Arsenic removal from drinking water with magnetite (Fe_3O_4) reduced graphene oxide (MRGO) nanocomposite material: Evaluations on process chemistry, system design and engineering applications

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Silent threat of arsenic

- Carcinogenic at even μg/L level concentrations
- Widespread in groundwaters due to being geogenic
- Detection & measurement requires advanced analytical techniques

Graphene based nano-adsorbents

- Large surface area/pore volume
- High mechanical stability
- Flexibility of surface chemistry
- Abundant production from natural resources

Core research questions

- How does a graphene based nano-adsorbent perform for arsenic removal from water under more realistic conditions beyond proof-of-concept approaches?
- What can be the role of arsenic speciation in adsorption under continuous column & larger scale conditions ?

Synthesis of magnetite (Fe_3O_4) reduced graphene oxide (MRGO) and MRGO coated sand

First graphene oxide is produced from graphite using a modified Hummers method, and then magnetite reduced graphene oxide is synthesized under N_2 environment according to the method by Yoon et al. (2016) [1]. For column experiments, MRGO is coated onto sand following [2-4].

For more details on MrGO synthesis, see also poster from Şengör et al. (2025) @EGU 25, titled "**Synthesis of M-rGO and M-rGO-sand coated reactive media for contaminant remediation**" [Session GMPV6.2]

During the synthesis of MRGO, the color transition from dark green to burgundy was observed

Appearance of the material before final washings

MRGO coated sand (no particles magnetized, indicating negligible MRGO detachment)

Arsenic speciation analysis with hydride generation flow injection atomic absorption spectrometry (AAS)

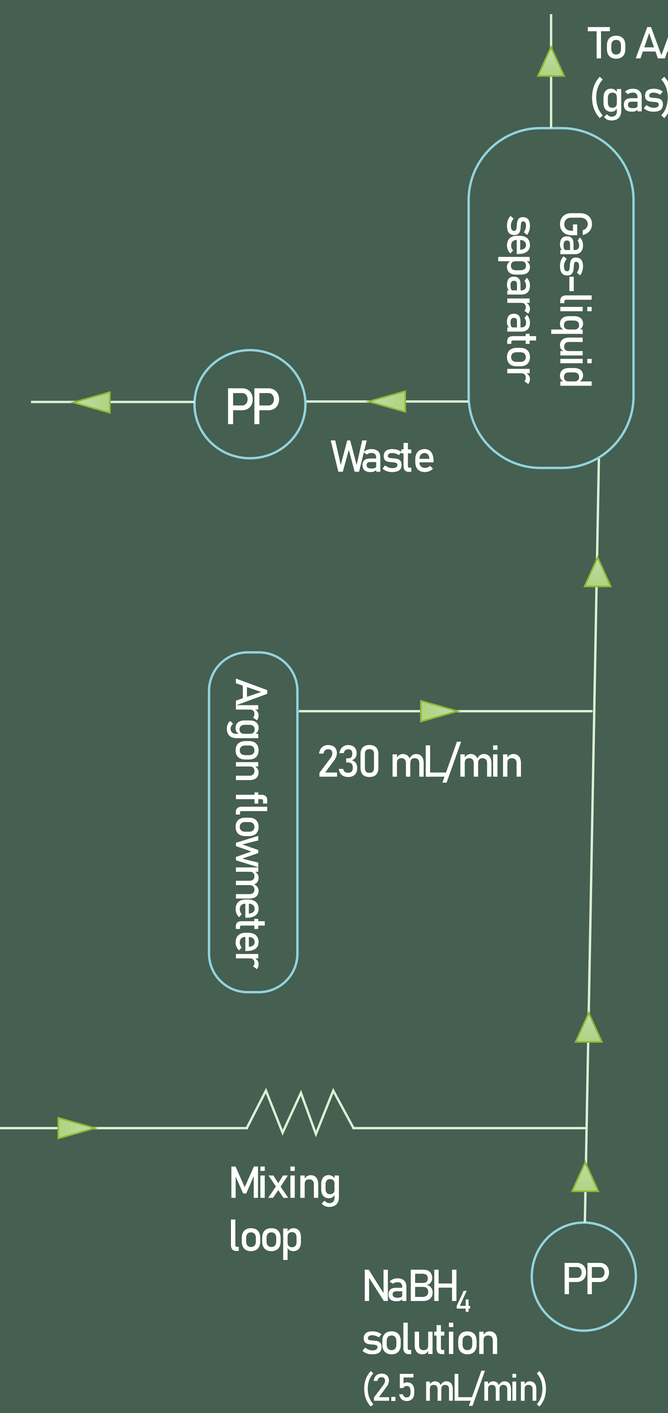
Why hydride generation flow injection AAS (HG-FI-AAS)?

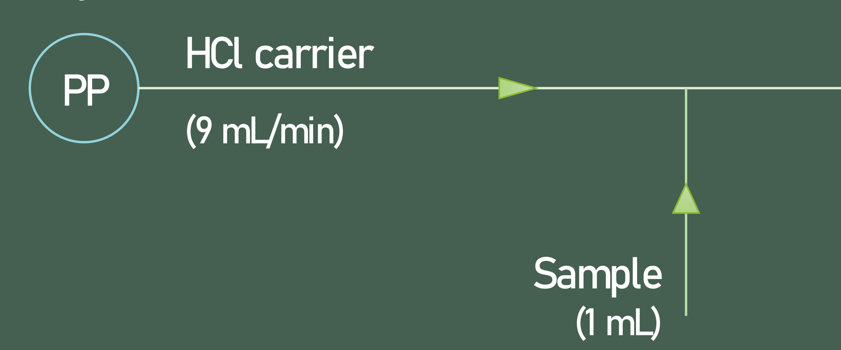
- Reliable technique, well-established for many decades
- Lower sample volumes (1 mL) as compared to methods involving solid phase extraction (up to 40 mL) [5-6]
- Shorter duration, 40 s/sample, as compared to durations such as 10-20 min/sample when any type of chromatographic technique is involved [5-6]

HG-FI-AAS optimized conditions*

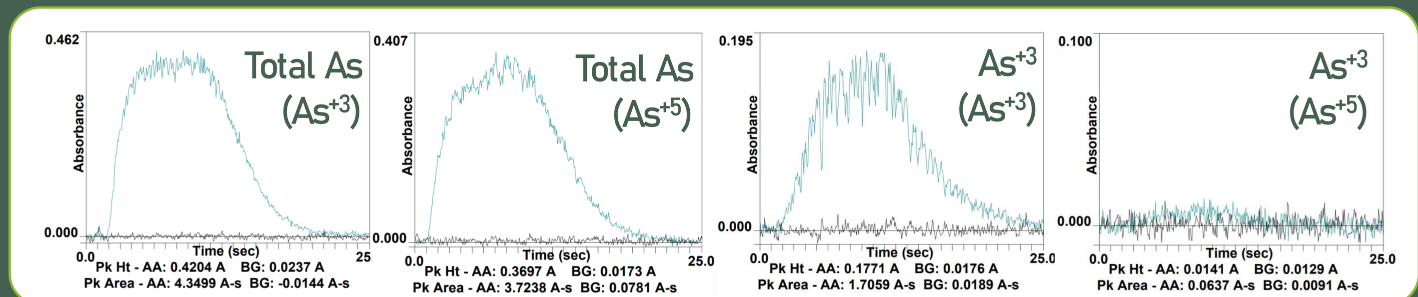
Parameter (Unit)	Value
Lamp type	EDL
Wavelength (nm)	193.7
Read time (s)	25
Air flowrate (L/min)	10
Acetylene flowrate (L/min)	2.5
Argon flowrate (mL/min)	230
Peak height/area	Peak height (As^{+3}) Peak area (Total As)
Carrier flowrate (mL/min)	9.0
Carrier matrix	0.1 M HCl (As^{+3}) 1.0 M HCl (Total As)
$NaBH_4$ flowrate (mL/min)	2.5
$NaBH_4$ concentration (%)	0.1 (As^{+3}) 3.0 (Total As)

*Method adapted from [7]

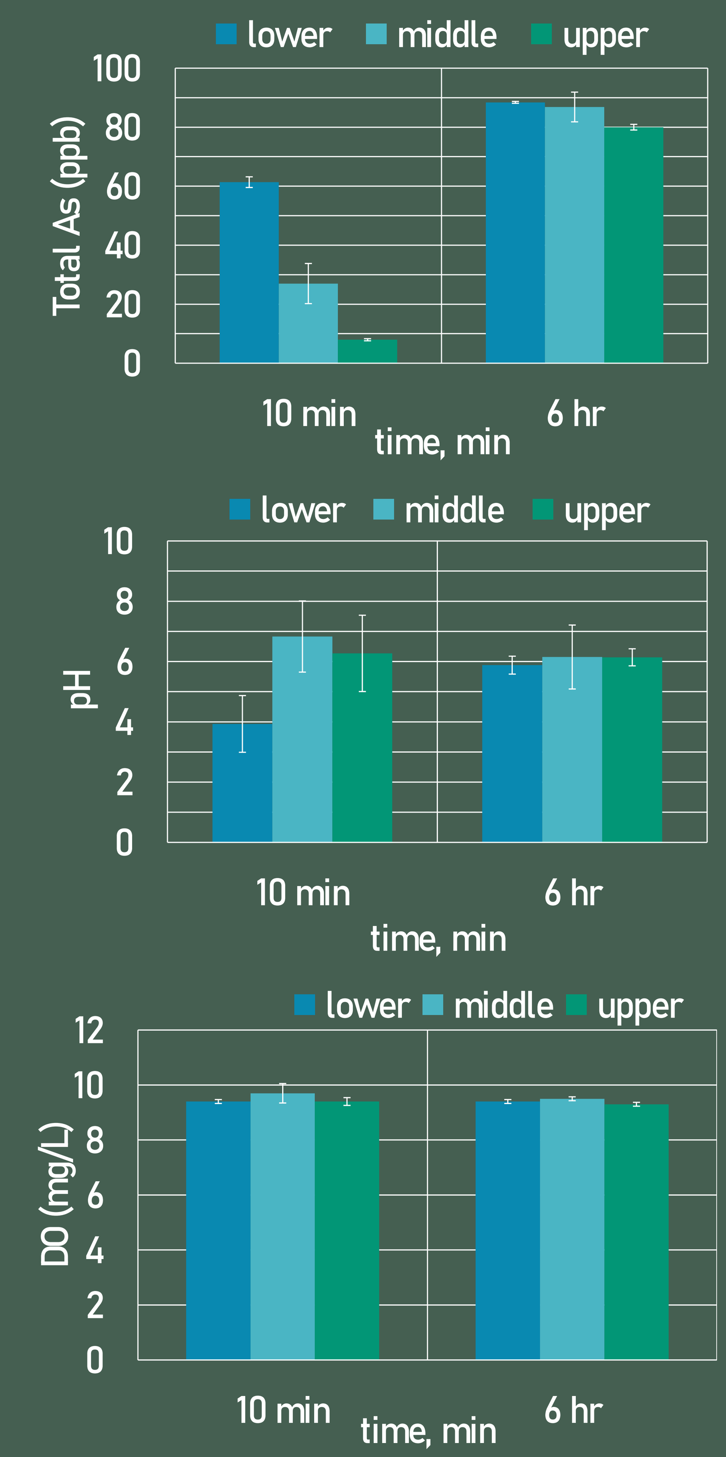




Arsenic speciation analysis signals from AAS

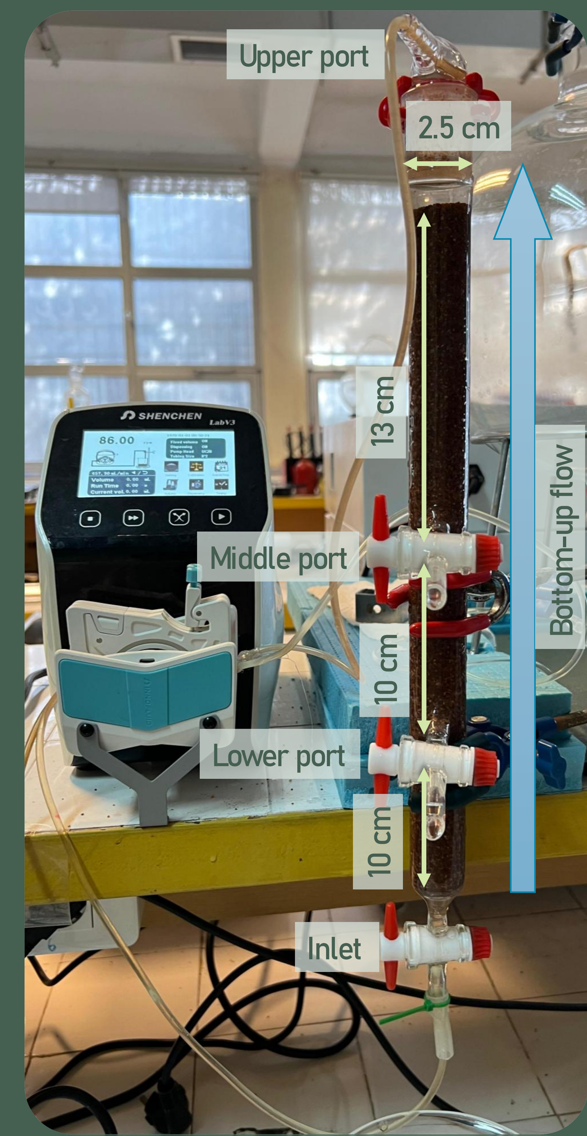


Column adsorption experiment results



Experimental conditions

- C_0: 89.92 ± 2.94 μg/L as As^{+3}
- Coating dosage: 1.0 mg MRGO/g sand
- Flowrate: 20 mL/min
- Run time: 6 hr
- Duplicate runs conducted



Discussion & Further Steps

- Column reaches breakthrough until 6 hr
- WHO drinking water guideline value of 10 ppb As can be reached with the column at 10 min
- Dissolved oxygen remains fairly stable during the run, pH variations for the lower port may be more significant (important for modeling studies)

What comes next?

- ❑ Trials under different conditions (low flowrate, As^{+5} as initial specie, synthetic and real groundwater samples)
- ❑ Modeling of the columns via a hydrogeochemical model (PHREEQC)
- ❑ Simulations and discussions about feasibility assessments and scaling up

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