact that children are exposed to potential risks is often ignored. The quality of the spaces we take our children to must become a priority in order to ensure that they are healthy and safe spaces.

Specialists need feasible approaches to help them customize options for creating sustainable and safer urban playgrounds. The possibility of exhausting some elements that make up the planet's natural capital has forced contemporary society to set targets, more and more precise and punctual, for maintaining and improving the current state.

THE PURPOSE AND OBJECTIVES OF THE RESEARCH

The purpose of the research is to treat the documented theoretical and practical problems regarding the heavy metal contamination of urban soil such as playgrounds, from Cluj-Napoca municipality, and its general and specific objective is to identify them, assess the level of contamination and the impact on the community. Pollutants of this type are primarily anthropogenic (emissions from traffic or industrial activities). Therefore, the main risk, as far as urban soils are concerned, is the presence of heavy metals, resulting from human activities, especially road traffic. Thus, documentation/studies/, the identification of potentially contaminated urban sites, soil analyzes and the creation of databases for statistical analyses, maps, the identification and recommendation of the best methods of sustainable rehabilitation of problem sites, the establishment of suitable plant species for restoration the structure of degraded soils, the identification of models of good practices in the use of urban land.

PhD THESIS STRUCTURE

The thesis is structured in two parts, comprising 8 chapters, has 148 pages, 3 appendices and 227 references.

PART ONE: Current state of knowledge

Chapter 1. contains documented information regarding soil and land degradation. Structured on three sub-chapters regarding the soil, the factors underlying its formation, punctuating the concept of soil quality. Land degradation worldwide and in Romania is treated in the second subchapter, followed by the third subchapter presenting the various aspects and forms of erosion (water, wind, anthropogenic, landslides).

Chapter 2. includes four sub-chapters and refers to urban land, emphasizing the impact of anthropogenic actions on it and contamination with heavy metals, dealing with a series of elements that have an influence on the phenomenon of degradation.

SECOND PART: Personal contribution

This part describes the materials and methods that formed the basis of the research, the statistical results, the conclusions and the recommendations aimed at achieving the proposed objectives.

Chapter 3., in its two sub-chapters, precisely presents the precise objectives of the research, emphasizing the significance of the landscape and its multidisciplinarity,

Chapter 4. Regarding the natural framework of Cluj-Napoca and Cluj county, summarizes the elements that can influence the results and lead to the elaboration of conclusions (relief, climate, SWOT analysis for the urban dimension, metropolitan area, parks) and has six subchapters.

Chapter 5. The Material and Method chapter has six sub-chapters, respectively general considerations regarding the particularities of the areas of which the targeted sites are part, the Six Sigma Methodology (DMAIC) as a working tool, followed by the description of the working methods regarding the method of metal detection heavy, the method of identifying the sites in order to assess the level of contamination, the sampling, the calculation of the pollution index and the pollution load, the statistical methods used.

Table 5.1. Location of children's playgrounds studied in Cluj-Napoca

Site Acronym	Location and Elevation	Vegetation	Pathways Type
CJ-AM1	Andrei Mureșanu site 1, 371 m 46°45'39.09"N 23°36'12.86"E	lawn, hedge, trees	concrete pavement
CJ-AM2	Andrei Mureșanu site 2, 369 m 46°45'42.39"N 23°36'22.63"E	lawn, hedge, trees	asphalt, rubber pavement
CJ-BZ1	Bună Ziua district site 1, 443 m 46°45'7.04"N 23°36'13.18"E	lawn	gravel, rubber pavement
CJ-BZ2	Bună Ziua district site 2, 459 m 46°44'56.29"N 23°36'2.06"E	lawn	-
CJ-CB	Colonia Borhanci, 352 m 46°44'56.58"N 23°38'22.68"E	lawn	-
CJ-G	Gheogheni district, 333 m 46°46'5.45"N 23°38'0.82"E	lawn, shrubs, trees	concrete and rubber pavement

- Calculation of pollution indices for heavy metals measured for threat assessment;

Pollution index calculation formula:

$$PI = Cn \div GB$$

(Cn - heavy metal concentration, GB - geochemical background reference value)

Pollution load index calculation formula:

$$PLI = \sqrt[n]{PI\ 1 \times PI\ 2 \times \dots PIn}$$

Chapter 6., Results and discussions includes 15 sub-chapters with the results obtained and the discussions based on them.

Chemical elements in soil: heavy metals and metalloids-database

A more detailed research was carried out on the elements for which the legislation in force in Romania provides reference values (ORDER No. 756/November 3, 1997), respectively: normal values, alert and intervention thresholds. These elements are: vanadium (V), chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd), mercury (Hg), thallium (Tl), lead (Pb), arsenic (As), antimony (Sb), selenium (Se). The samples were analyzed for the presence of these 14 elements, and following the analyzes it was found that:

- 6 elements were below the detection limit: Co, Se, Cd, Sb, Hg, Tl
- 8 elements, namely V, Cr, Mn, Ni, Cu, Zn, As, Pb were present in the soil

Results regarding levels of heavy trace elements

Analysis of variance showed that the differences observed between the mean level of heavy metals among the six locations were statistically significant only for Zn concentration. The coefficient of variation showed a larger dispersion than the mean for Mn, which suggests the heterogeneous presence of this element in the samples.

Table 6.1. Soil heavy metals in some public children's playgrounds and influence of the site location (Cluj-Napoca, 2022)

Parameter	Descriptive statistics							Analysis of variance		
	Average (mg/kg)	Median (mg/kg)	±SD	Skew	Max.	Min.	CV	Test Value	*P*	Sign.
V	69.78	74.00	20.14	−0.50	100	31	28.86	$F = 2.51$	0.0891	ns
Cr	35.00	31.00	14.14	1.27	63	20	40.40	$F = 0.51$	0.7662	ns
Mn	475.11	362.00	466.29	3.31	2280	108	98.14	$\chi^2 = 5.13$	0.4005	ns
Ni	33.50	31.50	12.92	0.48	62	14	38.57	$F = 2.06$	0.1417	ns
Cu	26.75	22.00	12.71	0.97	53	15	47.51	$\chi^2 = 10.61$	0.0597	ns
Zn	106.94	86.00	51.86	1.21	235	58	48.49	$\chi^2 = 13.18$	0.0218	*
As	13.92	13.00	4.14	1.95	25	10	44.85	$\chi^2 = 8.05$	0.1536	ns
Pb	32.13	35.00	14.41	0.80	67	14	29.74	$F = 3.33$	0.0561	ns

The relationship between heavy trace elements - Kendall tau correlations between the studied parameters

Significant positive correlations between certain elements associated with higher than background levels at some locations could suggest a common source of pollution with those elements. Statistically significant positive correlations were identified:

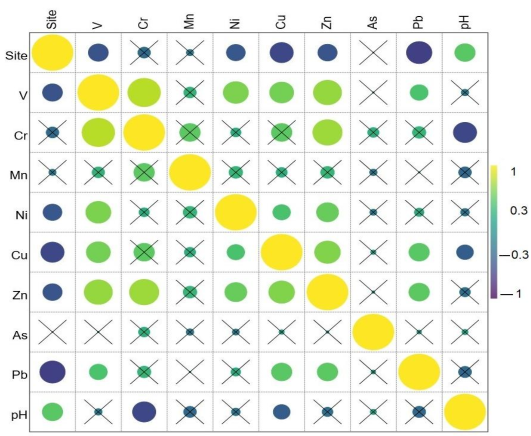

Fig. 6.3. Corelograma Kendall tau care arată relația dintre variabile
(original)

- V-Cr (τ=0.794), V-Ni (τ=0.611), V-Cu (τ =0.585), V-Zn (τ=0.687), V-Pb (τ=0.436)
- Cr-Zn (τ=0.714), Cr-V (τ=0.794)
- Ni-V (τ=0.611), Ni-Cu (τ=0.428), Ni-Zn (τ=0.537)
- Cu-V (τ=0.585), Cu-Ni (τ=0.428), Cu-Zn (τ=0.627), Cu-Pb (τ=0.497)
- Zn-V (τ=0.687), Zn-Cr(τ=0.714), Zn-Ni (τ=0.537), Zn-Cu (τ=0.627), Zn-Pb (τ=0.500)
- Pb-V (τ=0.436), Pb-Cu (τ=0.497), Pb-Zn (τ=0.500)
- As has no positive correlations with any of the eight elements studied
- Mn has no statistically significant correlations with any of the eight elements

Results obtained compared to reference levels

Compared to reference values from the sources cited above, of the eight heavy metals measured:

- sites CJ-AM1 and CJ-AM2 both exceeded the average reference values for seven out of eight heavy metals;
- the CJ-CB site exceeded them in three of the eight;
- CJ-BZ1 and CJ-BZ2 sites for two out of eight;
- CJ-G in only one in eight.

Heavy metal level and pH detected in the six sites

One of the most important factors controlling the immobilization (sorption) and respectively the mobility of heavy metals in the soil is pH. At the same time, the pH also influences other processes, such as the sorption of ionizable substances (phenolic compounds, from the class of alkyphenols). Low pH values associated with calcium deficiency and low water hardness can affect other processes in an unfavorable direction, as well as increasing the toxicity of metals as a result of increasing the mobility of aestora. The average pH values measured in the sample collection points are between 6.80 - 7.07.

The average levels of heavy trace elements did not reach the intervention level provided by the Romanian legislation for any of the detected elements.

- CJ-BZ1 - the average level of As has reached alert thresholds compared to standard thresholds and should be monitored, the other elements being below the alert level;
- CJ-BZ2 - the highest levels of Mn, and the lowest levels of V and Pb;
- CJ-AM1 - the highest levels of Cu among those investigated;
- CJ-AM2 - the highest levels of V, Ni, Zn and Pb among the sites;
- CJ-G - the only one where Cr was below the detection level and the lowest level of As;
- CJ-CB - all elements are below the alert level;

Graphical visualization of average heavy metal values versus normal level in the six sites includes graphs reflecting the levels of heavy metals detected in each site.

Results relating to unique pollution indices assigned to the corresponding pollution threat classes

According to the interpretation:

- for four of the analyzed elements, the indices fell into the classes without pollution to low pollution (V, Cr, Mn and Ni);
- Cu represents a moderate threat at the CJ-AM1 site;
- Zn represents a moderate pollution threat at the CJ-AM1 site and a strong pollution threat at the CJ-AM2 site;
- Pb represents a moderate pollution threat at CJ-AM1 and CJ-AM2 sites;
- As represents a moderate pollution threat at the CJ-BZ1 site;

Based on the results of the pollution load index, it was determined that CJ-G had no pollution, CJ-CB, CJ-BZ1 and CJ-BZ2 show only basic pollution, while sites CJ-AM1 and CJ-AM2 show a incipient or slight deterioration of soil quality.

Table 6.3. Ranking pollution index values for the measured heavy metals in the soil of six public children's playgrounds from Cluj-Napoca (2022).

Parameters		Sites					
		CJ-AM1	CJ-AM2	CJ-BZ1	CJ-BZ2	CJ-CB	CJ-G
PI	V	1.11 (2)	1.21 (2)	0.88 (1)	0.72 (1)	0.86 (1)	0.73 (1)
	Cr	0.76 (1)	1.05 (2)	0.43 (1)	0.62 (1)	0.53 (1)	<LOD
	Mn	1.11 (2)	0.85 (1)	0.57 (1)	1.80 (2)	0.49 (1)	0.61 (1)
	Ni	1.52 (2)	1.53 (2)	1.04 (2)	0.71 (1)	1.17 (2)	0.96 (1)
	Cu	2.15 (3)	1.87 (2)	0.84 (1)	0.98 (1)	1.10 (2)	0.90 (1)
	Zn	2.43 (3)	3.06 (4)	1.27 (2)	1.31 (2)	1.57 (2)	1.00 (1)
	As	1.55 (2)	1.63 (2)	2.56 (3)	1.55 (2)	1.35 (2)	1.19 (2)
	Pb	2.35 (3)	2.76 (3)	1.59 (2)	0.94 (1)	1.98 (2)	1.00 (1)
PLI		1.51	1.60	0.99	1.01	1.02	0.89
		II	II	I	II	II	I

Questionnaire results

The questionnaire launched publicly on social networks, regarding the knowledge of the level of interest of the citizens regarding the studied issue points out some important issues related to the phenomenon of land degradation, and the perception of citizens on the way of building and living. People are receptive and even eager for change, again, for a better quality of life, they know and discuss environmental problems, climate change, land degradation and their consequences, being convinced that something can still be done to at least slow down these phenomena.

Maps made using the CORINE Land Cover (CLC) methodology

The maps made using the CORINE Land Cover methodology visually reflect the condition of the land from the hypsometric point of view, the exposure of the slopes, the evolution over time of land use, geology and soils.

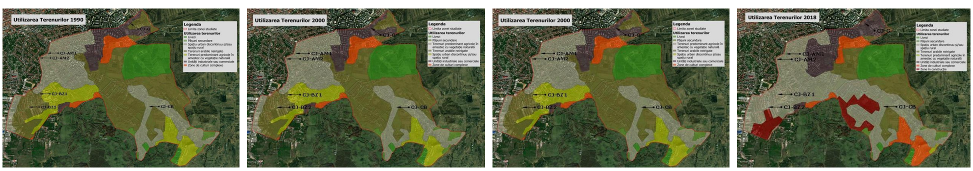

Fig. 6.8. Land use 1990-2018
(original)

Results obtained compared to reference levels

Compared to reference values, relative to the eight heavy metals measured:
-sites CJ-AM1 and CJ-AM2 exceeded the average reference values for seven out of eight heavy metals, site CJ-CB exceeded them in three out of eight, sites CJ-BZ1 and CJ-BZ2 for two out of eight, and CJ-G in only one in eight. The only element that showed high levels compared to the global average values in all studied locations was As, and Pb showed high levels in four sites compared to the average levels in România.

The SWOT analysis for the urban planning dimension, Cluj-Napoca emerged as a result of research and observations throughout the research

Discussion of possible sources of contaminants

Heavy metal pollution of urban soil in Europe showed that high levels of the five most common heavy metals accounted for 22% of anthropogenic (traffic and industry) enrichment, while 44% was geogenic enrichment.

In Cluj-Napoca, the main source of metal pollution is related to traffic, urban runoff, residential heating and the municipal waste dump. Proximity to pollution sources can be a cause of increased soil pollution in the urban environment and occurs through suspension and accumulation in the atmosphere during dry weather, transport by air masses, deposition on vegetation and surfaces and possibly washing into the ground with water of rain.

Sources and ways in which the human body comes into contact with heavy metals in soil and the impact on the population

The sources of heavy metals found in the environment are mainly natural or anthropogenic. Natural sources of heavy metals are igneous or sedimentary rocks, various types of erosion, or even soil formation processes. Anthropogenic sources of heavy metals are generally represented by activities in the field of industry, agriculture, construction and transport.

Discussions regarding the level of heavy metals in playgrounds and the method of detection in other large cities

Comparing the results from the present research with the levels reported in previously published works, in other large cities in different countries, for example the levels of V in the topsoil of the monitored playgrounds in the city of Cluj-Napoca are lower. The range of Zn levels was lower than the mean levels reported in Belgrade (Serbia) or Hong Kong (China). Pb levels were similar to the ranges measured in coastal municipalities in Montenegro, but the average of the six sites was higher than the average reported in Çanakkale (Turkey) and Uppsala (Sweden).

Phytoremediation solution for sustainable and non-invasive rehabilitation of urban soil quality

Phytoremediation can be an alternative ecologically sustainable soil remediation, considering that some of the conventional technologies for the remediation of metal-contaminated soils have often been too expensive, this method, increasingly appreciated in the last decade being a relatively emerging method inexpensive and ecological approach to the problem of heavy metal accumulation in soil. The element of time also comes into play, with the expected results appearing after a longer period compared to the contaminated soil replacement method.

The extent of these interventions can be decided according to the level of contamination identified and its threat. Although some of these mechanisms are only an immobilization of heavy metal pollutants without actually removing them, they have relevance in reducing the risk of exposure.

Chapter 7. Conclusions and recommendations.

General conclusions regarding heavy metals and their presence in the environment

Heavy metals are chemical elements with high molecular weight and density. The long-term persistence of these metals can have an important impact on human health in particular. They affect soil, subsoil, ground and surface water and air.

For these reasons, the identification of as many spaces as possible and their sustainable rehabilitation must be a goal in itself, especially when it comes to children's health.

Conclusions on the pollution load index

- ➢ the greatest contribution to the PLI among the elements, depending on the location, was made by Zn, Pb, As and Mn - from the calculation of the pollution load index it is clear that two playgrounds did not have t pollution (PLI = 0.89–0.99);
- ➢ three of the sites showed only basic pollution with an incipient deterioration of soil quality (PLI = 1.01–1.51);
- ➢ the average levels of heavy metals detected were within the permissible limits according to national legislation;

Conclusions regarding the XRF method for the detection of heavy metals

This method aims to determine as accurately as possible the chemical composition of a sample and reduce the minimum limits of doseable concentrations, a fact that can be expressed by increasing the limits of detection (LOD), it has the advantage of being a relatively cheap, fast method, it has a limit of low detection and is non-destructive so that the samples can be used for other analyses, by other methods, and the disadvantage is that it involves the use of a radiation source and therefore requires authorisation.

Conclusions regarding the relationship between parameters

The strongest monotonic relationship was found between V and Cr, Zn displayed a significantly positive monotonic correlation with five of the identified heavy metals (Cr, V, Cu, Ni and Pb), suggesting that they have a common source, Mn does not statistically significant correlations with none of the eight elements, As has no positive correlations with any of the eight elements we study and a statistically significant positive correlation was identified between the location of the park and soil pH. Playgrounds least threatened by pollution are located away from vehicular traffic and adjacent to large areas of vegetation, consistent with previous reports.

General conclusions

The process of urbanization has its downside, as urban sprawl inevitably displaces species, alters water cycles and flows, consumes large areas of irreplaceable wetlands and farmland, and transforms the global landscape. Sustainable soil management is crucial in the context of global environmental changes to prevent or stop various forms of degradation. Contaminants derived from the scale of anthropogenic activities affect life in all its forms and have a strong impact on human health, even if the levels of these contaminants are lower.

Recommendations

- ✧ urban parks and public playgrounds for children must be associated with health promoting activities and functions, and their quality deserves more attention to ensure the expected beneficial role;
- ✧ a better understanding of the factors that contribute to the degradation of urban soil quality and the identification of available options to mitigate these undesirable processes would help to design safer playgrounds;

- ✧constant monitoring of heavy metals in recreation spaces, especially in those intended for children, should become routine to ensure early and prompt interventions when necessary;
- ✧considering the fact that, unfortunately, heavy metals have become closely related to the anthropogenic space, becoming common pollutants in the urban environment, a multidirectional mitigation approach should be considered;
- ✧phytoremediation must be seen in the future as a less expensive, ecological, functional and aesthetic method of rehabilitating urban land, regardless of the type of degradation to which they are subjected, much more sustainable and durable than classic methods such as soil excavation, incineration, washing in situ or ex situ, to the extent possible.

Chapter 8. The main originality and personal contribution is the focus of the theme, researches, analyzes and interest, on sites such as playgrounds for children, their relatively small surface generating very punctual results.

- Serious documentation for a better understanding of the factors that contribute to the degradation of urban soil quality and the identification of available options to mitigate these undesirable processes, leading to the design of safer playgrounds.
- The interdisciplinary approach of the chosen theme, as a necessity to overcome the artificial boundaries between certain fields, thus providing an integrated picture, with various correlations between fields, in order to make the right decisions.
- Using DMAIC Six Sigma methodology.
- Realization of some maps of the studied area, respectively analyzes carried out using the CORINE Land Cover (CLC) methodology, thus being able to follow the evolution of land use over a period of 28 years old.
- Realization of the relationship between detected heavy trace elements **-** Kendall tau correlations **-** suggesting a common source of pollution.
- The imprint of the landscape designer's training in the thinking of the studied problem, namely the interest in the soil and the thought of its remediation by means of landscaping with plants.

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