BABEŞ - BOLYAI UNIVERSITY CLUJ NAPOCA

FACULTY OF ENVIRONMENTAL SCIENCE AND ENGINEERING

DOCTORAL SCHOOL ENVIRONMENTAL SCIENCE

MODEL FOR ASSESSING PROGRESS INTERVENTION PROGRAM IN REDUCING RISKS OF EXPOSURE TO HEAVY METALS (Pb, Cd) IN COPŞA MICĂ

SUMMARY OF THE DOCTORAL THESIS

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Acknowledgements

As a child, when I was trying to imagine how the year 2000 would look like, I firmly believed that we will all live in a better and cleaner world…Maybe in the air that we breathe or the waters of seas and oceans...

As an adult, while acquiring the knowledge of a graduate from the Faculty of Chemistry, as well as the vision of what we, the people, destroy within the biodiversity of our wonderful Earth, my conscience started to reproach me that we will not leave a less polluted world for future generations …

Therefore, developing a scientific study, which was to be my Doctoral thesis, regarding the intervention program to reduce exposure to heavy metals and associated risks in Copşa Mică area, seemed very interesting and useful for everything that I do and will leave behind in my professional activity; a thesis focused, regardless of subsequent studies, on environmental protection.

With the utmost respect, I address the first words of gratitude to the scientific coordinator of the thesis, Assoc. Prof. Dr. Gurzău Eugen Stelian, member of the Academy of Medical Sciences,whom I thank for the competent and professional suggestions provided during documentation, elaboration and writing of this doctoral thesis, for the contribution to my scientific training and especially for all the confidence!

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From the very beginning I was blessed to have remarkable parents who protected and loved me, a large family that makes me feel strong and emotionally fulfilled. Today I have my own family that has supported me both morally and financially and for whom no words are enough to express my affection and gratitude.

Bucharest, **Corina MORĂRESCU (LUPU)**

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Key Words: children, environmental protection, intervention strategies, lead, cadmium, modeling

CHAPTER I.

INTRODUCTION

Environmental pollution is considered to be the most dangerous and constant global threat. Environmental pollutants have a significant impact on ecosystems and upset the balance between the environment, human and non-human components, and this imbalance affects all life forms.

The bioavailability and bioaccumulation are key factors in the toxicity on living organisms and therefore most diseases related to heavy metal pollution are chronic and sometimes systemic (ATSDR 2000, Gulati 2010), in this case, past exposure is very important (Caussy et al., 2003 Gurzău et al., 2007). Perhaps the main characteristic of heavy metals consists in their toxicity in low concentrations. That is why it is not necessary the exposure at high levels as to produce toxicity.

Evidence of the effects of low exposure was stronger for cadmium, lead and mercury, and less certain for arsenic (Wirth, 2010).

The factors to be considered in order to assess the effects of exposure to heavy metals in public health are: distribution of exposure in population (risk groups), exposure-response relation (response variation, susceptible groups) risk aggregation (geographical aggregation of risk factors).

CHAPTER II.

ANALYSIS OF THE STAGE AT A NATIONAL AND INTERNATIONAL LEVEL OF THE DATA ON THE LEAD AND CADMIUM EXPOSURE AND HEALTH EFFECTS

2.1. The adverse effects of lead on human health.

2.1.1 Specific characteristics concerning children's exposure to lead

a) Overview

Lead toxicity prevention remains a huge challenge especially for children, because they are the most susceptible population group in non-occupational exposure (ATSDR, 2011) and because adverse effects on health due to this toxic occur at increasingly lower levels.

b) Sources and pathways of lead exposure

Sources of lead poisoning may be:

- Professional: plumbers, lead miners, printers, painters, ship builders, auto mechanics, steel industry workers, construction workers, gas pumps etc.
- From the environment: paint contaminated with Pb, soil / dust contaminated with Pb, plumbing, pottery, and leaded gasoline.

- ❖ Hobbies: painting, repair of electronics, making stained glass, pottery, redecoration of homes etc.
- ❖ Use of substances: cosmetics, gasoline additives, drugs (folk remedies), beverages contaminated with lead, food with high content of lead, contaminated water through the distribution network.

Children are exposed to lead coming from all these sources and different ways of contact, the toxicity being present in all environmental factors:

- soil (natural element, or from pollution);
- water (through industrial pollution of water sources or due to leaching of lead from lead pipes or plastic materials);
- food (natural lead content or increased due to cultivation in polluted areas or contamination during preparation or preservation);
- air (coming from industrial pollution or exhaust gases of motor vehicles);
- other sources: paints, lead toys

The lead intake in children is higher than in adults, as they are more at risk. A study was conducted in Ethiopia (Getaneh et al., 2014) in order to assess lead exposure and related health risks revealed a total risk value of 1.41 for children and 0.37 for adults.

The quantitative evaluation on the contribution of soil and dust in filling the body with lead has been the subject of various studies made in the USA: New Jersey (Yiin et al., 2002 Yiin et al., 2008), Philadelphia (Campbell and et al., 2011 Clark et al., 2011), Arkansas (Ferguson and al., 2011) Georgia (Kegler et al., 2010), Missourri (Berg et al., 2012), but also in other parts of the world - South Africa (Mathee et al., 2013) and Mexico (Cubillas-Tejed et al., 2011). Recently, in Ethiopia were reported average concentrations of lead in soil of 220.08 ± 135.95 μg/g (Getanh et al., 2014).

c) The effects of lead exposure on the health of the general population

The toxic effects of lead depend on the level of exposure and the age at which occurs.

Young children are the population group with the highest risk, especially because of the sensitivity of the central nervous system which is in full process of development. Among adults, the most sensitive are cardiovascular patients, the most important effect in the general population being high blood pressure and also those patients suffering from chronic kidney disease; lead has a nephrotoxic action on the kidney, through vascular sclerosis, atrophy of proximal convoluted tubule cells, interstitial fibrosis and glomerular damage.

Other effects of lead exposure concerns infertility, abortion, neonatal mortality and morbidity, as well as the immunosuppression given by the alteration of the humoral immune system.

d) Lead poisoning in children and their monitoring

Lead poisoning symptoms in children with high blood lead levels, is a medical emergency and children must be hospitalized. Symptoms that may indicate other pediatric diseases must be identified so that they cannot be omitted.

Children with blood lead between 10 μg/dL and 19 μg/dL require repeated monitoring. The foundation for the clinical management is made up of a very careful clinical and laboratory observation, medical treatment if it is necessary to eradicate the manageable sources of lead exposure in the environment. The most important factor in management is to drastically reduce the child's exposure to lead.

2.1.2. Data on the adverse effects in case of lead exposure in children.

The fetus, young children and pregnant women are widely recognized as sensitive populations with increased risk in developing adverse effects to chronic exposure to lead, including relatively low concentrations. (Bellinger et al., 1992 and Hu et al., 2006, Koller et al., 2004, Bellinger 2008). The effects of chronic exposure to lead on the kidney, high blood pressure and hematopoietic system were the subject of numerous studies, some of which achieved conflicting results. (Canfield et al. 2003, and Lanphear et al., 2005 and Lin et al., 2003).

Another indicator influenced by chronic exposure to lead is represented by the somatic development. Indexes like height and weight can be altered, it has been registered a delay in growth of about 1-1.5 years. (And Bellinger et al. 1992, and Chiodo et al. 2004, and Calderóna et al., 2001).

2.1.3. Lead poisoning prevention activities at community level

Because 10 μg Pb/dL is the minimum level of the range at which the effects are not identified, basic prevention activities - environmental interventions in large communities and nutritional and educational campaigns - should be targeted in order to reduce the lead level in blood, to at least 10 μg /dL. Blood lead levels between 10 and 14 μg /dL, are within the so-called borderline (CDC 2005).

Overexposure to lead is further manifested in two major risk groups: poor children who live in old, rented dwellings, poorly maintained and wealthier children who live in older dwellings that are being renovated.

Prevention methods are focused both on eliminating / reducing the lead intake from known exposure sources as well as on increasing the population's education and awareness level on the risks posed by this toxic.

In Europe, the lead-related economic impact was not examined in detail until 2008, when it was conducted a study to assess the expected social and economic benefits of minimized exposure. There were estimated annual costs in France due to childhood exposure and study data was published in 2011 on the basis of cost-benefit analysis results.

U.S. researchers recommend conducting the environmental investigation for a child with an elevated blood lead level having regard to:

(a) an environmental history,

(b) an inspection of the child's first residence and any buildings where they spend their time on a regular basis,

(c) measurement of lead in damaged paints, dust, soil or water

(d) control of any imminent danger and

(e) renovation of the house, which may require temporary relocation of the child.

Summarizing (Meyer et al., 2008), there are recommended three primary strategies for the prevention of lead poisoning:

- identification of the source,
- elimination or control of the source,
- monitoring environmental exposure and hazards.

Monitoring the distribution of heavy metal contamination in soil, including lead contamination, may be useful in establishing strategies to reduce the negative environmental impact.

2.1.4. Specific aspects of lead exposure in infant population in Romania

Although lead exposure in western countries can be prevented almost entirely due to the type of environmental contamination and exposure pathways, in other parts of the world the situation is different. The World Health Organization identifies the north-western part of Romania as a health risk "hot spot", where human exposure to lead is still very high.

High levels of lead in the environment in these areas are caused by the presence of non-ferrous metallurgy industry (Zlatna, Baia Mare, Copşa Mică etc.), mining areas rich in non-ferrous metals or road traffic. In our country have been conducted studies that focused almost exclusively on non-ferrous metallurgy areas. These regions are characterized by high levels of inorganic lead in the environment. The situation is different when sources are represented by road traffic, where we are dealing with organic forms of lead, even if the effects on the health of population groups at increased risk are identical for the two cases mentioned above (Gurzău et al., 1995 Gurzău et al. 1995, and Gurzău et al., 1996).

Copşa Mică faces the challenge of historical lead contamination that comes from the smelter. Lead concentrations in the soil, measured in parts per million, vary depending on the region, from the base levels which normally exist of $\leq$ 50 PPM to 60,000 PPM, depending on the relative distance to the expected emission source (Surdu et al., 2006). In a research project (Complex program of quality assurance and environmental security in rural areas polluted with pesticides and heavy metals, MESAR 2008-2010), was highlighted once again both the existence of lead-contaminated soil in the entire city of Copşa Mică, at dangerous levels as well as increased blood lead levels in children (Gurzau et al., 2002).

2.2. The adverse effects of cadmium on health

Cadmium is a metal present in zinc, lead and copper ores in the form of cadmium sulphide. Cadmium was discovered as chemical element only in 1817, and until 50 years ago has rarely been used in industry. Currently is a very important metal having many uses.

Cadmium is a toxic metal and its accumulation in the body increases with age. The biologic half-life of cadmium in the human body is of more than 10 years. Cadmium is one of the elements included in the Special Health Hazard Substance List because it is acknowledged as a possible carcinogen.

2.2.1. Non-occupational exposure to cadmium

For the general population, cadmium exposure can be the result of simultaneous exposure in different ways and pathways, so that the population located in the vicinity of certain industrial centres (smelters of ores or metals refineries) will be exposed to higher levels of cadmium (Jarup and Akkeson, 2009). The main way of exposure is the daily diet. Less than 10% of ingested cadmium is absorbed. Low levels of cadmium were found in the food base, particularly in cereals, grains and other plants (vegetables) that naturally extract cadmium from contaminated soil, from different fertilizers, manure and polluted groundwater. It is well-known the mass cadmium poisoning that took place in Japan in the JINTSU basin, caused by discharges of contaminated wastewater by a zinc mining company and characterized by osteoalgia and frequent fractures among the population in the area (it was called the "itai-itai" disease).

2.2.2. Acute and chronic health effects

The toxicity, absorption, distribution and excretion depend upon the solubility of cadmium compounds. (Klaassen et al., 2009 Larreglea et al., 2008). The cadmium exposure effects are classified into two categories: acute and chronic.

In humans, long-term exposure to cadmium is associated mainly with kidney disease (Malgorzata et al., 2003 and Moralesa et al., 2006; Gonick, 2008).

In the category of **acute effects** due to ingestion of food products with high levels of cadmium, falls headache, fever, pulmonary changes (shortening of breath, cough), vomiting, cramps and diarrhea.

Chronic effects mainly result from exposure to low levels of cadmium and are represented by chronic obstructive pulmonary or renal disease. May also occur, effects on the cardiovascular and bone system and bone.

Early prevention, diagnosis and intervention for children are important for the renal function recovery, and normal development of children (Rong et al, 2014).

CHAPTER III. PERSONAL CONTRIBUTION. MOTIVATION, OBJECTIVES, AREA CHARACTERIZATION, PRELIMINARY STUDY

3. 1. Reasons for choosing the topic

The reason for choosing the topic for this doctoral thesis is given by a tangible and very "painful" reality, namely "Heavy metal pollution (toxics - lead and cadmium) and ways of intervention by exposure control measures for the receiver". Why intervention, why sustainability, why children health status? For the simple fact that in Copşa Mică locality and area, for decades now, have been conducted dozens, maybe hundreds of evaluations, all types of studies (various approaches - Environment, Hydrobiology, health, social etc..) but the exposure in children remained the same. The answer to the question includes children, because they are the population group with increased susceptibility to lead and cadmium exposure, includes soil and dust, because they are the main source of exposure to those with increased susceptibility to lead and cadmium, and also includes intervention methods, more precisely how to manage exposure by reducing / removing contact at receiver level. Seemingly looks simple, in fact, as shown in this doctoral thesis, this approach involves substantial resources to develop scientific models that analyse the dynamic environment-health relation, and control the intervention "program success" by measurable indicators. If we do not have this approach then we would deliberately be condemning our future (meaning the children), knowing very well and extremely well-documented the fact that lead and cadmium pollution in Copşa Mică is already a matter of historical pollution (residual) and that currently do not exist in the world, intervention means for the exposure control through soil remediation when it comes to such a soil area and not only (very large), and when we have to take into account three key issues that are the basis of sustainable development (environmental protection, economic development and social issues), components that must be in an almost perfect balance as to achieve this "sustainable development". Now we have the reason behind this doctoral thesis, actually directed towards what we call: the environment in relation to health, as to ensure the safety and security of the citizen at individual and community-level.

3.2. General and specific objectives of the thesis

The general objective of this thesis is the elaboration and implementation of specific intervention programs to reduce both the population exposure to heavy metals - lead and cadmium, as well as the environmental risks in Copşa Mică.

There have been identified several specific objectives, characteristic to the elaboration of a single methodology in order to obtain a comparable database for Copşa Mică area by:

- identification of the study area in Copşa Mică exposed to heavy metals - lead and cadmium;
- development of sampling techniques and analysis methods of exposure biomarkers to lead;
- assessment of environmental conditions, risk factors and impact on population groups associated with exposure to heavy metals in the study area;
- elaboration of communication strategies, of a social marketing program in order to mitigate exposure and to decrease the lead exposure risk of populations at increased risk.

The aim of this thesis is to assess the relation between lead pollution and the health of children between 2-11 years from Copşa Mică, together with the development of intervention programs to encourage the reduction of exposure to heavy metals and environmental risks in the studied area.

The research was carried out in four stages, the target population being children living in the area affected by the polluting company from Copşa Mică.

Main objectives:

- Assessment of issues related to lead exposure and irritants in population at increased risk from Copşa Mică area;
- Health Risk Assessment in exposure to lead and cadmium in the infant population from Copşa Mică;
- The study of exposure biomarkers to Pb / Cd in correlation with various risk factors as to provide public health protection programs;

- Substantiating the fight against heavy metal contamination to ensure environmental quality and public health in accordance with the strategic European environmental and safety priorities.

Specific objectives:

- Analysis of the stage at a national and international level of the data on the lead and cadmium exposure and health exposure
- Risks and impact assessment on population groups associated with lead and cadmium exposure in the investigated areas;
- Comparative analysis of the evolution over time of blood lead values determined in samples of subjects from Copşa Mică;
- Statistical analysis in linear regression model of the relation between blood lead levels measured in the investigated subjects and several lead exposure risk factors, investigated through questionnaire;
- Elaboration of the intervention program and procedures on the integration of population-related information

3.3. Population, selection criteria of the study area

This paper has addressed several issues, namely:

a. **Identification of areas,** with high levels of lead and cadmium in the environment.

b. **Dividing the Copşa Mică area** into 2 areas, depending on the location of dwellings of the investigated subjects (area A and B): Area A - located in an area up to 70 m from potential sources of pollution; Area B - situated in an area comprised over 700 m of potential sources of pollution

c. **Identification of people** with increased susceptibility, as follows: children aged 2-6 years and 7-11 years, respectively, children aged 4-6 years. Establishing at each stage a sample of subjects who received questionnaires on exposure and health and to whom were determined biomarkers of effect and exposure.

d. Starting a **program** having as objectives the developing of **communication, social marketing** and **risk management strategies.**

3.4. Sampling and analysis of samples, statistical data analysis

1. The methodology for the application of **questionnaires regarding the exposure and health** of those investigated:

- in groups of 10-20 people under the supervision of an investigator / operator after a training on how to fill out the questionnaire and objectives, aim of the program

- at the end of completing the questionnaires the operator was required to check if all questions have answers and also the accuracy of the answers
- questionnaires were applied to selected people

The information was collected through the lead exposure questionnaire on potential risk factors that impact the relation between children exposure and health.

2. The determination of blood lead as a specific biomarker of exposure was achieved by taking a drop of capillary blood and the concentration reading was performed using the Lead Care System machine at every stage, modern method launched by the Centre for Diseases Control (USA).

3. The measurement of biomarkers of effect was performed at each stage:

- staturo-ponderal growth (height, weight)

4. **Determination of lead and cadmium concentration in dust, soil and plants** was established by using X-ray fluorescence technique.

3.4.1. The methodology of sampling and processing environmental samples

Sampling and determination of the lead concentration in soil using X-ray fluorescence technique

The soil was collected in metal free plastic bags. Soil samples were then labelled, sealed and transported to the laboratory where they were subjected to processing for assessment by X-ray fluorescence technique, using the Niton XL 700 device. The preparation of samples for analysis was carried out as follows: from the soil sample was extracted an amount of about 50 grams, which was subjected to drying a container on a heating plate. The dried soil was milled and sifted through the three sieves of the equipment, to the finest sieve.

After preparing the device, the soil sample is analysed using X-ray fluorescence.

The dust samples on the hands of investigated subjects and from their homes, respectively, were collected on special napkins, impregnated with deionized water containing benzalkonium chloride that secures the lead and were subsequently analysed by X-ray fluorescence.

3.4.2. Sampling and determination of lead and cadmium concentrations in vegetables harvested from the housing area of the investigated subjects using X-ray fluorescence technique.

Harvested samples (lettuce leaves) were labelled, sealed and transported to the laboratory where they were subjected to processing for assessment by X-ray fluorescence technique, using the Niton XL 700 device.

X-ray fluorescence allows reading through a radioactive source (Cd109), and the developing of X-ray spectrum for the analysed samples. The analysis is done within about 120 seconds, with a sensitivity of 1 sigma (0,001 ppm) and 99.99% accuracy, the limit of detection is 5 mg / kg of plants in the case of lead and 0.5 mg / kg in the case of cadmium.

3.4.3. Sampling and determination of the lead concentration in the dust on the hands of the investigated subjects using X-ray fluorescence technique

The dust samples on the hands of investigated subjects and from their homes, respectively, were collected on special napkins, impregnated with deionized water containing benzalkonium chloride that secures the lead and were subsequently analysed by X-ray fluorescence.

Readings are made in ‘thin layer’ system, but are made four readings, as follows:

1. the metallic support containing the wet napkin is placed in the number 1 position of the ‘thin layer’ platform
2. first measurement is carried out;
3. the sample is placed in number two position of the bench and the second measurement is carried out;
4. the support containing the napkin is rotated to 180 degrees;
5. the third measurement is carried out with the napkin in position number one of the bench;
6. the sample is positioned in number two and the fourth measurement is carried out;

This procedure ensures that the entire surface of the sample is measured by the device. The result of the determination is displayed after each measurement. After completing the four determinations, the device displays the final result on the screen, with a detection limit of 0,1 $\mu g/cm^2$ lead.

3.4.4. Statistical data processing methodology

Following the interviews given by parents of children within the study, has resulted information on exposure to metals, other potential risk factors for the studied effects of exposure to pollution factors (e.g. demographic factors - gender, age; socio-economic factors – parents’ education, of congestion etc.), which was introduced into the variables created in the database. Some data were analysed in Excel, by drawing up tables, graphs in various forms, which were then interpreted.

Advanced processing was carried out by the STATA program and resorted to using linear regression models. Regression coefficients and standard errors obtained from the use of the regression model show the correlation between the dependent variable studied and independent variable / variables introduced in the model.

CHAPTER IV

ANALYSIS OF THE INVESTIGATED AREA FROM A GEOGRAFICAL, METEO-CLIMATIC, ENVIRONMENTAL FACTORS, MAIN POLUTION SOURCES PERSPECTIVE

4.1.Overall data concerning Copşa Mică – Mediaş area

Overall information

- **Type of area**: Copşa Mică – Mediaş area includes: Copşa Mică City, Mediaş Municipality and rural areas Axente Sever, Micăsasa, Târnava, Şeica Mică, Valea Viilor
- **Estimation of the area under the exceeding incidence**

Considering the data from existing studies on Copşa Mică area it results that along the river valley Târnava Mare the polluted area is totalling 180.750 ha, of which 31.285 ha forestland fund and 149.465 ha agricultural land, of which 3.245 ha of forestland fund and 18.630 ha of agricultural land being considered seriously polluted. Severely affected area is of approx. 220 km^2.

Geographical location of area

In terms of physical geography, in the center of the area lays Copşa Mică, whose coordinates are 46°6′45″ north latitude and 24°13′50″ east longitude, and is located in the Transylvanian Depression, the south-west side, more precisely in Târnavelor Plateau. (Figure 1.).

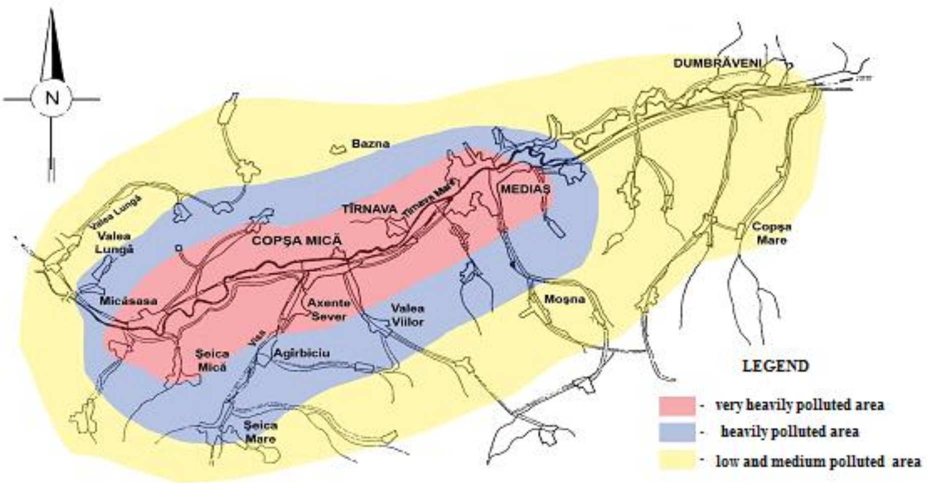

Figure 1. Map of Copşa Mică –Mediaş area affected by pollution

The northern boundary is marked by the Transylvanian Plateau and Blajului Plateau, in the western part by the Secaşelor Plateau and Amnaşului Plateau, and the southern boundary is marked by the Vurpărului Plateau and Hârtibaciului Plateau (Figure 2.).

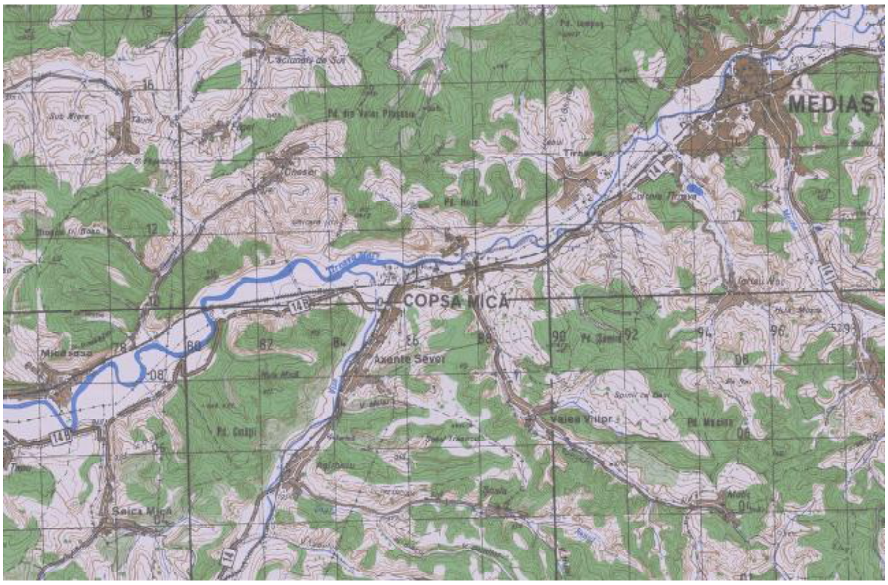

Figure 2. Geographical map of Copşa Mică-Mediaş area

Hydrological and hydrographic conditions

The hydrographic network of the studied area is composed of a segment of the middle course of Târnava Mare (72 km long), which drains an area of 1328 km^2, between the junction with Laslea and Ţapu creek and on the area of Sibiu county, as well as of the most important tributaries in this sector: Laslea, Valchid, Biertan, Aţel, Moşna, Visa, all left bank tributaries. Right bank tributaries are short and torrential, the only one more important being Eliseni creek. Some of them dry up during dry summers (Figure 3.).

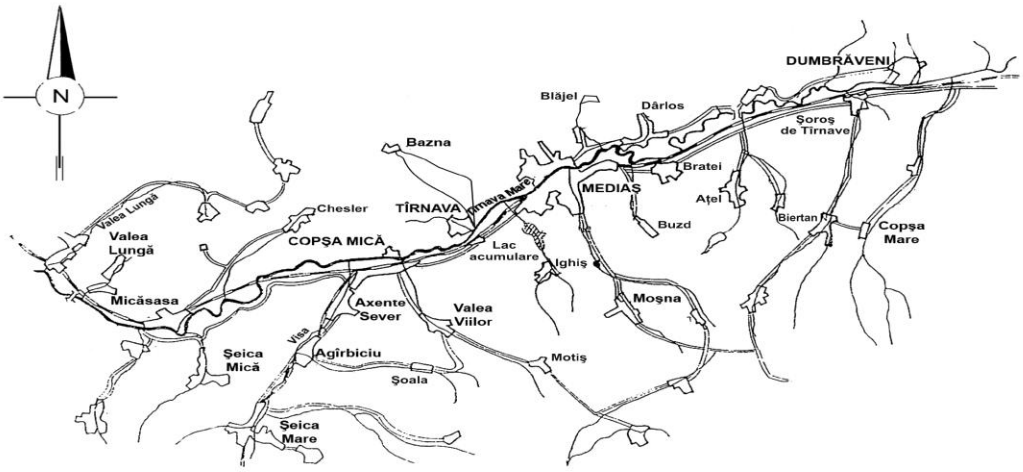

Figure.3. The hydrographic network of Copşa Mică-Mediaş area

There have been studied climatic (cloudiness, radiative regime of the area, air temperature, atmospheric precipitation and wind regime), pedological as well as flora and fauna conditions of the area.

4.2. Copşa Mică Industry

S.C. SOMETRA S.A. has been focused on the production of lead and zinc from ore concentrates, as well as on the capitalization of other metals like antimony, bismuth, cadmium, gold-silver alloy, and their derivatives. Copşa Mică was affected by pollutants generated from activities carried out for a period of over 60 years on the industrial platform S.C. SOMETRA S.A. and by the carbon black factory S.C. CARBOSIN S.A., which ceased its operation in the 90s.

S.C. SOMETRA S.A. is the biggest polluter in Romania and one of the biggest in Europe.

4.3. Analysis of the situation on the starting date of the doctoral thesis (year 2010)

4.3.1. Sample population investigated in Copşa Mică area in 2010

In 2010, a population-based sample that included children aged between 2 and 10 years, was investigated in Copşa Mică area. The investigated sample was drawn up from a group of 140 children whom the preliminary study was addressed to. All sampling in this chapter was done on a group of 53 children, out of the 140, for which we have obtained comparable data. From the participants in the study, were collected samples from environmental factors and biological samples to assess exposure to specific contaminants of this area, having as industrial branch the non-ferrous metallurgy, namely heavy metals (in this study were assessed lead and cadmium). In terms of gender distribution, the sample investigated included male and female subjects, most were male (37 subjects) and only 16 female subjects (Figure 6.).

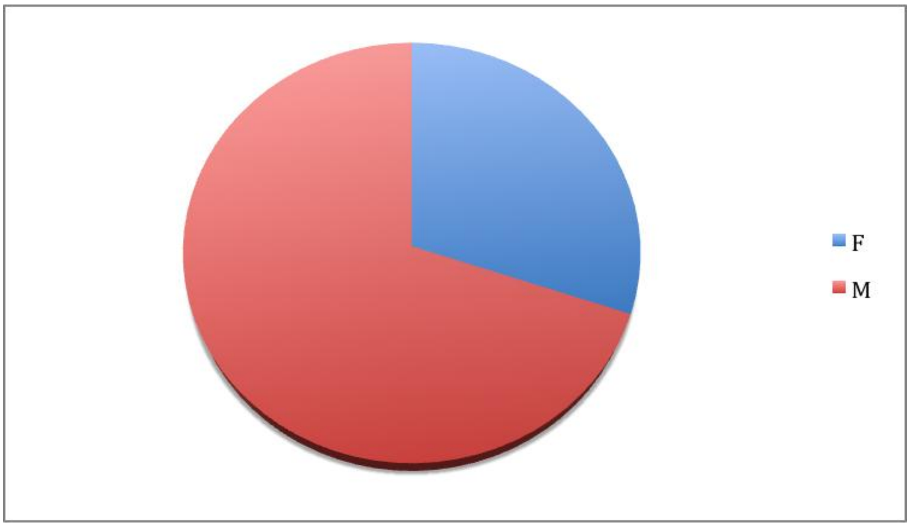

Figure.6. Gender distribution of subjects

4-6 years old age group, the age group to which is the most susceptible to lead exposure, included a larger number of subjects as compared with the 7-10 years old age group (Fig. 7).

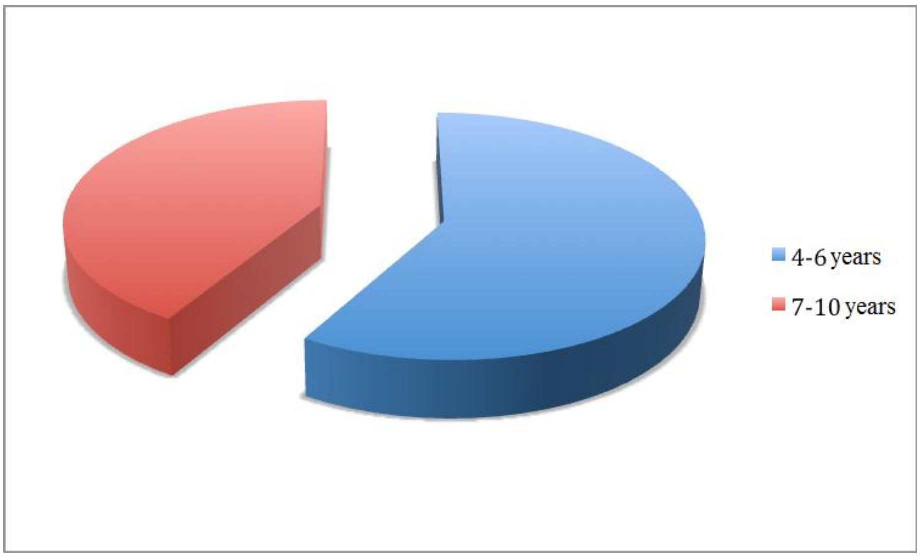

Figure.7. Distribution of subjects by age

The values of blood lead found (Figure 8.) exceeded the biological limit imposed by the U.S. CDC (Center for Disease Control), that is 10 mcg / dl.

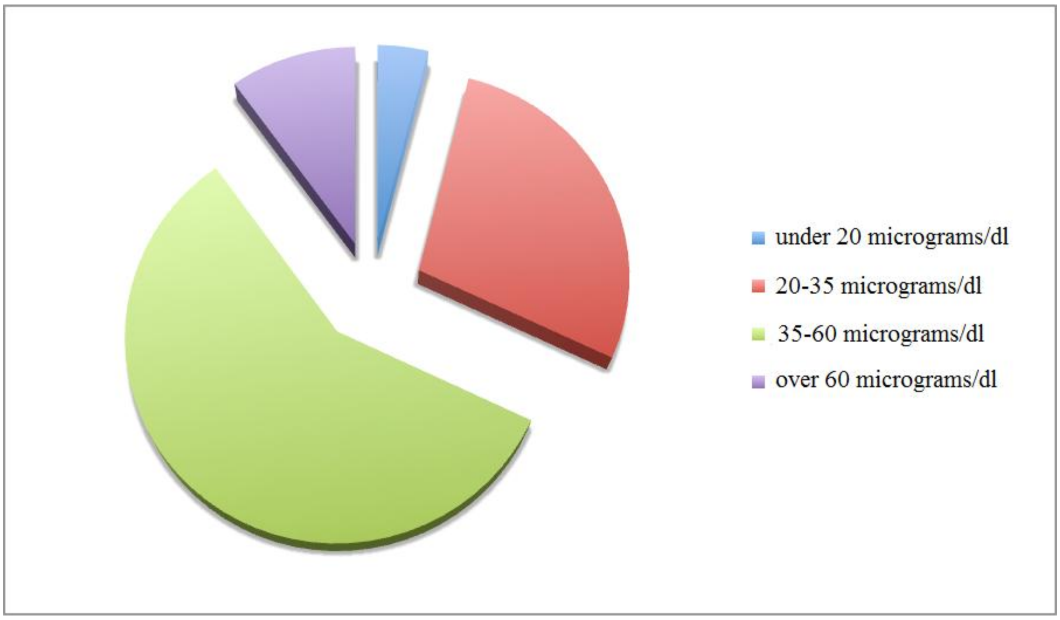

Figure.8. Distribution of subjects investigated by blood lead groups

Lead and cadmium were found in seasonal vegetables samples that were collected from subjects who had a garden. In comparison, as average and maximum value, the concentrations of cadmium in vegetables exceeded the measured lead concentrations in vegetables (Figure 9.). 7 36 14,08

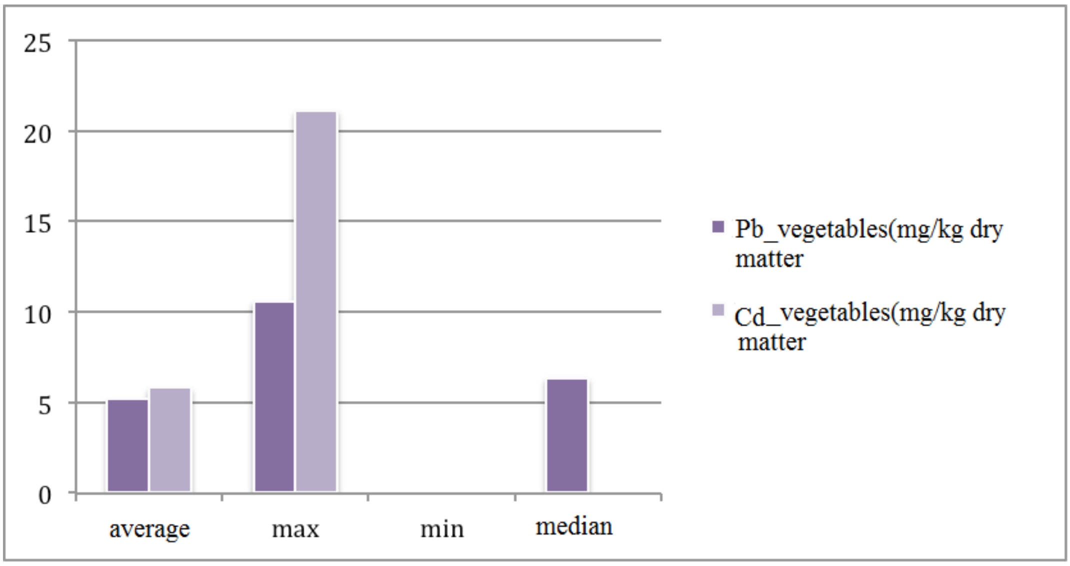

Figure.9. Measured Pb and Cd levels in vegetables in Copşa Mică area

Among the population-based sample investigated in Copşa Mică area, lead and cadmium were found on the hands of children, by using a special napkin, impregnated with a substance that seals heavy metals. The children's hands were thoroughly wiped with these napkins. Afterwards, these metals were determined in the laboratory. No lead was found on the left hand, but on the right hand were measured lead concentrations with values ranging from values below the detection limit of the method and a maximum value of about 511 $\mu g/cm^2$, with an average value of about 80 $\mu g/cm^2$ (Figure 10.).

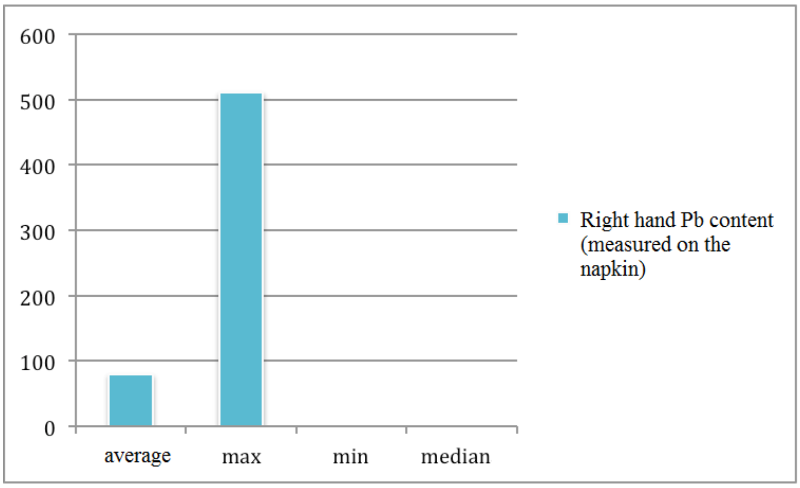

Figure.10. Right hand lead content

Regarding the content of cadmium, this was measured on the right hand of only one child whereas on the left hand were measured cadmium concentrations with values ranging from values below the detection limit of the method and a maximum value of about 38 µg/cm^2, with an average value of about 6 µg/cm^2 (Figure 11.).

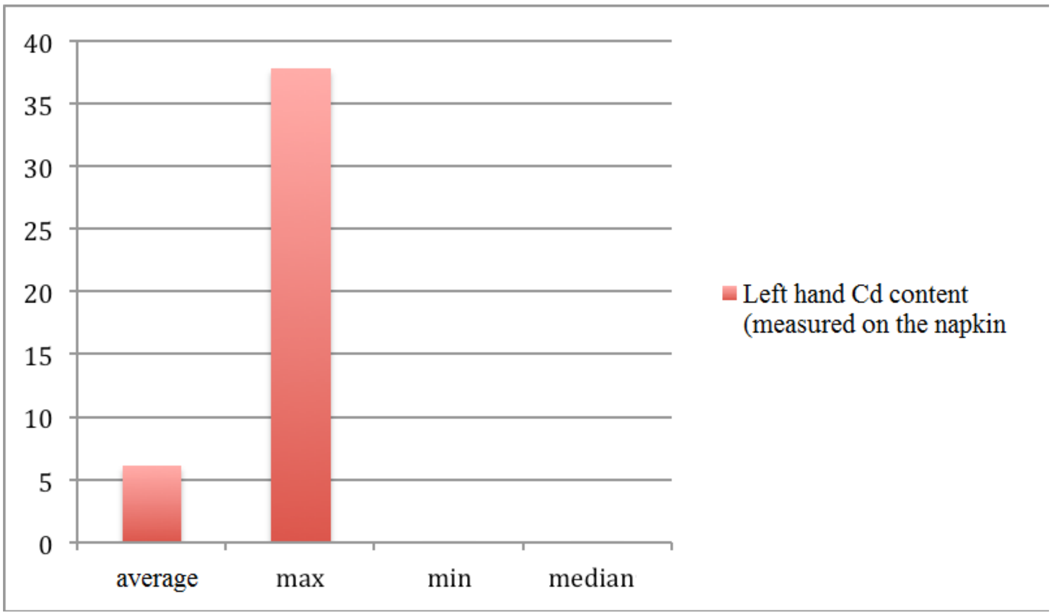

Figure.11. Left hand cadmium content

Regarding the blood lead values compared to lead content on the children's right hand (Figure 12.) was observed that high blood lead values correspond to high values of lead content measured on the right hand of children.

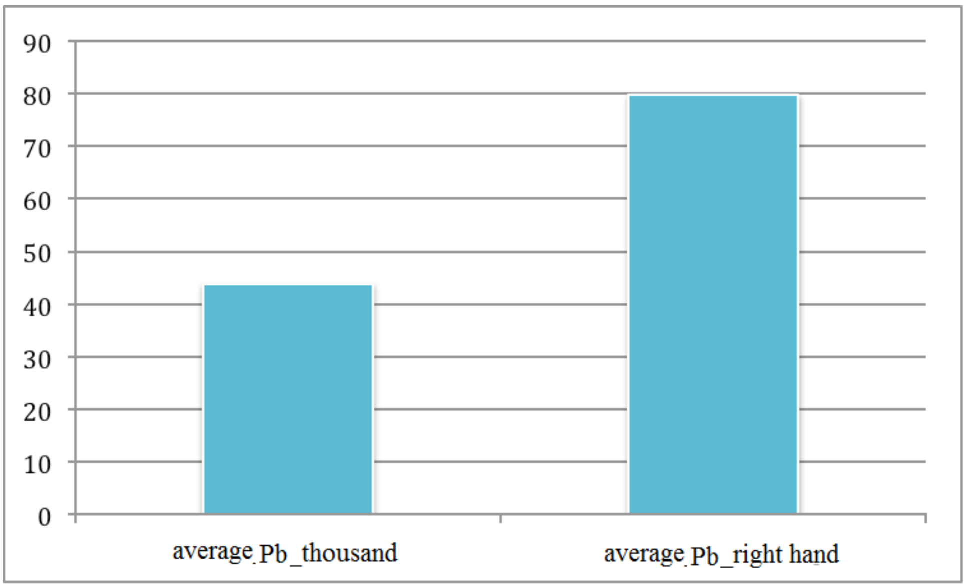

Figure.12. Average blood lead valued compared to the average right hand lead content value, of the population-based sample investigated in Copşa Mică

The lead levels determined in outdoor dust, in the vicinity of the dwelling, were relatively high. In one of the sampling points they exceeded the value of 1000 mg/kg dry matter (Figure 13).

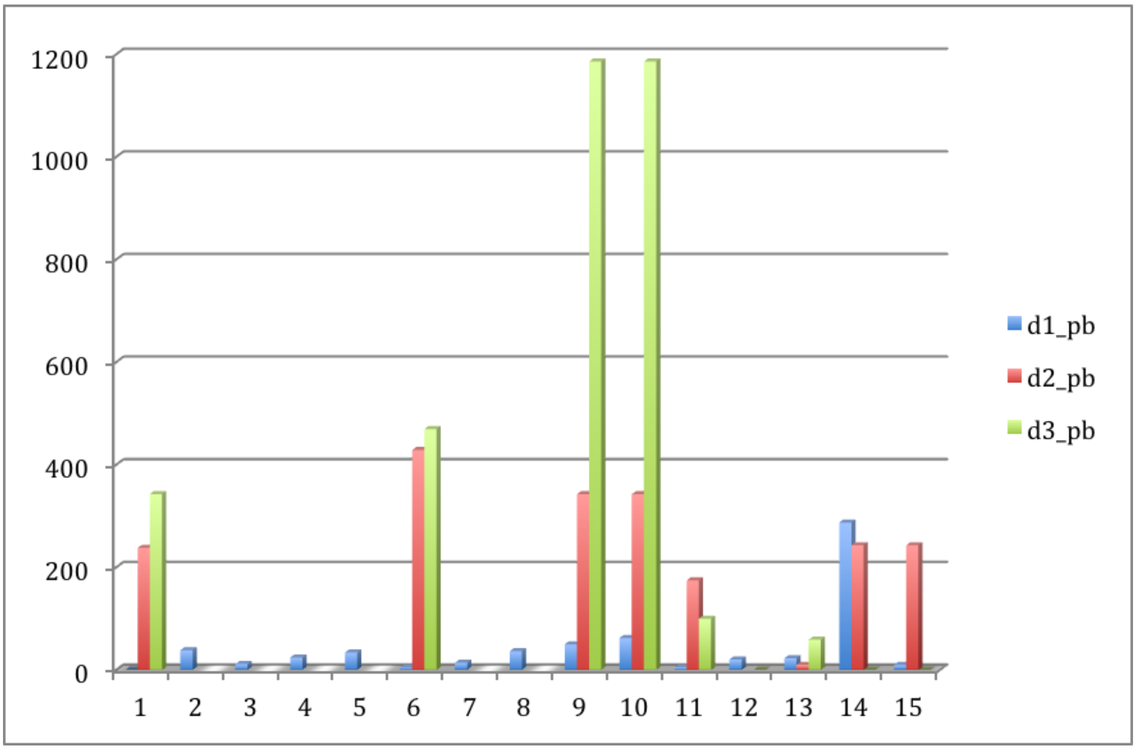

Figure.13. Lead levels measured in the dust outside the dwellings

The cadmium levels determined in outdoor dust, in the vicinity of the dwelling, were also relatively high. In one of the sampling points they reached the value of 70 mg/kg dry matter (Figure 14).

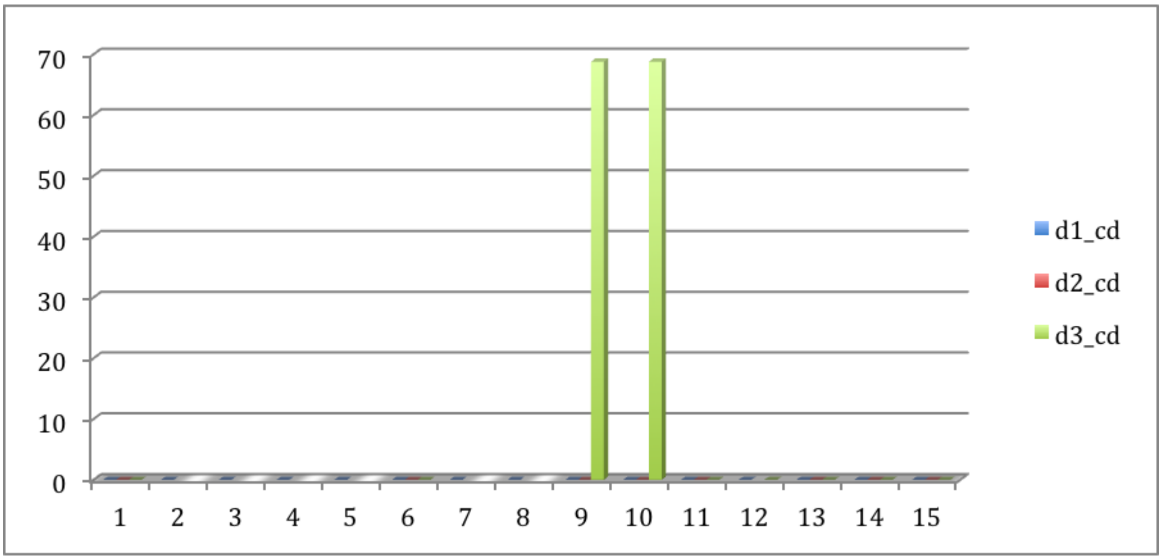

Figure 14. Cadmium levels measured in the dust outside the dwellings

In the case of cadmium, the concentrations in the collected soil at 5 cm were higher or very close as those determined in the soil from 30 cm (Figure 16).

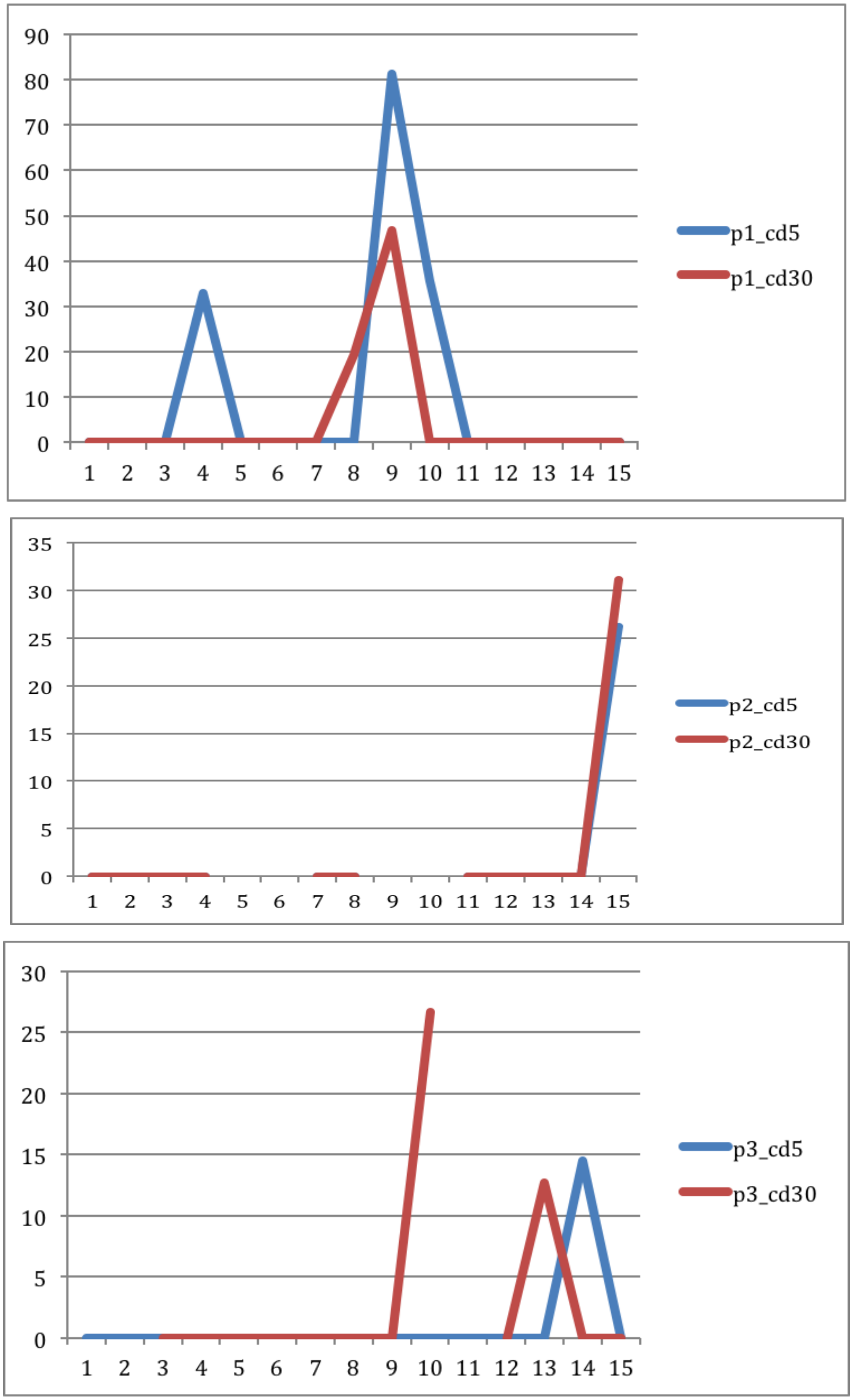

Figure 16. Cadmium levels measured in soil (samples collected at 5 and 30 cm) in the vicinity of the dwelling of a sample population group investigated in Copşa Mică

Lead concentrations measured in soil collected at 5 cm had high values for at all measuring points exceeding the intervention threshold of sensitive soils, of 100 mg/kg dry matter (fig.17.).

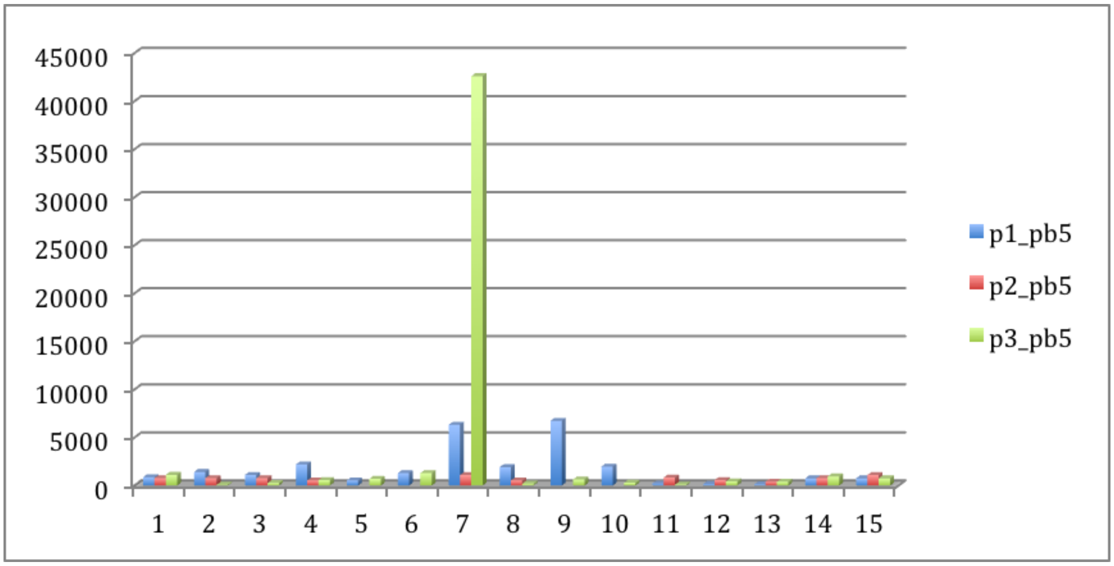

Figure 17. Lead levels measured in soil (samples collected at 5 cm) in the vicinity of dwellings of a sample population group in Copşa Mică

In the soil samples were cadmium was found, the measured values exceeded the intervention threshold for sensitive soils, 5 mg / kg dry matter (Figure 18.).

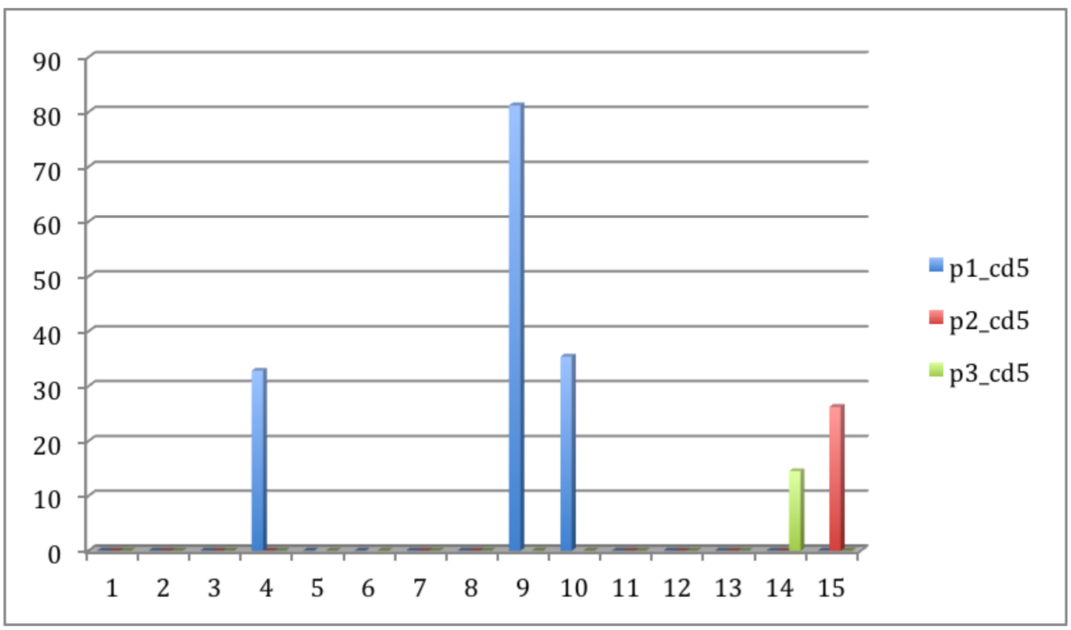

Figure 18. Cadmium levels measured in soil (samples collected at 5 cm) in the vicinity of dwellings of a sample population group in Copşa Mică

On average, it is noted that lead measured in soil collected from 5 cm, in the vicinity of dwellings of the subjects included in the study, had the highest value, and followed closely by lead measured in soil collected from 30 cm. The lowest average value was recorded for lead in the dust collected from outside the dwellings (Figure 19.).

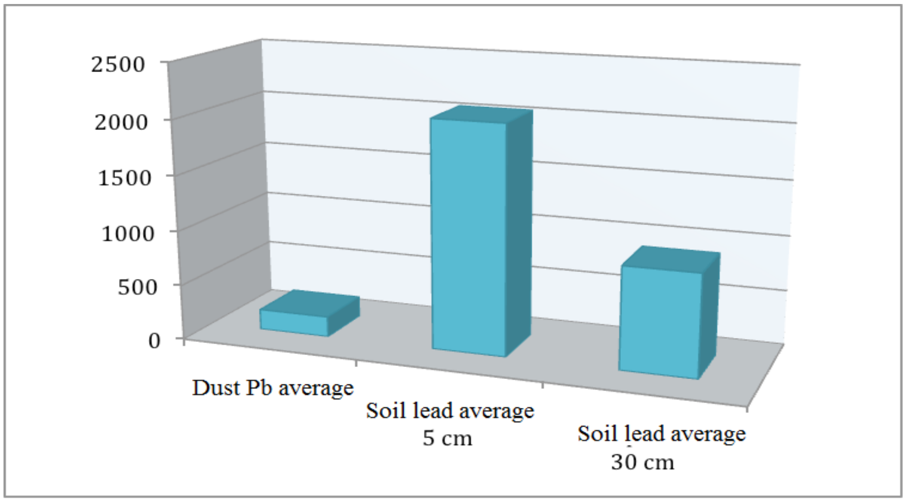

Figure 19. Average lead value of dust compared to the average lead value determined in the soil in the immediate vicinity of dwellings of the sample population investigated

4.3.2. Spatial distribution of lead and cadmium in Copşa Mică and in a wider neighbouring area

Spatial distribution of lead in the Copşa Mică town and surrounding areas was carried out in order to address two major issues, namely:

- The soil is the main source of pollution (historical pollution)
- Despite significant variation in soil lead concentrations, wide areas in terms of spatiality, recorded elevated lead values in soil (Figure 20.)

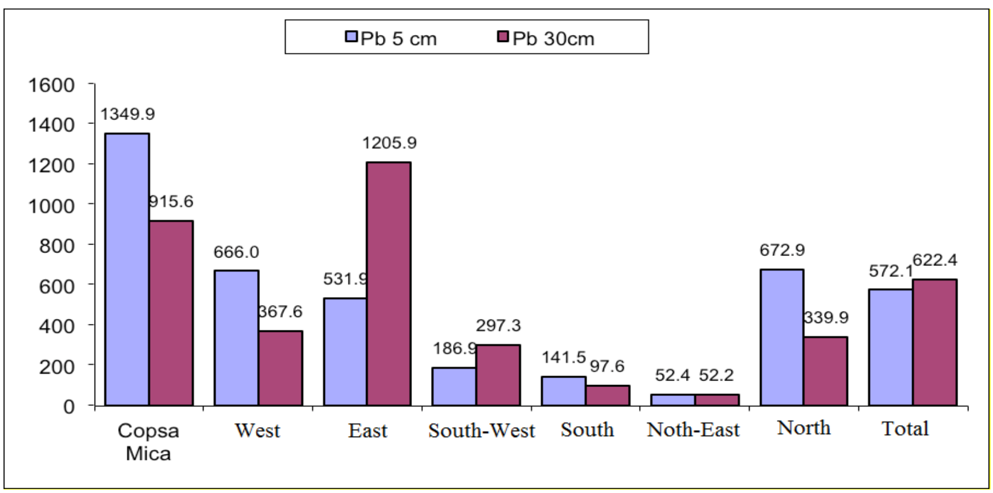

Figure 20. Spatial variation of lead concentration in different areas of Copşa Mică locality and surrounding areas (2 different depths)

Copşa Mică locality (values higher than other areas – similar to lead) recorded far higher cadmium concentrations than the surroundings (Figure 22).

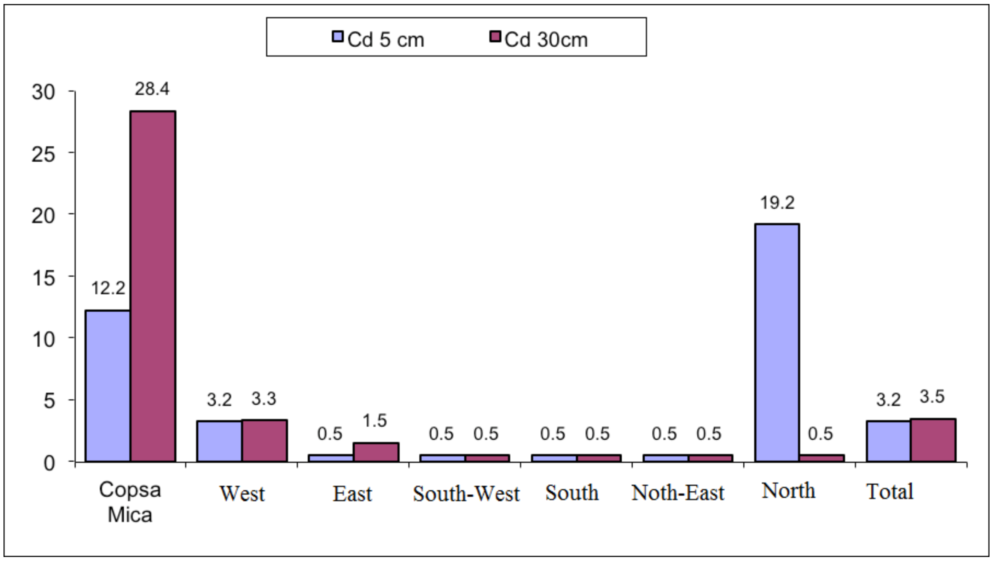

Figure 22. Spatial variation of cadmium concentration in different areas of Copşa Mică locality and surrounding areas (2 different depths)

CHAPTER V.

ASSESSMENT OF ENVIRONMENTAL CONDITIONS AND CHILDREN'S HEALTH FROM COPŞA MICĂ IN STAGE I OF THE STUDY (year 2011)

We resorted to an integrated approach which resulted in the selection of a sample of the population group with increased susceptibility represented by an extremely large number. This sample was represented by a number of 105 children investigated in 2011 and having a number of 80 parents who have filled out a specific questionnaire, standardized for this population group in previous studies. Exposure assessment of this population group has been carried out following specific aspects, namely:

- measurement of blood-lead concentration value in the investigated children;
- performing somatometric measurements (height and weight);
- collecting information related to lead exposure of the investigated children, information collected by interviewing their parents, relating to road traffic characteristics, the type of heating of the dwelling - methane gas/wood; smoking inside the house, individual factors - gender, age, socio-economic factors – parent’s education, family income, accommodation type, congestion indicators, others, information which subsequently has been entered in specific variables named and created in the database. Along with these variables, other variables have been also introduced, which represented the results of the blood-lead measurements as an exposure biomarker.

Depending on the residence of investigated children there were two exposure groups located at a different distance from the contamination source (under 500 and above 500 meters).

Descriptive statistics of the investigated sample

In Table 1 it is be noted that the investigated population distribution on age and gender groups is uniform with no statistically significant differences between the two areas as established depending on distance from source.

Table 1. Demographic description of investigated subjects area A and B in their entirety (sum)- distribution by gender and age groups

Age group	Gender		Total
	Girls	Boys	
7-11 years	15	18	33
	41,66	40,90	41,25
2-6 years	21	26	47
	48,34	48,10	48,75
Total	36	44	80
	100.00	100.00	100.00

The distribution by age and gender group of children who were enrolled in the study show an uneven distribution of preschool and school age group in both genders; taking into account their age, there appears a similarity between the two areas, in the significant variations by age - more girls in the 7-11 years age group and more boys in the 2-6 years age group (Table 2).

Table 2. Demographic description of subjects investigated in Area A and Area B - distribution by gender and age groups

Area A	Gender		Total
Age group	Girls	Boys	
7-11 years	10	8	18
	58,82	44,44	51,42
2-6 years	7	10	17
	41,18	45,56	48,58
Total	17	18	35
	100.00	100.00	100.00
Area B	**Gender**		
Age group	**Girls**	**Boys**	**Total**

7-11 years	11	8	19
	57,89	30,76	42,22
2-6 years	8	18	26
	42,11	69,24	57,78
Total	19	26	45

5.2. Assessment of lead exposure in children from Copşa Mică

5.2.1. Lead exposure biomarkers in investigated subjects

Area A and Area B

Blood lead values resulting from analysis carried out with Lead Care System, device designed for this type of assessment, in the children group with ages between 2 and 11 years, residing in Copşa-Mică town varied between the minimum value of 12,4 μg/dL up to maximum values of over 65 μg/dL. Blood lead levels over 65 μg/dL were quantitatively analysed, but above this value the assessment is in fact qualitative, only if we want to refer as to how much is this above μg/dL. Meanwhile, blood lead measurement results show that no child had normal blood lead levels, i.e. the category under 10 μg/dL.

Table 4. Blood lead mean distribution in investigated children, in relation to the distance from the main exposure source

Exposure area	**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
>700 m	45	40.60	14.11	12.4	>65
<700 m	35	43.21	18.52	24.7	>65

In the above table (no. 4) it can be seen that the mean blood lead levels recorded variable values, but we cannot conclude that there is an increasing trend nearer to the source of lead exposure, the highest value recorded was in the residential area with the highest population density, at a distance of under 700 m. In both cases (area A and area B) there have been recorded values of blood lead levels higher than 65 μg/dL.

5.2.2. The relation between blood lead and somatic development in investigated children

Area A

The association between height and weight on one hand, and blood-lead levels measured in children in Copșa Mică, on the other hand, show a negative correlation between blood lead measurements and height, and between blood-lead measurements and weight. The following tables show the linear regression coefficients and the statistical significance for assessing the impact of blood lead on the somatometric development in children. The results of the linear regression estimates indicate a negative correlation between blood lead measurements and height and weight in both instances, but without being statistically significant. (Tables 5 and 6).

Table 5. Blood lead measured in the group of children based on the 4 categories of blood lead levels (10-20, 20-35, 35-65, >65) and their height - Area A

Height	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	2.24	3.18	0.70	0.48	-4.06	8.55
age	0.04	0.63	0.07	0.94	-1.20	1.29
tip_loc	-1.21	1.61	-0.75	0.45	-4.41	1.98
educ_ma	1.14	1.68	0.68	0.49	-2.18	4.48
IPb_gr_2	-2.72	8.06	-0.33	0.73	-18.73	13.28
IPb_gr_3	-5.92	7.57	-0.78	0.43	-20.96	9.10
IPb_gr_4	-2.58	8.44	-0.30	0.76	-19.34	14.17
_cons	29.44	8.96	3.28	0.01	11.65	47.24

Table 6. Blood lead measured in the group of children based on the 4 categories of blood lead levels (10-20, 20-35, 35-65, >65) and their weight - Area A

Weight	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	0.53	0.67	0.80	0.42	-0.79	1.87
age	2.29	0.13	17.24	0.00	2.03	2.56
tip_loc	0.14	0.34	0.42	0.67	-0.53	0.82
educ_ma	0.36	0.35	1.02	0.30	-0.34	1.06
IPb_gr_2	-0.42	1.70	-0.24	0.80	-3.81	2.96
IPb_gr_3	-0.83	1.60	-0.52	0.60	-4.01	2.34
IPb_gr_4	-0.56	1.78	-0.31	0.75	-4.10	2.98
_cons	-2.49	1.89	-1.31	0.19	-6.25	1.27

Area B

The same procedure was used when analysing blood lead influence on height and weight in the investigated children within a second distance area from the main source of pollution. The results show a negative correlation between blood lead on one hand, and on the other hand, both as between height and as well as weight, for both instances, but without being statistically significant (Tables 7 and 8).

Table 7. Blood lead measured in the group of children based on the 4 categories of blood lead levels (10-20, 20-35, 35-65, >65) and their height - Area B

Height	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	-1.05	1.64	-0.64	0.52	-4.33	2.21
age	5.43	0.33	16.30	0.00	4.77	6.09
tip_loc	-0.86	1.18	-0.73	0.46	-3.21	1.49
educ_ma	-1.08	0.83	-1.29	0.19	-2.74	0.58
IPb_gr_3	1.12	2.68	0.41	0.67	-4.22	6.47
IPb_gr_4	0.05	2.80	0.02	0.98	-5.53	5.65
_cons	89.43	3.98	22.45	0.00	81.49	97.36

Table 8. Blood lead measured in the group of children based on the 4 categories of blood lead levels (10-20, 20-35, 35-65, >65) and their weight - Area B

Weight	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	-0.82	0.86	-0.95	0.34	-2.54	0.89
age	2.05	0.17	11.68	0.00	1.70	2.40
tip_loc	0.63	0.62	1.01	0.31	-0.60	1.87
educ_ma	-0.53	0.44	-1.21	0.22	-1.41	0.34
IPb_gr_3	1.11	1.41	0.79	0.43	-1.69	3.93
IPb_gr_4	-0.44	1.47	-0.30	0.76	-3.39	2.50
_cons	9.63	2.09	4.59	0.00	5.45	13.81

5.3. Assessment of risk factors and influence on children's exposure to lead

5.3.1. Risk factors influenced by behaviours / practices / habits

The statistical analysis of the information obtained after filling out the questionnaire by the children's parents, information/data that focused on the way some factors may influence exposure to lead in the investigated children, was carried out by test T. The test compared the variation in blood lead averages in children, in conjunction with the factors being investigated, some of those being associated with the increase/decrease in blood lead-levels in this population group with increased susceptibility. Below, in table 9, are shown the results of the assessment.

Table 9. Variation of average blood lead values depending on factors which may influence exposure to lead

Children playing with soil (code 1 = YES)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	52.16	2.11	24.66	0.00	47.83	56.48
1	54	1.78	30.24	0.00	50.40	57.59
diff	-1.83	2.76	-0.66	0.50	-7.36	3.69

Children playing with sand (code 1 = YES)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	44.72	2.63	16.98	0.00	39.18	50.25
1	55.97	1.53	36.37	0.00	52.89	59.06
diff	-11.25	3.04	-3.69	0.09	-17.47	-5.03

Spending time in holidays outside Copşa Mică (code 0 = NO)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	56.9	1.93	29.33	0.00	52.95	60.84
1	50.76	1.85	27.42	0.00	47.02	54.50
diff	6.13	2.68	2.28	0.02	.789	11.47

Previous occupational exposure to lead of the parents of investigated children (code 1 = YES).

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	53.11	1.46	36.33	0.00	50.19	56.03
1	56.89	3.07	18.48	0.00	50.11	63.66
diff	-3.77	3.40	-1.10	0.28	-10.98	3.43

Children washing their hands before eating (code 1 = NO).

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	53.68	1.36	39.45	0.00	50.97	56.39
1	59	3.49	16.89	0.00	47.88	70.11
diff	-5.31	3.74	-1.41	0.22	-15.74	5.12

The child puts dirty/fallen on the ground toys in his mouth (code 1 = YES).

Variable	Mean	Std. Err.		P>|t|	[95% Conf. Interval]	
0	51.43	1.59	32.28	0.00	48.24	54.63
1	58.58	2.13	27.43	0.00	54.17	62.99
diff	-7.14	2.66	-2.68	0.08	-12.49	-1.79

Income per family (code 1 = less than 2 million lei/month)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	5 .38	1.89	28.16	0.00	49.55	57.21
1	54.36	1.87	28.98	0.00	50.56	58.16
diff	-0.98	2.66	-0.36	0.71	-6.28	4.32

This paramount analysis helps us draw a major conclusion, for the purposes of developing some intervention measures to minimize health risks of this population group, namely, the fact that almost all analysed factors significantly influence blood lead levels.

CHAPTER VI.

ASSESSMENT OF ENVIRONMENTAL CONDITIONS AND CHILDREN'S HEALTH FROM COPŞA MICĂ IN STAGE II OF THE STUDY (year 2012)

6.1. Descriptive statistics of the investigated sample.

A group of children of different ages was readdressed. Was identified and addressed a number of 90 children and was obtained a questionnaire response rate of 35 parents. No subsequent zoning was performed, meaning the distance from the main source of pollution, because the assessment carried out in the previous chapter showed that the distance does not play a major role in the exposure of children from Copşa Mică, the issue related to hazard, exposure and risks being similar for the entire population with increased susceptibility in this locality. Of all children investigated females recorded a number of 16 children, and males a number of 19 children. All these children have parents who do not work at the non-ferrous metallurgy plant from Copşa Mică. All investigated children aged between 7 and 11.

6.2. Assessment of lead exposure in children from Copşa Mică

6.2.1. Lead exposure biomarkers in investigated subjects

For 7-11 years old children residing in Copşa-Mică, blood lead ranged between a minimum value of 14.6 μg/dL and maximum levels of over 65 μg/dL. Blood lead levels above 65 μg/dL were analysed quantitatively. The results of blood lead measurements have shown that none of the children had their blood lead level within normal limits, i.e. in the category below 10 μg/dL.

This time it is noted that in a situation in which all the investigated children had blood lead levels above normal levels, of 10 μg/dL, there is definitely a high tendency of exposure reduction, meaning that a significant part of the investigated children presents a reshuffling toward lower blood lead values, compared to previous year, showing that even if the intervention program did not have significant outcomes, it is operational and has obtained remarkable results.

6.2.2. The relation between blood lead and somatic development in investigated children

The results of the linear regression estimates indicate a negative correlation between blood lead and height & weight in both instances, but without being statistically significant. (Tables 13 and 14

Table 13. Blood lead measured in the group of children based on the 4 categories of blood lead (10-20, 20-35, 35-65, >65) and their height

Height	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	3.16	2.18	1.01	0.58	-2.14	6.33
age	0.22	0.43	0.09	0.83	-1.45	1.43
tip_loc	-1.34	1.42	-0.53	0.65	-2.53	1.32
educ_ma	1.56	1.55	0.42	0.54	-1.01	1.94
IPb_gr_2	-2.42	7.01	-0.12	0.36	-9.12	5.83
IPb_gr_3	-1.16	4.97	-0.98	0.43	-7.16	4.01
IPb_gr_4	-2.32	6.21	-0.65	0.67	-3.37	6.12
_cons	19.56	9.17	2.42	0.01	4.81	8.77

Table 14. Blood lead measured in the group of children based on the 4 categories of blood lead (10-20, 20-35, 35-65, >65) and their weight

Weight	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
gender	1.03	1.67	0.69	0.85	-0.71	1.33
age	2.12	1.22	3.25	0.45	1.06	5.92
tip_loc	0.32	0.66	0.43	0.75	-1.58	0.66
educ_ma	0.85	0.47	1.12	0.73	-1.23	1.85
IPb_gr_2	-0.74	0.38	-0.29	0.77	-2.42	1.03
IPb_gr_3	-0.52	1.14	-0.57	0.72	-2.31	1.16
IPb_gr_4	-0.14	1.11	-0.21	0.14	-0.11	1.92
_cons	-2.14	1.12	-1.65	0.32	-2.23	1.17

6.3. Assessment of factors and influence on children's exposure to lead

The statistical analysis of the information obtained after filling out the questionnaire was carried out by test T. The test compared the variation in blood lead averages in children, in conjunction with the factors being investigated, some of those being associated with the increase/decrease in blood lead-levels in this population group with increased susceptibility. Below, in table 15, are shown the results of the assessment.

Table 15. Variation in blood-lead average values based on factors which may influence lead exposure

Children playing with soil (code 1 = YES)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	31.24	1.14	16.74	0.00	13.92	42.02
1	23,55	2.31	23.62	0.00	14.52	48.11
diff	-5.32	3.21	-0.73	0.63	-3.11	6.91

Children playing with sand (code 1 = YES)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf	Interval]
0	31,86	6,14	8,81	0.00	25,12	40,01
1	16,77	0,42	19,00	0.00	9,01	21,00
diff	-2,87	1,01	-4,88	0.65	-1,12	-2,11

Spending time in holidays outside Copşa Mică (code 0 = NO)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Int rval]	
0	31,37	2,14	24,84	0.00	44,10	61,63
1	41,11	2,86	22,72	0.00	32,98	65,00
diff	1,13	1,99	4,11	0.34	3,34	19,47

Previous occupational exposure to lead of the parents of investigated children (code 1 = YES).

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Int rval]	
0	45,77	1.11	29,44	0.00	42,34	62,14
1	43,36	3.64	16,78	0.00	45,86	64,62
diff	-2.11	2.15	-2.77	0.48	-2,43	2,94

Children washing their hands before eating (code 1 = NO).

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	51,67	1.38	35,93	.00	49,84	59,04
1	52,93	4,61	14,96	0.00	43,95	63,93
diff	-1.96	3,01	-10,65	0.48	-9,06	5,35

The child puts dirty/fallen on the ground toys in his mouth (code 1 = YES).

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	51,80	2,95	29,08	0.00	41,94	57,63
1	57,36	3,14	22,04	0.00	49,52	61,41
diff	-6,91	1,62	-7,01	0.12	-8,08	-4,37

Income per family (code 1 = less than 2 million lei/month)

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
0	56,88	1.17	42,05	0.00	38,68	59,02
1	59,62	1.57	36,62	0.00	48,06	57,47
dif	-3,66	2.06	3,74	0.43	-9,54	-2,11

By comparing the results to the previous year, an important conclusion can be drawn from this paramount analysis, that is its impact on developing certain intervention measures for minimizing risks on health status of this population group, namely, the fact that for almost all the analysed factors it is noted that they significantly influence blood lead levels, as mentioned in the previous chapter of this doctoral thesis.

During the execution of this part of the doctoral thesis, it has been noted that already some of the families with children participating in this study started to wipe the dust with a damp cloth and have a more careful approach to vegetables consumption, fruits and animal products from the area.

6.4. The evolution of lead exposure in children from Copşa Mică in stage I and II of the study (year 2011, 2012)

To carry out a preliminary assessment for the purposes of determining whether the intervention program is really useful and works so that we can address this more inclusive aspect and to lead to active hazard control, exposure reduction and associated risks, a preliminary analysis was conducted in order to substantiate this approach and to support the needs described in the first two chapters of this thesis, namely, that the only way of solving the major environmental and health problems is an intervention program developed as a social marketing program, in order to change the resident population's behaviours in Copşa Mica. This assessment is shown in the table below, table no. 16.

Table 16. Average blood lead levels recorded in children in Copsa Mica in stage I compared to stage II and statistical testing of the difference

Variable	Mean	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Pb_mie01	43,56	1,08	5,32	0.00	16,11	51,45
Pb_mie02	38,73	1,12	3,15	0.00	18,53	41,84
diff	2,31	0,95	1,87	0.56	-0.66	5,37

CHAPTER VII.

ASSESSMENT OF ENVIRONMENTAL CONDITIONS AND CHILDREN'S HEALTH FROM COPŞA MICĂ IN STAGE III OF THE STUDY (year 2013)

7.1. Statistical analysis of the investigated children sample

For the final estimate of the compliance program results progress, program that was developed and implemented in Copsa Mica, starting 2011, reanalysed and corrected in 2012, a new assessment of children exposure in Copsa Mica was carried out by indirect determinations of exposure (indirect indicators - lead in soil and indoor dust) together with specific indicators, lead exposure biomarkers, represented by blood-lead concentration. The selected group of children for this assessment has been represented by children aged between 4 and 6 years old of the Copşa Mica kindergarten, located less than 700 meters from the main source of lead and cadmium pollution.

Total sample was represented by 40 children aged between 2-11 years old, 18 of which were determined blood lead, the latter being covered in the 4-6 years old age group and all attending the local kindergarten. Analysis of a site near the main source of pollution was chosen, a site which brings together an important group of local children (kindergarten).

7.1.1. Exposure biomarkers in the investigated group of children

Blood lead values obtained from analysis performed using the Lead Care System, in 4-6 years old children from Copşa-Mica, ranged from a low value of 3,7 μg/dL and maximum values of 21,7 μg/dL, registering only three values above 10 μg/dL, one basically very close the normal value (11), one just above the normal value (14), only one value hovering to more than 20 de μg/dL (Figure 24.).

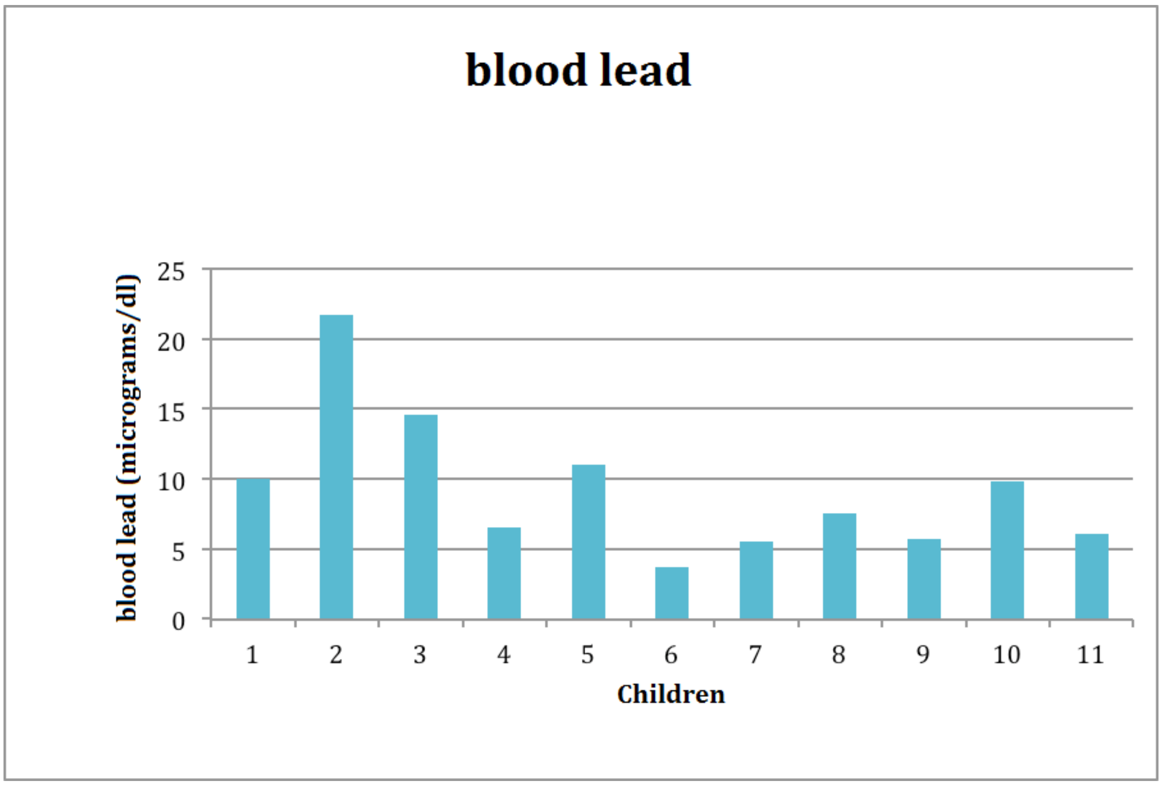

Fig.24. Investigated subjects distribution according to blood lead value

7.1.2. The results of the lead concentration determination in the indoor dust for kindergarten children from Copşa Mică

Lead concentration in the dust inside the kindergarten has shown that the intervention program which has made good progress among families (changes in practices, attitudes from the perspective of personal hygiene and housing) still shows deficiencies even if they are not major, due to dust transfer from the outside to the inside. Unlike the intervention program whom was characterized by social marketing, controlling this hazard it is extremely expensive, and the contribution it brings, paradoxically, is relatively minor, fact demonstrated by all analysis presented along this doctorate thesis.

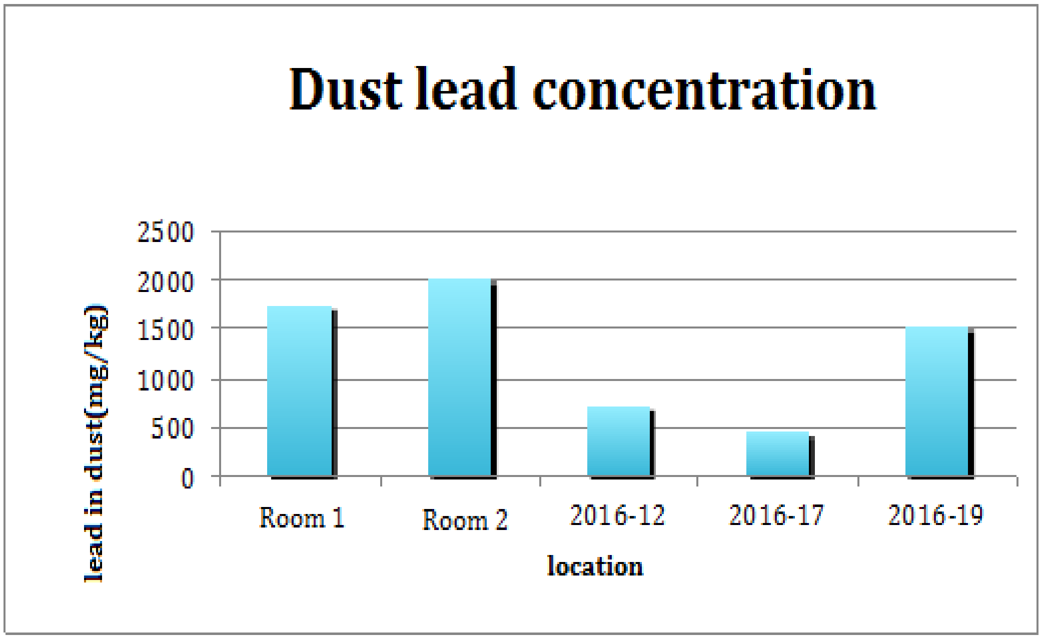

Figure 25. Lead concentration in dust inside the kindergarten and Copşa Mică dwellings

The measured values are rendered in figure number 25, Room 1, Room 2 are rooms of the kindergarten, and the numbers 2016-12, 17 and 19 correspond to dwellings investigated regarding children's lead exposure and the results of the intervention programme.

7.1.3. The results of the lead concentration determination in the soil from Copşa Mică

Reducing almost all activity in the non-ferrous metallurgy plant in Copşa Mică, did not lead to changes in the soil lead concentration, lead being residual. Concentration levels described below will remain around these values for many tens of years (fig.26.).

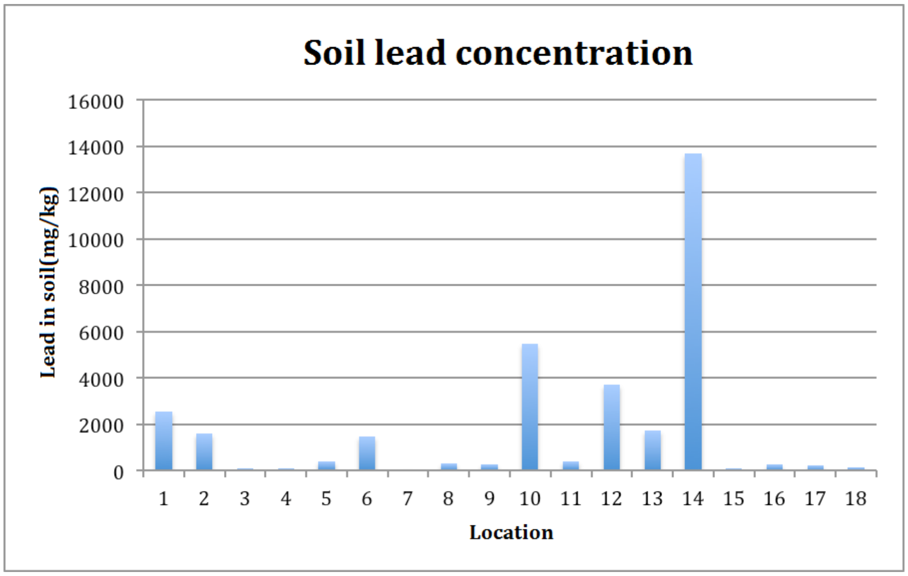

Fig.26. Soil lead concentration in Copşa Mică, specific in subjects investigated (kindergarten children of 4-6 years)

In other words, the only solution for the population group with increased susceptibility (children, who represent the future of the community) is to actively control the hazard at the receiver because cleaning the source (soil) in such a large area is not feasible in terms of sustainability.

CHAPTER VIII.

CASE STUDY – METHODS OF ANALYSIS, ASSESSMENT AND IMPLEMENTATION OF AN INTERVENTION PROGRAM TO CONTROL LEAD EXPOSURE AND ASSOCIATED RISKS IN CHILDREN FROM COPŞA MICĂ

8.1. Assessment of environmental conditions and children's health from Copşa Mică

The objective of the study was to examine trends in lead exposed children in Copşa Mică in 2011-2013 by tracking spatial and temporal dynamics of common exposure variables.

It was hypothesized that between 2011 and 2013, contact with contaminated environmental components was still a significant lead exposure pathway in children. Exposure pathways were additionally influenced by personal hygiene and temporal relationship between hand washing and outdoor play, contact with contaminated soil or dust by playing outdoors and geographical location.

8.1.1. Methodology

Subjects were identified as being children with ages between 2-11 years living in Copşa Mică in 2011, had participated in the exposure assessment conducted in 2011-2013 and had been examined for blood lead during the period 2011-2013.

The inclusion was also limited to children who had a parent who was actively employed in the local non-ferrous metal smelter (primary lead / zinc) and to parental consent.

Data collection:

Each subject was given a questionnaire which consisted of five questions. The questions assessed the washing of hands, hand washing frequency and time sequence, playing outdoors and the outdoor playground.

Soil samples were collected from playgrounds, using EPA 6200 (2007) method: *X-ray fluorescence spectrometry to determine in situ the concentrations of soil and sediment elements.*

Statistical analysis:

Data were analysed using SAS (version 9.1.3, SAS Institute Inc., Cary, NC, USA). The data were first layered by age and blood lead levels for 2011, 2012 and 2013.

Geostatistical analysis:

For each subject investigated in 2011, 2012 and 2013 geographical position was determined by using a Garmin eTrex GPS device with accuracy to 15 m.

Concentrations of lead in soil from geocoded sites and blood lead of subjects were mapped in ArcMap (version 9.3.1, ESRI, Redlands, CA, USA) using basic Kriging interpolation methods (Cress 1988). The significant results were used to create maps with the estimated blood lead and with the concentration of lead in the playgrounds soil, in 2010.

8.1.2. Statistical analysis of the lead exposure biomarker in investigated subjects - blood lead levels

Table 18. Demographic and exposure characteristics between 2011-2013[a]

	2011	**2012**	**2013**
Age (Years)	6.73±2.54	7.05±2.49	9.5±3.24
High-risk group (2-6 years)	40 (46.51)	26 (36.11)	4 (12.50)
Low-risk group (≥6years)	46 (53.49)	53 (63.89)	28 (87.50)
Blood lead [µg/dl]	53.04±12.39	21.25±9.6	20.51±8.84
Normal blood lead ≤10µg/dl	7 (8.14)	12 (15.0)	3 (8.82)
High blood lead ≥10 µg/dl	79 (91.86)	68 (85.0)	31 (91.18)
Playing with soil:			
Yes	47 (61.04)	41 (67.21)	31 (93.94)
Blood lead [µg/dl]	53.77±12.40	23.71±10.17	20.57±8.97

No	30 (38.96)	20 (32.79)	2 (6.06)
Blood lead [µg/dl]	52.16±11.58	19.28±10.17	14.95±4.31
Hand washing before eating			
Yes	--	61 (92.42)	14 (43.75)
Blood lead [µg/dl]	--	20.58±9.81	19.34±10.26
No	--	5 (7.58)	18 (56.25)
Blood lead [µg/dl]	--	21.16±10.93	21.07±7.97

[a]***The table presents N (%) for categorical variables and ±DS mean for nominal variables***

The study included in 2011, 86 children along with their parents (out of 105, 80 fully analysed, 86 selected), 79 children in 2012 (out of 90, 35 fully analysed, 79 selected) and 34 children completed our study in 2013 (out of 40, 18 fully analysed, 34 selected).

Blood lead levels in children were analysed in two ways: 1) average values and 2) percentage of children who had higher blood lead than the international standard of 10 µg/dL. The average blood lead decreased in 2011-2013 to 53.04 µg/dL ± 12,38 in 2011, to 21,25 µg/dL ± 9,6 in 2012 and 20.51 µg/dL ± 8,3 in 2013.

In 2013, despite the sharp drop, three children remained (of those examined, representing a rate of less than 6%) with blood lead values higher than the international standard, level considered a health-hazard and known to affect growth. The percentage of children with blood lead higher than the international standard has remained relatively high in 2012, although a decrease from 2011 was observed.

8.1.3. Assessment of risk factors with possible influence on children's exposure to lead (questionnaire)

The models obtained in 2011 and 2013 were found to be significant with *F values* = 6,91 (p^a 0,0004), and 8,85 (p^a 0,0002), suggesting that the results which influence the level of lead in blood, by year, are representative for the population of local children. In 2011, blood lead level was associated with playing in the sand (p^a 0,0003) and negatively associated with time spent in another home during summer (p^a 0,393). In 2012, blood lead level was associated with the frequency of playing on the ground (p^a 0,0001) and the frequency of playing in the sand (p^a 0,0001). In 2013 no association was observed between the model or independent variables and changes in blood Pb levels in subjects' blood.

8.1.4. Exposure distribution model and its spatialization for the purpose of intervention

In 2012 blood Pb levels in children from Copşa Mică (Figure No. 27) were estimated using basic Kriging interpolation methods.

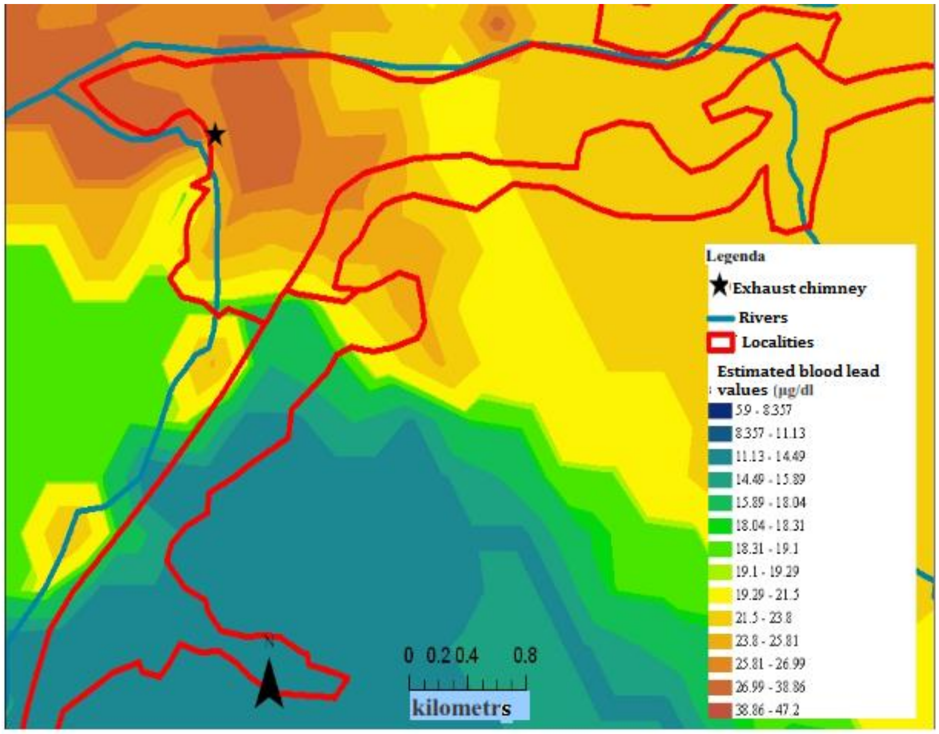

Figure 27. Blood lead estimation in Copșa Mică area - 2012

Soil Pb concentrations (PPM) were mapped in the playground in 2012 - based on measurements from 2010 (Figure 28).

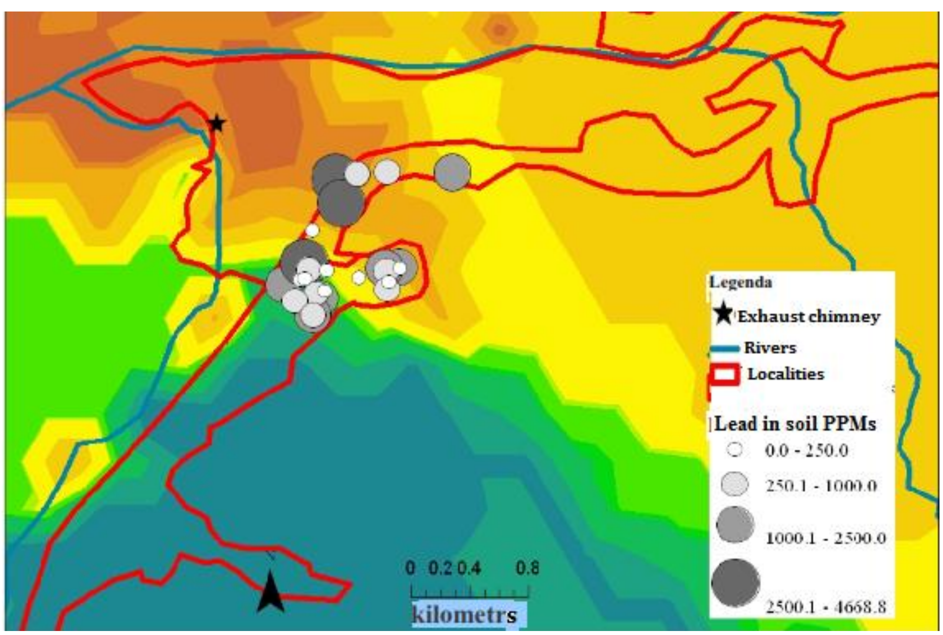

Figure 28. Soil lead concentrations in playgrounds and estimated blood lead values - 2013

Lead was found in 30 soil samples, with values between 24,3 PPM and 4668,8 PPM, which revealed soil contamination in the playground area for children. In this area, the distribution of estimated blood lead levels in children in the area coincided with the soil Pb contamination level in the playgrounds.

CHAPTER IX
DISCUSSIONS AND OVERALL CONCLUSIONS

9.1. Discussions related to the development of the intervention program as a social marketing approach

The design of an effective communication shall take into account all segments involved, in the following sequence:

- Source-related - **the source characteristics** of messages (to be reliable and attractive, to specify its reporting to the receivers); must be mentioned the residual character of lead in soil and dust in the Copşa Mică (historical pollution);
- **the message content** must be associated with the main source of exposure (in this case, soil and dust, especially, along with plants and animals grown in the area
- **the message structure** - took into account everything that is specific in Copşa Mică area, from the point of view of children's understanding / level of rationality, their parents, the community in general along with what meant working with local authorities;

  communication channel - were analysed all communication means, their attributes, the role of direct experience of the receiver in relation to the content of the message, analysis and handling of possible contradictions; from 2011 the communication channels with the increased susceptibility population group and those who come in direct contact and influence the formation of healthy behaviours in this population group (family, especially the mother, kindergarten, school) were extremely well structured, in fact it was visible in major results obtained in the control of children's exposure to lead and cadmium in Copşa Mică;
- **receiver** - was a hard work in understanding the overall behaviour of the community, not only of the group of children investigated;

  Once these steps were achieved, was carried out the implementation of the intervention program, which included numerous specific activities within the family, kindergarten and school in Copşa Mică.

In order to minimize the effects associated with lead exposure in children with increased susceptibility, a specific action known as social marketing was carried out, action less used in areas of non-ferrous metallurgy and generally in areas with historical lead and cadmium pollution. The achieved effects are discussed in the overall conclusions. These results are extremely encouraging and show us how we need to deal with similar situations that exist in many other "hot" areas in Romania, contaminated with heavy metals as those in this thesis (lead, cadmium, and other metals / metalloids).

9.2. CONCLUSIONS

In Copşa Mică there is a load of hazardous lead concentrations in soil near homes, playgrounds, schools, football fields, and other similar locations. Children continue to play outdoors and come in contact with contaminated soil. The program for temporary reduction of contamination in playgrounds has not proven effective since the 2012 testing revealed a permanent lead contamination through migration. While risk communication, blood lead level screening and behaviour modification interventions were beneficial as it is highlighted by the results of this study, they have not fully improved the risk.

Even if the average blood lead values decreased and the exposure covariates for playing on the ground and personal hygiene were not significant in 2013, GIS analysis revealed that the level of lead in children's blood is somehow correlated with the distribution of surface soil contamination at the playground in the community. The exposure model has remained consistent and will remain so indefinitely until achieving a contamination decrease to a greater extent.

In a recommendation with regard to CDC instructions on children's exposure to lead, the American Academy of Pediatrics has suggested that the only viable long-term effort concerning public health is to reduce contamination (AAP 1998). Studies conducted in Uruguay and Sweden in communities where there is a load of historical lead contamination as that of Copşa Minor, gathered similar results of permanent lead exposure in children, despite risk communication for many years, blood lead levels screening and behaviour modification interventions (Manay 2008; Stroh et al., 2009). The efforts of education at home have proved to be beneficial in communities with baseline blood lead of 15 μg/dL or higher, but only with a reduced effect on the blood lead level in children. (Leoh et al., 2008).

There were several limitations to our study. The group of subjects could not be localized on the day of the study. Neighbours and friends of missing subjects reported that: some children moved due to the inactivity of the smelter, motivated by a number of global economic factors, others were away on holiday in another city and some could not be identified. The type of housing stock in the city is likely to have diminished the spatial distribution of blood lead. Many participants in the study lived in the Colonia neighbourhood located on the hill above the smelter, which is composed of blocks of flats, therefore of several homes. The assessment of exposure to other factors such as nutrition, lead in paint and drinking water quality exceeded the scope of this study, but based on the results from 2011-2013 and spatial analysis results, it is clear that the results were seriously influenced, as the local authorities established that they were not usual ways of exposure.

The Copşa Mică case is not unique in terms of contamination of the environment and human lead poisoning. For example in Uruguay (Mañay et al., 2008), lead pollution received official attention for the first time during the episode of contamination "La Teja" in 2001. This took place in the neighbourhood of La Teja in Montevideo, where high lead levels were discovered in the blood of children (up to 20 µg/dL), which resulted in corrective responses from the health and environmental authorities. The Ministry of Health appointed an interinstitutional committee, with delegates from authorities such as health, environment, employment, education, social security, and non-governmental organizations (NGOs). Subsequently were carried out further researches on lead pollution, which included multidisciplinary studies, the main focus being on children exposed to lead in the environment. Uruguay adopted the CDC reference dose for blood lead levels in children, of 10 microg / dL (CDC 1991) and blood lead levels of 30 microg / dL for workers. Most studies have considered soil pollution as the main source of lead exposure and therefore environmental authorities have adopted the reference Canadian soil concentrations: residential areas and playgrounds (> 140 mg / kg) or industrial areas (> 600 mg / kg).

The results of the blood lead levels obtained from similar lead exposure human studies, carried out over a period of 10 years, have shown significant reductions of the blood lead levels after 10 years, in people with non-occupational exposure. Phasing out leaded gasoline is believed to have contributed to this improvement. New laws have been adopted to address occupational and environmental exposures and prevent new cases of lead contamination. Moreover, was planned a systematic program of screening surveillance for people exposed to occupational lead and for children.

Another example of addressing complex environmental and health phenomena is that discussed by Musmeci et al (2009) and refers to the Gela area, Italy. For this area was designated a multidisciplinary working group in order to analyse existing data on pollution - exposure - effects and to supplement current knowledge on pollutants cycle. It was considered that the environmental and health impact assessment and economic cost estimation are crucial to the development of environmental rehabilitation plans.

Worldwide, there are many communities like that of Copşa Mică, with historical contamination and that face a continuous struggle in order to reduce environmental exposures once they are identified and characterized. Our study points out that despite efforts of improvement, blood lead in children are still high in the Copşa Mică area. While a reduction in soil contamination to a wider extent is an absolutely necessary intervention for the area, risk communication, blood lead screening and efforts to change children's behaviour were beneficial and must continue.

FINAL CONCLUSION

In Copşa Mică were conducted numerous studies related to the presence of the non-ferrous metallurgy plant in the city. These studies (tens, maybe hundreds) had countless approaches, ranging from technology studies, environmental studies, health studies to social studies and more, some of them having a certain more or less integrated character, bringing together various aspects and having relatively complex conclusions. However, with one exception, none of these studies has responded to an elementary thing, namely, transferring scientific knowledge in the real world so that a specific program of measures and decisions to meet the needs of the community for the purpose of solving the major problems facing this community - lead and cadmium exposure. We are talking about lead and cadmium exposed children, talking about the future of some generations. Personally, I always thought that science needed to support us, to give, as much as possible, an answer to our problems, to help us find solutions to solve these problems. Because of this I had this approach in my doctoral thesis and for this reason I am at peace with myself that I managed to develop a model (albeit complex and expensive by dynamic assessments made) that will improve the living conditions of children (group with increased susceptibility to lead and cadmium exposure) in the town of Copşa Mică, by controlling their exposure to lead and cadmium in soil and dust (the main sources of exposure to the two metals investigated). This model is definitely a success given the obtained results, but in order to multiply this success this model it is imperative to be also transferred to other similar areas in Romania, as we know exactly which and how many "hot" areas are in Romania that have historical lead, cadmium, and other metals and metalloids pollution. A "lesson learned", even if using significant resources, becomes helpful / useful when it is paid forward, and Romania, by its nature of current environmental conditions requires the use of knowledge and specific models in addressing health problems in relation to environmental factors.

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