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Norway rat, *Rattus norvegicus* in metropolitans, a bio-indicator for heavy metal pollution (Case study: Tehran, Iran)

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ABSTRACT

The present research aims to assess the potential use of the Norway rat, *Rattus norvegicus* as a bio-indicator for lead and cadmium accumulation in 10 urban zones in Tehran, the metropolitan city, Iran. During April to May 2014 we collected twenty adult Norway rats from the different predefined zones. By referring to the air pollution data collected over 15 years, the sampling areas were detected to collect rats. ANOVA test showed that the mean concentrations of cadmium and lead were significantly different for the areas studied as the highest value for both metals recorded in the central areas, exhibiting decreased trends towards the north. In the central parts of Tehran, the mean levels of lead and cadmium concentrations were found to be 73.06 and 5.20 $\mu g.g^{-1}$ in the rats' hepatic tissues, respectively. Meanwhile, the lead and cadmium concentrations were 1.85 and 0.07 $\mu g.g^{-1}$, respectively in the northern parts of Tehran. In addition, we examined the concentration of lead and cadmium in the sludge obtained from the sampling points. The results also corresponded to the metal concentration in the rats liver samples. Therefore, the present study verified that the Norway rat could be used potentially as a bio-indicator for heavy metal contamination in polluted metropolitans, such as Tehran.

Key words: Bio-indicator, Environmental pollution, Heavy metals, Metropolitan, Norway rat.

INTRODUCTION

Nowadays, environmental pollution is an important problem in big cities in the world. Some trace metals such as copper and zinc are harmless in low concentrations, but some metals like lead and cadmium are toxic even in very low concentrations and are potential cofactors, initiators or promoters in many illnesses including cardiovascular diseases and cancer (Shore & Rattner 2001). Lead and cadmium are the two most abundant toxic metals in the environment. The common sources of lead and cadmium include natural and anthropogenic processes such as combustion of coal and mineral oil, smelters, mining, alloy processing units, paint industries, are diverse in nature (Dwivedi *et al*. 2001). The amount of lead used in the present decade far exceeds that consumed in previous decades. Like many other industrial cities, the metropolitan Tehran is one of the polluted cities in the world that anthropogenic factors have had direct or indirect impact on its air and environment over the past and present centuries (Mollashahi *et al.* 2014). Emissions from transportation, industrial and household applications, wastes burning are some of the major threatening factors which affect human health in the large cities while imposing not only a direct economic cost regarding cure induced costs but also threatening long-term productivity (Jitendra & Tanvi 1997).

The anthropogenic activities and vehicular emissions contribute to the entry of toxic metals to human's and other animal's food chains. To evaluate the level of pollution generated by heavy metals and their impact on living organisms as well as to prevent risks to public health in urban areas, investigation into bio-monitoring and bio-accumulator species of toxic heavy metal is inevitable.

Such species should have some specific characteristics such as being typical to the environment studied; abundant and ubiquitous; easy to sample; having exobiotic substance's bio-concentration potential to a detectable level; and tolerable against high concentrations of different toxic substances (Philips 1977; Gragnaniello *et al.* 2001).

In recent years, considerable scholarly attention has been devoted to the use of mammalian species specially rodents as bio-indicators of environmental quality (Shore & Rattner 2001; Damek 2003; Martiniaková 2011).

The accumulation of heavy metals in some free - living rodents has been extensively studied (Clark 1979; Stansley & Roscoe 1995; Ieradi *et al*. 1996; Wijnhoven *et al.* 2007) but comparatively, few studies have been conducted on the accumulation of metals in the rodent species inhabited in urban areas (Sures *et al.* 1998; Sures *et al*. 2000b; Sures *et al*. 2002). Some studies, however, have showed that urban rats have an exceptional heavy metal accumulation capacity (Mousavi *et al.* 2006). The aim of the present study was therefore to detect the potential employment of the Norway rat in an urban system as a bio-indicator for lead and cadmium accumulation and then to map the concentration of heavy metals (lead and cadmium) to show how these elements are spread through Tehran city. Schleich *et al.* (2010) reported that rats living close to the aluminum factories show higher lead and cadmium level in their liver and bone structure. High concentration of lead and cadmium in the rats living in urban systems was reported by Mousavi *et al.* (2006) who reported that the average concentration of lead and cadmium in the Norway rats sampled from Nour, Iran, was 15.53 $\mu g.g^{-1}$ and 2.06 $\mu g.g^{-1}$, respectively. Shore & Rattner (2001) studied rats and concluded that they could potentially be used as environmental pollution bio-indicator.

MATERIALS AND METHODS

Sampling

Between April and May 2014, twenty adult Norway rats (550 ± 30 g) were collected from different zones in Tehran (the capital of Iran) by air gun.

Sludge samples were collected exactly from the rat sampling points and subsequent metal analysis was performed to show differences between lead and cadmium pollution at these two levels.

Meanwhile, the captured rats were transferred to the laboratory and immediately weighed and dissected. Samples of liver were frozen at -20 °C to be processed for metal analysis. Based on the Department of Environment report (2014) on Tehran air pollution zoning, the sampling points were chosen in a systematic-random design.

Laboratory procedures and statistical analysis

After defrosting the samples in the laboratory, each was weighed to the nearest 0.0001 g, put onto petri dishes and placed in a dryer at 105 °C. After obtaining the stable weight, the samples were ashed at 450 °C and digested in 2 mL of 65% nitric acid and then the entire solution was diluted to 10 mL with deionized water. The samples thus were analyzed with the flame atomic absorption spectrometer. The final results were presented as concentrations in $\mu g.g^{-1}$ of the dry weight.

The normal distribution of the data was checked with Kolmogorov-Smirnov test.

In the case of non-normally distributed data, we used Mann-Whitney U and Kruskall-Wallis H tests to investigate significant differences between the heavy metal concentrations (cadmium and lead) in zonal areas of Tehran, respectively. The specimens were sexed (by examining baculum in males) and their age determination was calculated by the ratio of their average weight and body length respectively. ANOVA also was used to analyze the differences among the group means. For all analysis including ANOVA and nonparametric tests we used the SPSS software package v. 19 was used for statistical analysis.

RESULTS

Our results indicated that there were significant differences between the areas of sampling. The concentration of cadmium was higher in rats sampled from the central zone, i.e. Shoush area and Inqlab Square, while the lowest concentration was recorded for the northern parts (ANOVA: $F = 21.25$, $P<0.05$) (Fig. 1). ANOVA also confirmed that the mean concentration of lead in the liver samples was higher in Inqlab Square and Shoush area located in the central parts of the City ($F = 43.21$, $P<0.05$). The present results indicate that the lead and cadmium concentrations in the liver samples are in accordance with their amount in the sludge samples. Regression analysis confirmed such significant relationship (Table 1 and Fig. 4).

The results demonstrated that the examination of adult free-living rats may be considered as an appropriate method to obtain an index of lead and cadmium contamination in urban areas. The maximum concentrations of cadmium in the liver and sludge samples were 6.85 and 7.39 $\mu g.g^{-1}$, respectively belonging to the central parts of Tehran.

Mann-Whitney U test showed that the amount of lead was significantly higher in sludge compared to the liver samples ($p<0.05$), while this result was not confirmed for cadmium-based contamination.

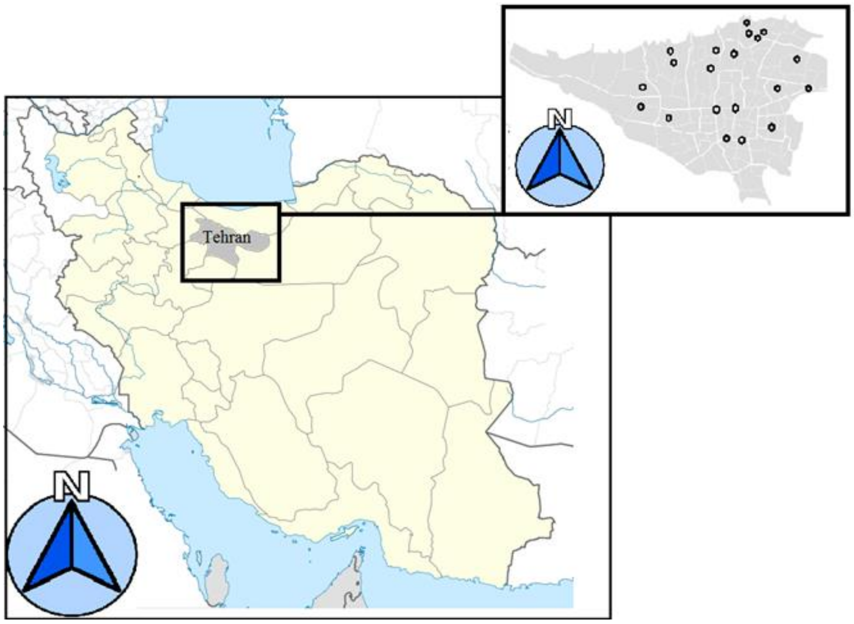

Fig. 1. Study area and sampling points.

Table 1. Relationships between Cd and Pb concentrations in liver and sludge based on Regression analysis.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.803[a]	.644	.624	12.41300	1.698

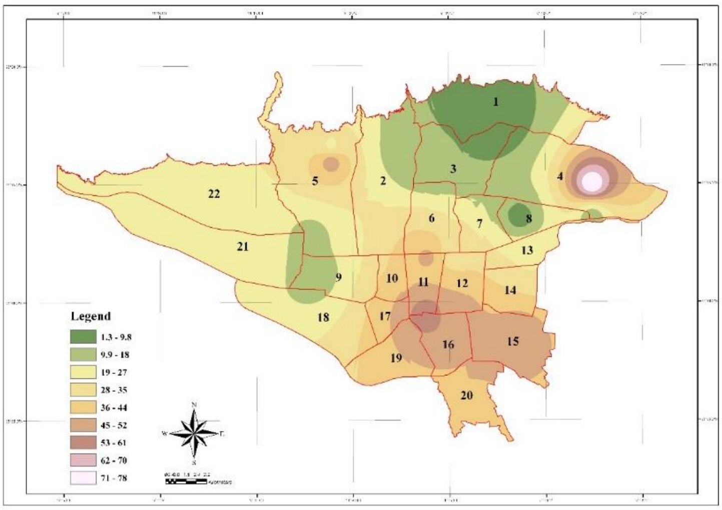

Fig. 2. Lead concentration zoning in Tehran.

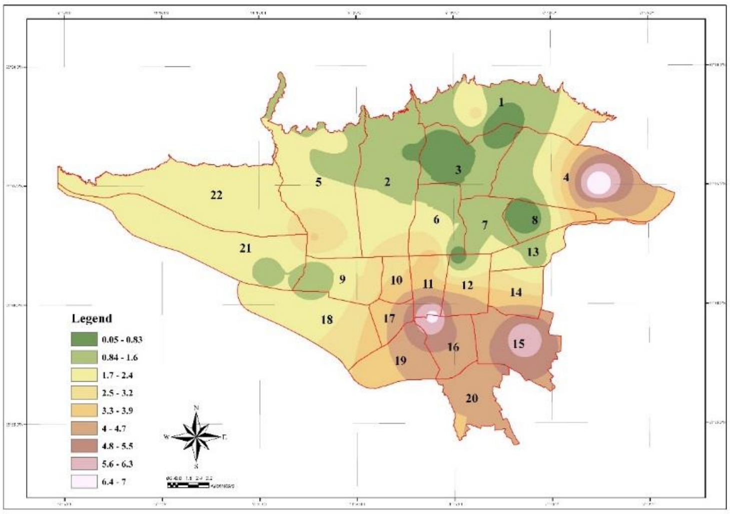

Fig. 3. Cadmium concentration distribution in the examined rats.

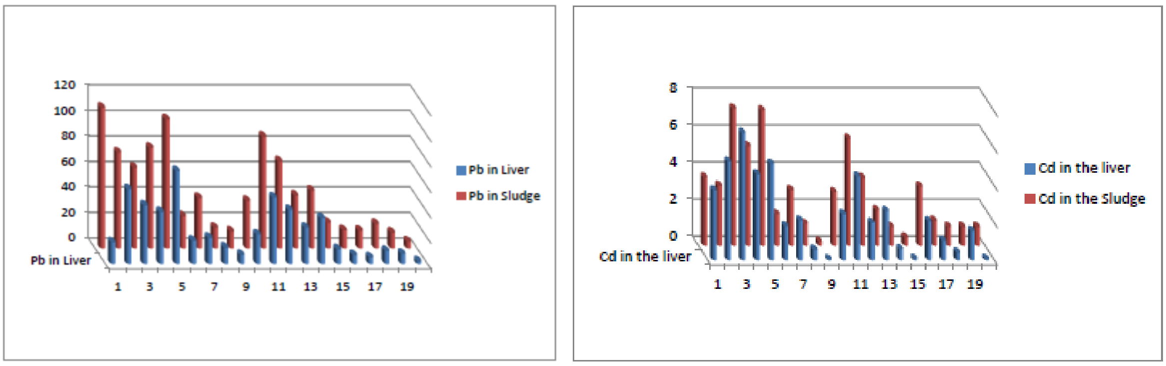

Fig. 4. The comparison between mean concentration of lead and cadmium in sludge and liver samples.

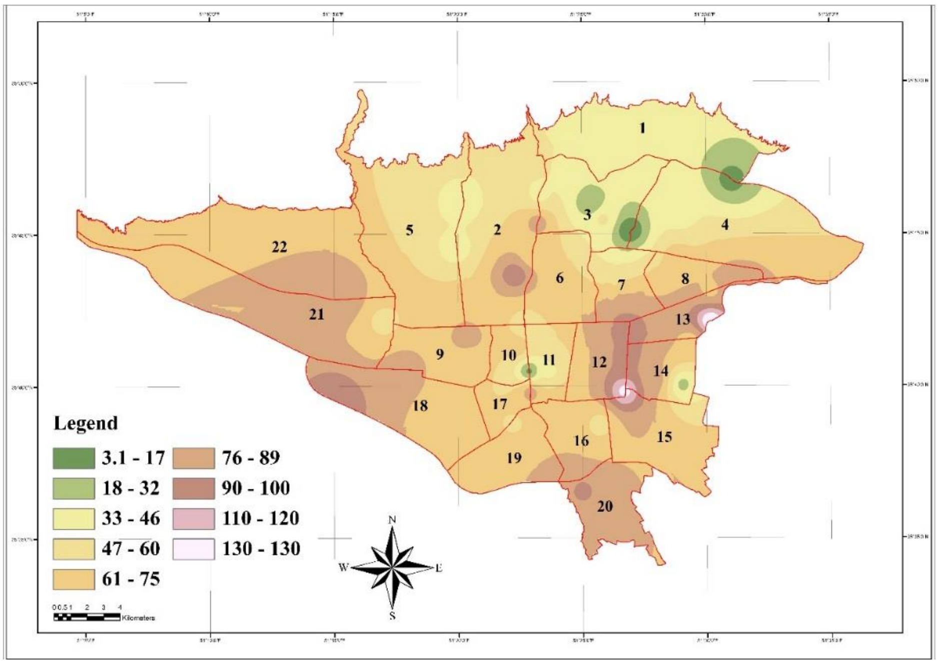

Fig. 5. Lead pollution distribution based on its concentration in *P. eldarica* (from Mollashahi *et al.* 2014).

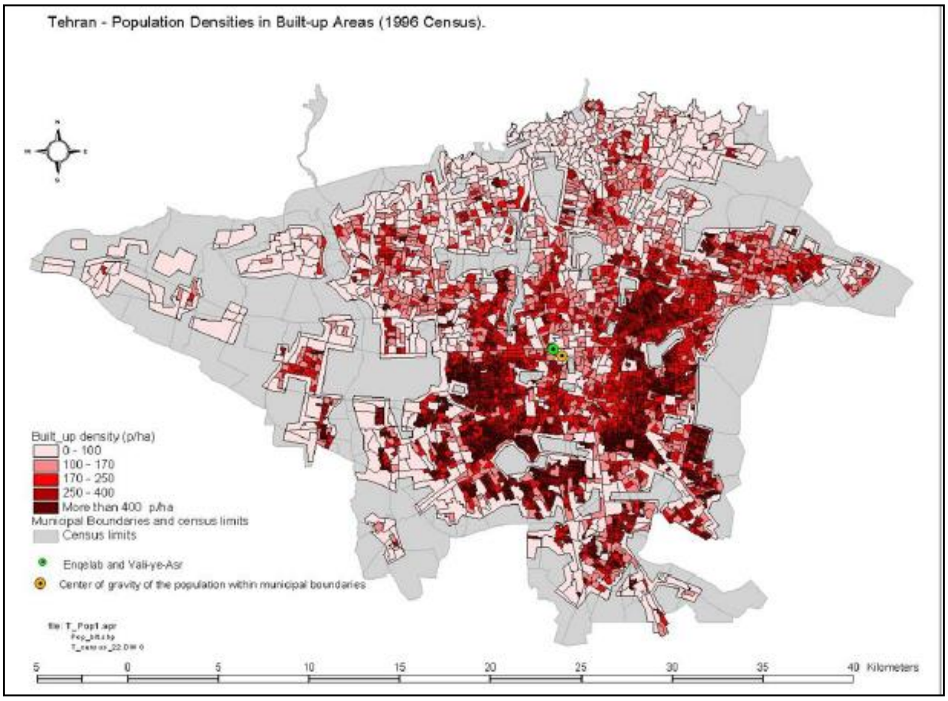

Fig. 6. Building density in Tehran (Bertaud & Malpezzi 2003).

DISCUSSION

It is generally known that cadmium and lead are mainly accumulated in the hepatic tissue of animals (Mollashahi *et al.* 2014). So, some of them can be used potentially as pollution bio-indicator in the ecosystems. Such animal models allow us to evaluate potential human health risk associated with environmental contamination. With regard to the criteria described for the zoonotic diseases, free - living rodents such as brown rats in the urban systems are very ideal models to monitor pollution distribution, especially heavy metals. We found higher concentration of lead and cadmium in the liver of wild rats as well as sludge samples in the central parts of metropolitan Tehran in comparison with the northern parts. Similar results are also reported in other organisms such as *Pinus eldarica* by Mollashahi *et al.* (2014) who found that zonal areas including no. 14 and 15 showed higher lead concentration.

These areas were located almost in the central parts of Tehran (Fig. 5).

They stated that because of the highest population and traffic, there were high heavy metal concentrations in these areas. Small rodent species, especially those that are relatively abundant and widely distributed in urban systems, may serve as a bio-indicator to detect certain toxic hazards such as heavy metals in the ecosystem (Philips 1977; Gragnaniello *et al.* 2001).

Similar results are also obtained by Mousavi *et al.* (2006) who suggested that the average concentration of cadmium in adult rats was significantly variable among different parts of Noor City in the northern part of Iran.

Also, according to Hani & Pazira (2011), Cd in Tehran soil was associated with distinct sources such as agricultural and industrial pollution. The high accumulation of heavy metals in the liver of brown rats was also reported by Schleich *et al.* (2010) and Wunschsmann *et al.* (2002). Based on the annual reports published by the Department of Environment (DOE, 2014), the central parts of Tehran, i.e. the municipality zones of 10, 11, 12 and 17 are the most polluted areas which is in accordance with our results.

One of the important reasons for the centralization of Tehran pollution is probably an increase in population, since most people want to live in the center of Tehran.

Bertaud & Malpezzi (2003) showed that the highest building density was found in the center of Tehran (Fig. 6). This means that there is a dense population living in these areas and consequently there is heavy traffic in the center of this city (Fig. 6).

In spite of omitting lead from gasoline over the recent decade, it seems that this metal has been deposited in the soil and sludge for a long time and is still present in food chains.

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موش نروژی در شهرهای بزرگ، شاخص زیستی برای آلودگی فلزات سنگین (مطالعه موردی: تهران، ایران)

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چکیده

این پژوهش با هدف ارزیابی امکان بهره‌گیری از موش نروژی (*Rattus norvegicus*) به عنوان شاخص زیستی آلودگی به سرب و کادمیوم در ده منطقه شهری کلان‌شهر تهران انجام پذیرفت. با استناد به داده‌های آلودگی هوا که در طی پانزده سال گذشته ثبت گردیده بود مناطق نمونه‌گیری از موش نروژی مشخص گردیدند. تحلیل واریانس نشان داد که میانگین غلظت کادمیوم و سرب به طور معناداری در بین مناطق مختلف مورد مطالعه تفاوت دارد به طوری‌که بالاترین این مقادیر در مناطق مرکزی کلان‌شهر تهران به ثبت رسید و با حرکت به مناطق شمالی این شهر، از غلظت این دو عنصر کاسته می‌شود. در بخش‌های مرکزی تهران میانگین سرب و کادمیوم در بافت کبد این جاندار به ترتیب معادل ۷۳/۰۶ و ۵/۲۰ میکروگرم در هر گرم وزن خشک تعیین شد. همچنین در مناطق شمالی این شهر غلظت سرب و کادمیوم به تریب معادل ۱/۸۵ و ۰/۰۷ میکروگرم در هر گرم وزن خشک ثبت گردید. به علاوه، غلظت عناصر مذکور در لجن فاضلاب محل نمونه‌گیری موش‌ها نیز مورد سنجش قرار گرفت. این نتایج نیز با نتایج به دست آمده در مورد میانگین این فلزات در بافت کبد جاندار مورد مطالعه مطابقت دارد. بنابراین مطالعه اخیر نشان داد که موش نروژی قابلیت مطالعه به عنوان شاخصی زیستی از سلامت محیط، از نظر آلودگی به فلزات سنگین در شهرهای آلوده‌ای مثل کلان‌شهر تهران را دارد.

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