THE ASSESSMENT OF HEAVY METALS CONCENTRATION IN BACAU CITY SOIL. NECESSITY AND WORKING METHODS

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Abstract: When we analyse the distribution of the heavy metals in urban soil, the unique characteristics of the urban environment are limiting the efficacy of the statistical methods. The paper arguments the necessity of conducting a research project to analyse the distribution of Pb, Cd, Ni, Mn, As, in the soil of Bacau City, Romania and presents the working methods which shall be used.

Keywords: GIS, heavy metals, urban soil, urban environment

1. INTRODUCTION

When the distribution of heavy metals in soil is analysed, an important factor for identifying the anthropogenic sources of contamination is represented by the original chemical properties of the soil. In a natural and undisturbed environment, the soil presents, in most cases, a vertical layered structure: horizon O, A, B and C (Figure 1) [1].

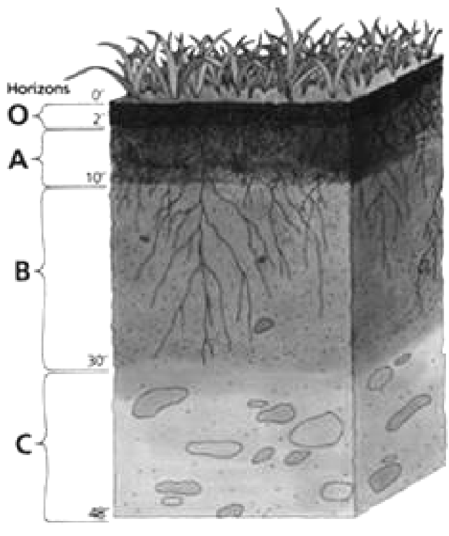

Fig. 1. Soil vertical layered structure: O) Layer formed by organic materials: remains of plants, partially decomposed; A) Surface of the soil, layer formed by minerals, accumulated organic materials and organisms; B) Subsoil: this layer accumulates metals, clays, non-metals and organic compounds; C) Unconsolidated sub-layer of soil, this can accumulate soluble compounds drained from horizon B [1].

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Each of these layers has specific microbiological and functional properties [1], so by analysing the structure, it can be determined the origin of the soil: rocks alteration, sedimentary activities or volcanic activities. And because the geological characteristics of the base rock are present in the soil that covers it, the natural concentration of metals can be estimated. In this way, analysing the natural distribution and by statistical calculations, the anthropogenic contribution and possible pollution sources can be differentiated [2-6].

This method, very efficient in natural and undisturbed environment, has a limited applicability in the urban environment, where the soil, in general, has more than one source and does not present a layered structure [7-10]. In this case, the urban soil properties cannot be linked by the geological proprieties of the base rock.

The urban soil is referred in literature as "created soil" [11]. It is highly modified by human activities like terrestrials and subterranean constructions, infrastructures reconstructions, the maintenance of parks and green zones, in which the local soil is mixed with soils from other locations [12-14]. In this case, when assessing the concentration of the metals in urban soil, the results obtained from statistical methods exclusively, have limited validity.

As an alternative to "classical" methods, the geographical informational systems (GIS) and geographical positioning systems (GPS) can be used for analysing, presenting and modelling geochemical data. These methods were used more often during the last four years, for digital graphic presentation of heavy metals distribution in urban soil [15-18]. The identification of possible contaminated areas may be facilitated by geochemical maps representing the distribution of trace metals in soil.

A GPS can assure the precision of positioning (the locations for prevailing soil probes, by example) and the transfer of the coordinates in computers. A GIS can use data to create accurate distribution maps [19].

Additional information can be stored into GIS databases and used in analytical processes and complex correlations. The data can be: population density, studied area topography, the localisation and characteristics of the industrial areas, emissions types, etc. For example, correlating distribution maps for certain metals with demographical data, and the location of residential areas and industrial ones, the impact on population health can be predicted [20].

In this paper we analyse the necessity of conducting a research project to investigate the distribution of Pb, Cd, Ni, Mn, As, in the soil of Bacau City, Romania and how using GIS in Bacau City area can provide us a better understanding of the quality of the soil and of the heavy metal enrichment factor.

2. HEAVY METALS CONTAMINATION OF THE URBAN SOIL

2.1. Heavy metals sources and the impact on health

By definition, the urban environment is a highly modified environment in order to sustain a large amount of humans [11]. The high density of population, intense industrial activity, permanent and high traffic on the roads, a developed subterranean infrastructure network, a subunit fraction between uncovered soil (green areas, vacant lands not used as storage lands) and covered soil (covered with buildings, roads, pavement, vacant lands used to deposit debris) are just some specific characteristics. Every day, the urban environment is polluted by more or less toxic emissions, organic or metals, emissions derived from specific activities: industrial, commercial, municipal, traffic [21-25]. All of these are eventually deposited into the soil, and determine the change of physical and chemical properties of the urban soil, transforming it into a human exposure indicator [26].

Metals are non-degradable and cumulative in soil, and deposits are made on a daily basis as a result of permanent human activity. Because of that, metals are a contaminant factor for soil and a possible danger for inhabitant's health. Metals accumulated in contaminated soil may be transferred to humans directly, by inhaling the dust raised from top soil, or by ingesting, or by dermal contact [27], and indirectly, through plants and animals grown on contaminated soil and used for food.

Some metals, like Cu, Mn, Zn, are important for human's health and represent a danger only if their concentration is too high, but other metals, like Pb, As, Cd, Hg, are toxic even at trace level (Table 1).

Table 1. Metal toxicity, sources and effects on humans [17, 28, 29, 30, 31].

Metal	Effects on humans	It can be found in:
Arsenium (As)	skin diseases when exposed to low concentrations; in the case of long exposure may provoke cancer of the skin, kidneys, lungs, liver;	alloys; electronic components; pigments for paints used in tanning; fireproof wood products; agricultural fertilizers;
Cadmium (Cd)	neuropathy; lung diseases; lung cancer;	agricultural fertilizers; pigments for paints, plastics, ceramics, glass; welding electrodes; residues from combustion of petroleum or metallurgical processes; recycled paper;
Manganese (Mn)	is one of the essential elements for human health – a low level of Mn in the body leads to neurological problems, nausea, osteoporosis, and in case of children may cause mental retardation; in high concentrations it acts as a neurotoxin causing irreversible neurological and psychiatric problems, including Parkinson's and schizophrenia	Methylcyclopentadienyl Manganese tricarbonyl (MMT) - which replaced tetraethyl lead in gasoline; steel composition; pigments for paints, glass or ceramic; electric batteries;
Lead (Pb)	in case of children: even in low concentrations may cause central nervous system disorders, hyperactivity, anaemia; in case of adults may cause hypertension, liver and kidney damage, infertility;	dyes with a protective role; sealants; car batteries; alloys used in electronics; fertilizers, insecticides; gas exhaust and gases emitted from foundries; recycled paper;
Nickel (Ni)	allergens - 30% of world population have allergies to nickel; has not a high toxicity, but can cause respiratory problems and in extreme cases may lead to cancer;	alloys; electric batteries; waste from treatment plants and waste water; fertilizer;
Chrome (Cr)	has a low toxicity; may cause dermatitis through direct contact; in the case of long exposure or high concentrations of the isotope Cr (VI) may cause cancer;	composition of steel; alloys; composition of bricks; glass and ceramic pigments; detergent composition;
Copper (Cu)	has a low toxicity to humans, but is highly toxic to animals; in the case of young children if they are exposed to high concentrations can develop haemoglobin deficiencies, ex. anaemia; in the case of adults, Cu is accumulating in the liver, leading to necrosis;	composition of materials used for gas and water pipelines; printed circuits (PBC); materials for roofs and boilers; tools and ornaments;
Zinc (Zn)	is one of the essential elements for human health; if deficient, in the case of children, can cause anaemia and growth problems; if it comes in too high concentrations, it can interfere in the immunological and metabolic processes, especially in the uptake of calcium;	antioxidant alloys; composition of brass, bronze;

In urban areas, metals can be emitted from a wide variety of sources: industrial, residential, commercial. They may be schematized as follows (Figure 2) [11].

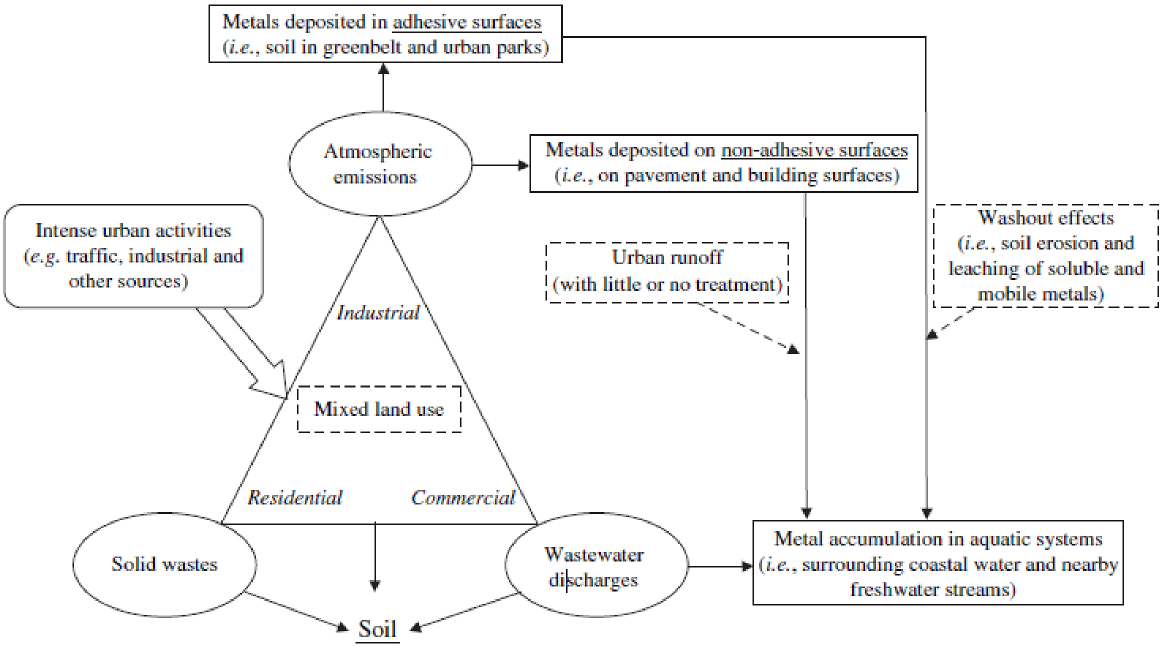

Fig. 2. The processes and the transport of metals in urban settings [11].

2.2. Dispersion, deposition, fixation and soil relocation of metals

Among the most common ways to pollute directly with metals the urban soil are: burial of waste that contains metals, engine oil leaks, leaks from landfills or pipelines carrying sewage [32-34]. Another source of direct pollution with metals is the use of fertilizers, fungicides substances, and incompletely treated compost for the maintenance of green spaces and gardens in residential areas [35-37].

The main sources for metal pollution in urban environment are the atmospheric emissions. These may come from industry, metallurgical industry especially, from thermal and electrical plants based on fossil fuel combustion, from exhaust gases, from particles emitted by tires and asphalt, from dust spread during demolition, from waste incineration, etc [38-40]. The particles from air tend to adhere to surfaces they encounter, forming films or layers of dust. From there, they will be transported by air currents to be deposited on land or in water [41].

Natural soil has the property to be crossed vertically by rain, thus carrying metals and fixing them deep into the soil. Only a small amount of them are back into the atmosphere, as dust, and can be relocated by air currents.

Urban soil had lost this property. Unlike natural soil, where agricultural or suburban soil cover large areas, the urban soil is fragmented and consists mainly of playgrounds, small parks and gardens in residential areas or green bends near roads [42]. The presence of subterranean structures also limits the depth of the soil restricting the water circulation. The saturation or ponding effect may appear. In this way, the metals are deposited in the top soil, from where will be dispersed by air currents and relocated [21].

A large part of urban soil is covered with artificial materials: asphalt, concrete, metal, tiles and wood. These areas have very different characteristics of permeability, porosity and adhesion, and also have the ability to deposit metal particles, becoming, themselves, sources of emission. Dust and particles deposited on these surfaces can be easily reintegrated in atmospheric circulation or taken by rainwater through urban runoffs. This process is a separation one also, the finest particles being taken more easily into the atmosphere, increasing the risk of inhalation [43].

3. THE NECESSITY OF A STUDY ON BACAU CITY SOIL

3.1. A short description of Bacau City

Bacau City, the capital of the Bacau County, is located in NE of Romania. City area is 43 square kilometres, divided into 12 districts and a population of approximately 180,000 people. There is no clear delimitation between the residential areas and the industrial ones. More, as a result of urban development and integrating some of the nearest villages as districts (Gherăieşti, Şerbăneşti, Izvoare), there are industrial units inside the city [44-45].

The collection and treatment of municipal wastewater is carried out by the Water Company of Bacau. The wastewater treatment plant was rehabilitated in 2010 to European standards. The disposal of municipal wastes is done in the South of the city, in a mixed deposit which occupies an area of 13.3 hectares. This will be shut down. The new ecological deposit, designed to receive the wastes from the whole county, is under construction.

The heat supply for the population had been provided by district heating plants, until year 2000. They had small capacity and used for combustion coal or oil. In 2002 the population started to use heating units for apartments, which use natural gases and electricity for combustion. In 2008, CET Bacau, the local electro-thermal plant, put into service a 14Mwe CHP group, that uses coal for combustion, and the district plants were converted into reheating units or were decommissioned.

The green area of the city is highly fragmented and relatively small, providing only 18 square meters per inhabitant instead of 26, as European standards stipulate [46]. It consists of 7 parks and recreation areas, green street bends, green areas around blocks and houses. In some districts (Şerbăneşti, Izvoare), the green areas near houses are transformed into vegetable gardens and the bigger ones in agricultural lands for corn and potatoes crops. The products are used by the families or sold into the local market. In 2002 was founded the Special Protection Areas for Birds, which covers 202 hectares (Figure 3) [44-45].

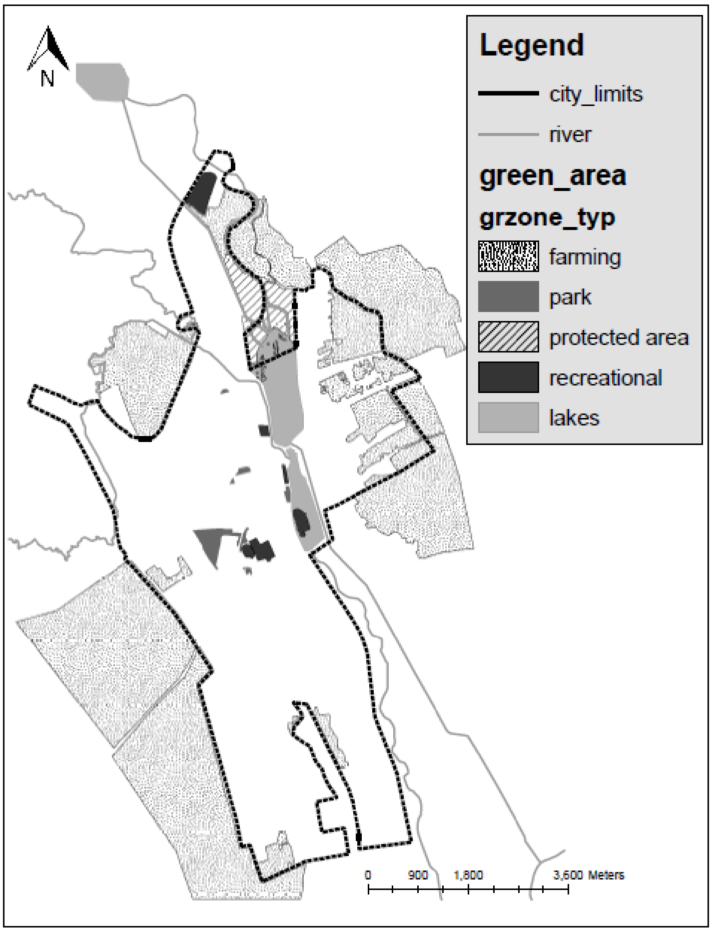

Fig. 3. Distribution of green areas by type [44-45].

Documented from 1399, Bacau City represented even then an important commercial centre and a traffic hub, linking the northern Moldavia with the South and Transilvania [47]. Today, Bacau City is crossed by 2 European roads (E85, E574), 3 national roads (DN15, DN2F, DN2G) and is the starting point for 6 county roads. Inside the town there is a dense network of streets, with daily jams (Figure 4) [44-45].

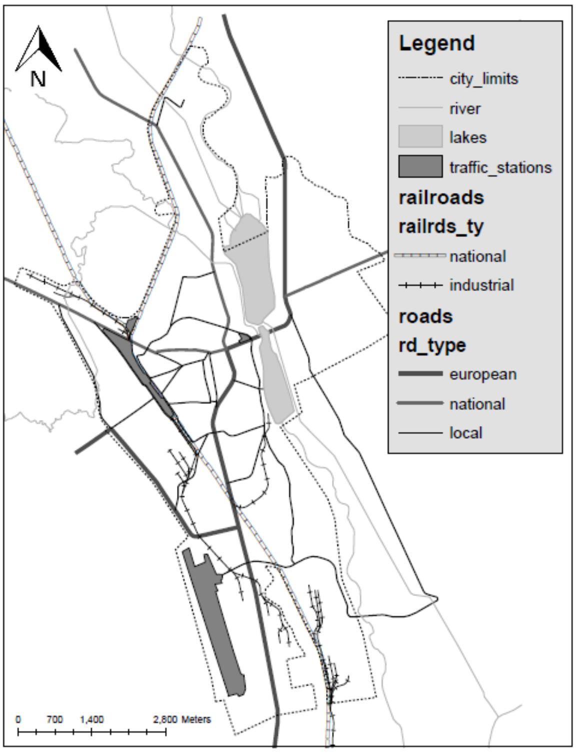

Fig. 4. Distribution by type of the main roads (rd_type) and of the railways (railrds_ty) [44-45].

Bacau City was connected to the national railroad in 1872, when the line Piteşti - Bucureşti - Buzău - Galaţi - Tecuci – Roman was put into operation. A second line, to Piatra Neamţ was added in 1885, both of them being operational today. There is also an internal rail network serving the major industrial units (Figure 4).

The airport was built in 1946 and became international in 1975. "The aircraft plant" (named Aerostar Bacau today) started producing airplanes in 1953 and a military unit was added in time. Today, the airspace is covered mainly with commercial flights, but with testing and training flights, also.

Medieval Bacau was known for its guilds of craftsmen in processing leather and tanning, for its grain mills and for its sawmills and processing wood workshops. By the end of 19th century and the beginning of 20th century sets up the first modern factories: Letea Factory (pulp and paper – closed now, have been producing since 1881, till 2009 it was the most important factory from SE of Europe producing paper for gazettes; since 2003 it has been operating here a processing station for waste paper and producing recycled paper), mechanized workshops for tannery and leather products (the most important, "Filderman Workshops" which started to produce in 1923 have been transformed in "Partizanul Factory" in 1948 during nationalization; this factory functioned till 2003 and its buildings were destroyed between 2004-2006), first mechanized mill for grains (destroyed in 2006) and first modern typography (today a complex with offices and restaurants).

The great industrial boom started in 1960s. New plants and factories were constructed even in new industrial domains: metallurgical, machinery construction and industrial equipment, food, wood and furniture manufacturing, production of textiles, fabrics and clothing. In the 1970s two large compounds were built: chemical fertilizer factory and mixed fodder factory.

Today, some of them are still producing, and others are closed, their buildings being destroyed, or used by new industrial units, or transformed into commercial centres, or deposits (Figure 5 and Figure 6) [44-45].

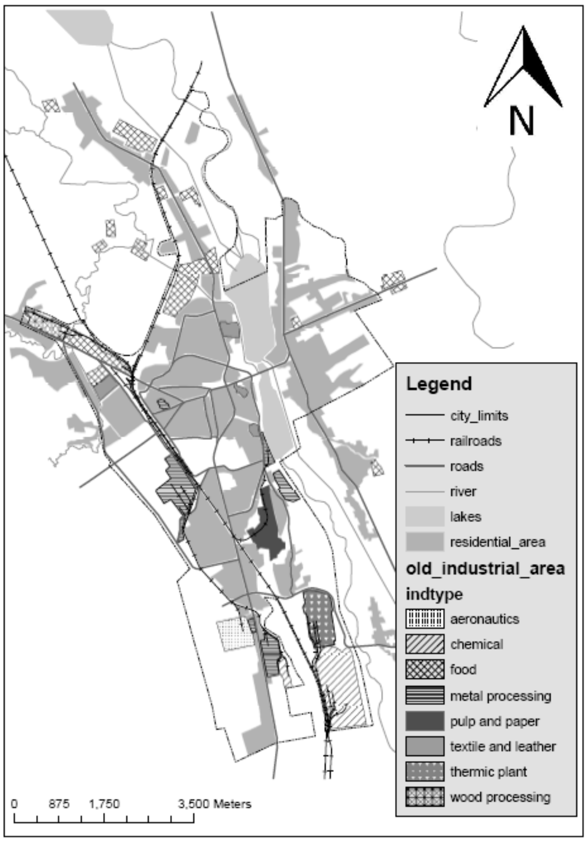

Fig. 5. Distribution of industry units still active in 2000 [44-45].

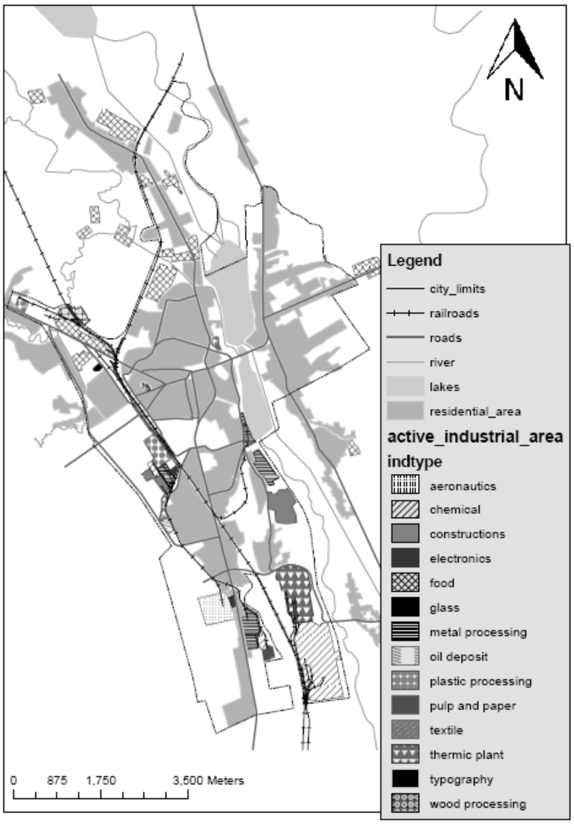

Fig. 6. Distribution of active industry units today [44-45].

3.2. Studies about metal pollution in Bacau City

Regional Environmental Protection Agency Bacau (Agentia Regionala pentru Protectia Mediului Bacau – ARPM Bacau) developed several projects on studying heavy metal concentrations in different environments within the Bacau City Area [45].

The earliest study found in the literature is dating from 1993-1994 [48] and targeted the analysis of concentration for Cu, Pb, Cd, Ni, Zn, Fe and Mn in dust roads and vegetation adjacent major roads. The results are presented in Table 2.

Table 2. The results from the 1993-1994 study [48].

Metal	Year	Dust roads		Vegetation	
		The maximum value determined (ppm)	Number of samples where the metal has been identified (%)	The maximum value determined (ppm)	Number of samples where the metal has been identified (%)
Cu	1993	20	17.7%	45	47%
	1994	120	58.3%	30	21%
Pb	1993	250	81.8%	40	54%
	1994	240	75%	30	62%
Cd	1993	not analysed	-	not analysed	-
	1994	5	12,5%	not analysed	-
Ni	1993	20	65%	11	47%
	1994	50	37,5%	0	0%
Zn	1993	395	100%	207	100%
	1994	880	100%	120	100%
Fe	1993	6850	100%	4000	100%
	1994	10700	100%	1050	100%
Mn	1993	3520	100%	235	100%
	1994	2670	100%	75	100%

Since January 2009, ARPM Bacau performed measurements by atomic absorption spectrometry to determine the emissions of metals: Pb, Cd, Ni, in atmosphere (Table 3). Samples were taken from the BC 2 - automatic station air quality monitoring (Figure 7) [45].

Fig. 7. Locations for the automatic stations (BC1, BC2) and manual monitoring stations for air quality in Bacau City [45].

There were no records of exceeding the annual limit imposed by the 448/2007 Order of Environment Ministry for metals in atmosphere.

Table 3. Table values for metals concentration emitted into the Bacău City atmosphere. Data were taken from annual reports and half annual reports of the ARPM Bacau [45].

		Pb	Cd	Ni
2009	Maximum monthly average	0.0745 µg/mc	2.42 ng/mc	9.51 ng/mc
	Has been registered in	November	November	September
	Annual limit value	0.5µg/mc	5 ng/mc	20 ng/mc
2010	Maximum monthly average	0.099 µg/mc	1.81 ng/mc	8.25
	Has been registered in	September	January	January
	Annual limit value	0.5µg/mc	5 ng/mc	20 ng/mc

No data were found in the literature about the analysis of metals in the water of Bistrita River. The groundwater and the surface water quality were analysed on the area of landfill waste and the Amurco SRL Bacau platform. Conclusions are found in Table 4. Determined concentrations were not specified.

In September 2008 and September 2009 soil samples were taken from 2 points: the intersection at Bacau University and Arboretum Park Hemeius, and analysed by ARPM Bacau in atomic absorption spectrometry laboratory to determine the concentration of Zn, Cu, Ni, Pb. Another studies on soil quality, were done by the major industrial pollutants: SC CET Bacău, SC LeteaBacău, SC AmurcoBacău, SC AerostarBacău. The areas examined were inside of production platforms and neighbourhood lands. Conclusions are presented in Table 4. Determined concentrations were not specified.

Table 4. Summary of studies on metals in water and soil. Data were taken from annual reports of ARPM Bacau [45, 49].

Study period - the type of activity	The study area - the environment studied	Metals	Conclusions
2008 - monitoring	Bacau University courtyard - soil	Cu, Pb	comparing with the limit values on sensitive soils, the concentration of copper is between normal value and the alert threshold, and lead concentration is below the limit value (H.G. 756/1997)
2008 - monitoring	SC Letea SA Bacău - soil	metals	the concentrations of metals, phenols, hydrocarbons and sulphates in soil exceed normal values, but not the alert threshold.
2008, 2009 - monitoring	municipal waste deposit - groundwater, surface water	Fe, Mn	groundwater and surface water are significantly polluted with ammonia, nitrites, chlorine, iron, manganese
2008 - environmental accident	SC Amurco SRL Bacău – groundwater, surface water	Cu, Cr, Zn, Pb, Ni, Mn	the quality of groundwater is changed in the monitoring wells because of failure of urea and phosphoric acid installations. Key indicators monitored: ammonium nitrate, calcium, fixed residue, CCOMn, phosphates, sulfates and heavy metals (Cu2, Cr6 +, Zn2 +, Pb2 +, Ni2 +) and Mn 2 +
2008 - monitoring	SC Aerostar SA - soil	metals	historical pollution with heavy metals and petroleum residues, Cadmium exceeded the limit value without exceeding the threshold
2009 - monitoring	SC CET SA Bacău - soil	metals	there has been exceeding the attention values (H.G. 756/1997) for Cu in the coal crushing plant area, and Zn in the power station area, without to exceed the intervention values. In the deposit of slag and ash area, most indicators are below the attention values, except Cu. The concentrations detected are over these values in

			the south and east of the area without having exceeded the action levels.
2009 - monitoring	Bacau University courtyard - soil	Zn, Cu, Cd, Ni, Pb	monitoring indicators were below the action levels of sensitive land use specified in the H.G. 756/1997

4. WORKING METHODS

From the description of Bacau City we can conclude that it presents several metal pollution sources: industry (metallurgy and machine and equipment construction, wood processing, chemical manufacturing, agricultural fertilizers and detergents, waste paper processing), the non-ecological waste management, traffic (street, rail and air), and thermal power plants using fossil fuels for combustion. As the number of studies on concentrations of metals in soil is small and covers only a small part of the city area, we can say that the data are insufficient to have an overview of soil quality in Bacau.

Therefore, a team from the Faculty of Engineering of the „Vasile Alecsandri" University of Bacau proposed a study that will cover the entire area of the Bacau City and will refer to determine the distribution of metals: Pb, As, Cd, Mn and Ni, in soil. Given the specific characteristics of the urban environment, it is taken into account only the soil surface (sampling depth 0 - 20 cm) and it will be used a geographic information system implemented using ArcGIS specialized software.

4.1. System organisation

The system consists of a series of maps, with specific attributes, organized as layers that can be overlaid for analysis and visualization of correlations and results. The entire set is projected in the same geographical projection system: Stereo 1970. The layers are (Figure 8):

- a physical map of the Bacau City representing the base map. It is a raster image, a satellite image, imported from Google Earth;
- a map of the main roads. It was published "as a Shape File" following the main roads on the base map. The table associated to the map contains for each object the type of the road: European, national or town streets;
- a distribution map of railways. It was published "as a Shape File" following the railways on the base map. The table associated to the map contains for each object the type of the route: for passengers or for industry;
- a map of watercourses. It was published "as a Shape File" following the watercourses on the base map. Table associated to the map contains no information at this time;
- a map of the lakes. It was published "as a Shape File" following the lakes on the base map. Table associated to the map contains no information at this time;
- a map of the green areas. It was published "as a Shape File" following the green zones on the base map. The table associated to the map contains for each object the type of the surface: park, recreation area, natural protected area, gardens and agricultural crops;
- a map of active industrial areas. It was published "as a Shape File" following the production platforms on the base map. The table associated to the map contains for each object the type of the represented industry: metallurgy, machinery and equipment, food, chemical, clothing, glassware and plastic production, pulp and paper;
- a map of historic industrial areas, which functioned until 1990. It was published "as a Shape File" following the production platforms on the base map. The table associated to the map contains for each object the type of the represented industry: metallurgy, machinery and equipment, food, chemical, clothing, glassware and plastic production, pulp and paper;
- a map of areas for storage and waste treatment. It was published "as a Shape File" following the storage areas on the base map. The table associated to the map contains for each object the type of the deposit: municipal household waste, industrial waste, storage, packaging, electrical and electronic equipment for cars, holding of medical waste, scrap metal warehouse, etc. The treatment plants for industrial wastewater are also included.

Fig. 8. Component layers.

4.2. Soil sampling

The entire perimeter of the Bacau City is planned to be covered. The procedures for setting the sampling points and for sampling the probes were established according to H.G. 1408/2007 [50].

The area was divided into cells of 1 km side (Figure 9) the natural protected area being included. Among the marginal cells were kept all the cells that contain a significant portion of the city land or land from outside the city but with interest for the study (ex. agricultural land or land under the flight corridor). The result was a total of 54 cells.

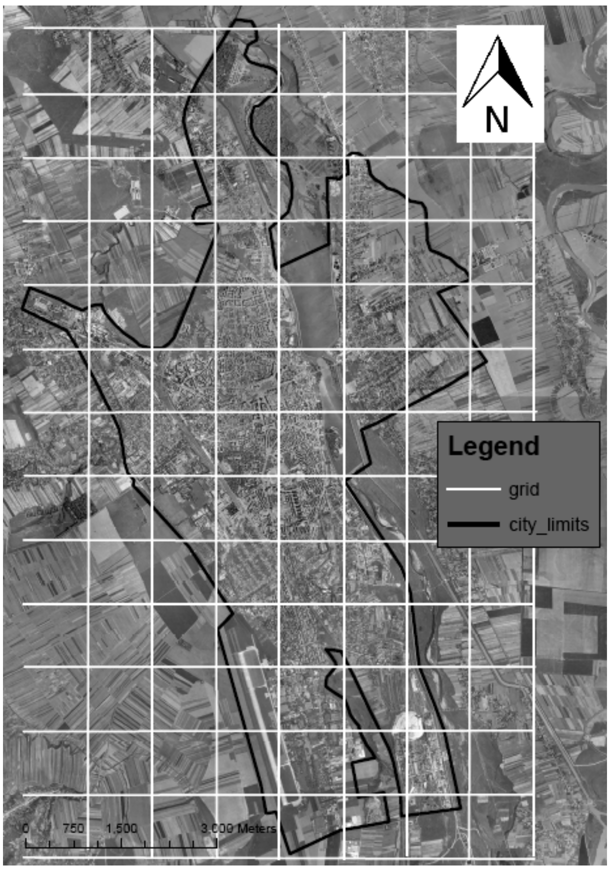

Fig. 9. The grid and the limits of the study area.

To obtain a regular network of sampling points, the centre of each cell was taken into consideration. For that, each cell centre was marked, it was assigned an identification number and the corresponding geographical coordinates were taken (Figure 10).

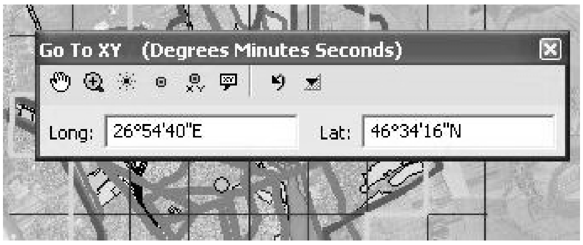

Fig. 10. Example of location point.

Positioning in the field can be done using GPS. Where on the planned position the soil cannot be sampled (soil is covered with buildings, asphalt or other materials that cannot be removed), it will be selected a new position as close to the original set, and the new coordinates will be recorded.

For each location, 9 samples will be taken as follows: it will be drawn a square by 2 m on side and the centre at the point determined by coordinates. Then it will be taken samples from the centre, the 4 corners and the middles of the sides. Where the position does not allow, the procedure will be changed so it could be taken a minimum of 5 samples. The change of procedure will be documented. The soil from all the 9 sample points will be mixed, resulting a single probe with the same identification number as the location. The soil will be sent to the laboratory.

Following this activity it will result a new map presenting the distribution of sampling locations, and the table associated will contain for each sample point: the identification number, the geographical coordinates, the concentrations for the studied metals, additional information about the changes of the sampling procedure.

4.3. Making distribution maps

ArcGIS provides a range of interpolation methods for achieving distribution maps, the choice depending on the dispersion of the sampling points. If it is used a regular structure for the sampling points, the most appropriate interpolation method for representing surfaces depending on concentrations is the “kriging method”.

This is a weighted average method to determine the value z on the points of a grid, weights being determined on the basis of position data and the degree of spatial continuity of the data through determination of the semi-variogram. The weights are determined so that the average estimation error to be zero and the version of the estimation to be minimum (principle of minimum sum of squared errors or the principle of least squares).

Even if it is difficult to implement this method directly, it is highly developed by the ArcGIS software. The only condition to obtain accurate distribution maps is to determine the distribution model correctly.

The steps to be followed are:

1. data from experiments will be statistically analysed and it will be obtained the distribution patterns and the diagrams of variation for each metal
2. in ArcGIS, it will be selected the Geostatistical Analyst Tools from the View Menu. It will be selected the Geostatistical Wizard option where it will be specified the table for concentrations and the filtering condition;
3. the interpolation method will be selected, in our case “kriging method”, and it will be specified the subtype. As the expected value of z’s outlined trend is considered to be constant over the entire grid (x, y), the subtype is "Ordinary Kriging”;
4. in this step it will be selected the distribution type used to generate the surface (Figure 11). This will be selected regarding the distribution pattern obtained through the statistical analysis of the data. This window also allows the preview of the variogram and the preview of the generated surface;
5. the last step validates the generated model (Figure 12). For a better representation, the software introduces more intermediate points. This step permits the preview of the complete generated model and the possibility to eliminate the points for which the calculated error is too high.

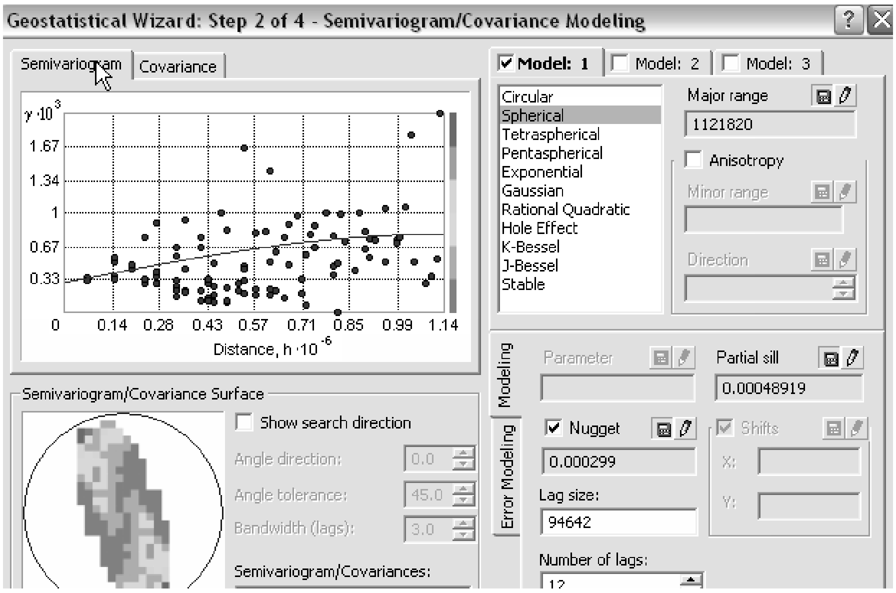

Fig. 11. Example of generated variogram and surface.

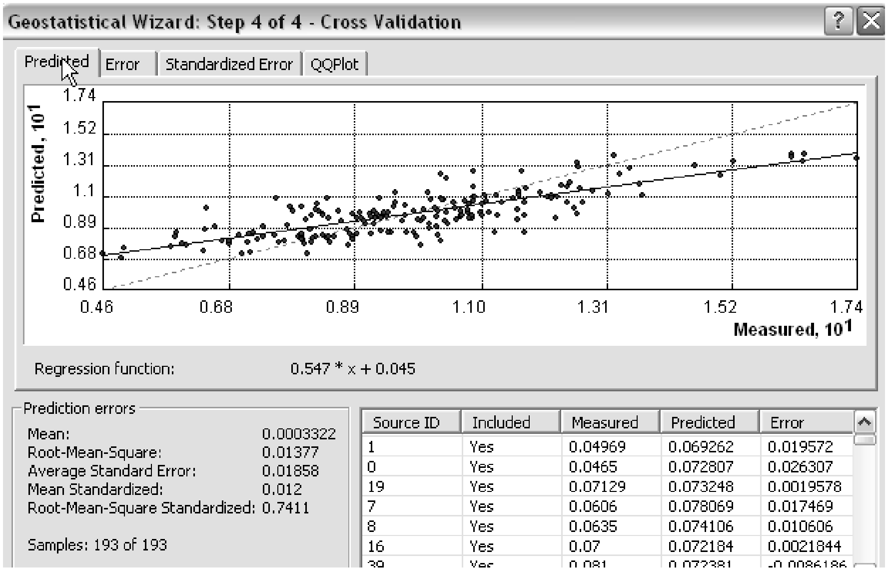

Fig. 12. Example of cross-validation window.

4.4. Analysis of the distribution maps

Primarily, the distribution maps represent an effective method to validate the statistical analysis, but also a way of viewing the physical-geographical context of how heavy metal concentrations vary in soil of Bacău City.

Analysis possibilities are many more: the development of correlations between the metals, by overlaying the maps of the distribution for different metals and establish the common emission sources; the analysis of points of maximum by overlaying maps of active industrial areas, or maps of the traffic, or maps of the waste deposits; the identification of possible areas of historical pollution, by overlaying the map of industrial zones that have been active until 1990 with the distribution maps; or the identification of areas that are requiring further studies.

CONCLUSIONS

This study, that the authors propose, is an identification of the current situation in terms of metal concentration in Bacău City soil. It may be used as a reference for future monitoring, and depending on the results achieved it will be the launch point for other lines of research. The authors also believe that the use of GIS can be extended to other areas of analysis in environmental quality.

AKNOLEGMENTS

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