# Content of Heavy Metals in Tobacco of Commonly Smoked Cigarettes in Romania

**LUMINITA AGOROAEI[1], NELA BIBIRE[2*], MIHAI APOSTU[2], MONICA STRUGARU[1], IOANA GRIGORIU[1], ELENA BUTNARU[1]**

[1]"Grigore T. Popa" University of Medicine and Pharmacy of Iasi, Faculty of Pharmacy, Department of Toxicology,16 Universitatii Str., 700115, Iasi, Romania

[2]"Grigore T. Popa" University of Medicine and Pharmacy of Iasi, Faculty of Pharmacy,Department of Analytical Chemistry,16 Universitatii Str., 700115, Iasi, Romania

*The composition of tobacco, as well as tobacco smoke, is complex, gathering a large number of substances with major toxicological implications, many incompletely studied. Among the toxics present in both tobacco and tobacco smoke, heavy metals are included. The paper presents the results of a study on content in six heavy metals, Cd, Pb, Cr, Ni, Cu and Zn, in tobacco of 15 varieties of cigarettes commonly smoked in Romania. The metals were determined through atomic absorbtion spectrophotometry, after heated mineralization with nitric acid. The results are expressed in μg/g tobacco dried at 105°C. The concentrations range in the intervals: Cd: 0.71-1.58; Pb: 2.26-5.18; Cr: 1.85-7.01; Ni: 0.74-1.09; Cu: 6.90-14.21; Zn: 1.21-5.47. The study confirms the ability of tobacco plant to retain heavy metals into the leaves.*

*Keywords: tobacco, cigarettes, heavy metals, atomic absorbtion spectrophotometry*

The composition of tobacco, as well as tobacco smoke, is complex, gathering a large number of substances with major toxicological implications, many incompletely studied.

In 2003, one in 10 deaths was related to tobacco comsumption, while in 2008, according WHO data, one person loosing life every 6 s due to tobacco related illnesses [1].

About 4000 chemicals (inorganic and organic) have been identified in tobacco [1-3].

Among the inorganic components, the following metals have been detected: Cd, Pb, Cr, Ni, As, Hg, Co, Cu, Zn, Fe, Mn, Bi, Ce [1,4-6].

Tobacco smoking is an important source of heavy metals in both human body and environment [1].

The heavy metals are toxic in low levels, being easily assimilated in the human body during smoking. Exposure to metals through tobacco depends on the amount of metal present in tobacco, a percentage that is transferred to the tobacco smoke and the percentage that is absorbed [2].

The heavy metals of tobacco are responsible for carcinogenicity (especially lung cancer) (Cd, Pb, Cr and Ni), peripheral arterial disease, genetic disorders etc. [1,2,7-9]. Many researchers demonstrated the role of reactive oxygen species in the toxicity of heavy metal ions [1].

The level of heavy metals in tobacco vary within wide limits and depends on [1,5,6]:

-plant variety;

-development stage of the plant;

-physico-chemical attributes of soil – influence the mobilization and the transfer of metals from soil into the plant:

-*p*H – the acidic *p*H (5.5-6.5) favours a better absorption of metals in plant (the increase of *p*H at least one unit by alkalinization of soil with $CaCO_3$ may result in a 50% reduction of Cd level in leaves);

-redox conditions – affects the mobility of oxidised metals;

-interactions between metals in the absorption from soil (absorption of cadmium is stimulated in the presence of lead);

-agricultural practices – the use of fertilizers (responsible for large amounts of As, Hg, Pb, Cd, Cr, Po);

-precipitations;

-technological processing of tobacco (which enriches the metal content in leaves);

-type of product (cigarettes, cigars, chewing tobacco, snuff, etc.).

Tobacco plant accumulates heavy metals in the following order of leaves > roots > stems [1].

In general, tobacco plants accumulate heavy metals like Cd, Pb, and Zn, preferentially. Cadmium is the most absorbed heavy metal, so it is the most studied metal in tobacco plant, the toxicity of the metal being an important reason too [1].

## Experimental part

Six heavy metals potentially toxic, Cd, Pb, Cr, Ni, Cu and Zn, were determined in tobacco of 15 cigarette varieties (brands) from market, commonly smoked in Romania.

After removing filter and paper, 2.5 g of homogenized tobacco was mineralized with 20 mL extra pure nitric acid (65%, 1.4 g/mL) by heating on a sandbath at 150°C until total digestion. The metals were determined through atomic absorbtion spectrophotometry (Buck Scientific 200A Flame Atomic Absorption Spectrophotometer). Quality control of determinations was achieved by measuring known standard solutions of heavy metals covering the range of concentrations found in samples.

The results were expressed in μg/g tobacco dried at 105°C.

## Results and discussions

In table 1, the concentrations of heavy metals in tobacco of analyzed cigarettes are presented. Table 2 contains the limits and the mean values of these concentrations.

* email: nelabibire@yahoo.com; Tel.: (+40)23226780

| Cigarette brand (sample) | µg/g tobacco dried at 105°C | | | | | |
|---|---|---|---|---|---|---|
| | Cd | Pb | Cr | Ni | Cu | Zn |
| I | 1.00 | 3.44 | 3.74 | 0.79 | 8.77 | 1.28 |
| II | 1.23 | 4.60 | 2.81 | 0.79 | 9.89 | 2.23 |
| III | 1.39 | 5.18 | 6.33 | 1.04 | 11.13 | 2.70 |
| IV | 0.80 | 4.77 | 6.81 | 0.96 | 7.41 | 1.91 |
| V | 1.55 | 2.73 | 2.23 | 0.94 | 12.43 | 3.04 |
| VI | 1.58 | 4.71 | 2.88 | 0.81 | 9.56 | 2.57 |
| VII | 0.71 | 3.97 | 3.24 | 1.07 | 6.96 | 1.80 |
| VIII | 0.80 | 4.77 | 4.86 | 0.82 | 7.41 | 1.21 |
| IX | 1.11 | 4.76 | 5.82 | 1.09 | 14.21 | 5.47 |
| X | 0.94 | 3.51 | 3.81 | 0.94 | 8.94 | 2.38 |
| XI | 1.16 | 3.72 | 6.06 | 1.00 | 10.66 | 3.36 |
| XII | 0.72 | 4.30 | 7.01 | 0.74 | 10.27 | 2.08 |
| XIII | 0.76 | 2.26 | 1.85 | 0.78 | 9.74 | 2.08 |
| XIV | 1.20 | 4.81 | 4.90 | 0.96 | 6.90 | 1.68 |
| XV | 0.98 | 4.01 | 3.27 | 0.92 | 7.67 | 2.07 |

**Table 1**
CONTENT OF HEAVY METALS IN TOBACCO OF ANALZYED CIGARETTES

| Value | µg/g tobacco dried at 105°C | | | | | |
|---|---|---|---|---|---|---|
| | Cd | Pb | Cr | Ni | Cu | Zn |
| Minima | 0.71 | 2.26 | 1.85 | 0.74 | 6.90 | 1.21 |
| Maxima | 1.58 | 5.18 | 7.01 | 1.09 | 14.21 | 5.47 |
| Median | 1.05 | 4.15 | 3.81 | 0.93 | 9.65 | 2.15 |
| Mean±SD | 1.06±0.28 | 4.10±0.84 | 4.37±1.71 | 0.91±0.11 | 9.46±2.09 | 2.39±1.03 |

SD – standard deviation

**Table 2**
MINIMA, MAXIMA, MEDIAN AND MEAN VALUES OF THE HEAVY METALS CONCENTRATIONS IN TOBACCO

Cadmium is an irritant, thiol depletion inducer and carcinogen toxic [1,10,11]. It is considered that 40-60% of cadmium inhaled from tobacco smoke goes directly into the blood stream (it is volatile at 320°C) [1]. A cigarette contains 1-2 µg Cd, of this 0.1-0.2 µg are inhaled; smoking more than 20 cigarettes daily can increase Cd concentration in body by ten-folds [1]. The content of cadmium in fat tissue of male smokers can be higher (four times) than of non-smokers [12].

The lowest level of cadmium was recorded in sample VII (0.71 µg/g), followed closely by sample XII (0.72 µg/g) and sample XIII (0.76 µg/g), while the maximum concentration of cadmium was found in tobacco sample VI (1.58 µg/g), followed by tobacco sample V (1.55 µg/g) and sample III (1.39 µg/g). Mean concentrations recorded in the 15 tobacco varieties is 1.06 µg Cd/g tobacco, which is close to the value recorded in Germany in 1998 (1.0 µg/g) (table 3).

Lead is a blood toxic (causes inhibition of hemoglobin biosynthesis, anemia), neuronal (produces encephalopathy), vascular, renal, and carcinogen toxic. Smokers have significantly higher blood lead levels than non-smokers [1,2,10].

In tobacco brand XIII a concentration of 2.26 µg Pb/g was recorded; this minimum value is followed, in ascending order, by the value 2.73 µg Pb/g (V) and 3.44 µg Pb/g (I). The highest concentration in lead, 5.18 µg/g, was determined in sample III; two other samples with high levels were registered for cigarette brands XIV (4.81 µg/g) and IX (4.76 µg/g). Mean concentration of lead, 4.10 µg/g, is close to the value recorded in China in 1998 (4.48 µg/g); it is a high value compared to the concentrations reported by other countries (table 3).

Chromium is a methemoglobin inducer, an irritant, allergenic and carcinogen agent (lung, sinonazal cavity), and genotoxic. In 1979 were reported limits from 0.24 to 14.6 µg Cr/g tobacco [1,10,13,14].

The least contaminated with chromium were tobacco samples XIII (1.85 µg/g), V (2.23 µg/g), and II (2.81 µg/g), while the most contaminated were samples XII (7.01 µg/g), IV (6.81µg/g) and III (6.33µg/g). The mean value, 4.37 µg Cr/g tobacco, is higher than the dates identified in the literature (table 3).

Nickel is a toxic of CNS and myocardium, sensitization and carcinogen (in lungs) agent. It is considered that nickel may be combined with carbon monoxide in tobacco smoke of the primary current, with formation of the $Ni(CO)_4$. The smoke of a cigarette may contain up to 50 µg Ni, of which 1.1% is found in the primary current [1,10,13,15,16].

In the analyzed samples, the lowest level of nickel was recorded in tobacco sample XII (0.74 µg/g), while highest concentration in sample IX (1.09 µg/g). Other tobacco samples with high levels of nickel are VII (1.07 µg/g) and III (1.04 µg/g). Mean concentrations of nickel, 0.91 µg/g, is the lowest average recorded in our study. Except the value of 0.22 µg Ni/g tobacco, reported in Turkey, in 2001 (table 3), the mean determined in our study is less than levels found in literature.

Copper is a hemolytic and methemoglobin inducer toxic (in high doses) [10]. In analyzed tobacco samples, copper concentrations ranged between 6.90 µg/g (XIV) and 14.21 µg/g (IX), being the highest concentrations recorded in our study. The mean value, 9.46 µg Cu/g tobacco, is close to the concentration level registered in Germany in 1993 (table 3).

Zinc is a central nervous system, cardiovascular and muscle toxic, but, as in the case of copper, manifests toxicity in high doses; copper and zinc are both oligoelements and, therefore, normally present in the human body in certain limits [10]. The lowest level of zinc was recorded in tobacco of cigarettes brand VIII (1.21 µg/g), while the highest value was determined in tobacco of sample IX (5.47 µg/g). These values, and the mean value of 2.39 µg Zn/g too, are much smaller than similar concentrations reported in the literature.

In table 3, the concentrations of the six metals in tobacco reported in the literature by different country are presented.

Table 4 presents the distribution of the first three elevated concentrations of metals in tobacco samples. Related to this criteria, we estimate that tobacco sample IX is the most contaminated (recording maximum concentrations for nickel, copper and zinc), followed by tobacco samples III and V.

| Country | µg/g tobacco | | | | | |
|---|---|---|---|---|---|---|
| | Cd | Pb | Cr | Ni | Cu | Zn |
| USA (1997) | 0.98 | - | - | - | - | 35.1 |
| Russia (1998) | 1.11 | 1.86 | 0.88 | - | - | - |
| Germany (1993) | - | - | - | 2.4 | 9.70 | - |
| Germany (1998) | 1.00 | 1.62 | 1.26 | - | - | 36.3 |
| Finland (1986) | | | | | 15.6 | 50 |
| Italy (1989) | - | 7.39 | - | - | - | - |
| Yugoslav (1978) | | | | | 18.9 | - |
| Hungry (1995) | 1.89 | 1.17 | - | 5.4 | - | 57.6 |
| Poland (2008) | 0.61 | 0.56 | - | - | - | - |
| Turkey (2001) | - | - | 1.63 | 0.22 | - | - |
| China (1998) *(Cd pollution)* | 2.22 | 4.48 | 0.46 | - | - | - |
| China (2005) | 0.18 | 0.64 | - | 2.23 | 4.13 | - |
| India (2010) | 0.45 | 1.94 | 4.07 | 8.79 | 14 | 27 |
| Pakistan (2008) | - | 14.35 | - | - | - | - |
| Egypt (1999) | | | | | | 76.8-190 |
| Jordan (2005) | | | | | 12.90 | 55.62 |
| Mexico (1991) | 4.41 | - | - | - | - | - |

**Table 3**
METAL CONCENTRATION LEVELS IN TOBACCO REPORTED BY DIFFERENT COUNTRY [1,5]

| Cigarette brand (sample) | Cd | Pb | Cr | Ni | Cu | Zn |
|---|---|---|---|---|---|---|
| I | | | | | | |
| II | | | | | | |
| III | ●●● | ● | ●●● | ●●● | ●●● | |
| IV | | | ●● | | | |
| V | ●● | | | | ●● | ●●● |
| VI | ● | | | | | |
| VII | | | | ●● | | |
| VIII | | | | | | |
| IX | | ●●● | | ● | ● | ● |
| X | | | | | | |
| XI | | | | | | ●● |
| XII | | | ● | | | |
| XIII | | | | | | |
| XIV | | ●● | | | | |
| XV | | | | | | |

**Table 4**
DISTRIBUTION OF THE HIGHER CONCENTRATION LEVELS OF HEAVY METALS IN TOBACCO

**the first three elevated values of concentrations (in descending order):**
**● – the maxima value**
**●● – the second higher value**
**●●● – the third higher value.**

## Conclusions

Six heavy metals potentially toxic have been determined in tobacco of 15 varieties (brands) of cigarettes from market, commonly smoked in Romania.

Reported to the mean values of metal concentrations in tobacco of analyzed cigarettes, the highest level was recorded in copper, followed in descending order by chromium, lead, zinc, cadmium, nickel.

The study confirms the ability of tobacco plant to retain heavy metals into the leaves.

We consider that the evaluation of heavy metal contamination of cigarette tobaccoes smoked in Romania needs more detailed studies.

## References


1.VERMA, S., YADAV, S., SINGH, I., Food Chem. Toxicol., **48**, nr. 8-9, 2010, p. 2291-2297.
2.LAZAREVIC, K., NIKOLIC, D., STOSIC, L., MILUTINOVIC, S., VIDENOVIC, J., BOGDANOVIC, D., Cent. Eur. J. Public Health, **20**, nr. 1, 2012, p. 62–66.
3.RODGMAN, A., PERFETTI, T.A., The Chemical Components of Tobacco and Tobacco Smoke, CRC Press, 2008, p. 910-916.
4.GOLIA, E.E., DIMIRKOU, A., Commun. Soil Sci. Plant Anal., **40**, nr. 1-6, 2009, p. 106-120.
5.MÜLLER, G., EGGERSGLUESS, D., RAJU, N.N., Proceedings of the International Conference on Heavy Metals in the Environment, 6-10 Aug 2000, Ann Arbor, Michigan, USA, http://www.cprm.gov.br/pgagem/Manuscripts/mullergcigarettes.htm.
6.ZDREMTAN, M., Simpozionul International Horticultura - Stiinta, Diversitate si Armonie, 24-25 mai 2007, Iasi, Ed. "Ion Ionescu de la Brad", Iasi, 2007, p. 1137-1140.
7.DROCHIOIU, G., MURARIU, M., MANGALAGIU, I.I., Plantele medicinale si metalele grele, Ed. Tehnopress, Iasi, 2011.
8.DROCHIOIU, G., POPA, K., DIRTU, A., MANGALAGIU, I., MURARIU, M., Proceedings of the 11-th International Mineral Processing Symposium, 21-23 Oct 2008, Belek-Antalya, Turcia, p. 899-904.
9.PAVEL, P.B., DIACU, E., BARBU, C.H., Rev. Chim. (Bucharest), **64**, no. 1, 2013, p. 22
10.COTRAU, M., POPA, L., STAN, T., PREDA, N., KINCSES-AJTAY, M., Toxicologie, Ed. Didactica si Pedagogica, Bucuresti, 1991.
11.NORDBERG G.F., NOGAWA, K, NORDBERG,. M., FRIBERG, L.T., Handbook on the Toxicology of Metals, 3rd Edition, **2**, Elsevier Inc., editors NORDBERG, G.F., FOWLER, B.A., NORDBERG, M., FRIBERG, L.T., 2007, p. 451.
12.MUSSALO-RAUHAMAA, H., SALMELA, S.S., LEPPÄNEN A., PYYSALO, H., Arch. Environ. Health, **41**, nr. 1, 1986, p. 49-55.
13.RUSU, L.C., Rev. Chim.(Bucharest), **64**, no. 1, 2013, p. 102
14.LANG RD, S., COSTA, M., Handbook on the Toxicology of Metals, 3rd Edition, **2**, Elsevier Inc., editors NORDBERG, G.F., FOWLER, B.A., NORDBERG, M., FRIBERG, L.T., 2007, p. 489.
15.KLEIN, C., COSTA, M., Handbook on the Toxicology of Metals, 3rd Edition, **3**, Elsevier Inc., editors NORDBERG, G.F., FOWLER, B.A., NORDBERG, M., FRIBERG, L.T., 2007, p. 745-746.
16.THYSSEN, J.P., JOHANSEN, J.D., MENNÉ, T., NIELSEN, N.H., LINNEBERG, A., Acta Derm. Venereol., **90**, nr. 1, 2010, p. 27-33


Manuscript received: 19.12.2013