

Arsenic (epa) has  
adopted an arsenic  
maximum



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Arsenic contaminations in water have been considered as serious health problems. Long-term drinking water containing arsenic has been reported to cause various cancer as well as skin lesions, gangrene in leg, skin, lung, bladder, liver (Anawar et al., 2001). The World Health Organization (WHO) has amended the maximum permissible limited arsenic concentration in drinking water from 50 to 10  $\mu\text{g L}^{-1}$ , and the U. S.

Environmental Protection Agency (EPA) has adopted an arsenic maximum contaminant level of 10  $\mu\text{g L}^{-1}$ . Therefore, effective treatment techniques for arsenic removal from water is obvious to meet the standard. In the last decade, many studies (table 1) have been done in nano-based adsorbents for the removal of arsenic from wastewater, as well as drinking water. In natural water arsenic predominantly remain as arsenite (As(III)) and arsenate (As(V)) form (Mehta et al., 2015). However, the presence of monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) in natural waters has also been reported (Anderson and Bruland, 1991). As(III) is more toxic and more difficult to remove from water than arsenate (As(V)). Removal of As(III) using simple treatment is difficult and hence an oxidation step is always necessary to achieve higher removal.

Fe–Mn binary oxide material is found to completely oxidize As(III) to As(V) and is effective for both As(V) and As(III) removal, particularly the As(III). And absorption of As(III) by Fe–Mn binary oxide nanomaterial is reported to be two times higher than by  $\text{MnFe}_2\text{O}_4$  and  $\text{CoFe}_2\text{O}_4$  (Zhang et al., 2007, 2010), as the bimetal oxide magnetic nanomaterials possess increased number of the surface hydroxyl groups. This adsorption is controlled dominantly by intraparticle diffusion. However, the applicability of an adsorbent lies on its

regeneration capacity also. Zang et al. (2010) found that about 80-90% of  $\text{MnFe}_2\text{O}_4$  nanomaterials can be regenerated using 0.

1 M NaOH (Zhang et al., 2010). Composites of iron oxide encapsulated in macroporous silica (FeXMOSF) showed excellent arsenic absorption capacity, which is 4–6 times higher than those of nano-sized iron oxides and other nanoadsorbents (table 1). In addition, this composite shows excellent arsenic absorption capacity in case of real wastewater sample (Yang et al.

, 2014). Yang et al. (2014) argues the applicability of FeXMOSF composites in arsenic removal from real wastewater without any pre-treatment. Toxic As(III) can also effectively be removed (100–120 mg/g) from aqueous solution using hybrid nanocrystalline surfactant-modified akaganeite  $\gamma\text{-FeO(OH)}$ . As(III) reacts with hydroxyls of the material and during this sorption, electron transfer from adsorbate to substrate occurred. (Deliyanni et al., 2006). The presence of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in natural water is found to enhance As(V) adsorption capacity of nanomaterial (Peng et al.

, 2005).  $\text{CeO}_2\text{-CNTs}$  exhibit high As(V) absorption capacity in presence of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  at a concentration of 10 mg/L, due to the ternary surface complex reaction among solid surface, cations, and As(V) anions. The cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) exchange with the surface groups first and then As(V) anions are combined to the liquid–solid interface, and the following surface complex forms. Again, the As(V)-loaded  $\text{CeO}_2\text{-CNTs}$  can be efficiently regenerated 94% by NaOH solution (Peng et al., 2005).

The presence of small amount (several mg/L) of  $\text{Zn}^{2+}$  in the drinking water is also found to significantly enhance the adsorption of both As (IV) and

As(III) to magnetite ( $\text{Fe}_3\text{O}_4$ ) nanoparticles where, arsenic and zinc first form a soluble metal-like complex in the solution, and this complex then adsorb to magnetite nanoparticles. However, one of the limitations of this technique is that strong adsorption of arsenic can only occur under relatively acidic conditions. Hence, Under neutral or slightly alkaline conditions, adsorption of arsenic to magnetite becomes much weaker and this treatment approach becomes much less efficient (Yang et al., 2010). Phosphate is the greatest competitor with arsenic in water for adsorptive sites on the adsorbent.

Removal of arsenic from contaminated water depends on pH, contact time, initial concentration of arsenic or chromium,  $\text{PO}_4^{3-}$  concentration in water, and adsorbent concentration (Qu et al., 2013). In natural groundwater containing more than 5 mg/L phosphate and 1.13 mg/L of arsenic, less than 60% arsenic uptake is possible using magnetite-maghemite nanoparticles (Chowdhury and Yanful, 2010).

Nanoscale hydrated iron (III) oxide (HFO) particles exhibit high sorption affinity toward both arsenates and arsenites. The polymeric sorbent, where cation and anion exchangers act as a host material for dispersing HFO nanoparticles within the polymer phase, can effectively remove arsenic (Cumbal and Sengupta, 2005). Organic arsenic (MMA and DMA) can be removed from water using nanocrystalline  $\text{TiO}_2$  (Jing et al., 2005).