Low-cost technologies based on heterogeneous photocatalysis and zerovalent iron for arsenic removal in the Chacopampean plain, Argentina

María E. Morgada[1], Karina Levy[1], Miguel Mateu[1], Martín Meichtry[1] Gerardo López[2], Detlef Bahnemann[3], Ralf Dillert[3], Prosun Bhattacharya[4], Jochen Bundschuh[5], Marta Litter[1,6]

[1]Gerencia Química, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina
[2]Universidad Tecnológica Nacional – Nanotek S.A., Santa Fe, Argentina
[3]Institut für Technische Chemie, Gottfried Wilhelm Leibniz Universität Hannover, Hannover, Germany
[4]Department of Land and Water Resources Engineering, Kungliga Tekniska Högskolan, Stockholm, Sweden
[5]International Technical Cooperation Program, CIM (GTZ/BA), Frankfurt, Germany —Instituto Costarricense de Electricidad (ICE), UEN, PySA, San José, Costa Rica
[6]Instituto de Investigación e Ingeniería Ambiental, Universidad de San Martín, Buenos Aires, Argentina
Phone: XX541167727016, fax: xx541167727886, litter@cnea.gov.ar

Introduction

The Chacopampean Plain in Argentina constitutes one of the most extended areas in the world with very high arsenic concentrations in groundwater, amply surpassing the standard requirements for drinking water (Argentine and WHO limit: 10 µg L^{-1}). The situation is more serious in rural areas, where low water quality, poverty and malnutrition cause a high incidence of HACRE (Chronic Endemic Regional Hydroarsenicism).

Advanced oxidation processes using solar irradiation in bottles may be suitable technologies for the treatment of polluted waters for drinking purposes. Among them, Heterogeneous Photocatalysis with TiO_2 and Zerovalent Iron (ZVI), both simple and low-cost processes, are promising for removal of As from water.

HP is based on the use of a semiconductor, TiO_2, which under UV irradiation (e.g. solar light), originates active oxidizing species ($HO^\bullet$, $O_2^{\bullet-}$) able to oxidize As(III) (a difficult form to be removed from waters) to As(V). Then, by the addition of iron as Fe^{3+} or packing wire, arsenic can be easily removed by adsorption or coprecipitation on iron oxides.

ZVI is based on the direct treatment of water with iron in its elemental form. In contact with As, complexes or other As-Fe forms are built up on the fresh iron oxides formed *in situ* as the result of Fe(0) corrosion. Iron packing wire, iron wool or iron nanoparticles (NZVI) can be used. In this work, a new commercial NZVI, NanoFe®, was tested.

Materials & Methods

- ✓Arsenic-containing synthetic waters, around 1000 µg L^{-1}, pH ~ 7.8
- ✓Real well waters of two small villages of Argentina: Los Pereyra (Tucumán) and Las Hermanas (Santiago del Estero)
- ✓600 mL-PET bottles covered internally with a TiO_2 (Degussa P25) layer.
- ✓Iron source: $FeCl_3$, packing wire, iron wool (Virulana©) and NanoFe® (Nanotek S.A. of Argentina)
- ✓Irradiation by solar light or UV lamps ($\lambda_{máx}$ = 366 nm, 800-5000 µW cm^{-2}).
- ✓As(V) quantification: UV-Vis spectrophotometry, ICP-AES or TXRF.

HP (TiO_2 in bottles) + Fe addition

Sample	$[As]_i$ (µg L^{-1})	$[As]_f$ (µg L^{-1})	t_{irrad} (h)	As removal (%)
1	1000	140	6	86
2	1000	180	6	82
3	1000	200	6	80
W1	961	31	10*	96.8
W2	1090	13	4.2	98.8
W3	551	30	4.9	94.5
W4	1530	14	3.8	99.1
W5	1830	25	10*	98.6
W6	1630	<10	5.1	>99.4

**Partially clouded day*

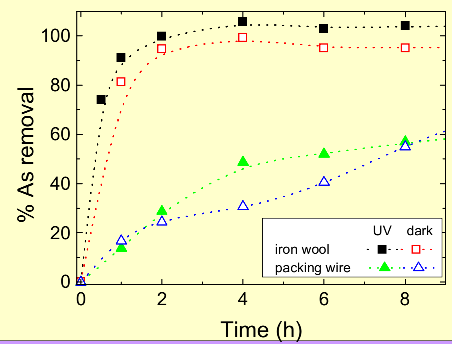
Samples 1–3: synthetic waters + packing wire

W1–W6: Well waters from Las Hermanas + Fe^{3+} addition

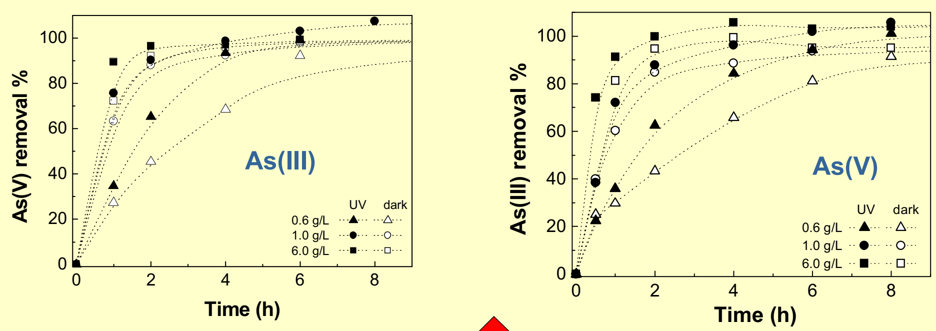
✓In all cases, removal efficiency > 80%.
✓Removal higher in natural waters, probably enhanced by the presence of NOM.

Zerovalent iron

Arsenic-containing synthetic waters



✓$[As]_0$ = 1000 µg L^{-1}.
✓Removal faster with iron wool
✓UV irradiation: no changes in efficiency



✓$[As]_0$ = 1000 µg L^{-1}.
✓Three iron wool masses under UV irradiation or in the dark.
✓UV light enhances removal at the lowest iron concentration

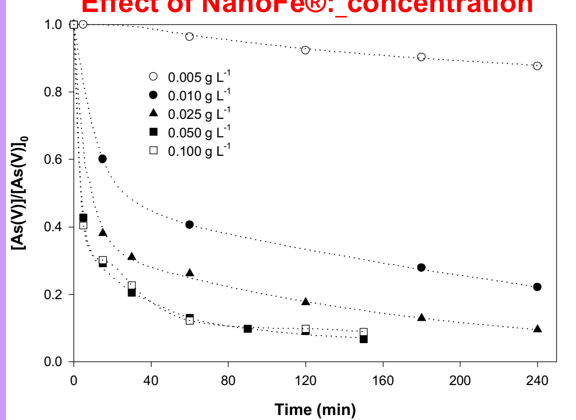
Natural waters: Los Pereyra, Tucumán, packing wire

Sample	$[As]_i$ (µg L^{-1})	$[As]_f$ (µg L^{-1})	[Fe(0)] (g L^{-1})	t_{irrad} (h)	As removal (%)
T1	340	97	6	6	71.5
T2	340	174	6	-	48.8

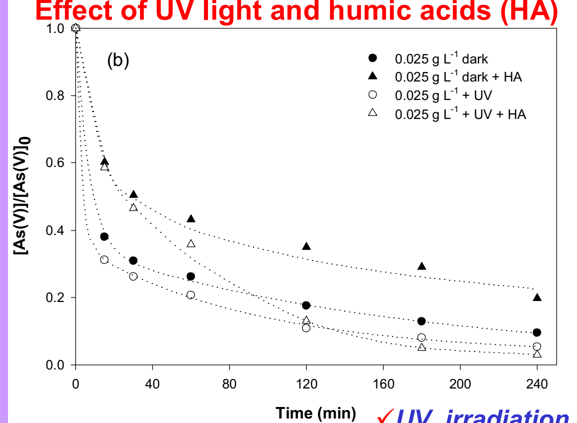
Higher removal efficiency under UV irradiation, probably enhanced by NOM.

Nanozerovalent iron (NanoFe®)

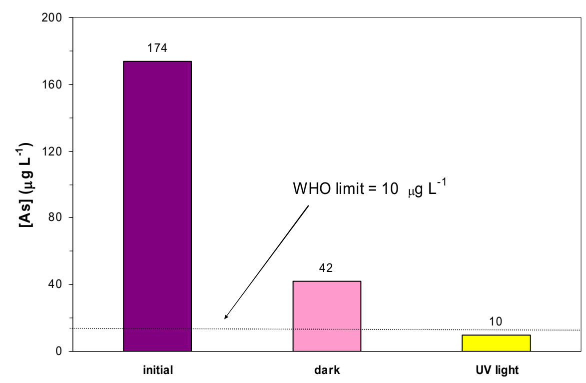
Effect of NanoFe®: concentration



Effect of UV light and humic acids (HA)



Natural waters from Tucumán



✓Removal efficiency increases with NanoFe® concentration.
✓Low amount of material needed for an excellent removal: [NanoFe®] < 0.05 g L^{-1}

✓UV irradiation enhances As removal.
✓HA: detrimental in the dark
✓HA+ UV: excellent removal

Removal efficiency very much improved under UV irradiation.

Conclusions

- ✓Arsenic efficiently removed from both synthetic arsenical solutions and natural groundwater samples by HP + Fe addition and by ZVI, reaching 70-95% removal.
- ✓Cheap materials: TiO_2, iron packing wire, iron wool can be used.
- ✓NanoFe®: excellent material and only a very low mass is needed.
- ✓NOM decreases removal in the dark.
- ✓NOM improves removal under UV light.
- ✓Good results in natural waters.
- ✓HP can remove simultaneously chemical and microbiological contamination.

References

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