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Review

Small-scale and household methods to remove arsenic from water for drinking purposes in Latin America

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ABSTRACT

Small-scale and household low-cost technologies to provide water free of arsenic for drinking purposes, suitable for isolated rural and periurban areas not connected to water networks in Latin America are described. Some of them are merely adaptation of conventional technologies already used at large and medium scale, but others are environmentally friendly emerging procedures that use local materials and resources of the affected zone. The technologies require simple and low-cost equipment that can be easily handled and maintained by the local population. The methods are based on the following processes: combination of coagulation/flocculation with adsorption, adsorption with geological and other low-cost natural materials, electrochemical technologies, biological methods including phytoremediation, use of zerovalent iron and photochemical processes. Examples of relevant research studies and developments in the region are given. In some cases, processes have been tested only at the laboratory level and there is not enough information about the costs. However, it is considered that the presented technologies constitute potential alternatives for arsenic removal in isolated rural and periurban localities of Latin America. Generation, handling and adequate disposal of residues should be taken into account in all cases.

Contents

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1. Introduction

Arsenic removal from waters to reach levels in accordance with the regulations for drinking water purposes (<10 μg L^{-1}, World Health Organization, 2004) is not an easy task. Particularly, for populations with low economical resources like those of many Latin American (LA) periurban and rural isolated communities, economical aspects are perhaps the most important factors for the selection of the technology, considering the size of the population, incidence of chronic illnesses, lack of safe water, poverty conditions, and other socioeconomic variables, including cultural and political issues, aspects that few times are taken into account.

The presence of arsenic in ground- and surface water used for drinking purposes can cause serious health problems, especially the incidence of HACRE (Hidroarsenicismo Crónico Regional Endémico in Spanish, Chronic Endemic Regional Hydroarsenicism), see McClintock et al., submitted for publication. Due to these health problems, it can be estimated that 14 million people out of the around 500 million living in LA are considered to be at risk in the LA regions. Taking into account the relevance of the problem, a large amount of scientific and technological work has been devoted in recent times to develop new economic, emergent technologies for arsenic remediation (Litter, 2002, 2006a, 2006b; Litter and Jiménez González, 2004; Litter and Mansilla, 2003; Bundschuh et al., 2010). As indicated there, efforts put to solve the problem at medium and large scale in several LA countries, i.e. those serving to more than 1000 people by centralized water networks, were successful, but only in very few cases the problem has been actually solved in isolated settlements (defined as those inhabited by less than 50 persons) or isolated houses (defined as those separated by some hundreds or thousands of meters), where centralized drinking water supply systems are absent. Although several novel simple technologies have been developed, in spite of the great health problems above mentioned, low attention by the local authorities or international agencies caused that alternative successful techniques still remain at the laboratory scale or have been tested only in few experiments in field (Cornejo et al., 2006b; de la Fuente et al., 2006). Practically no action has been implemented to ensure As-safe drinking water supplies in rural or periurban areas to accomplish the national regulations for As in drinking water, which in most of the LA countries match that of the World Health Organization (2004). A great effort should then be put to develop short-scale point-of-entry or point-of-use systems at household level appropriate for the conditions prevailing in these isolated communities (not connected to a central water supply system). Not only drinking water or water for food preparation needs to be remediated or replaced–which is only a few percent of the total domestic water consumption–but also that used for irrigation purposes should be treated, since As can contaminate the crops.

All technologies for As removal rely on a few basic chemical processes that can be applied alone, simultaneously or in sequence: oxidation/reduction, coagulation–filtration, precipitation, adsorption, ion exchange, solid/liquid separation, physical exclusion, membrane technologies, biological methods, etc. (Litter et al., 2010a, 2010c). As it is well known, most As removal technologies are efficient when the element is present in the pentavalent state, because it forms oxianions, mainly $H_2AsO_4^-$ and $HAsO_4^{2-}$, in a pH range of 2–12, while the trivalent form is uncharged at pH below 9.2 (H_3AsO_3). This is the reason why many As remediation methods use, previously to other processes, an oxidation step to oxidize As(III), if present, to As(V). However, oxidation without help of other physical or chemical transformations does not remove As from water and have to be followed by other processes. As it is obvious, boiling of water for purification does not remove As and, on the contrary, this process increases As concentration by evaporation. This is a fact commonly ignored by most of the potentially affected people.

In what follows, some small-scale technologies studied and applied in poor, isolated, decentralized rural and periurban populations of LA will be described. Some of these technologies are merely adaptation of conventional methods like coagulation–filtration, or adsorption, using very cheap materials, while other are based on novel technologies such as biological or photochemical processes. No references to studies or papers of other regions of the world will be made, but they can be consulted in several recent references on the subject (e.g., Höll and Litter, 2010; Litter et al., 2010a; Mohan and Pittman, 2007; Morgada and Litter, 2010; Ravenscroft et al., 2009).

It is important to emphasize that for the use of techniques, the population has to be trained for proper handling and disposal of the wastes, to prevent additional environmental or health risk.

2. Combined oxidation, adsorption, coagulation/flocculation methods

In LA, different technologies for single households were developed or adapted by scaling down and simplifying conventional methods used in water treatment plants for As removal, such as those described in Litter et al., 2008, 2010c. These methods use the oxidation, adsorption and coagulation sequence (Sastre et al., 1997; Esparza and Wong, 1998). Some examples follow.

A household scale low-cost As removal methodology was developed in Peru (Esparza, 2002; Esparza and Wong, 1998; Castro de Esparza et al., 2005; Castro de Esparza, 2010) using ALUFLOC, a