

Metallic Iron for Water Treatment: Lost Science in the West

Chicgoua Noubactep^{1,2}

¹Angewandte Geologie, Universität Göttingen, Goldschmidtstraße 3, D-37077, Göttingen, Germany.

²Pan African University Institute of Water and Energy Sciences (including Climate Change) PAUWES c/o University Abou Bekr Belkaïd - Tlemcen, B.P. 119, Pôle Chetouane, Tlemcen 13000, Algeria.

*Corresponding author: Noubactep C, Angewandte Geologie, Universität Göttingen, Goldschmidtstraße 3, D-37077, Göttingen, Germany, Tel: 49 551 39 3 3191; Fax: 49 551 399379; E-mail: cnoubac@gwdg.de

Received date: Feb 23, 2017, Accepted date: Mar 15, 2017, Published date: Mar 21, 2017

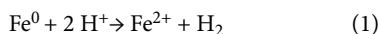
Copyright: © 2017 Noubactep C. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Letter to the Editor

Voltaire (1694-1778), the French philosopher said: "There are many ways to waste own time: Doing nothing, doing the wrong thing, doing the good thing at the wrong time" (own translation). The situation is quite different if the time is robbed by someone else or even by a professional mistake. There is a clear evidence that researchers on metallic iron (Fe^0 - termed as zero-valent iron) for water treatment as performed for the past three decades have wasted time in wrongly rediscovering aspects carefully documented in the scientific literature [1,2] and textbooks [3,4] before 1940.

Actually, going through the Author's Guidelines of many scientific journals, one realizes that referencing recent articles is strongly recommended. This recommendation can be justified by the evidence, that scientific knowledge is progressively accumulated, assuming that all relevant available results are considered by newer publications. Indeed, the state-of-the-art knowledge should be presented before knowledge gaps are identified.

The recent introduction of the Fe^0 technology for environmental remediation was coupled with the assumption that contaminant reductive degradation is the cathodic reaction simultaneous to Fe^0 oxidative dissolution [5,6]. Efforts to support this statement reported on works dating back to 1972 [7]. However, relevant works addressed either (i) wastewater treatment or (ii) situations where Fe^0 is used at acidic pH values or in organic solvents [8,9]. The whole effort has overseen the evidence that aqueous iron corrosion after Equation 1 is spontaneous and quantitative. Thus, before discussing the impact of any solute (usually present in trace amounts), the action of the solvent (H_2O or H^+) should have been properly considered.



Equation 1 shows clearly that Fe^0 oxidative dissolution produces Fe^{II} species and H_2 . Both are stand-alone reducing agents and their reducing capacity is increased upon adsorption to mineral surfaces, abundantly generated within the $\text{Fe}^0/\text{H}_2\text{O}$ system [8,10,11]. Owing to the low solubility of Fe^{II} (and Fe^{III}) species at the pH values of natural waters ($\text{pH} > 5.0$), iron hydroxides and oxides are generated and act as contaminant scavengers. This is the fundamental mechanism of contaminant removal in $\text{Fe}^0/\text{H}_2\text{O}$ system [8-13].

The contemporary Fe^0 remediation technology was introduced for groundwater remediation [7] and later scaled down for water treatment at small scale [9,14]. This is exactly the opposite of what is reported in the ancient use of Fe^0 for safe drinking water provision [1,2].

Around 1875, Fe^0 was already established as material for water filtration at household level [1,15]. Between 1881 and 1883 Fe^0 filters

were successfully tested for water supply at large scale in Antwerp (Belgium) [16,17]. The city then had 200,000 inhabitants. The best Fe^0 filter used a porous material termed as sponge iron (Bischoff process). Because filter clogging was difficult to control, the waterworks at Antwerp developed and implemented the revolving purifier (Anderson process) in which iron fillings are shaken with water to produce iron hydroxides and oxides for contaminant removal [1,17,15]. This effort preceded the introduction of iron electrocoagulation in water treatment (1905) [18]. In other words, the ancient literature is rich in scientific articles describing the mechanism of aqueous contaminant removal by Fe^0 . That is considering Fe^0 as generator of iron hydroxides and oxides [9-11,12,15]. Properly considering this in 1990 would have saved time for the whole research community.

Considering that a mechanistic discussion is still taking place within the research community on Fe^0 for water treatment and that this research (was initiated and) is mainly performed in the Western Europe and North America[19-21], it is fair to state that science loss (knowledge loss) has occurred in the West. This is contrary to the common belief that knowledge loss is characteristic of endangered minorities in the Third World [22]. [22] gives an overview of indigenous knowledge systems (IKSs). IKSs are bodies of knowledge of the indigenous people of particular geographical areas. This locally available knowledge can be opposed to mainstream science that is universal in essence. [23] compared the current Fe^0 research community to a knowledge system challenging mainstream science. A critical aspect of the behaviour of the Fe^0 research community is that issues of discussion are experimentally verifiable. Two examples for illustration: (i) it has been redemonstrated that porous Fe^0 materials are the best choice for water filters [24] and (ii) the rationale for the volumetric Fe^0 : gravel ratio of 1:3 used in the Bischoff process has been established [25].

It is time for the Fe^0 research community to go back to the highway of mainstream science and accelerate a science-based development of their technology. This simple and applicable technology has the potential to help achieving the UN Sustainable Development. [26] argued that a tool to achieve the UN SDGs is to translate existing knowledge into practical solutions. It appears that designing efficient Fe^0 filtration systems is one of the best available approaches for an appropriate, demand-based, affordable and efficient water treatment technology [14].

Acknowledgement

The manuscript was improved by the insightful comments of anonymous reviewers from Bioenergetics. The author acknowledges support by the German Research Foundation and the Open Access Publication Funds of the Gottingen University.

References

1. Devonshire E (1890) The purification of water by means of metallic iron. *Journal of the Franklin Institute* 129: 449–461.
2. Baker MN (1934) Sketch of the history of water treatment. *Journal American Water Works Association* 26: 902–938.
3. Davis F (1891) An elementary handbook on potable water. Silver, Burdett & Co, Boston.
4. Hill JW (1898) The purification of the public water supplies. D Van Nostrand Company, The University of California.
5. Matheson LJ, Tratnyek PG (1994) Reductive dehalogenation of chlorinated methanes by iron metal. *Environ Sci Technol* 28: 2045–2053.
6. Weber EJ (1996) Iron-mediated reductive transformations: investigation of reaction mechanism. *Environ Sci Technol* 30: 716–719.
7. Gillham RW (2010) Development of the granular iron permeable reactive barrier technology: good science or good fortune
8. Noubactep C (2013) Relevant reducing agents in remediation Fe⁰/H₂O systems. *Clean – Soil, Air, Water* 41: 493–502.
9. Noubactep C (2013) Metallic iron for water treatment: A critical review. *Clean – Soil, Air, Water* 41: 702–710.
10. Gheju M, Balcu I (2011) Removal of chromium from Cr(VI) polluted wastewaters by reduction with scrap iron and subsequent precipitation of resulted cations. *J Hazard Mater* 196: 131–138.
11. Ghauch A (2015) Iron-based metallic systems: An excellent choice for sustainable water treatment. Freiberg Online Geoscience
12. Noubactep C (2010) The fundamental mechanism of aqueous contaminant removal by metallic iron. *Water SA*
13. Tang S, Wang XM, Liu ST, Yang HW, Xie YF, et al. (2017) Mechanism and kinetics of halogenated compound removal by metallic iron: Transport in solution, diffusion and reduction within corrosion films. *Chemosphere*
14. Noubactep C (2016) Designing metallic iron packed-beds for water treatment: A critical review. *CLEAN - Soil, Air, Water* 44: 411–421.
15. Mwakabona HT, Ndé-Tchoupé AI, Njau KN, Noubactep C, Wydra KD, et al. (2017) Metallic iron for safe drinking water provision: Considering a lost knowledge. *Water Res*
16. Tucker WG (1892) The purification of water by chemical treatment. *Science* 20: 34–38.
17. Van CW (1998) Easton & Anderson and the water supply of Antwerp (Belgium). *Industrial Archaeology Review*
18. Noubactep C, Schöner A (2010) Metallic iron for environmental remediation: Learning from electrocoagulation. *J Hazard Mater* 175: 1075–1080.
19. Colombo A, Dragonetti C, Magni M, Roberto D (2015) Degradation of toxic halogenated organic compounds by iron-containing mono-, bi- and tri-metallic particles in water. *Inorganica Chimica Acta* 431: 48–60.
20. Casentini B, Falcione FT, Amalfitano S, Fazi S, Rossetti S, et al. (2016) Arsenic removal by discontinuous ZVI two steps system for drinking water production at household scale. *Water Res* 106: 135–145.
21. Song X, Chen Z, Wang X, Zhang S (2017) Ligand effects on nitrate reduction by zero-valent iron: Role of surface complexation. *Water Res* 114: 218–227.
22. Mapara J (2009) Indigenous knowledge systems in Zimbabwe: Juxtaposing postcolonial theory. *The Journal of Pan African Studies* 3: 139–155.
23. Noubactep C (2011) Metallic iron for water treatment: A knowledge system challenges mainstream science. *Fresenius Environ. Bull* 20: 2632–2637.
24. Hussam A, Munir AKM (2007) A simple and effective arsenic filter based on composite iron matrix: Development and deployment studies for groundwater of Bangladesh. *J Environ Sci Health A* 42: 1869–1878.
25. Btatkeu-K BD, Olvera-Vargas H, Tchatcheueng JB, Noubactep C Caré S (2014) Determining the optimum Fe⁰ ratio for sustainable granular Fe⁰/ sand water filters. *Chemical Engineering Journal* 247: 265–274.
26. Hering JG, Maag S, Schnoor JL (2016) A call for synthesis of water research to achieve the sustainable development goals by 2030. *Environ Sci Technol* 50: 6122–6123.
27. Chen Y, Tang X, Zhan L (2009) In "Advances in environmental geotechnics: proceedings of the International Symposium on Geoenvironmental Engineering in Hangzhou, China.