Iran's first waterworks with granular ferric hydroxide-based dearsenification – a look back over the first two years of operation

C. Bahr¹, F. Tarah² & M. Mahdyarfar²

¹GEH Wasserchemie GmbH & Co. KG, Osnabrück, Germany

²Delta Niroo Gameron Co., Tehran, Iran

ABSTRACT: Like many other countries, Iran has numerous regions with high levels of geogenic arsenic (As) in groundwater which jeopardize safe drinking water supply in these areas. In an effort to address this problem in Iran's Kerman Province, a large-scale drinking water dearsenification plant was erected at a waterworks there. The plant, which utilizes ferric hydroxide adsorption beds making it the first of its kind in the country, has now been in operation for over two years' time. Due to the relatively high As content of the groundwater treated, the plant had to be designed with a combined process approach to realize optimum treatment performance. The process configuration selected, comprising (a) pH reduction of the inlet raw water, (b) multiple adsorber lines operated in parallel with time-staggered adsorbent exchange and (c) lead/lag configured beds and a standby bed making up each line, permits realization of long bed life of the adsorbent media used.

1 INTRODUCTION

Geogenic arsenic (As) contamination of drinking water is a health threat encountered in many regions world-wide. This is well documented, e.g. by a recently published international sourcebook (Murcott, 2012) providing updated As contamination data – which can vary substantially among regions within a given country – for a total of 105 countries around the world. The precarious situation in India and Bangladesh in

this regard has been a much-discussed topic for many years. High As contamination levels have been determined in many other countries as well, calling attention to the need for urgent action in this respect.

Iran is another example, where As concentrations ranging up to 1.48 mg L^{-1} have been recently been established in the Kurdistan Province. Earliest reports of As-caused diseases in the area date from the 1980's (Mosaferi *et al.*, 2003). Iran's groundwater regions potentially subject to high As contamination can be thought of roughly as a belt extending from the country's northwest corner to its southeast corner (MIM, 2015) (see Fig. 1).

As compared with various other methods used for dearsenification, such as flocculation, ion exchange and reverse osmosis, adsorber beds have proven to be the most reliable and easiest method to implement from a technical point of view. Ferric hydroxide-based granular materials have proven to be the best adsorbents for As removal due to their very high selectivity and adsorption capacity (Amy *et al.*, 2005).

Accordingly, decision makers in Iran opted to move ahead with construction of a large-scale drinking water dearsenification plant using adsorber bed technology.

2 METHODS

2.1 Bardsir drinking water treatment plant

Erected in 2013, Bardsir waterworks is located in Kerman Province in Southeastern Iran. The Iranian company Delta Niroo Gameron Co. designed,

Figure 1. Regions with potentially high arsenic contamination. Geological Survey of Iran (MIM, 2015).

financed and constructed this plant as a BOO project (Build Own Operate) and now operates it on behalf of municipal authorities to supply drinking water to local consumers. The Bardsir waterworks provides a volume treatment capacity of up to 4 million m³ year⁻¹ and is therefore able to meet the needs of roughly 85,000 consumers for As-free drinking water supply. The plant comprises 5 treatment lines operated in parallel, each of which can be switched on or off-line as required to achieve the desired water production rate. Each treatment line consists of 3 adsorber beds, two of which are operated in a lead/lag configuration while the other is held in standby mode. Each bed contains 5.3 metric tons of granular adsorbent.

2.2 Granular ferric hydroxide adsorbent

The adsorbent media used for As removal is GEH[®] 102 granular ferric hydroxide. This media, developed in Germany in the 1990s at Technische Universität Berlin, was the first ferric hydroxide-based granular adsorbent available for drinking water treatment (Driehaus *et al.*, 1998).

GEH[®] 102 is a synthetically manufactured ferric hydroxide composed of akaganeite (β -FeOOH) with a ferrihydrite (Fe(OH)₃) component. It 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⁻¹ as determined by the BET method. The adsorbent is certified in accordance with NSF/ANSI Standard 61 and other internationally recognized specifications for use in drinking water treatment and has been utilized successfully for al-most 2 decades by users worldwide.

3 RESULTS AND DISCUSSION

3.1 Raw water

The raw water fed into the plant is groundwater extracted from a depth of 170 m below ground level. It has relatively high As content, i.e. concentrations ranging up to 250 µg L⁻¹. The As content averaged 145 µg L⁻¹ over the year 2015. The typical composition of the water is given in Table 1.

3.2 Operation, optimization and performance

The plant is designed for around-the-clock (24/7) operation. Each treatment line can be operated at a volumetric flow rate of up to 94 m³ h⁻¹. This flow rate corresponds to a flow speed of 16 m h⁻¹ and an empty bed contact time (EBCT) of 3 min through each adsorber bed. The plant's internal As limit, set voluntarily at a lower level than the WHO guidelines to ensure additional consumer safety, in the blended clean water is <5 µg L⁻¹. The As concentrations in the raw water, the individual bed effluents and the blended clean water are determined at regular intervals using a portable rapid tester.

Table 1. Raw water composition.

Ca ²⁺ mg L ⁻¹	Mg ²⁺ mg L ⁻¹	Na ⁺ mg L ⁻¹	HCO ₃ ⁻ mg L ⁻¹	SO ₄ ²⁻ mg L ⁻¹	Cl ⁻ mg L ⁻¹	NO ₃ ⁻ mg L ⁻¹
53	13	48	176	78	66	12
pH	Conductivity µS cm ⁻¹	TDS mg L ⁻¹		As µg L ⁻¹	Hardness mmol L ⁻¹	
68	598	407		250 (max)	19	

Three technological approaches were combined to realize optimum dearsenification performance:

- The 2 active adsorber beds in each line are operated in a lead/lag configuration, therefore permitting better utilisation of each bed's adsorption capacity.
- Exchange of exhausted adsorbent media is done in a time-staggered sequence, i.e. for only one treatment line at one time and only when the internal As limit has been reached in the blended clean water. The averaging effect provided by blending permits operation of individual lines with higher effluent concentrations, therefore further improving utilisation of adsorption capacity.
- Sulfuric acid is added to the raw water as required to reduce its pH level from 6.8 to 6.0. This increases the adsorption capacity of the media by roughly 20%. This is later counteracted by addition of caustic soda to the clean water to bring its pH up to neutral.

Evaluation of plant operating data shows that the adsorbents used under these conditions attain bed lives in the range of 50,000 to 60,000 BV. In practical terms this means that one of the 15 adsorber beds in the plant must be recharged with fresh adsorbent on an average of every 3–4 months. The As-free water is sold for a price of roughly €0.60 per m³ water supplied.

4 CONCLUSIONS

Experience gathered to date in the Bardsir waterworks shows that its granular ferric hydroxide-based adsorber process provides clean drinking water which consistently complies with the WHO As guideline value (As < 10 µg L⁻¹) in spite of the challenging nature, i.e. relatively high As content, of the raw water treated. The process has proven to be a reliable and cost-efficient water treatment technology requiring only minimum maintenance. The granular ferric hydroxide-based dearsenification plant in Bardsir has achieved recognition as a beacon project for future waterworks of this type in Iran.

REFERENCES

- Amy, G., Chen, H.-W., Drizo, A. & Brandhuber, P. 2005. Adsorbent treatment technologies for arsenic removal.

- AWWA Research Foundation & AWWA. ISBN 1-58321-399-6.
- Driehaus, W., Jekel, M., Hildebrandt, U. 1998. Granular ferric hydroxide – a new adsorbent for the removal of arsenic from natural water. *J. Water Supply Res. T.* 47(1): 30–35.
- Ministry of Industries and Mines of Iran (MIM) 2015. Favorable Environments for As. Geological Survey of Iran <http://www.gsi.ir/>.
- Mosaferi, M., Yunesian, M., Mesdaghinia, A., Nadim, A., Nasser, S. & Mahvi, A.H. 2003. Arsenic occurrence in drinking water of I.R. of Iran: the case of Kurdistan Province. *Proceedings of BUET-UNU International Symposium "Fate of Arsenic in the Environment"*, Dhaka, Bangladesh.
- Murcott, S. 2012. *Arsenic Contamination in the World. An International Sourcebook*. IWA Publishing, London, UK.