SOIL CONTAMINATION IN AN URBAN AREA
-AVAILABLE LEAD, COPPER AND ZINC IN THE SOILS OF OPORTO, PORTUGAL

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ABSTRACT

The Oporto's urban *metabolism*, especially for the last 20 years, and it's geographical context contributed to transform the management and planning of this urban area in especially difficult task.

Knowing that the heavy metals are one of the residues of human activity that pose severe problems for sustainable urban development because they can hardly affect the human health, we tried first to evaluate the Oporto's soil contamination levels by heavy metals and then understand and identify the potential souces of emissions.

Besides knowing that lead and other heavy metals are leached slowly to lower soil horizons we made a survey of more than 100 sites in Oporto urban area where we collected some urban soil samples that were afterwards analysed and compared with other values found at Manchester and some other cities.

We found the higher values of lead in the old city centre -"Baixa"- either in 1990, 1991 or 1992. The mean values for the city centre almost double the periphery ones.

In almost all cases the lead concentrations decreased away from the kerb demonstrating that at present, and in a recent past, vehicular emissions of lead are the major source of lead in surface soil near the main traffic routes.

The local variability of lead in urban soils and the significantly higher concentrations of heavy metals in inner cities emerge clearly from our data analysis.

The local pockets of extremely high values indicate the need for more information on contaminated land and the importance of developing databases to support the decision-maker's process.

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Oporto is the second most important city of Portugal. Located closely to the sea, in the NW part of the country (Fig.1) with approximately 300 000 inhabitants distributed in an area of 4000ha (Fig.2).

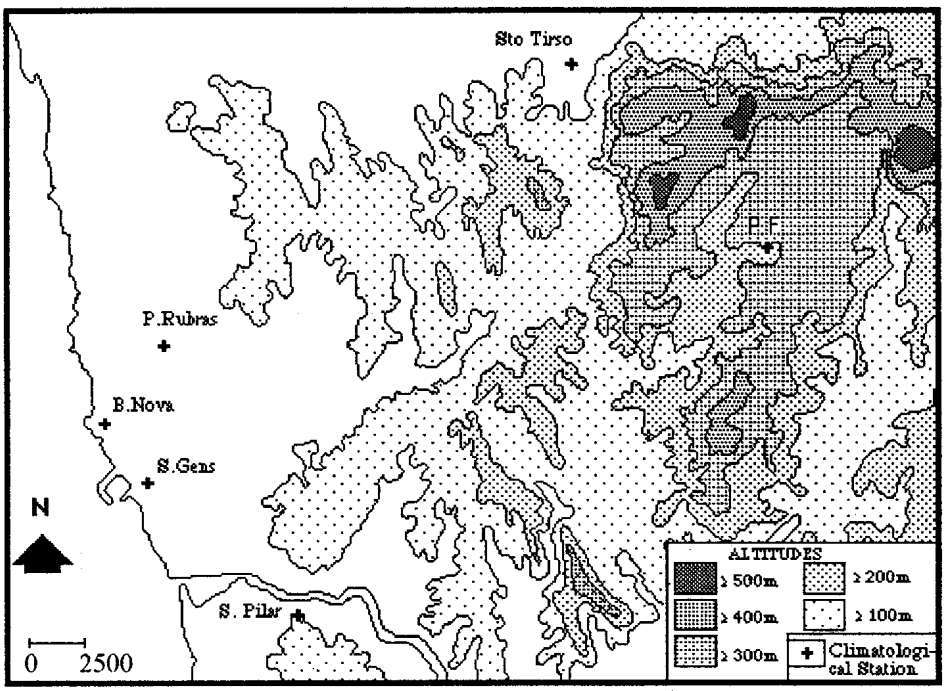

Fig.1 - Oporto and its geographical environment (Lat.41°8'-41°11'N; Long. 8°33'-8°41'W)

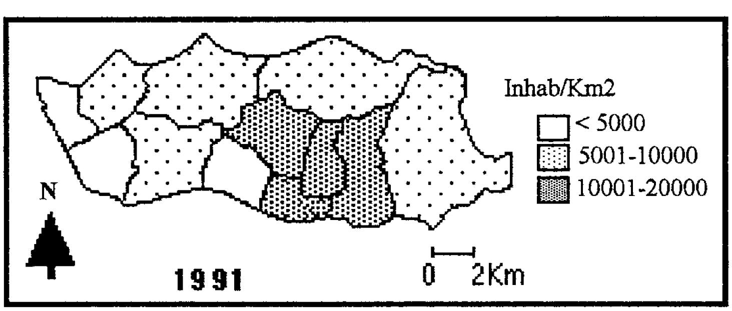

Fig.2 - Population density within Oporto in 1991.

About 1/5 of its area is occupied by built space for residential, commercial and industrial use.

The national and regional ranking of the city, included in one of the more rich and productive areas of the country, contributes to drain every day to the city more than 1 million of person. The nearly 310 000 vehicles daily entering the city boundaries witness well the great vitality of the area (Fig.3).

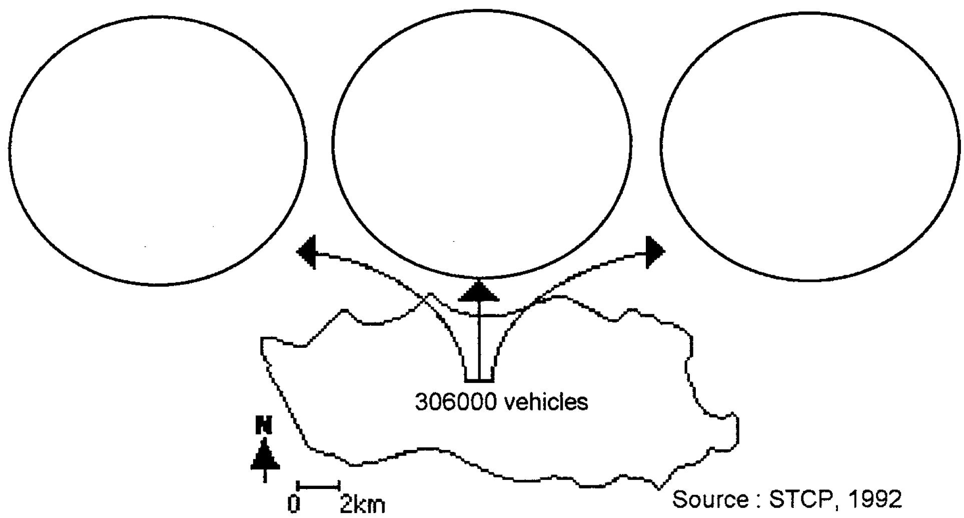

Fig.3 - The probable emissions delievered by the amount of vehicles daily entering Oporto according with traffic fluidity (Monteiro, 1993).

If we put together the increased urban *metabolism*, especially for the last 20 years, and the geographical context of Oporto, a city with an historical archive of more than 8 centuries (1147), it's obvious that it has not been an easy task the management and planning of this urban area.

The decision-makers most relevant targets for the last 2 decades have been focussed on the rapid economic growth. So, the city was a stage for several simplistic and easy answers, to the frequent signals of entropy shown. Usually the solutions were already out-of-date and obsolete when applied. What meant that the main problems persist and appear now and then with different faces.

During the 80's, with the development of new accessibilities within the area and with the new technologies highly spread, the city gradually lost interest to the investors and to the residents and was successively abandoned. This favored the emergence of some naked and inert niches within the city centre wich carried aditional severe socio-economic problems.

By the end of the 80's, beginning of 90's, the new philosophies defending a renewal of the international economic patterns, underlining the need for socio-productive flexibility and the enterprises aptness to rapid changes according to the market requirements, reinforced the extraordinary and unique feature of the urban areas to suit this kind of development.

But the urban area attractiveness now, must include higher environmental standars. The new investments in the cities require cared environment and better quality of life. The promiscuous miscellaneous of functional areas and the lack of attention on all the ecossystem components is no more admissible.

The sustainability of the new development projects must be cautiously anchored and weighted among all the other variables included in the cost-benefit anlysis during the decision making process.

Having this in mind, and while we were trying to demonstrate the impacts of Oporto's urbanization process on the regional climate, we needed to have some roughly idea of the soil contamination by heavy metals.

Knowing that the heavy metals are one of the residues of human activity that pose severe problems for sustainable urban development because they can hardly affect the human health (Table I), we tried first to evaluate the Oporto's soil contamination levels by heavy metals and then understand and identify the potential souces of emissions.

METAL	TYPICAL SOURCES	EFFECTS
Lead	Smelting, battery manufacture, metal recovery, crystal glass production, pigment manufacture, ceramic and paint industries. Organic compounds used in petroleum refining	Fatigue, insomnia, headache, loss of appetite, constipation. With increased exposure, blue colouratio of gum margins, abdominal cramps, weakening of muscles due to disturbance of peripheral nervous system. encephalopathy- intense headaches, convulsions, coma, death
Source: ROWLAND, A., COOPER, P., Environment and Health Edward Arnold, London, 1983, p.169-170.		

Table I - Lead typical sources and its effects on human health.

As the already vast bibliography, about this subject, show the lead can come from a lot of different sources and through a huge type of pathways (Fig.5).

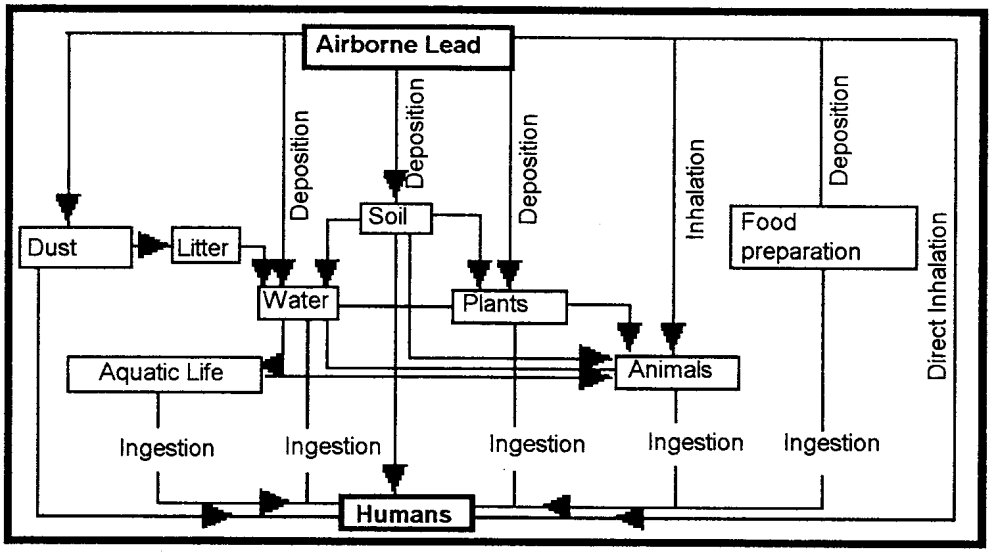

Fig. 5 - Potential pathways of lead
(adapted from World Health Organization, 1977)

The relationship between the present typical way of life and the increased heavy metals levels on air, soil and water come out clearly if we compare what would be the natural levels with actual ones (TableII). Especially on air and soil the values found in nowadays largely exceed the predicted *natural* ones.

TYPE OF ENVIRONMENT	Estimated lead *natural* levels	Typical lead levels found nowadays	*Ratio* present/natural
AIR - rural	0.01 - 0.1 ng/m^3	0.1 - 1 00 ng/m^3	10-1000
AIR - urban	0.1 - 1.0 ng/m^3	0.1 - 10 µg/m^3	100-10000
SOIL-rural	5 - 25 µg/g	5 - 50 µg/g	1-2
SOIL-urban	5 - 25 µg/g	10 - 5000 µg/g	2-200
WATER-rivers	0.005 - 10µg/l	0.005 - 10 µg/l	1
WATER-oceans	0.001 µg/l	0.005 - 0.015 µg/l	10
FOOD	0.0001 - 0.1 µg/g	0.01 - 10 µg/g	100

1n = 10^3µ

Table II - Comparison between the *natural* lead levels with those recorded nowadays (adapted from ROSE, 1983, p.85).

Measurements of atmospheric lead at the Science Faculty building (in the Oporto's city centre) show concentrations ranging from 0.0069 to 3.8 µg/m^3 with 10% of all observations exceeding the Portuguese guideline of 2 µg/m^3 (Vasconcelos, 1988).

Vasconcelos et al. (1988), demonstrated that there was a considerable increase of lead in the atmosphere at the stations closer to the ground and particularly on working days (Table III). This heavy metal appeared also with higher levels during stable and calm days (Table IV).

STATION	LEAD LEVEL (µg/m^3)	DAY OF WEEK

Science Faculty (17m high)	0.30	Work days
Science Faculty (17m high)	0.29	Weekend
Science Faculty (3m high)	0.48	Workday
Science Faculty (3 m high)	0.44	Weekend

Source: Vasconcelos, M.T. et al., 1988, p.2104

Table III - Lead levels found in the Oporto's atmosphere in various days of the week.

LOCALIZAÇÃO	LEAD LEVEL (µg/m3)	WEATHER
Science Faculty (17m high)	0.33	DRY
Science Faculty (17m high)	0.27	RAINY
Science Faculty (17m high)	0.29	WINDY
Science Faculty (3m high)	0.58	DRY
Science Faculty (3m high)	0.32	RAINY

Source:: Vasconcelos, M.T. et al., 1988, p.2104

Table IV - Lead levels found in the Oporto's atmosphere under different weather conditions.

So, the pattern of occurrence of high atmospheric concentrations is influenced by both human activity and weather.

The high lead levels recorded in the Oporto's atmosphere are as much significant as the majority of the days the weather conditions favor the cleaning of the air and the dispersion of the pollutants. Beyond this Oporto mean lead concentrations of 0.48 µg/m3 found at the station 3m above the ground exceeds the mean values reported to some more industrialized cities like Chicago or Tucson (Table V).

CITY	LEAD LEVELS (µg/m^3)
Porto - Science Faculty (3m high)	**0.48**
Oslo	0.383
Chicago	0.359
Copacabana	0.499
Tucson, Arizona	0.47

Source: Vasconcelos, M.T. et al., 1988, p.2105

Table V - Comparison of lead levels found in the Oporto's atmosphere with other cities.

In spite of knowing that the levels of lead in the soil reflect the historical build-up of heavy metals and not the immediate weather or traffic conditions, although lead and other heavy metals are leached slowly to lower soil horizons we made a survey of 84 sites in Oporto urban area.

Under suggestion and supervision of Professor Ian Douglas, from Manchester University, U.K., and with the technical support of the Geography Department of the same university, we collected some urban soil samples that were afterwards analysed and compared with other values found by Jasem Al-Ali (1993) at Manchester.

We initiated collecting soil samples in July 1990 and repeated in 1991, 1992 and 1993.

The mean EDTA-extractable lead contents determined, ranged from 110.9 µg/g in 1990 to 132 µg/g in 1991 (Table VI).

	Jul-90 COPPER (μg/g)	Jul-91 COPPER (μg/g)	Jul-92 COPPER (μg/g)	Jul-90 LEAD (μg/g)	Jul-91 LEAD (μg/g)	Jul-92 LEAD (μg/g)	Jul-90 ZINC (μg/g)	Jul-91 ZINC (μg/g)	Jul-92 ZINC (μg/g)
Average									
TOTAL	34,8	32,1	45,9	110,9	132	126,2	103,5	63,5	92,1
"Baixa"	28,8	22,7	32,4	**158,5**	**178,7**	138,4	109,5	66,4	99
"City Centre"	**35,8**	**38,7**	**47,8**	47,9	123,8	**149,1**	**129,4**	**68,7**	89,3
Periphery	33,1	15,9	40,9	89,3	89,2	118,3	134	50,4	**99,1**
Standard Deviation									
TOTAL	34,8	43,1	47	78,4	103,2	71,6	164,1	56,1	82,6
"Baixa"	13	11,6	5,8	75	159,4	92,6	103,9	53,9	41,2
"City Centre"	37,7	48,9	48,8	48,3	85,6	105,4	74,5	59,9	77,6
Periphery	29,9	14,7	44,9	60,1	87,2	65,7	251,2	44,7	96,8

Table VI - Mean and standard deviation of total and partial Oporto soil samples EDTA contents (Monteiro, 1993).

The higher values of lead were found in the old city centre -"Baixa"- either in 1990 or 1991 (Table VI). The mean values for the city centre almost double the periphery ones.

Several soil samples showed concentrations above the 200 μg/g[1] at the sites close to the centre (Table VII and Fig.6).

The highest individual lead concentration was 380 μg/g, the highest copper 308μg/g and the highest zinc 1320 μg/g.

A more extensive random survey of 183 sites in 1993 wich determined both EDTA-extractable (available) and Aqua Regia-extractable (total) lead, copper and zinc revealed available lead ranging from 12 to 1552 μg/g, copper from 1 to 146 μg/g and zinc from 8 to 504 μg/g. The total concentration ranges were: lead - 15 to 10125 μg/g, copper - 5 to 362 μg/g; zinc - 8 to 825 μg/g.

SAMPLE Nº	LOCATION	YEAR	LEAD (μg/g)
30	Pç. Exército.Libertador	1991	292
30	Pç. Exército.Libertador	1992	200
49	Lg. 1º Dezembro	1990	328
49	Lg. 1º Dezembro	1991	288
49	Lg. 1º Dezembro	1992	252
50	R.Saraiva de Carvalho	1991	208
51	Av.Rodrigues de Freitas	1990	360
51	Av.Rodrigues de Freitas	1991	292
51	Av.Rodrigues de Freitas	1992	232
54	R. Ferreira de Castro	1990	200
54	R. Ferreira de Castro	1991	244
56	Campo 24 de Agosto	1991	204
59	Av. Aliados	1990	212
59	Av. Aliados	1991	380
60	R.Ramalho Ortigão	1990	266
60	R.Ramalho Ortigão	1992	260
61	Pç. da Liberdade	1992	212
63	Lg. do Padrão	1990	280
63	Lg. do Padrão	1992	352
64	Lg. Moreira da Silva	1990	302

[1]The risk guideline for plants is 150 μg/g

66	Pç. Sá Carneiro	1990	300
66	Pç. Sá Carneiro	1992	244
72	Gonçalo Cristovão	1991	480
75	Pç.Filipa de Lencastre	1990	280
76	Pç. Stª Teresa	1990	204
77	Pç. Parada Leitão	1991	260
80	Rotunda da Boavista	1990	236

Source: Monteiro, 1993

Table VII - EDTA lead concentration above 200 µg/g at Oporto

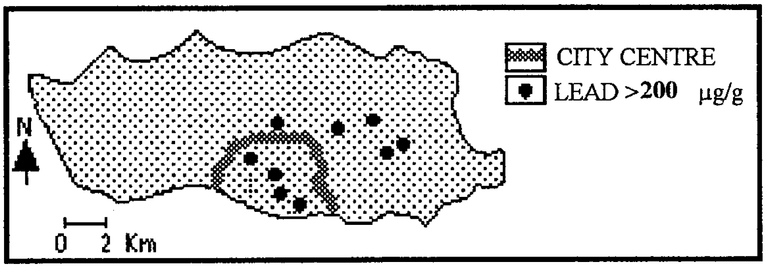

Fig.6 - Soil samples collected at Oporto with > 200 µg/g of lead (Monteiro, 1993)

The pattern concentration closely corresponds to that in Manchester, U.K., with high levels of lead in surface soils in the older, more central parts of the city and then relatively high concentrations close to the main traffic arteries running out from the city centre (Table VIII).

Manchester also exhibits the general tendency of decreasing surface soil load away from main roads (Douglas et al., 1993).

To test this in Oporto, the large, tree-covered roundabout, Rotunda da Boavista was sampled intensively in 1991 and 1992 with three transects running from the kerb to the centre (Fig.7).

DISTANCE TO THE KERB (m)	PRINCESS ROAD (µg/m^3)	A6 -SALFORD (µg/m^3)	RD A62-OLDHAM (µg/m^3)	ASHTON NEW ROAD (µg/m^3)
2	410.4	328.4		
4	244.8	196.5	286.2	332.5
6	183.6	180.8	204.6	176.7
8	144.5	141.0	145.8	140.3
10	109.6	126.1	125.5	119.7
15	98.2	108.8	123.6	114.1
20	79.3	97.6	136.4	92.8
25	66.0	104.3	126.5	76.6
30	58.5	101.0	126.0	74.2
35	52.8	112.0	109.8	82.2
40	51.8	118.2	113.2	89.3

Table VIII - Mean lead levels found in Manchester (JASEN, AL-ALI, 1990)

In all cases, except on one occasion the lead concentrations decreased away from the kerb demonstrating that at present, and in a recent past, vehicular emissions of lead are the major source of lead in surface soil near the main traffic routes (Fig.7).

The local variability of lead in urban soils and the significantly higher concentrations of heavy metals in inner cities emerge clearly from our data analysis.

Local pockets of extremely high values indicate the need for more information on conatminated land and the importance of developing databases to support the decision-maker's process.

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