

# NANORREMEDIATION OF A SOIL POLLUTED WITH PCBs AND Cr

**M. Gil-Díaz<sup>1</sup>, R. A. Pérez<sup>2</sup>, J. Alonso<sup>1</sup>, E. Miguel<sup>2</sup>, S. Diez-Pascual<sup>1</sup>, M. C. Lobo<sup>1\*</sup>**

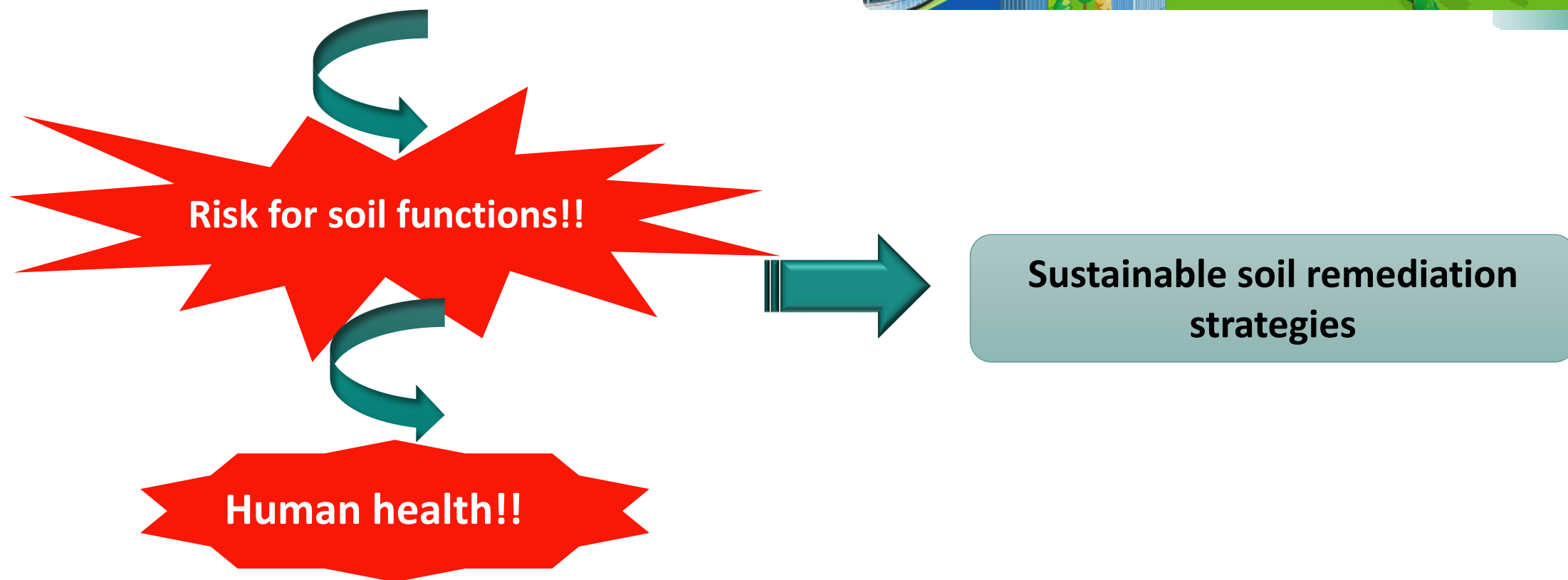
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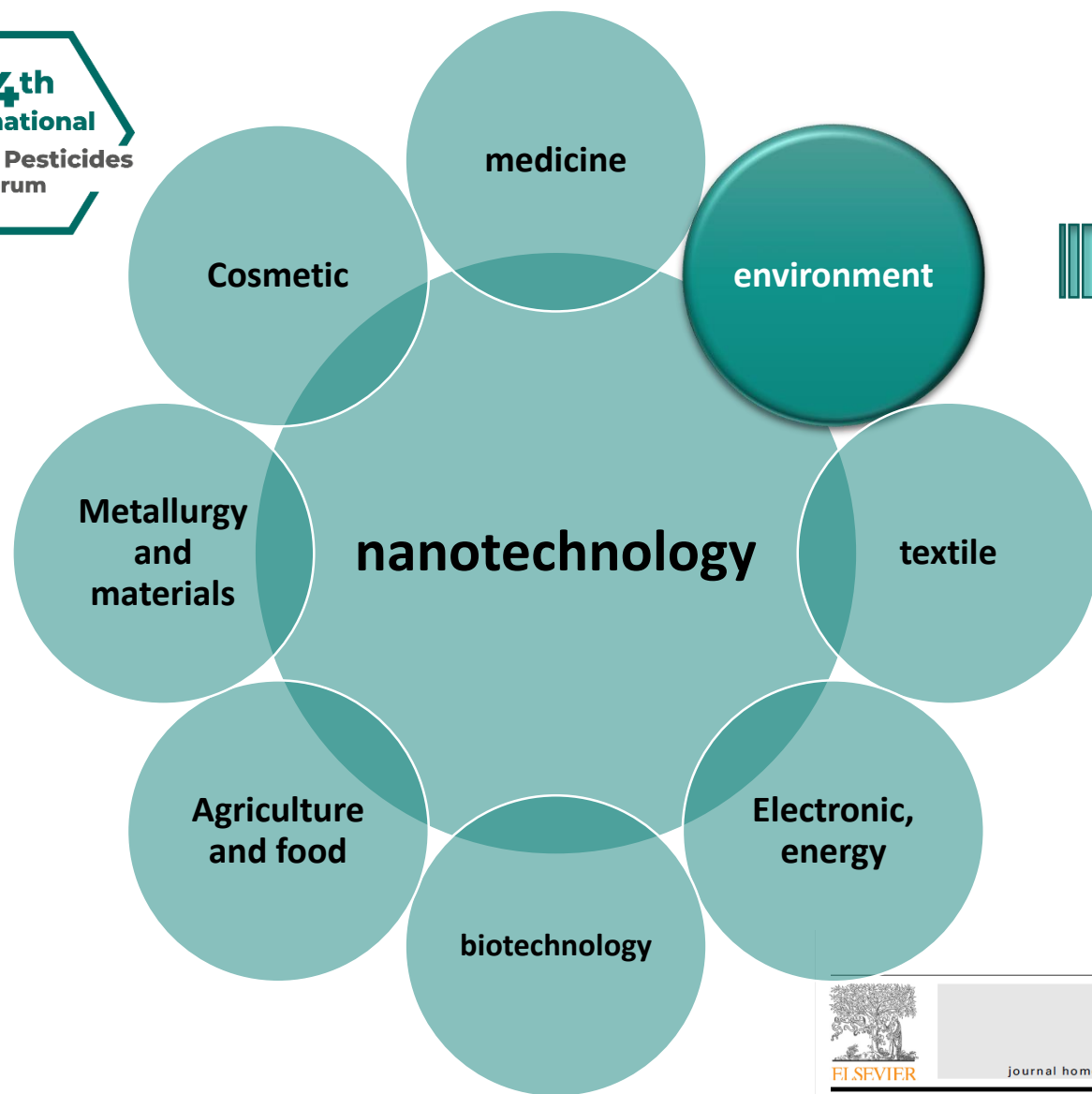
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- Antropogenic activities cause soil pollution.
- 2.5 millions of potentially polluted sites in EU.
- Common soil pollutants: metal(loid)s and organic compounds.
- Metal(loid)s and POPs can co-exist in the soil.





**Iron nanoparticles  
promising results for  
remediation of soil polluted  
with metal(loid)s or organic  
pollutants**

Chemical Engineering Journal 399 (2020) 125809

Contents lists available at ScienceDirect

**Chemical Engineering Journal**

journal homepage: [www.elsevier.com/locate/cej](http://www.elsevier.com/locate/cej)

Magnetite nanoparticles for the remediation of soils co-contaminated with As and PAHs

D. Baragaño<sup>a,\*</sup>, J. Alonso<sup>b</sup>, J.R. Gallego<sup>a</sup>, M.C. Lobo<sup>b</sup>, M. Gil-Díaz<sup>b</sup>

Chemosphere 238 (2020) 124624

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**Chemosphere**

journal homepage: [www.elsevier.com/locate/chemosphere](http://www.elsevier.com/locate/chemosphere)

Zero valent iron and goethite nanoparticles as new promising remediation techniques for As-polluted soils

D. Baragaño<sup>a</sup>, J. Alonso<sup>b</sup>, J.R. Gallego<sup>a,\*</sup>, M.C. Lobo<sup>b</sup>, M. Gil-Díaz<sup>b</sup>

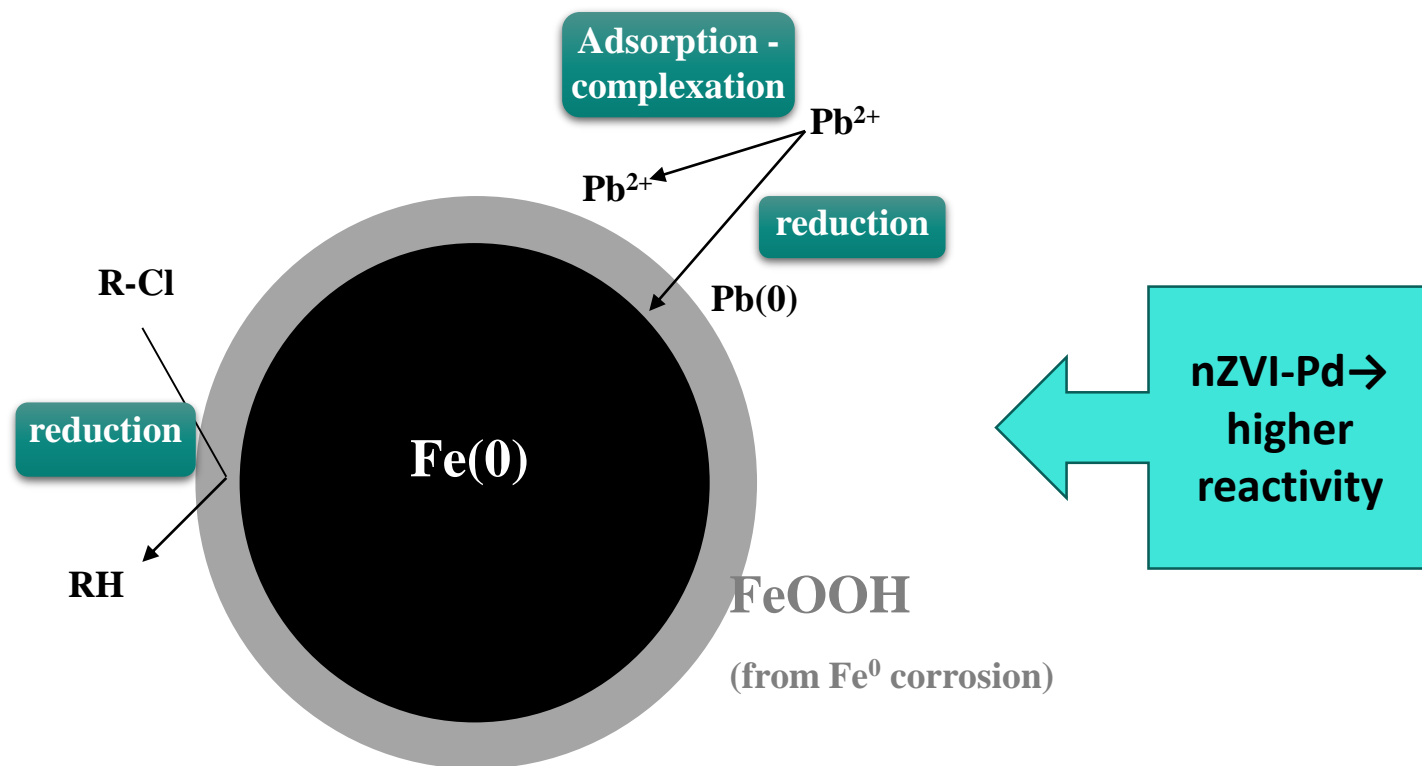
Environ Sci Pollut Res (2012) 19:550–558  
DOI 10.1007/s11356-011-0576-3

RESEARCH ARTICLE

**Application of nanoscale zero valent iron (NZVI) for groundwater remediation in Europe**

Nicole C. Mueller · Jürgen Braun · Johannes Bruns · Miroslav Černík · Peter Rissing · David Rickerby · Bernd Nowack

# Nano scale zero valent iron (nZVI): core-shell structure



Science of the Total Environment 675 (2019) 165–175



Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



Chemosphere 149 (2016) 137–145



Contents lists available at ScienceDirect

Chemosphere

journal homepage: [www.elsevier.com/locate/chemosphere](http://www.elsevier.com/locate/chemosphere)



Journal of Hazardous Materials 321 (2017) 812–819



Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: [www.elsevier.com/locate/jhazmat](http://www.elsevier.com/locate/jhazmat)



Nanoremediation and long-term monitoring of brownfield soil highly polluted with As and Hg

M. Gil-Díaz <sup>a,\*</sup>, E. Rodríguez-Valdés <sup>b</sup>, J. Alonso <sup>a</sup>, D. Baragaño <sup>b</sup>, J.R. Gallego <sup>b</sup>, M.C. Lobo <sup>a</sup>



A nanoremediation strategy for the recovery of an As-polluted soil

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Viability of a nanoremediation process in single or multi-metal(loid) contaminated soils

M. Gil-Díaz <sup>a</sup>, P. Pinilla, J. Alonso, M.C. Lobo



14<sup>th</sup>  
International  
HCH and Pesticides  
Forum

Iron nanoparticles are effective for remediation of soil with mixture of pollutants??



Introduction

Goals

Experimental

Results & Discussion

Conclusions

To evaluate the effectiveness of different types of commercial iron nanoparticles for the remediation of an industrial soil co-contaminated with Cr and PCBs:

- Nanoscale zero valent iron (nZVI)
- nZVI with Pd as catalyzer (nZVI-Pd)
- Nano-magnetite ( $\text{nFe}_3\text{O}_4$ )

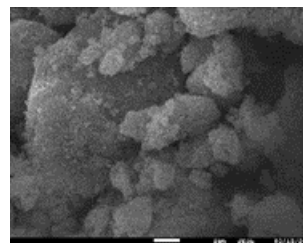
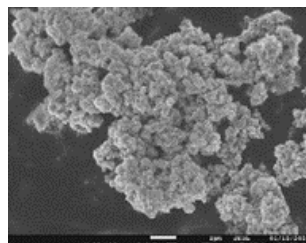
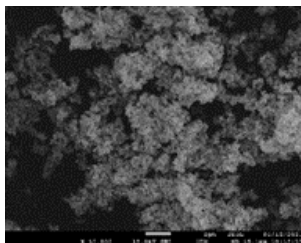
## Soil characteristics

pH	6.29
EC (dS/m)	2.7
N (%)	0.06
OM (%)	0.81
Ca (mg/kg)	594
Mg (mg/kg)	90
Na (mg/kg)	31
K (mg/kg)	155
Cd (mg/kg)	<LD
Cr (mg/kg)	214
<b>Cr(VI) (mg/kg)</b>	<b>65</b>
Cu (mg/kg)	9.1
Ni (mg/kg)	<LD
Pb (mg/kg)	10
Zn (mg/kg)	30
Sand (%)	64
Silt (%)	25
Clay (%)	11
PCB28 (tri-CB) (ng/g)	33.9
PCB52 (tetra-CB) (ng/g)	193
PCB101 (penta-CB) (ng/g)	512
PCB138 (hexa-CB) (ng/g)	719
PCB153 (hexa-CB) (ng/g)	531
PCB180 (hepta-CB) (ng/g)	292
<b>ΣPCBs (ng/g)</b>	<b>2281</b>

- Industrial soil from Asturias, historically polluted
- [Cr(VI)] exceeds allowed levels (50-2 mg/kg depending on land use, BOPA, 2014).
- [PCBs] exceed allowed levels (RD 9/2005)

## Characterization of iron nanoparticles

Characteristic	nZVI	nZVI-Pd	nFe <sub>3</sub> O <sub>4</sub>
Producer	Nanolron (Czech Republic)	Nanolron (Czech Republic)	IoliTec Nanomaterials (Germany)
Physical state	Aqueous suspension (80% water)	Aqueous suspension (80% water)	Solid
Composition	14-18% Fe(0) y 2-6% Fe <sub>3</sub> O <sub>4</sub>	14-18% Fe(0) y 2-6% Fe <sub>3</sub> O <sub>4</sub> , Pd 0.1%	Iron(II,III) oxide >98%
Organic stabilizer	3% polyacrylic acid	3% polyacrylic acid	-
Mean diameter (nm)	60	< 50	20-30
Specific surface area (m <sup>2</sup> /g)	25	30	90
Zeta potential (mV)	-32	-21	-10



- Zeta potential
- Scanning Electron Microscopy (SEM)
- X-ray diffraction (XRD)
- X-ray photoelectron spectrometry (XPS)
- ATR-FTIR

**scientific** reports

**OPEN** Iron nanoparticles to recover a co-contaminated soil with Cr and PCBs

M. Gil-Díaz<sup>1,2,3</sup>, R. A. Pérez<sup>2</sup>, J. Alonso<sup>4</sup>, E. Miguel<sup>2</sup>, S. Díez-Pascual<sup>1</sup> & M. C. Lobo<sup>4</sup>

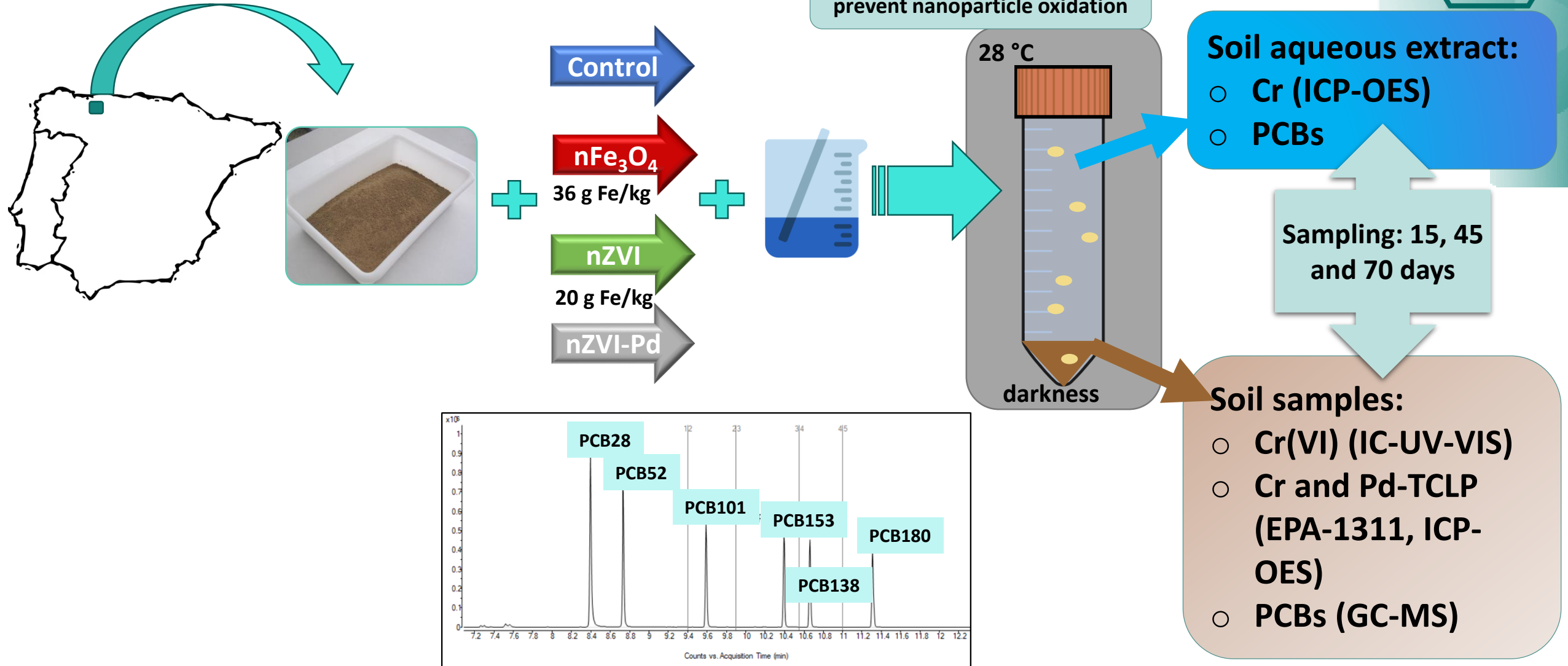
Scientific Reports | (2022) 12:13544

| <https://doi.org/10.1038/s41598-022-07558-w>

nature portfolio

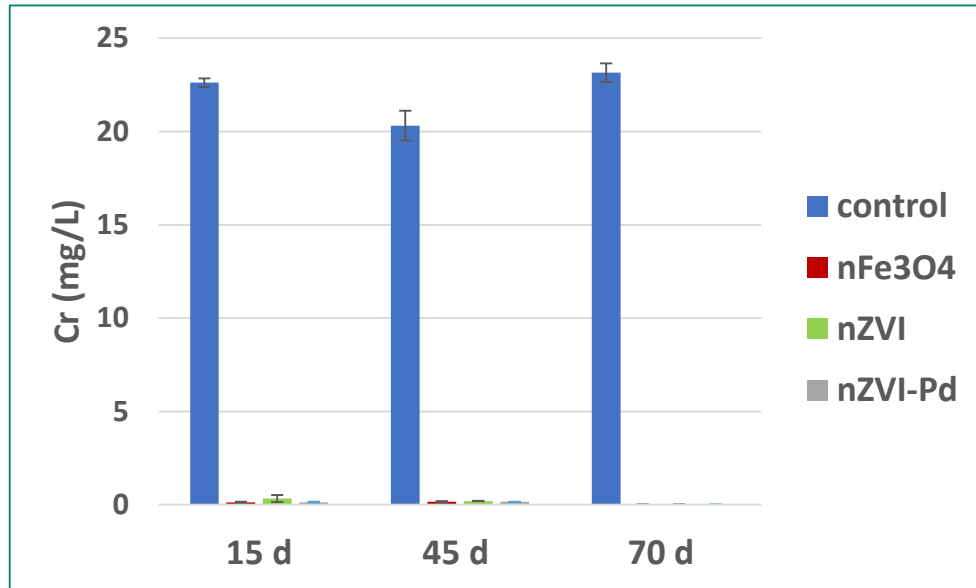
1

## Batch experiment



## Soil aqueous fraction

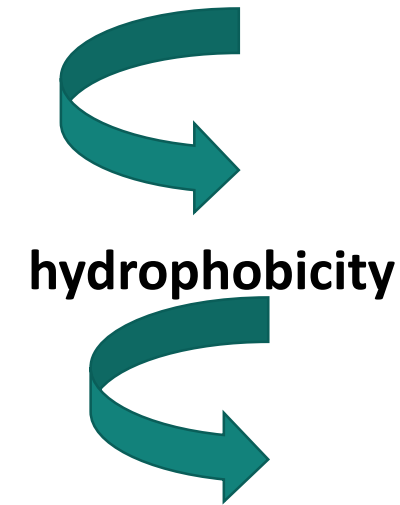
Cr



- nZVI, nZVI-Pd and nFe<sub>3</sub>O<sub>4</sub> significantly reduced Cr concentration in the extracts at the three sampling times.
- No differences among sampling times.

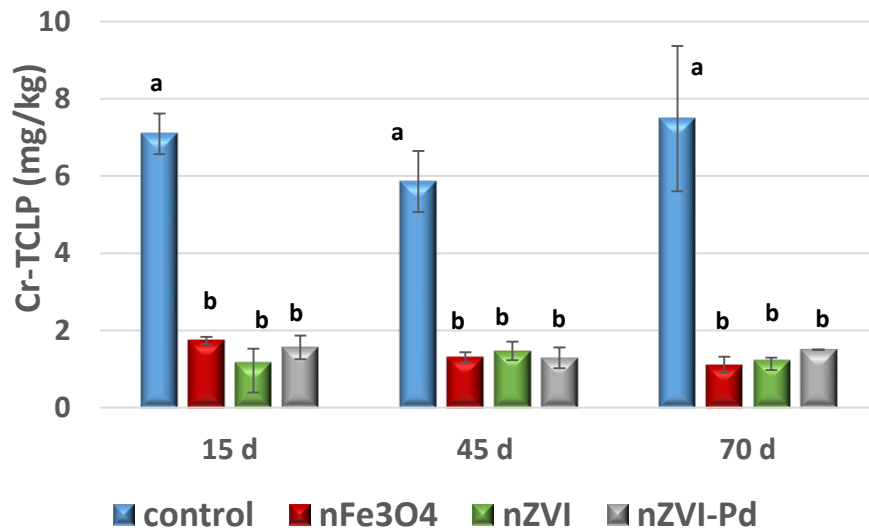
PCBs

PCBs were not detected in aqueous fraction for any of the treatments at any sampling time.

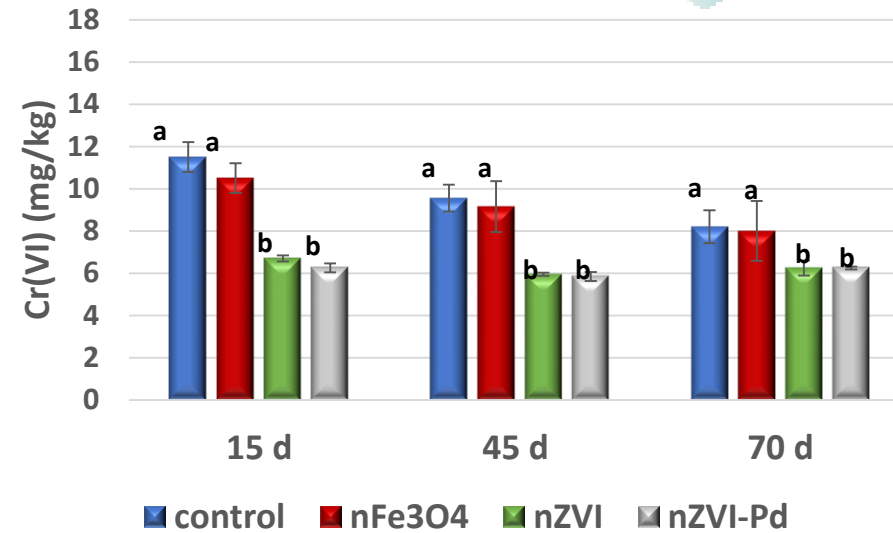


Limited PCB leaching

## Cr availability in soil (TCLP)



## Cr(VI) in soil



- nZVI, nZVI-Pd and nFe<sub>3</sub>O<sub>4</sub> significantly reduced Cr availability in soils at the three sampling times and was stable for at least 70 days.
- No differences among nanoparticles or sampling times.

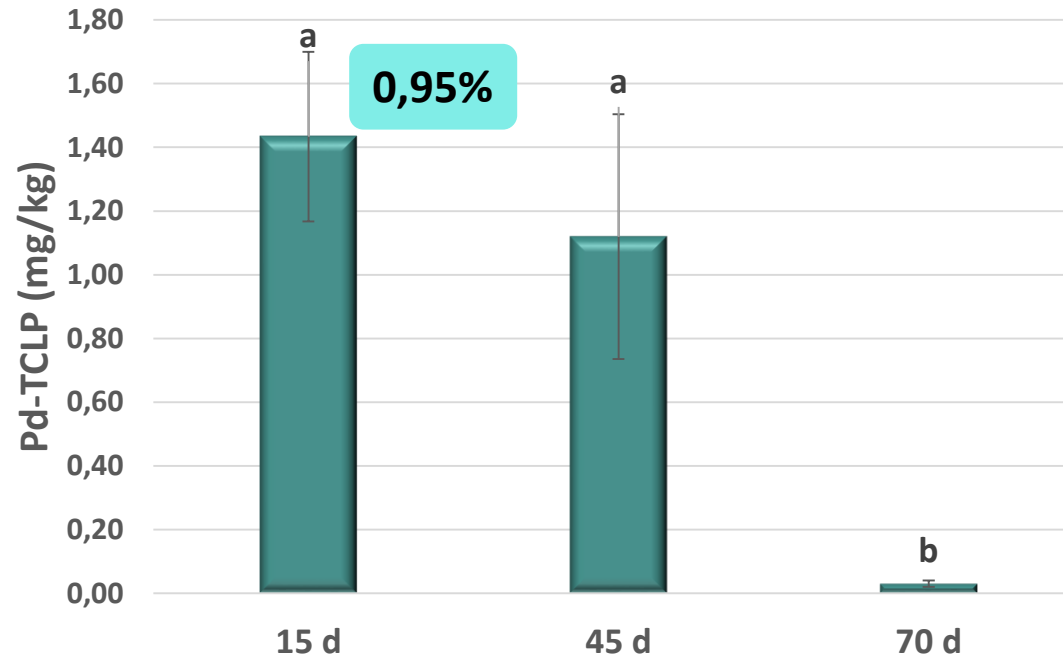
Soils from nZVI and nZVI-Pd → similar Cr(VI)



Interactions mechanisms:

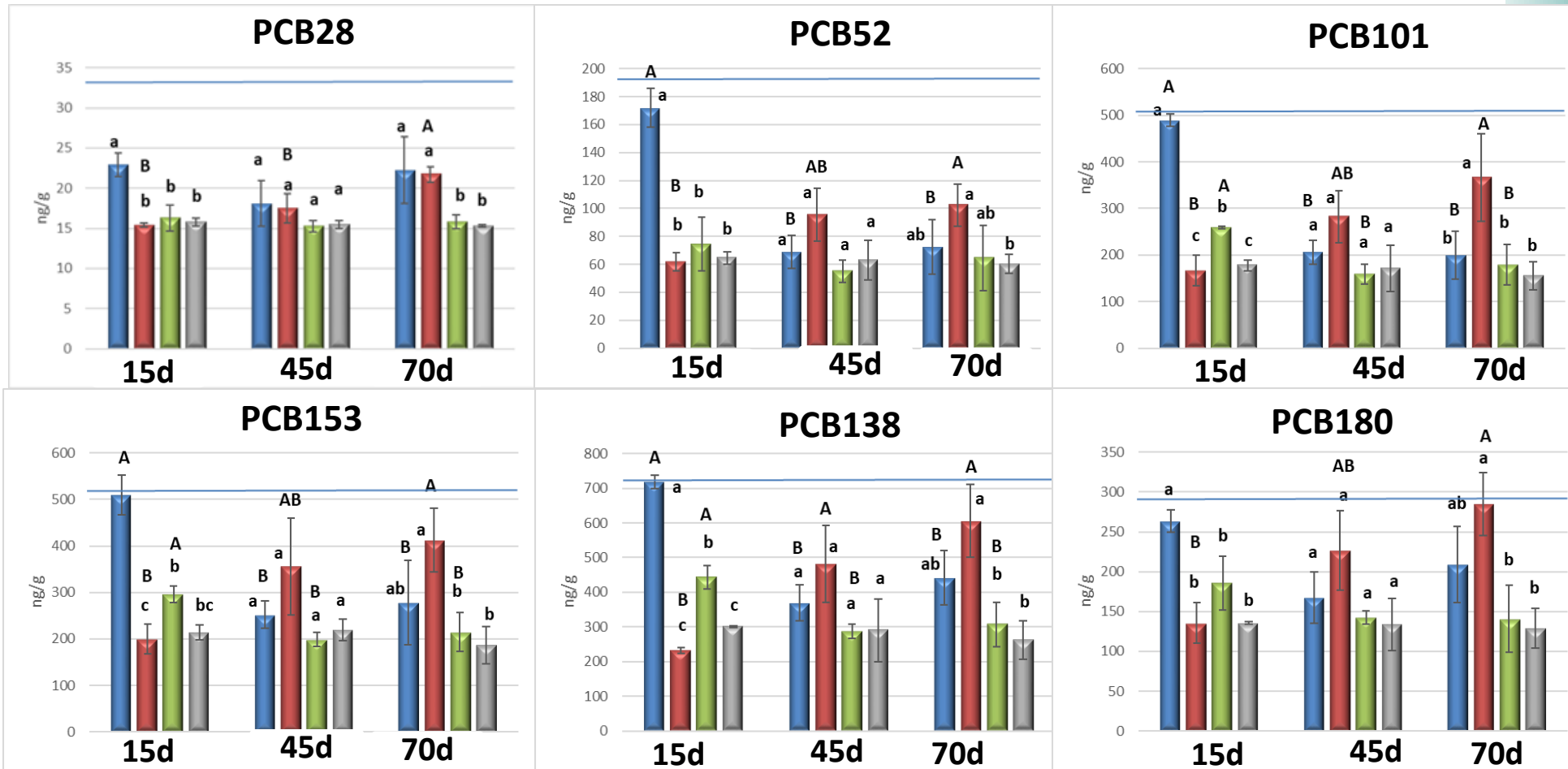
- Cr(VI) reduction to Cr(III)
- Adsorption of Cr(VI) on the shell

## Pd availability in soil samples treated with nZVI-Pd(TCLP)



- **Total Pd in nZVI-Pd treatment:  $150 \pm 30$  mg/kg**
- **Pd-availability maximum at first sampling time (15 days), and decreased with time.**

# PCBs in soil samples



control

nFe<sub>3</sub>O<sub>4</sub>

nZVI

nZVI-Pd

nFe<sub>3</sub>O<sub>4</sub>: reduction  
after 15 days. 45 and  
70 days → increase →  
reversible adsorption.

- nZVI-Pd more effective than nZVI after 15 days. No differences at longer times (degradation 38-68%).
- Control: biodegradation after 45 days (similar results to nZVI and nZVI-Pd).
- nZVI and nZVI-Pd faster than bioremediation and effective for Cr(VI) immobilization.

- The addition of nZVI, nZVI-Pd or nFe<sub>3</sub>O<sub>4</sub> to a soil co-contaminated with Cr and PCBs significantly reduced the leachability of Cr in soil and the immobilization was stable for at least 70 days under the experimental conditions.
- The nZVI and nZVI-Pd showed higher effectiveness for the reduction of Cr(VI) to Cr(III) compared to that of nFe<sub>3</sub>O<sub>4</sub>.
- After 15 days of interaction between soil-nanoparticles, the PCBs concentration significantly decreased in soils treated for the three types of iron nanoparticle. However, nFe<sub>3</sub>O<sub>4</sub> exhibited a reversible process of PCBs adsorption. nZVI-Pd showed higher degradation rate than nZVI after 15 days but on day 45, similar results were found for both nanoparticles (mean 60% degradation).
- The use of nZVI-Pd implies the incorporation of Pd into the soil, although we observed that the available content was lower than 1% of the total and it decreased over time.

- Due to bioremediation processes, the control soils showed a reduction in PCBs concentration in the 45-day sampling time, reaching similar values to those found in soils treated with nZVI and nZVI-Pd. In this regard, bioremediation would be feasible for soil polluted exclusively with PCBs but not when soil also includes metals such as Cr.
- The addition of nZVI or nZVI-Pd under pseudo-anaerobic conditions could be used for the remediation of soils co-contaminated with Cr and PCBs.



THANK YOU FOR YOUR ATTENTION!!!

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