# REMOVAL OF ARSENIC IN DRINKING WATER TREATMENT WITH GRANULAR FERRIC HYDROXIDE (GEH®)

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## RESUMEN

Fixed-bed **adsorption** has proven to be the simplest and most reliable **dearsenification** process for ground water in drinking water production. Synthetic **granular ferric hydroxide** has a highly successful track record as an arsenic adsorbent both in large-scale units in water treatment plants as well as in compact point-of-use (POU) units. Adsorption capacities attained in practice are dependent on the composition of the raw water processed, in particular its pH level and concentrations of competitive anions. Typical treatment capacities until media exchange in practice range from 100,000 to 300,000 bed volumes of water treated. Advantages of arsenic removal by adsorption are removal of 100 % of arsenic, low maintenance requirements and no need for the use of chemicals.

**Palabras Clave: Adsorption, Dearsenification, Granular ferric hydroxide**

## INTRODUCCIÓN

Dearsenification of ground water is the most urgent drinking water treatment problem facing many regions worldwide. As compared with various other methods used for dearsenification, such as flocculation, ion exchange and reverse osmosis, adsorption has proven to be the most reliable and easiest method to implement from a technical standpoint. Granular ferric hydroxide (abbreviated in this presentation as "GEH") was developed in Germany in the 1990's at Technical University Berlin, providing the world's first ferric hydroxide-based granular adsorbent for drinking water treatment (*Driehaus et al. 1998*). GEH has official certification for use in drinking water treatment (e.g. ANSI/NSF Standard 61) in many countries and has been used successfully for many years worldwide.

**Granular Ferric Hydroxide (GEH)**

GEH (Figure 1) is a synthetically manufactured ferric hydroxide composed of akaganéite (β-FeOOH) with a ferrihydrite (Fe(OH)3) component. The granular adsorbent has a particle size distribution ranging from 0.2 to 2.0 mm and a high specific surface area for adsorption, approx. 300 m2/g as determined by the BET method (*Saha et al. 2005*). GEH complies with all quality requirements of European Standard EN DIN 15029.

Figure 1. Granular ferric hydroxide (GEH)

**GEH Treatment Units in Waterworks**

In regions with centralized drinking water treatment and supply, GEH is used in adsorber beds housed in large-scale plastic or stainless steel pressure vessels (Figure 2).
These beds generally process water throughputs in the range of 10 to 100 m3/h, for the most part in continuous operation (*Driehaus 2002*). GEH adsorber beds are normally dimensioned for operation at a water flow speed of 10-15 m/h with an empty bed contact time (EBCT) of 3 - 5 minutes. Three typical water treatment units located in different regions in Germany, waterworks "B, "N" and "S" were studied in detail with regard to their arsenic breakthrough behaviour. The relevant analysis data of the raw water treated at each site is summarized in Figure 3.

Figure 2. GEH adsorption system with FRP-vessels

**POU units in Argentina**

The 10 µg/L arsenic limit specified for drinking water by the WHO Guidelines is not complied with in all areas in Argentina to date. As a result, great demand has arisen from end users in highly contaminated regions (e.g. La Pampa) for point-of-use (POU) drinking water treatment units. Unlike the large-scale GEH adsorber beds used in centralized water works, POU units provide lower water throughput rates and are operated only intermittently in accordance with users' demand. POU units are self-operated by end users and therefore simplicity of operation and minimum maintenance are prime requirements. In recent years, roughly 400 POU units consisting of one or more GEH adsorber beds and a downstream activated-carbon filter bed (average pore size: 5 µm) have been installed in Argentina alone. The 6.4 cm diameter adsorber beds hold approx. 550 g GEH and are normally operated at a throughput of 1 L/min. These POU treatment units are inspected on site at regular intervals, including determination of outlet arsenic concentration by commercially available rapid testing systems.

**Field Experience with Large-Scale Treatment Units**

Evaluation of data gathered at the three different waterworks shows that EFH adsorbers provide lifetime throughput capacities (lifetime = operating life before outlet arsenic concentration reaches 10 µg/L limit) of up to 300,000 bed volumes (Figure 3). In field practice this translates to an adsorbent replacement interval of 3 - 5 years and more.

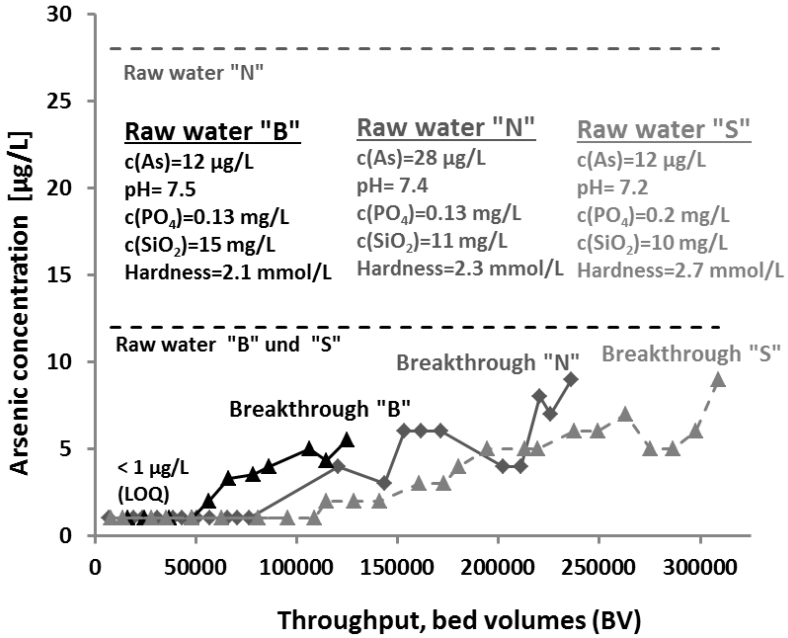

Figure 3. Arsenic breakthrough plots for GEH adsorber beds in three typical waterworks in Germany

In general the adsorption capacity of GEH beds is highly dependent on the chemistry of the inlet water treated, e.g. its arsenic concentration and pH level. Other factors have also been identified as adsorption inhibitors, primarily phosphate, silicate and vanadium concentration as confirmed by literature sources (Sperlich 2005, Guan 2008). The only maintenance work required with GEH adsorbers in waterworks is occasional backwashing of the bed. This is required in the event suspended particulates from the inlet raw water accumulate in the adsorbent, causing increased pressure drop across the bed. The spent GEH has an arsenic content of roughly 2 - 10 g/kg. Leaching tests (e.g. TCLP from the United States EPA) show that the arsenic is securely bonded with the GEH and is not elutable under normal conditions. As a result, exhausted GEH can be disposed of as common municipal refuse.

**Field Experience with POU Treatment Units**

POU units with GEH in Argentina are primarily used in residences, however a number of systems are also in use in schools and other public institutions. The units are dimensioned to provide water supply for a family of 4 with a combined consumption of roughly 10 litres of treated water daily. Depending on the arsenic content of the water treated, the service lifetimes attained in field practice are on the order of 0.5 - 1.5 years, corresponding to a lifetime throughput capacity of 4,000- 12,000 bed volumes. These capacity figures, much lower than those achieved with the larger-sized beds described above, are attributable to the relatively high arsenic concentrations and high pH values of the ground water treated. In addition, the POU units, due to their compact design, have lower empty bed contact times (EBCT < 1 min). Table 1 provides an overview of the POU units and their typical operating conditions – including bed replacement interval - in four different regions in Argentina.

Table 1. Overview of installed POU units

| City / Province | POU units installed | Arsenic in water [µg/L] | pH in water | Replacement interval |
|---|---|---|---|---|
| **Junín** / Provincia de Buenos Aires | 200 | 80-120 | 8.2 | 2x yearly |
| **Suipacha** / Provincia de Buenos Aires | 100 | 100 | 8,0 | 2x yearly |
| **Villa María** / Provincia de Córdoba | 20 | 25 | 7.9 | yearly |
| **Chivilcoy** / Provincia de Buenos Aires | 10 | 50 | 7.8 | yearly |

In groundwater regions with extremely high arsenic concentration, two or more GEH adsorbers can be used in series to enhance treatment effectiveness (lead/lag configuration). Regular backwashing of POU units is normally not required.

## Conclusions

Field experience in recent years shows that GEH adsorbers realize highly efficient water dearsenification both in waterworks and in POU units, providing a reliable water treatment technology requiring only minimum maintenance.

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