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Use of pigeons as bioindicators of air pollution from heavy metals at Rabat-Salé (Morocco)

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Abstract – Adult *Columba livia* pigeons were used as bioindicators of atmospheric pollution by heavy metals, from different sources (road traffic, earthenware workshops). Concentrations in pigeon tissues varied according to metals. Lead and cadmium showed higher accumulation in kidneys, while zinc was the found in whole organs. Except for Oulja, where lead is commonly used in earthenware production, lead and cadmium were accumulated according to the density of road traffic, thus the highest lead concentrations were found in the town centre, followed by Kamra where car traffic is moderate, and with the lowest concentrations of lead in rural areas. On average, high concentrations of cadmium were observed in the kidneys of pigeons in the town centre, and a lower content ratio (25 times) was found in rural areas (Allal Behraoui). The low metal concentrations in the pigeons blood and organs was due to the limited presence of industry in Rabat-Salé.

Riassunto – Il piccione domestico è stato usato come bioindicatore di inquinamento atmosferico da metalli pesanti, di differenti provenienze (traffico veicolare, lavorazione della terracotta). La concentrazione degli inquinanti nei tessuti è risultata diversificata a seconda dei metalli. Piombo e cadmio hanno mostrato la maggiore accumulazione nei reni, mentre lo zinco è stato rinvenuto in tutti gli organi. Ad eccezione di Oulja, dove il piombo è comunemente usato nella lavorazione della terracotta, l'accumulo di piombo e cadmio è legato alla densità del traffico veicolare, per cui le massime concentrazioni di piombo sono state trovate nel centro della città, seguite da Kamra, dove il traffico è moderato, con i valori minimi nelle aree rurali. In media, alte concentrazioni di cadmio sono state osservate nei reni dei piccioni del centro della città, mentre nelle aree rurali (Allal Behraoui) questo metallo ha mostrato valori 25 volte inferiori. Le basse concentrazioni di metalli nel sangue e negli organi dei piccioni, sono dovute alla limitata presenza di industrie a Rabat-Salé.

INTRODUCTION

Studies based on bioindicators of air pollution are very rare in Morocco. Lichens were used in some cases (Ghizlane *et al*. 2007), and studies of air pollution showed that the main sources of lead pollution at Rabat-Salé are road traffic and the use of galena (PbS) in earthenware production (Elabidi *et al*. 2000). This study is aimed at studying air pollution from heavy metals at Rabat Salé, using pigeons as bioindicators.

According to many authors (Watanabe *et al*.1990, Schilderman *et al*.1997, Nam *et al*. 2004), pigeons are very good bioindicators of air pollution, due to their biology and ecology; they have a limited mobility over the year, a high metabolic rate, a higher inhalation than man, and they ingest grains, stones and food contaminated by heavy metals. Moreover, the analysis of pollutants in a biological matrix is very interesting since it supplies precise information on the biological availability of pollutants.

The purpose of this study was to evaluate metal contamination by Pb, Cd and Zn, their distribution in tissues, and the use of pigeons in the biomonitoring of air pollution in different areas of Rabat-Salé city, namely urban, industrial and rural.

METHODS

Thirty-one, male and female adult pigeons (*Columba li-*

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via) were captured using Japanese nets between December 2006 and March 2007 at 14 sites in Rabat-Salé, which were previously classified according to their road traffic density: Kamra, classified as a high density area, the centre of town classified as an average density area, Oulja with higher industrial activity (Craftsman industry complex), and Allal Bahraoui, low density and rural (Fig. 1).

Blood samples were collected using blood tubes with EDTA. Kidneys, liver, lungs and heart were stocked in polythene bags, after dissection, at -20°C until analysis.

About 0.5 g of fresh pigeons organs were digested at 120°C for 4 hours with 4 ml of nitric acid suprapur (65% Merck) and the volume of the final solution was adjusted to 50 ml with deionized water (Auger 1989). The determination of Pb and Cd was performed using a Graphite Furnace - Atomic Absorption Spectrometer (Varian AA-Z 220); Zn concentrations were measured by flame AAS (Varian AA 20) in the Toxicological Laboratory of the National Health Institute in Rabat.

The validity of the analytical methods was checked by internal control, using standard samples (Regional Council of Research of Canada: DORM-2) and by external control using inter calibration exercises (IAEA-0140, 1997, IAEA-433, 2004, for the organs, and PLO 03, 2007, for the blood).

The lead, cadmium and zinc concentrations were compared by t-Student test (unpaired samples).

RESULTS

Tab. 1 shows the lead, cadmium and zinc concentrations in the different pigeon organs (kidneys, liver, lungs and heart) of the pigeons at the four studied sites in Rabat-Salé city. In general the distribution of the heavy metals varied according to the targeted organ and the metal.

The average lead concentrations varied between organs, and in general showed a preferential accumulation in the kidneys and liver (five times higher in kidneys and in liver than in lungs and heart). The highest lead concentrations in the kidneys were found at Oulja Salé (0.56 mg/kg fresh weight; the difference with the other three areas was highly significant (P<0.02 between Oulja and the centre of town; P<0.001 between Oulja and the two other areas). The lowest concentrations were found at Allal Behraoui rural area (0.12 mg/kg fresh weight; difference with the other areas highly significant, P<0,001). The highest lead concentration in liver was found at Oulja (0.56 mg/kg fresh weight; difference with the other three areas highly significant, P<0.001) while the lowest concentrations was found at Allal Behraoui (0.07 mg/kg of fresh weight; difference also highly significant, P<0.001). The lead concentrations in lungs and heart were very low, with the highest value, 0.12 mg/kg in pigeon lungs at Oulja Salé, and with the lowest values (0.002 mg/kg) in pigeon hearts at Kamra and Allal Behraoui. No significant difference in lead concentration in the heart was found between Kamra and Allal Behraoui (P=0.361) or for the lungs between the center of town and Allal Behraoui (P=0.084), while the difference was statistically significant for the other sites. The highest lead concentrations in the blood were found at the Oulja site (31.11 μg/l) while the lowest were encountered at Allal Behraoui (11.13 μg/l, that is 1/3 compared to Oulja). The differences in lead concentrations between all the studied areas were highly significant (P<0.001).

High cadmium concentrations were observed in the

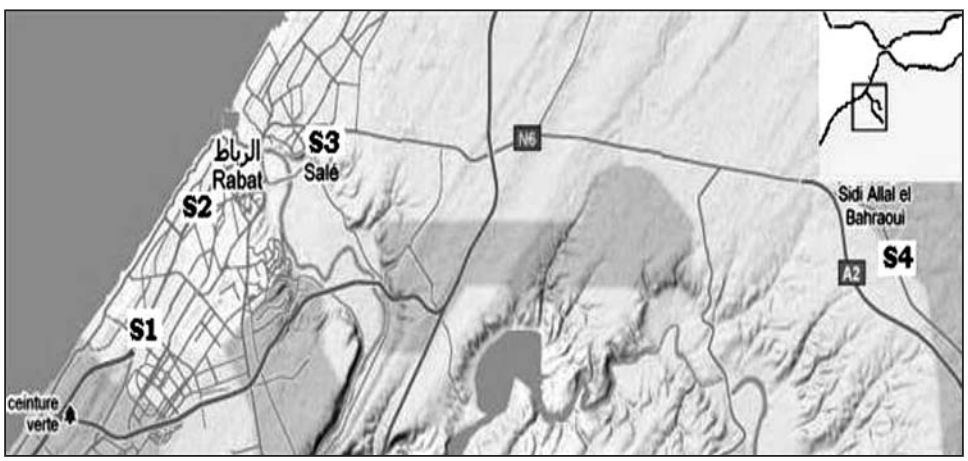

Figure 1. Location of the study sites in Rabat-Salé (Morocco) – *Localizzazione delle aree di campionamento a Rabat-Salé (Marocco).*

Table 1. Average lead, cadmium and zinc concentrations in the organs of pigeons in Rabat-Salé (means ± standard deviation) – *Concentrazioni medie di piombo, cadmio e zinco negli organi dei piccioni domestici a Rabat-Salé (medie ± deviazioni standard).*

		N	Blood	Kidney	Liver	Lung	Heart
Lead	Kamra	10	16.40±1.60	0.29±0.02	0.12±0.01	0.10±0.01	0.02±0.005
	centre of town	9	22.12±2.56	0.48±0.04	0.37±0.06	0.07±0.02	0.06±0.01
	Oulja	6	31.33±2.85	0.56±0.06	0.56±0.05	0.12±0.03	0.11±0.03
	Allal Behraoui	6	11.17±2.14	0.12±0.03	0.07±0.01	0.05±0.02	0.02±0.01
Cadmium	Kamra	10	1.58±0.35	0.58±0.05	0.19±0.02	0.003±0.001	0.003±0.002
	centre of town	9	2.24±0.30	3.07±1.11	0.20±0.04	0.030±0.007	0.019±0.008
	Oulja	6	1.13±0.30	0.26±0.03	0.13±0.02	0.008±0.002	0.002±0.001
	Allal Behraoui	6	0.34±0.04	0.12±0.03	0.07±0.03	0.005±0.003	0.004±0.001
Zinc	Kamra	10	3463±256	18.0±3.5	13.4±3.1	8.3±1.7	12.2±1.3
	center of town	9	4449±398	31.0±3.2	29.0±2.8	11.9±0.4	20.5±1.3
	Oulja	6	6998±396	36.9±1.1	120.3±3.3	29.3±1.3	26.4±1.4
	Allal Behraoui	6	5608±224	35.55±2.5	50.1±4.2	11.9±1.5	19.8±1.3

kidneys from the town centre (3.07 mg/kg fresh weight) with a highly significant difference between this and the other areas (P<0.001). Conversely, the lowest cadmium concentrations in the kidneys were found at Allal Behraoui, with 0.12 mg/kg of fresh weight, that is, 25 times lower than that in the town centre, with a highly significant difference in concentration between this and the other sites. The maximum cadmium concentrations in liver were found in the town centre (0.20 mg/kg fresh weight); the difference between this site and Kamra not significant (P= 0.617) while the difference between this site and the other two was highly significant (P< 0.003). The minimum average concentrations were found at Allal Behraoui (0.07 mg/kg of fresh weight) with a significant difference in concentration between this and the three other sites (P<0.004). It emerged that cadmium was accumulated preferentially in kidneys, compared to liver, with a 15 times higher ratio in the centre of town, 3 times at Kamra, and two times higher at Oulja and at Allal Behraoui.

Cadmium concentration in the lung and heart was very low. The highest cadmium concentration was found at the town centre in the pigeon lungs (0.03 mg/kg in fresh weight), while the lowest value was found at Oulja (0.002 mg/kg in fresh weight in the heart). The difference in cadmium concentration was not statistically significant between Kamra and Allal Behaoui for lung and heart (P = 0.148 and P = 0.504 respectively), nor between Behraoui and Oulja for the lungs (P= 0.151). Between the other sites, the difference in cadmium concentration was significant (P<0.005).

The average cadmium concentrations in blood were low for the four studied sites. The concentration differences in cadmium between the Kamra and Oulja sites was not significant (P=0.20), while this difference was highly significant (P<0.001) between the other sites. The average concentrations at the three urban sites, town centre, Kamra and Oulja were 2.24; 1.58 and 1.13 μg/l respectively, while the concentration found in the rural area was five times less than in the urban areas (0.34 μg/l,).

The maximum zinc concentrations in liver were found in Oulja with 120 mg/kg fresh weight, and the lowest ones, 13.4 mg/kg at Kamra; the differences between all study sites were highly significant (P<0.001). Unlike lead and cadmium, the lowest zinc concentrations in kidneys and in liver, were not found in the rural area, but in the urban area, with 18 mg/kg in kidneys and 13.4 mg/kg in liver at Kamra. The highest zinc concentrations in kidneys were found at Oulja with 36.9 mg/kg; the difference between this site and Allal Behraoui was not significant (P = 0.27), while it was highly significant between this site and the two other ones (P<0.001).

Contrary to lead and cadmium, the lungs and heart contained significant amounts of zinc; the highest concentrations were found in the lungs at Oulja with 29.3 and 26.4 mg/kg in fresh weight respectively. The lowest concentrations were found at Kamra in the lungs and heart, 8.3 and 12.2 mg/kg respectively. All the sites differed significantly between each other (P<0.001), except for the town centre and Behraoui (P=0.985).

The zinc concentrations in the blood (Tab. 1) differed between the all sites (P<0.001), so that a space typology was apparent from Oulja to Allal Behraoui, town centre, and Kamra.

DISCUSSION

Contamination levels in pigeon organs showed that lead is accumulated mainly in kidneys and in liver, with 46% of lead found in the whole analysed pigeons in kidneys, 36% in liver, 11% in lungs and 7% in the heart.

The lead accumulation in kidneys and in liver could be related to the eating habits of pigeons, which can ingest stones where lead particles from air pollution are fixed to their surface; a phenomen identified also by Hutton e Goodman (1980).

The high lead concentrations in the different organs at Oulja result from pollution caused, on one hand by the potters and foundry at this site and, on the other hand, by vehicle exhaust systems. In the Oulja area, where the pigeons were captured, there are many potters who use Galena (PbS) to make their earthenware and which consequently discharges large amounts of lead into the air (Elabidi *et al*. 2000). There is also a foundry which discharges all kinds of metals into the air,. In addition, road traffic is quite intense also in this area.

The differences in lead concentrations among the other sites can be explained by road traffic intensity. The centre of town is the area where the traffic is the densest, next comes Kamra where the traffic can be considered average, and finally Allal Bahraoui, a rural area where the traffic is very low.

The role of the kidneys in the accumulation of lead may be clarified. The lead concentrations found in the pigeon kidneys at Rabat-Salé varied significantly according to road traffic intensity. The values we found were scaled along a road traffic intensity gradient: high, medium, and low (0.48; 0.29 and 0.12 mg/kg respectively). Similar observations were made by Hutton e Goodman (1980), Antonio Garcia *et al*. (1988), Schilderman *et al*. (1997), Kim *et al*. (2001), Nam & Lee (2006).

Comparable values to those of our study were found in The Netherlands and in South Korea. For The Netherlands, Schilderman *et al*. (1997) showed that lead concentration in pigeons' kidneys was 0.53μg/g fresh weight in areas of Amsterdam with average road traffic, while it was 0.30 and 0.41 ± 0.19 μg/g in areas with low traffic in Maastricht. Moreover, also in a low density traffic area in Assen the average lead content was 0.41 ± 0.19 μg/g in fresh weight. According to Lee (1991), the average lead concentrations in South Korea was 0.59 μg/g in fresh weight in pigeons from Songnam, which is considered a rural area.

Other authors found higher values than ours. The lead concentrations found by Nam e Lee (2006) in Seoul were 4.13 μg/g in urban areas and 1.45 μg/g in fresh weight in rural areas, while Kim *et al*. (2001) found lead contents in the kidneys of pigeons of 5.75 μg/g , fresh weight, in residential districts of Seoul.

In comparison to the lead concentrations found in similar cases throughout the world, the concentrations found in our study can be considered relatively low, and comparable with those found in large cities, in areas with low or average road traffic. These low concentrations can be explained on one hand, considering the use of unleaded petrol in Morocco since 1990 for newly manufactured cars, and on the other hand, considering the low density of the lead industry in Rabat-Salé. Except for the pollution from earthenware production, a small foundry and from cars, there is no other source of lead pollution in this area.

The lead levels in the blood found at Rabat-Salé are significantly lower than those found in the literature. Schilderman *et al*. (1997) found lead levels in the blood of pigeons in Amsterdam from 73 μg/l, in areas with medium road traffic, to 235 μg/l, for high traffic areas, and similar values were found by Hutton & Goodman (1980). As in the case of other organs, the introduction of unleaded petrol and the lack of lead industries in Rabat-Salé can explain these low concentrations of lead in the blood of the pigeons at Rabat-Salé.

Cadmium, like lead, is discharged into the environment by motor vehicles. It is related to the wear of tyres (Johnston e Janiga 1995). This can explain the high cadmium concentrations observed in the organs of pigeons in the centre of town, where car traffic is densest, and the low cadmium concentrations found in the rural area. Furness (1996) found high cadmium concentrations in pigeon kidneys near the Heathrow airport of London, and linked these high concentrations to lead released by the wear of airplane tyres.

The low cadmium concentrations found in lungs, compared to those found in the kidneys and liver, showed that contamination from atmospheric exposure is much lower than that related to the eating habits of pigeons. A close relationship between the cadmium concentrations found in pigeon kidneys and their intestinal concentration has been shown by Hutton & Goodman (1980).

A comparison of the cadmium contamination levels of the Rabat Salé pigeons with those in other large cities (Tab. 2), shows that cadmium concentrations in kidneys, liver and lungs of the Rabat-Salé pigeons are more or less similar to those found in literature.

The highest concentrations of zinc in the blood, kidneys and in the liver were encountered in the areas with agricultural activity, namely Oulja and Allal Behraoui. This accumulation of zinc in the blood and organs of pigeons could be explained by the use of fertilizers which usually contain zinc at an impure state and which represents a

Table 2. Comparison of cadmium concentrations at Rabat-Salé pigeons with literature data – *Confronto tra le concentrazioni di cadmio tra i piccioni di Rabat-Salé e dati reperiti in letteratura*.

Location	Kidney	Liver	Lung	Reference
United Kingdom				
London Suburban (n=15)	0.45	0.12		Hutton & Goodman (1980)
Cambridgeshire Rural (n=15)	0.54	0.15		
Netherlands				
Amsterdam urban (n=8)	2.51	0.53	0.03	Schilderman *et al*. (1997)
Maastricht urban (n=5)	0.67	0.27	0.02	
Assen urban (n=7)	0.60	0.13	0.02	
Korea				
Seoul urban (n=9)	0.76	0.17	0.04	Lee (1991)
Seoul urban (n=7)	0.92	0.33		Kim *et al*. (2001)
Seoul urban (n=12)	1.05	0.24	0.22	Nam & Lee (2006)
Songnam rural (n=3)	1.38	0.19	< 0.01	Lee (1991)
Duckjuk Island rural (n=8)	0.06	0.11	0.09	Nam e Lee (2006)

source of significant benefits to soils (Perrono 1999). Pigeons may ingest zinc together with stones and soil containing large amounts of this element.

In conclusion, the distribution of lead, cadmium and zinc in the different organs of pigeons in Rabat-Salé, showed that the accumulation of these trace elements occurs mainly in kidneys and liver, which act as filters of these trace elements. Despite this access restriction, an accumulation of these metals can also be observed in the heart and lungs.

The comparison at organ level in an urban area (Kamra site) showed that in general, metal concentration follows the order: kidneys>liver>lungs>heart. The concentrations in the pigeons blood and organs are different for each metal. Heavy metal concentrations in the blood and organs of the pigeons generally occurs in the order: cadmium<lead<zinc.

Variations in the road traffic density at Rabat Salé, could be responsible for the spatial variation of the metal concentrations in the blood and in different organs of the pigeons, because of the use of lead in fuel and of cadmium in car tyres.

The low metal concentrations in the pigeon blood and organs is the result of a the limited number of metal industries in Rabat-Salé. However, agriculture activities should not be forgotten, especially those concerning the use of chemical fertilisers in soils, that may sometimes cause the accumulation of elements such as zinc which was found in rural areas.

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