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# Risk-Based Approach for Thermal Treatment of Soils Contaminated with Heavy Metals


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## Generalities:

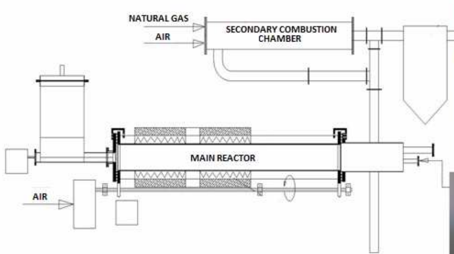
**The growing awareness on environmental pollution together with more coherent legislation requirements on Romania’s human health protection field increased the concern for the management of contaminated soils at national level. Currently, Romania has about 900.000 ha of industrial polluted lands of which 70% are used for agricultural activities and which urgently need to be decontaminated. This paper presents some results achieved in the framework of the RECOLAND research project.**
***RECOLAND proposes an integrated approach for identifying appropriate solutions for decontamination of complex polluted soils (various types of pollutants as: PCBs, heavy metals, pesticides and PAHs), considering human risk assessment.***
**The paper focuses on incinerationas a decontamination method, and risk assessment before and after applying the thermal remediation methodology.**

*Contaminated area by a Romanian industry*

## Materials and methods:

**Incineration, pyrolysis, electroremediation, bioremediation and phytoremediation methods have been tested in a laboratory or at real scale using soil provided from one of the most polluted area of Europe - Romania. Since 1936, this area has been extensively contaminated by two industries: a plant where carbon black was produced until 1993; and a second one processing nonferrous metals like lead, zinc and cadmium from 1939 to 2009.**

**A rotary kiln pilot plant incinerator with a capacity of maximum 30 kg/h of solid material has been used for the thermal treatment of the polluted soil at three process temperatures: 600℃, 800℃ and 1000℃ and two residence times: 60 min. and 30 min. The main reactor where the process took place was inductively heated at the desired temperature by a belt of electrical resistances. During the operation, the reactor was permanently rotated around its axis in order to allow both a better mixing between the combustion air and soil and also a better diffusion of heat inside the layers of solid material to be treated. The retention time of the material inside the reactor has been inspected both by the reactor’s inclination angle and the rotation speed.**
**Analysis of the soil samples for heavy metal content was conducted using an atomic absorption spectrophotometer. Ni, Pb and Cd have been analyzed.**




*Laboratory soil incineration pilot plant*
*Patent Number RO 127125-A0*

## Incineration process phases:

**Step 1: Raw soil**

**Step 2: Grinding phase**

**Step 3: Loading and incineration phase**

**Step 4: Laboratory analysis phase**

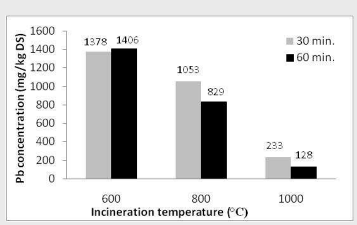
## Risk assessment methodology :

**US EPA 98 approach (US EPA, 1989) was used for the human exposure assessment and quantification of risk from Cd, Ni and Pb contaminated soils. The risk assessment tool developed within the framework of the RECOLAND project* has been used for risk evaluation considering different exposure pathways (soil ingestion, dermal contact, vegetable ingestion and meat ingestion) according to the local context (agricultural scenario). The generally accepted lifetime health risk ($10^{-6}$) was as a starting point for all discussed thermal treatment experiments considered.**

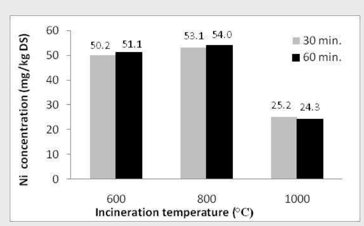
# Results and conclusions

**The results shows that:**

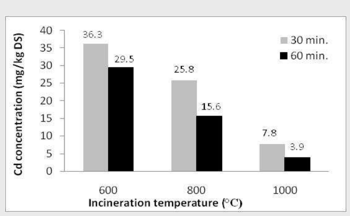
- **Both *temperature* and *retention time* strongly influence the behavior of heavy metals in soil and also the soil’s fertility due to the increment ofpH values (alkalinity) and reduction of the total nitrogen, mobile potassium and phosphorus;**
- **In an oxidative atmosphere, both *Cd and Pb* have more or less the *same vaporisation trend* related to the process temperature and to the fact that the binding forces of metal ions to soil decrease with pH increment;**
- **For all three studied metals, the evaporation rate strongly increases after 800℃ while soil retention time with in the reactor did not have much influence on Pb concentration at 600℃;**
- **Concerning the efficiency of removing Cd, Ni and Pb from the contaminated soil, as expected, the *best results were gained for a process temperature of 1000℃* ;**
- **Regarding the residence time, for both cases (30 min. and 60 min.), the *removing efficiency* was as follows: *Ni<Pb<Cd;***
- **Risk assessment from Cd, Ni and Pb considering the new concentration levels from the decontaminated soils (see the Table) indicated that *an acceptable risk was obtained only concerning the bottom ash Pb concentration* (process temperature of 1000℃ and the residence time of 30 min);**
- **If incineration is the single alternative for contaminated land management, a regulatory approach alone is not sufficient to take into account by the decision-makers, but also an appropriatecontrol of environmental pollution (emissions, fly ash, and bottom ash).**




**Effect of temperature and time on Pb concentration within soil;**




**Effect of temperature and time on Ni concentration within soil;**




**Effect of temperature and time on Cd concentration within soil;**

**Risk values related to contaminated soil with Cd, Ni and Pb before and after incineration**

| Experimental condition | Cd | Ni | Pb | ΣCd,Ni,Pb |
|---|---|---|---|---|
| **No treatment** | $1.48 \times 10^{-4}$ | $1.65 \times 10^{-5}$ | $1.26 \times 10^{-5}$ | **$1.77 \times 10^{-4}$** |
| **30 min. @ 600°C** | $7.18 \times 10^{-5}$ | $3.87 \times 10^{-6}$ | $7.52 \times 10^{-6}$ | **$8.32 \times 10^{-5}$** |
| **30 min. @ 800°C;** | $5.11 \times 10^{-5}$ | $4.10 \times 10^{-6}$ | $5.82 \times 10^{-6}$ | **$6.10 \times 10^{-5}$** |
| **30 min. @ 1000°C;** | $1.54 \times 10^{-5}$ | $1.94 \times 10^{-6}$ | $1.27 \times 10^{-6}$ | **$1.81 \times 10^{-5}$** |
| **60 min. @ 600°C** | $5.84 \times 10^{-5}$ | $3.94 \times 10^{-6}$ | $7.68 \times 10^{-6}$ | **$7.00 \times 10^{-5}$** |
| **60 min. @ 800°C;** | $3.09 \times 10^{-5}$ | $4.17 \times 10^{-6}$ | $4.52 \times 10^{-6}$ | **$3.96 \times 10^{-5}$** |
| **60 min. @ 1000°C;** | $7.72 \times 10^{-6}$ | $1.88 \times 10^{-6}$ | $7.02 \times 10^{-7}$ | **$1.09 \times 10^{-5}$** |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