*Radioprotection*, vol. **44**, n° 5 (2009) 285–289

DOI: 10.1051/radiopro/20095055

# Behaviour of Lead-210 in continental environment: Comparison with stables isotopes of lead

C. Tamponnet

*Institut de Radioprotection et de Sûreté Nucléaire, IRSN/DEI/SECRE, Blg. 159, Centre d'Études de Cadarache, 13115 St. Paul-lez-Durance, France*

**Abstract.** Lead-210 is a natural radioactive isotope and a decay product of the Uranium-238 decay chain found in the natural environment along with Radon-222 and Polonium-210. Lead-210 contribution to the internal exposure of man through ingestion is 20% but represents 70% of the internal exposure of man through inhalation due to the uranium and thorium decay series.
Transfer of lead-210 in the environment has been relatively poorly studied when compared to other radionuclides (Caesium-137, Strontium-90, Cobalt-60, Tritium, Carbon-14, etc.) even if we register a recent increase in the number of scientific publications. Therefore, this study reviews experimental data concerning the transfers of Lead-210 in the different compartments (atmosphere, freshwaters, sediments, soils, plants, animals) of continental environments (terrestrial and freshwater) from its natural sources.
Moreover, it compares these data with those concerning the stable isotopes of lead. Indeed, stable lead is found in all the terrestrial and freshwater ecosystems but with an important variation in its concentration according to location and sampling type. Such a global contamination of the environment is mainly due to its industrial use. Lead toxicity is coming from its physiological behaviour similar to those of essential elements such as calcium and magnesium. A list of transfer factors for Lead-210 and stable isotopes of lead between the different compartments of the terrestrial and freshwater ecosystems is provided.
The main conclusion of this review is that the behaviours of Lead-210 and stable isotopes of lead are quite similar in terrestrial environments although some discrepancies are noted in freshwater environments. The nature of these discrepancies is discussed.

Lead-210 is a natural radioactive isotope and a decay product of the Uranium-238 decay chain found in the natural environment along with Radon-222 and Polonium-210 (See figure 1). Lead-210 contribution to the internal exposure of man through ingestion is 20% but represents 70% of the internal exposure of man through inhalation due to the uranium and thorium decay series.

Transfer of lead-210 in the environment has been relatively poorly studied when compared to other radionuclides (Caesium-137, Strontium-90, Cobalt-60, Tritium, Carbon-14, etc.) even if we register a recent increase in the number of scientific publications. Therefore, this study reviews experimental data concerning the transfers of Lead-210 in the different compartments (atmosphere, freshwaters, sediments, soils, plants, animals) of continental environments (terrestrial and freshwater) from its natural sources.

Moreover, it compares these data with those concerning the stable isotopes of lead. Indeed, stable lead is found in all the terrestrial and freshwater ecosystems but with an important variation in its concentration according to location and sampling type. Such a global contamination of the environment is mainly due to its industrial use. Lead toxicity is coming from its physiological behaviour similar to those of essential elements such as calcium and magnesium.

## 1. STABLE LEAD AND LEAD-210 IN TERRESTRIAL ENVIRONMENT

### 1.1 Atmosphere

In the atmosphere, stable lead is of anthropogenic origin and comes from its industrial use. It is found mainly under particular form. Its main chemical forms are as carbonates, oxycarbonates, oxides and sulphates. Its ubiquitous concentration is around 0.1 ng $\cdot$ m$^{-3}$ (See table 1 hereunder).

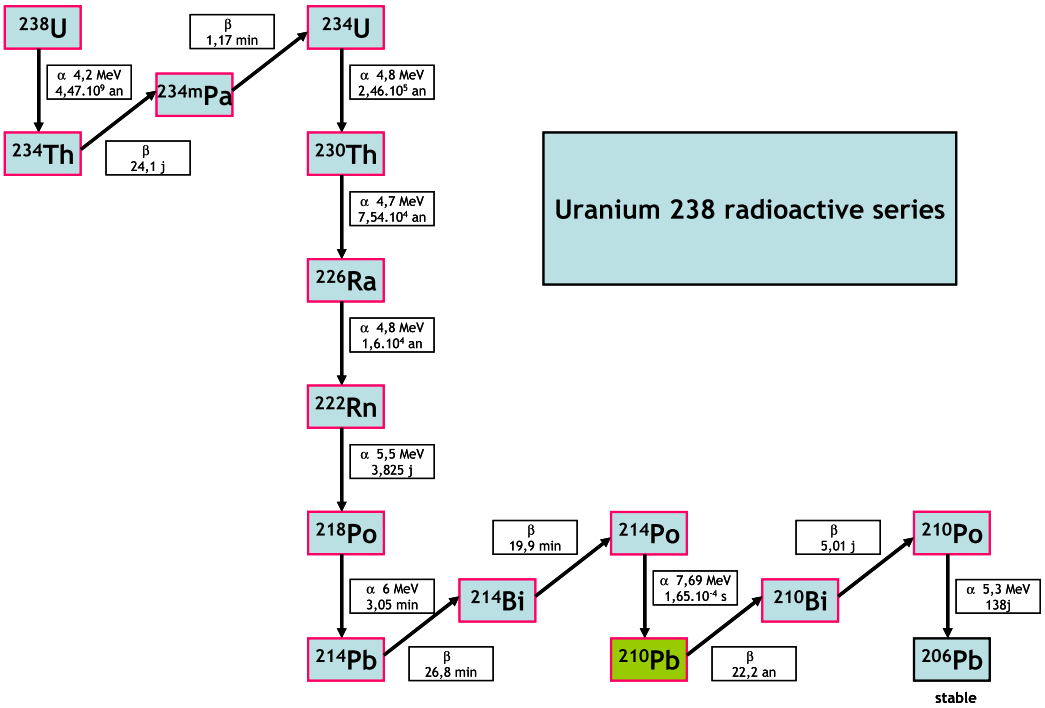


**Figure 1.** Uranium 238 natural radioactive series.

**Table 1.** Concentration of stable and radioactive Lead in atmosphere.

| | Values | Unit | Reference |
|---|---|---|---|
| **Stable Lead** | 0.1 | $ng \cdot m^{-3}$ | [1] |
| **Lead-210** | 500 | $\mu Bq \cdot m^{-3}$ | [2] |

There is no real anthropogenic source of Lead-210. Its presence in the atmosphere comes from the release of Radon-222 under gaseous form from Radium-226 located in the lithosphere. But according to [2], this release can be enhanced by the various mining activities. Its ubiquitous concentration is around $500\,mBq \cdot m^{-3}$ (see table 1 here above).

### 1.2 Soils

Stable lead in soils can have a natural (coming from background rocks) and/or anthropogenic (contamination by human activity) origin. Because of its low mobility, it tends to accumulate in soils.

Lead-210 in soil is of natural origin. It may deposit from the atmosphere and/or comes from the transformation of Radon-222 kept in the soil.

From data obtained (See table 2 hereunder), it seems that partition coefficients ($K_D$) are identical whatever the isotope of lead concerned (either stable or radioactive).

### 1.3 Plants

Lead (stable and/or radioactive) may contaminate plants either via foliar transfer or via root uptake. But foliar transfer seems quite marginal because of the low penetration of lead through leaves (effects of cuticular membranes). Therefore, available data focus on root transfer.

**Table 2.** Soil-soil solution partition coefficient for stable and radioactive Lead.

| | *Type of soils* | *Values* | *Unit* | *Reference* |
|---|---|---|---|---|
| **Stable Lead** | Sandy soils | 20 | $1 \cdot kg^{-1}$ | [3] |
| | Organic soil | $9\ 10^3$ | $1 \cdot kg^{-1}$ | [3] |
| **Lead-210** | Sandy soils | $2.7\ 10^2$ ($2.7–2.7\ 10^4$) | $1 \cdot kg^{-1}$ | [4] |
| | Organic soils | $2.2\ 10^4$ ($8.1\ 10^3–6.0\ 10^4$) | $1 \cdot kg^{-1}$ | [4] |

Soil-Plant transfer Factors seem to be in the same range for both stable and radioactive lead (See Table 3 hereunder).

**Table 3.** Soil-plant transfer factor for stable and radioactive Lead.

| | *Plant types* | *Values* | *Unit* | *Reference* |
|---|---|---|---|---|
| **Stable Lead** | Cereals | 2.30 (0.89–5.53) | - | [5] |
| | Fruit Vegetable | $5\ 10^{-3}$ | - | [5] |
| | Root Vegetable | $2\ 10^{-2}$ | - | [5] |
| | Leaf Vegetable | $6\ 10^{-2}$ | - | [5] |
| **Lead-210** | Cereals | $4.7\ 10^{-3}$ | - | [6] |
| | Fruit Vegetable | $2.\ 10^{-3}$ | - | [7] |
| | Root Vegetable | $2\ 10^{-2}$ | - | [6] |
| | Leaf Vegetable | $1\ 10^{-2}$ | - | [8] |

## 2. STABLE LEAD AND LEAD-210 IN AQUATIC ENVIRONMENT

### 2.1 Waters

Lead is mainly found in freshwater as suspended particles. Its ubiquitous concentration in freshwaters is indicated in table 4 for both stable and radioactive isotopes.

**Table 4.** Concentration of stable and radioactive Lead in freshwater.

| | *Values* | *Unit* | *Reference* |
|---|---|---|---|
| **Stable Lead** | 1–10 | $mg \cdot m^{-3}$ | [1] |
| **Lead-210** | 10 | $mBq \cdot kg^{-1}$ | [2] |
| | 20 | $mBq \cdot kg^{-1}$ | [11] |

Lead-210 is mainly found in freshwater under particular and dissolved forms, their respective proportion varying according to the river studied. For instance, 77% of Lead-210 is under dissolved form in the Ottawa River (Canada, [9]) although 85% of Lead-210 is under particular form in the Rhone River (France, [10]).

### 2.2 Suspended solids

A study from Benoit on the partition of heavy metals between freshwater and matter in suspension [12], demonstrated that stable lead and Lead-210 behave differently in the studied freshwaters. Indeed, while the slope of log ($K_D$)/log (Total suspended solids) is the same for stable lead and Lead-210, $K_D$ values for Lead-210 are uniformly lower by a factor of 4. A possible explanation is that this dissimilarity may be attributable to differences in speciation between stable lead and Lead-210 that are persistent on the time scale corresponding to the water residence time or lead removal rate.

### 2.3 Biota

Some differences may be noted between Concentration Factors (CF) for freshwater animals concerning stable and radioactive lead isotopes: stable lead Concentration Factors seem lower by a factor of 100 (See Table 5 hereunder).

**Table 5.** Concentration Factors of stable and radioactive Lead in freshwater biota.

| | *Type of Biota* | *Values* | *Unit* | *Reference* |
|---|---|---|---|---|
| **Stable Lead** | Fish | 100–300 | $1 \cdot kg^{-1}$ | [6] |
| | Bivalve | $2{,}9.10^2$ | $1 \cdot kg^{-1}$ | [13] |
| | Shrimp | $2{,}4.10^2$ | $1 \cdot kg^{-1}$ | [13] |
| **Lead-210** | Fish | $8\ 10^3$ | $1 \cdot kg^{-1}$ | [14] |
| | Bivalve | $2.3\ 10^4$ | $1 \cdot kg^{-1}$ | [14] |
| | Shrimp | $1.5\ 10^4$ | $1 \cdot kg^{-1}$ | [14] |

## 3. CONCLUSION

The main conclusion of this synthetic review is that the behaviours of Lead-210 and stable isotopes of lead are quite similar in terrestrial environments. Indeed, in many models, data from stable lead are used to validate the behaviour of Lead-210 [15]. Movements of stable lead and Lead-210 are quite similar in the terrestrial environment. They are found naturally in rocks and soils and also in the atmosphere via natural emanation of Radon-222 for Lead-210 via resuspension due to mining and metallurgical activities for stable and radioactive isotopes of lead. Therefore, they are contaminating terrestrial ecosystems via dry and wet deposition.

On the contrary, some discrepancies are registered between stable and radioactive isotopes of lead in freshwater environments. This seems to be attributable to differences in speciation between stable lead and Lead-210.

## References

[1] INERIS, Le Plomb et ses dérivés. Fiche de données toxicologiques et environnementales des substances chimiques (INERIS, France, ERIS-DRC-01-25590-ETSC-Api/SD-N°00df257, 2003).
[2] UNSCEAR, Sources and Effects of Ionizing Radiation. Volume I : Sources. Annex B: Exposures from natural radiation sources (UNSCEAR, Vienna, Austria, 2000) pp. 84–141.
[3] Sheppard S.C and Sheppard M.E., *Water, Air & Soil Pollution* **57-58** (1991) 79–91.
[4] Sheppard M.E. and Thibault D.H., *Health Phys*. **59** (1990) 471–482.
[5] Cobb G.P., Sands K., Waters M., Wixson B.G. and Dorward-King E., *Environ. Toxicol. Chem.* **19** (2000) 600–607.
[6] AIEA, Handbook of parameter values for radionuclide transfers in temperate environment. Technical Report Series N° 364 (AIEA, Vienna, Austria, 1994).
[7] Kohler M., Gleisberg B. and Niese S., *Applied Radiation and Isotopes* **53** (2000) 203–208.
[8] Radhakrishna A.P., Somashekarappa H.M., Narayana Y. and Siddappa K., *J. Environ. Radioactivity* **30** (1996) 31–54.
[9] Joshi S.R., McRea R.C., Shukla B.S. and Roy J.C., *Water Air Poll.* **59** (1991) 311–320.
[10] Dominik J., Burrus D., and Vernet J.P., *Earth Planet. Sci. Lett.* **84** (1987) 165–180.
[11] Noshkin V.E., Robison W.L. and Wong K.M., *The Science of Total Environment* **155** (1994) 87–104.

[12] Benoit G., *Geochimica et Cosmochimica Acta* **59** (1995) 2677–2687.
[13] Hameed P.S., Shaheed K. and Somasundaram S.S.N. *J. Environ. Radioactivity* **37** (1997) 17–27.
[14] Langre M. and Rabache M. (2004) Toxiques alimentaires, E.J.L., 95pp.
[15] Baes C.F., Sharp R.D., Sjoreen A.L. and Shor R.W., A Review and Analysis of parameters for assessing transport of environmentally released radionuclides through Agriculture (Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA, ORNL Report n°5786, 1984)