Memorandum

CENE 476 Fall 2016
To: Dr. Odem, Grading Instructor
CC: CRKL Engineering & Dr. Baxter, Technical Advisor
From: Lizzie Tague, CENE 476 Student
Date: December 1st, 2016
Subject: Sustainable Water Treatment Literature Review

Objective

The content of this memorandum consists of information pertinent to the design of a sustainable water treatment system. The water treatment system must remove concentrations of Arsenic and Nitrate from a groundwater source through a low cost, low energy, sustainable system. Within this literature review a sustainable method for Arsenic and a sustainable method for Nitrate will be discussed.

The water treatment system will consist of several components specific to each contaminant. Removing arsenic from the groundwater will be addressed by exploring the option of a ceramic membrane filter and furnace slag as forms of adsorption. Addressing the removal of nitrate will be the subsurface biological treatment. These methods are further described in the following sections.

Arsenic Removal

There are multiple methods available to remove arsenic from groundwater that are considered sustainable based on low energy and low cost. Pairing adsorption with ceramic membrane filters is an efficient and effective method that is cost-effective and involves minimal energy. This treatment technique is suitable for developing countries with arsenic contaminated water. Synthesizing nanoscale iron oxide particles and depositing them on porous alumina tubes develops tubular ceramic adsorbers, which can remove arsenic from water [1]. This treatment technology is cost effective, easy to use, and is low energy [1]. As the contaminated water runs through the ceramic filter adsorption occurs when the arsenic encounters the ceramic membranes. Iron oxides are used to develop the ceramic since heavy metals are attracted towards the iron oxides and this reduces the concentration of metals [1]. The ceramic membrane is porous allowing for adsorption and ultrafiltration to take place and ensuring high water fluxes at very low operating pressures [2]. Due to the ceramic character of the membrane, there is a high thermal resistance, allowing for higher temperature situations, a good corrosion resistance suitable for environmental effects, and a good mechanical strength and service lifetime [2]. There are several benefits to this method as the process is low cost, minimal operation, compact, and user friendly [1]. In addition, this can be scaled to meet any requirements from residential use to municipal plant use, and there are no liquid wastes generated from the process [1]. This method is the most suitable for rural and developing areas with arsenic contaminated groundwater.

In addition to the iron oxides, trials have been run using blast furnace slag to assist in the adsorption process. Blast furnace slag, BFS is a steel by-product which can assist and is effective in removing arsenic. Since the most common adsorbents for arsenic removal are metal oxides and hydroxides of iron or alumina, BFS is suitable to be a low cost and available adsorbent [3]. There is significance in the role of BFS as the important major chemical compounds are what make up BFS and it is recovered from high temperatures, is environmentally safe due to the tightly bound matrix of the present metals, and it does not leach easily [3]. This is also a component that would be suitable in developing countries, and it can be paired with the previously mentioned method. The removal of arsenic using a BFS dose of 10 g/L was more than 99.9% and thus this is an effective solution [3]. Using either method would be efficient, effective, and suitable, as would using them in a third option of a combination of both the BFS and the ceramic membrane.

Nitrate Removal

Removing nitrate from groundwater can be an expensive process, depending on the methods used. A lower cost and low energy system that can be implemented are permeable reactive barriers. The use of permeable reactive barriers is a form of subsurface biological treatment [4]. Subsurface biological denitrification treatment is a natural process of oxidization of nitrate to nitrogen gas [4]. This process has been evaluated for groundwater treatment in the United states as well as Europe and other places around the world [4]. Enhancing this natural occurring process involves injection of carbon sources and other materials into the soil [4]. This is done by adding material such as woodchips or straw mixed with sand or gravel and creating an underground wall through which groundwater flows [4]. The woodchips act as an organic carbon source for the soil bacteria to feed on while the convert nitrate to nitrogen gas [4]. The addition of sand or gravel offer permeability for the barrier, which should be a greater or similar permeability of the surrounding soil, forcing the water flow through the barrier rather than around the barrier [4]. Previous studies and uses have shown permeable reactive barriers to be effective and more cost efficient than conventional methods. The reduction of nitrate ranges from 60 to 100 percent reduction at a cost 25 percent of the cost of conventional treatment [4]. A few parameters involved with the denitrification process include dissolved oxygen, temperature, organic carbon, and pH of the groundwater. The presence of oxygen will distract the bacteria from consuming the nitrate and instead they will consume the oxygen. Promoting denitrification in groundwater can be done by adding carbonaceous materials to the soil, creating an environment with low oxygen levels, supporting the growth of the bacteria responsible for denitrification [4]. At certain temperatures denitrification, can occur and for every 10 degrees Celsius increase the denitrification rate about doubles [4]. Temperatures of groundwater typically stays constant with minimal changes when depths reach thirty feet or greater below the surface [4]. Organic carbon is an important factor in denitrification. Since the bacteria responsible for denitrification are heterotopic, they need sources of organic carbon [4]. For these type of barriers, this carbon source is the woodchips, straw, or sawdust material [4]. These materials are inexpensive, specifically when available locally. Optimum pH for groundwater to be denitrified falls between 7 and 8.5, and most groundwater falls in this range [4]. The groundwater pH has not been observed to change from upstream to downstream of the barrier when tested [4]. This treatment method involves minimal maintenance, involving only periodic replacement of the carbon source which depends on the subsurface conditions and the type of carbon source used [4]. It has been found in long term studies that sand and sawdust barriers last for several years and have a service life expectancy of decades with minimal to no maintenance [4].

There are several advantages and disadvantages of these permeable reactive barriers for nitrate removal. This method is simplistic, little to no required operator attention, minimal required monitoring, lower capital costs and lower operation and maintenance costs than other treatment types, and there are no waste disposal issues [4]. The disadvantages include that while this type of treatment has been explored in several parts of the world, it is still experimental and there has not been an experience of it in applications of drinking water [4]. There is also the possibility that this method could increase total organic carbon and iron in groundwater and this system is only applicable for shallow aquifers at this point in time [4]. Subsurface biological denitrification through permeable reactive barriers can treat groundwater and has been used for nitrate removal, however applications for drinking water have yet to be proven and costs are still wary as this is an experimental process [4].

Summary

In conclusion, there are methods to treat groundwater contaminated with arsenic and nitrate through use of sustainable, low cost, low energy solutions. Arsenic can be removed through adsorption using ceramic membrane filters and metal oxides. Nitrate removal can be achieved through denitrification subsurface treatment using permeable reactive barriers. These discussed methods can achieve the objective to have a sustainable treatment process for groundwater.

References

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