Arsenic exposure in drinking water: an unrecognized health threat in Peru

Christine Marie George,a Laura Sima,b M Helena Jahuira Arias,c Jana Mihalic,d Lilia Z Cabrera,e David Danz,f William Checkleya & Robert H Gilmana

Objective To assess the extent of arsenic contamination of groundwater and surface water in Peru and, to evaluate the accuracy of the Arsenic Econo-Quick™ (EQ) kit for measuring water arsenic concentrations in the field.

Methods Water samples were collected from 151 water sources in 12 districts of Peru, and arsenic concentrations were measured in the laboratory using inductively-coupled plasma mass spectrometry. The EQ field kit was validated by comparing a subset of 139 water samples analysed by laboratory measurements and the EQ kit.

Findings In 86% (96/111) of the groundwater samples, arsenic exceeded the 10 µg/l arsenic concentration guideline given by the World Health Organization (WHO) for drinking water. In 56% (62/111) of the samples, it exceeded the Bangladeshi threshold of 50 µg/l, the mean concentration being 54.5 µg/l (range: 0.1–93.1). In the Juliaca and Caracoto districts, in 96% (27/28) of groundwater samples arsenic was above the WHO guideline, and in water samples collected from the section of the Rimac river running through Lima, all had arsenic concentrations exceeding the WHO limit. When validated against laboratory values, the EQ kit correctly identified arsenic contamination relative to the guideline in 95% (106/111) of groundwater and in 68% (19/28) of surface water samples.

Conclusion In several districts of Peru, drinking water shows widespread arsenic contamination, exceeding the WHO arsenic guideline. This poses a public health threat requiring further investigation and action. For groundwater samples, the EQ kit performed well relative to the WHO arsenic limit and therefore could provide a vital tool for water arsenic surveillance.

Introduction

An estimated 200 million people worldwide are exposed to arsenic concentrations in drinking water that exceed the recommended limit of 10 µg/l as set out in the guidelines of the World Health Organization (WHO).1 The majority of this exposed population lives in southern Asian countries such as Bangladesh, Cambodia, India, Nepal and Viet Nam. In addition, elevated levels of arsenic have been found in several countries in Latin America, such as Argentina, Bolivia, Chile and Mexico. Recent estimates suggest that at least 4.5 million people in Latin America are exposed to arsenic levels higher than 50 µg/l – the Bangladeshi threshold.2 In Peru, the current national regulatory standards for arsenic in drinking water are based on WHO's recommended limit; however, little is known about the extent of arsenic contamination of the drinking water and about its health implications in the country.

Exposure to moderate to high (more than 50 µg/l) levels of arsenic in drinking water is associated with an increased risk of lung, bladder and skin cancer,3 as well as with numerous cardiovascular;4 neurological;5 skin lesion6 and respiratory diseases,7 and with increased all-cause mortality.8 Chronic exposure to arsenic is also associated with deficits in children's cognitive and motor functions.9

Arsenic contamination of drinking water can occur naturally or as a consequence of human activities such as mining. Natural sources of arsenic in Peru are mainly enargite-bearing copper, zinc and lead deposits. Historically, Peru, together with China, France, Germany, Mexico and the former Soviet Union have been among the main global producers of arsenic, used primarily in insecticide and pesticide production.10 Peru is also a world leader in gold, silver and copper production.11 It has been estimated that about 1.6 million people in the country live within 5 km of active or historical mining operations.12

A study performed in the Rimac river basin showed that mine tailings resulted in elevated arsenic, copper and lead concentrations in the river and its tributaries.13 Consistent with this finding, elevated arsenic in drinking water was also found in La Oroya, a small industrial town that had a smelter for processing copper, zinc and lead.14 Despite the scientific evidence that mining activities could be damaging to human health, there are no systematic environmental surveillance studies with thorough data collection for most areas of the country where mining takes place.

Kits such as the Arsenic Econo-Quick™ (EQ) kit (Industrial Test Systems, Inc., Rock Hill, United States of America), the Digital Arsenator (Wagtech WTD, Gateshead, England) and the EZ kit (Hach Co., Loveland, USA)15–19 have already been assessed for measuring arsenic concentrations in groundwater. However, an evaluation of the accuracy of these kits for measuring arsenic in surface water has not been published yet. These kits have been used almost exclusively in the United States and Asia.

We selected the EQ kit for this study because it has a shorter reaction period (12 minutes compared with 20–40 minutes for the Hach EZ kit, and 40 minutes for the Digital

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Abstracts in العربية, 中文, Français, Русский and Español at the end of each article.
Arsenic exposure through drinking water in Peru

Christine Marie George et al.

Research

There is only one study available to date that has evaluated the accuracy of this kit by comparing results with those obtained in the laboratory (the gold standard). Therefore, further validation of the kit is still required.

The objectives of the field study reported here were to measure arsenic concentrations in drinking water in areas of Peru with historical or current mining activities and to test the accuracy of the EQ kit for measuring arsenic concentrations both in groundwater and in surface water.

Methods

Samples of water were taken in 12 districts—Achaya, Ananea, Caracoto, Chuçuito, Crucero, Juliaca, La Oroya, Lima, Platería, Puno, San Antón and Taraco—between August and October 2012. With the exception of Lima, all these districts are located in regions with historical or current mining. Water samples from a total of 151 sources (groundwater and surface water) were collected by a local team of field research assistants. Surface water samples were collected from rivers, springs and municipal piped water, whereas all groundwater samples came from household drinking water sources.

All sources were analysed using the gold standard—inductively-coupled plasma mass spectrometer (ICP-MS) analysis—and 139 of these were tested using the EQ kit (serial #481298). The field team received one day's intensive training on how to use the EQ kit to test the arsenic content of the water. For analysis with the EQ kit, water samples were collected in 50-ml reaction bottles—which were used for the test—while 20-ml scintillation vials were selected to collect the samples for ICP-MS analysis.

Detection of arsenic

Field testing kit

The EQ kit measures water arsenic concentrations between 0 and 1000 µg/l in a 12-minute reaction. This kit uses a series of reagents including zinc powder and tartaric acid that are added to the reaction bottle containing 50 ml of the water sample. If arsenic is present in the water, the reaction produces arsine gas which reacts with a reaction strip containing mercuric bromide present in the bottle. This results in a coloured end product ranging from light yellow to brown. The colour of the reaction strip is then compared to the reference scale given by the manufacturer.

Inductively-coupled plasma mass spectrometry

All water samples collected were prepared by vortexing followed by acidification with 1:1 optima grade nitric acid (HNO₃) solution (Fisher Scientific, Columbia, USA) and allowed to digest at room temperature for 48 hours. Before ICP-MS analysis, the sample was diluted 1:20 with 1% HNO₃ and 0.5% hydrochloric acid (Fisher Scientific, Columbia, USA). For quality control, an additional 10% of samples, which comprised a standard reference containing trace elements in water (1643e, National Institute of Standards and Technologies, Rockville, USA) and reagent blanks, were also analysed according to the sample preparation method described above. An internal standard was added to all samples analysed to normalize the instrument’s detector counts to an absolute scale and to correct for any signal drift of the instrument.

Arsenic was detected by using an Agilent 7500ce ICP-MS (Agilent Technologies, Santa Clara, USA). Sample analysis was conducted in helium mode to reduce polyatomic interferences. Sample values were corrected for background, recovery of the standard

Table 1. Arsenic concentrations, by district and source type, Peru, 2012

<table>
<thead>
<tr>
<th>District</th>
<th>Community</th>
<th>Source type</th>
<th>No. of samples</th>
<th>Mean arsenic concentration, µg/l (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achaya</td>
<td>Achaya</td>
<td>Groundwater</td>
<td>1</td>
<td>4.6</td>
</tr>
<tr>
<td>Calapuja river</td>
<td>River</td>
<td></td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>Ramis river</td>
<td>River</td>
<td></td>
<td>3</td>
<td>16.9 (7.1–31.5)</td>
</tr>
<tr>
<td>Chuquillana</td>
<td>Groundwater</td>
<td></td>
<td>2</td>
<td>2.9 (2.1–3.8)</td>
</tr>
<tr>
<td>Lluncha</td>
<td>Groundwater</td>
<td></td>
<td>2</td>
<td>1.7 (0.1–3.4)</td>
</tr>
<tr>
<td>Ananea</td>
<td>Groundwater</td>
<td></td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Caracoto</td>
<td>Caracoto</td>
<td>Groundwater</td>
<td>20</td>
<td>67.0 (31.9–113.1)</td>
</tr>
<tr>
<td>Caracoto</td>
<td>Municipal water supply</td>
<td>1</td>
<td>4.25</td>
<td></td>
</tr>
<tr>
<td>Chuçuito</td>
<td>La Raya</td>
<td>Municipal water supply</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Crucero</td>
<td>Crucero</td>
<td>Municipal water supply</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Juliaca</td>
<td>Néstor Cáceres Velázquez</td>
<td>Groundwater</td>
<td>27</td>
<td>51.7 (1.6–154.8)</td>
</tr>
<tr>
<td>Sector Palca Pampa Taparachi</td>
<td>Groundwater</td>
<td>48</td>
<td>62.0 (1.2–193.1)</td>
<td></td>
</tr>
<tr>
<td>La Oroya</td>
<td>La Oroya</td>
<td>Municipal water supply</td>
<td>1</td>
<td>7.1</td>
</tr>
<tr>
<td>La Oroya</td>
<td>River</td>
<td></td>
<td>5</td>
<td>7.7 (2.2–13.3)</td>
</tr>
<tr>
<td>Yauli</td>
<td>Municipal water supply</td>
<td>2</td>
<td>7.2 (4.3–10.1)</td>
<td></td>
</tr>
<tr>
<td>Yauli</td>
<td>Stream</td>
<td></td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Lima</td>
<td>Oasis</td>
<td>Municipal water supply</td>
<td>3</td>
<td>2.5 (0.9–4.2)</td>
</tr>
<tr>
<td>Pampas</td>
<td>Municipal water supply</td>
<td>2</td>
<td>3.5 (3.3–3.6)</td>
<td></td>
</tr>
<tr>
<td>Rimac river</td>
<td>River</td>
<td></td>
<td>14</td>
<td>21.7 (14.6–42.5)</td>
</tr>
<tr>
<td>Platería</td>
<td>Potojani Chico</td>
<td>Groundwater</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Puno</td>
<td>Collacachi</td>
<td>Spring</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Collacachi</td>
<td>River</td>
<td></td>
<td>1</td>
<td>5.8</td>
</tr>
<tr>
<td>Collacachi</td>
<td>Groundwater</td>
<td></td>
<td>2</td>
<td>1.65 (0.3–3.0)</td>
</tr>
<tr>
<td>Mi Perú</td>
<td>Spring</td>
<td></td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Mi Perú</td>
<td>Groundwater</td>
<td></td>
<td>1</td>
<td>0.82</td>
</tr>
<tr>
<td>San Antón</td>
<td>San Antón</td>
<td>Groundwater</td>
<td>2</td>
<td>52.5 (45.6–59.4)</td>
</tr>
<tr>
<td>Taraco</td>
<td>Ramis</td>
<td>Groundwater</td>
<td>3</td>
<td>29.6 (9.6–63.0)</td>
</tr>
<tr>
<td>Ramis</td>
<td>River</td>
<td></td>
<td>2</td>
<td>7.5 (1.4–13.6)</td>
</tr>
</tbody>
</table>

reference material and, analytical limit of detection (LOD). The analytical LOD, calculated as three times the standard deviation (SD) of the lowest detectable calibration standard (1 µg/l), was determined to be 0.136 µg/l. For values below LOD, a value of 0.5 LOD (0.068 µg/l) was assigned to the samples.

**Statistical methods**

A computerized data analysis system, SAS software version 9.3 (SAS Institute Inc., Cary, NC, USA), was used to perform the statistical analysis.

**Results**

**Arsenic concentrations in water samples**

A total of 151 water samples were included in the present study (Table 1); 111 samples were obtained from groundwater and 40 from surface water. Of surface water samples, 29 were taken from untreated water sources and 11 from treated municipal water. A total of 116 samples (77%) contained arsenic in excess of WHO’s 10 µg/l recommended limit and 62 (41%) had arsenic in excess of 50 µg/l.

Of the 111 groundwater samples, 96 (86%) had arsenic in excess of 10 µg/l; 62 (56%) had arsenic in excess of 50 µg/l. The arsenic concentrations measured by ICP-MS ranged from 0.1 to 193.1 µg/l (mean: 54.5 µg/l; SD: 36.2 µg/l).

Of the 40 surface water samples, 20 (50%) had arsenic concentrations in excess of 10 µg/l (mean: 12.2 µg/l; range: 0.1–42.5; SD: 11.1 µg/l).

**Mapping of study sites**

Figures 1–3 depict the geographic coordinates for all the water sampling sites in Peru, a previously published data set of 113 active mines, 138 ore-processing plants, 3 smelters, and 7743 former mining sites (compiled by van Geen et al.).

**Arsenic concentrations by district**

Table 1 summarizes the results obtained for each of the 12 districts surveyed; the arsenic concentrations were measured in the laboratory using ICP-MS. The highest concentrations were found in wells in Juliaca (range: 1.2–193.1 µg/l). High levels were also detected in wells in Caracoto (range: 31.9–113.1 µg/l). The 14 surface water samples collected from the section of the Rímac river running through Lima were found to have arsenic levels between 14.6 and 42.5 µg/l (mean: 21.7 µg/l; SD: 5.0 µg/l).

**Arsenic Econo-Quick kit performance**

When the results were classified as arsenic concentrations above or below WHO guideline of 10 µg/l, the EQ kit correctly determined 90% (125/139) of the water samples collected compared to ICP-MS measurements as the gold standard. When samples were divided by source
type, 95% (106/111) of groundwater samples and 68% (19/28) of surface water samples were correctly identified by the kit as having arsenic levels above or below the WHO recommended limit. The kit correctly determined that the arsenic status of 75% (104/139) of water sources sampled were above or below the Bangladeshi standard of 50 µg/l. When samples were divided by source type, 69% (77/111) of groundwater samples and 96% (27/28) of surface water samples were correctly identified by the kit as having arsenic below or above the Bangladeshi standard.

Most of the misclassifications were above the WHO arsenic guideline. There were two groundwater samples and eight surface water samples classified above the limit when the actual ICP-MS measurements were close to the threshold (49–61 µg/l).

**Discussion**

All of the wells tested in Caracoto and 95% of those tested in Juliaca exceeded WHO’s recommended limit of 10 µg/l for arsenic. In spite of this, all the wells were being used as a source of drinking water by local families, who reported being unaware of the high arsenic concentrations. These findings point to an alarming public health threat in Peru that calls for immediate attention and resolution. Research is urgently needed to identify all relevant sources of arsenic contamination of the water in Peru.

All water samples collected from the section of the Rimac river that runs through Lima had arsenic in excess of the WHO recommended limit, in some cases as much as four times higher. A survey conducted in 2005 showed that upstream sections of the Rimac river basin that were adjacent to mine tailings had arsenic levels as high as 31 µg/l.

In addition, geographic information systems data indicate that a smelter, a refinery and a legacy mine are located on the Rimac river approximately 8 km upstream from our first sampling points. Lima also has many manufacturing outlets along the same river. All these factors may be contributing to the elevated arsenic levels and should be further investigated.

Rural communities are disproportionately affected by arsenic contamination, as they usually use decentralized drinking water, often unregulated, and many depend mainly on groundwater. Portable arsenic test kits such as the EQ kit could provide a low-cost and easy-to-use rapid method of arsenic testing in rural settings to identify if water sources are...
The EQ kit correctly identified most water sources as safe or unsafe relative to the recommended limit from WHO. When samples were divided by source type, the performance of the kit for measuring arsenic in groundwater relative to the WHO guideline was higher than observed in a previous study (95% versus 89%). Furthermore, in the present study the performance of the EQ kit relative to the WHO guideline was comparable to that of other commonly used field arsenic test kits on the market. In a previous study, 93 to 95% of the wells tested were correctly classified by the Hach EZ kit against the WHO recommended limit, and 83 to 90% of the wells were correctly classified by the Digital Arsenator. However, these kits have a longer reaction time, compared with the EQ kit. The EQ kit correctly determined the arsenic status of 75% of the water samples tested relative to the Bangladeshi standard; in a previous study, the same kit correctly determined the arsenic status of 92% of the samples. This large difference may be a reflection of the large proportion — close to 40% — of groundwater samples that came within 10 µg/l of the arsenic cut-off of 50 µg/l based on ICP-MS measurements. This finding suggests that this colorimetric kit is not capable of correctly classifying water samples that are very close to the Bangladeshi arsenic standard. However, a growing body of scientific literature demonstrates that water arsenic concentrations below 50 µg/l can cause harmful health effects. Therefore, we doubt that the inability to correctly classify water sources at an arsenic concentration more than five times higher than the WHO arsenic guideline will be a major barrier to the kit’s use as a surveillance tool.

In Peru, the Ministry of Health is responsible for national drinking water quality. However, no systematic attempts have been made to conduct countrywide arsenic surveillance or mitigation. The country has only one arsenic treatment plant. It was established in 1982 in the city of Ilo, in an area with high levels of natural arsenic from volcanic rock formations. The Pan American Center for Sanitary Engineering and Environmental Sciences, in Peru, has developed a household-level coagulant using aluminium sulfate and ferric chloride, called ALUFLOC, to remove natural arsenic in groundwater. But the extent of use of this product in Peru is unknown.

A national policy for arsenic surveillance and mitigation is therefore urgently needed in Peru. The EQ kit represents a low-cost method for identifying arsenic contamination in groundwater (0.17–0.60 United States dollars) and it is fast and easy to use. Therefore, this kit could be a useful surveillance tool for the quick detection of arsenic contamination in groundwater.

In Bangladesh, where an estimated 45 million people are exposed to very high arsenic concentrations in drinking water, the Department of Public Health Engineering undertook a countrywide water-arsenic-testing campaign from 1999 to 2005, in collaboration with the World Bank. Through this programme they tested almost 5 million wells using field arsenic test kits. A similar approach should be effective in Peru, at least in the initial phases of the programme. Water should
Arsenic exposure through drinking water in Peru
Christine Marie George et al.

MLTT

In the present study we report widespread arsenic contamination of the groundwater used for drinking in 12 districts of Peru, including Juliaca and Caracoto. Our findings reveal an alarming public health threat that needs to be addressed immediately. Equally alarming are the arsenic concentrations found in the section of the Rímac river that flows through Lima. These study findings demonstrate the prevalence of high arsenic concentrations in drinking water that remain unrecognized and that endanger the health of the population. To our knowledge, no systematic attempts have been made to conduct arsenic surveillance or mitigation countrywide. The EQ kit used for our study performed well. This is consistent with the findings of previous studies in Bangladesh. Therefore, the EQ kit could become a significant surveillance tool for the rapid identification of arsenic contamination of drinking water.

Competing interests: None declared.

Summary

In the present study we report widespread arsenic contamination of the groundwater used for drinking in 12 districts of Peru, including Juliaca and Caracoto. Our findings reveal an alarming public health threat that needs to be addressed immediately. Equally alarming are the arsenic concentrations found in the section of the Rímac river that flows through Lima. These study findings demonstrate the prevalence of high arsenic concentrations in drinking water that remain unrecognized and that endanger the health of the population. To our knowledge, no systematic attempts have been made to conduct arsenic surveillance or mitigation countrywide. The EQ kit used for our study performed well. This is consistent with the findings of previous studies in Bangladesh. Therefore, the EQ kit could become a significant surveillance tool for the rapid identification of arsenic contamination of drinking water.

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Arsenic exposure through drinking water in Peru

Christine Marie George et al.

Resumen

Exposición al arsénico en el agua potable: una amenaza inadvertida para la salud en Perú

Objetivo Evaluar el grado de contaminación por arsénico de las aguas subterráneas y superficiales en Perú, así como la precisión del kit Arsenic Econo-Quick™ (EQ) para la medición de concentraciones de arsénico del agua en el campo.

Métodos Se recogieron muestras de agua de 151 suministros de agua en 12 distritos de Perú, y se midieron las concentraciones de arsénico en el laboratorio por medio de una espectrometría de masas de plasma con acoplamiento inductivo. El kit de campo EQ se validó mediante la comparación de un subconjunto de 139 muestras de agua analizadas por mediciones de laboratorio y el kit EQ.

Resultados En el 86% (96/111) de las muestras de agua subterránea, el arsénico superó el límite de 10 mg/l de la concentración de arsénico establecida por la Organización Mundial de la Salud (OMS) para el agua potable. El 56% (62/111) de las muestras superó el umbral de Bangladesh de 50 mg/l; la concentración media era de 54,5 mg/l (diapason: 0,1-93,1). En los distritos de Julica y Caracoto, el 96% (27/28) de las muestras de agua subterránea presentaban las concentraciones de arsénico superiores a la concentración máxima permitida por la OMS en 95% (106/111) de las muestras de agua subterránea y en 68% (19/28) de las muestras de agua de superficie. La concentración media de arsénico en las muestras de agua subterránea fue de 54,5 mg/l, similar al nivel máximo permitido en Bangladesh (50 mg/l) y en la recomendación de la OMS (10 mg/l).

Conclusión De los resultados obtenidos, se puede concluir que el arsénico es una amenaza para el sistema de bebedero en Perú, con niveles superiores a los máximos permitidos en la mayoría de los casos. El kit EQ es un herramienta valiosa para la detección de arsénico en el campo, pero es necesario que se realicen investigaciones adicionales para establecer normativas más estrictas y medidas preventivas.

Résumé

Exposition à l’arsenic dans l’eau potable: une menace méconnue pour la santé au Pérou

Objectif Évaluer l’ampleur de la contamination par l’arsenic des eaux souterraines et des eaux de surface au Pérou et évaluer la précision du kit Arsenic Econo-Quick™ (EQ) pour mesurer les concentrations d’arsenic dans l’eau sur le terrain.

Méthodes Des échantillons d’eau ont été prélevés à partir de 151 sources d’eau dans 12 districts du Pérou, et les concentrations en arsenic ont été mesurées en laboratoire à l’aide de la spectrométrie de masse à plasma à couplage inductif. Les kits EQ utilisés sur le terrain ont été validés en comparant un sous-ensemble de 139 échantillons d’eau analysés par des mesures en laboratoire et le kit EQ.

Résultats Dans 86% (96/111) des échantillons d’eau souterraine, la concentration en arsenic était supérieure à la directive de l’Organisation mondiale de la Santé (OMS) de 10 µg/l pour l’eau potable. Dans 56% (62/111) des échantillons, elle dépassait la norme bangladaise de 50 µg/l. La concentration moyenne était de 54,5 µg/l (plage: 0,1-93,1). Dans les districts de Julica et Caracoto, 96% (27/28) des échantillons d’eau souterraine présentaient des concentrations en arsenic supérieures aux recommandations de l’OMS, et tous les échantillons d’eau prélevés dans la section de la rivière Rimac traversant Lima présentaient des concentrations en arsenic supérieures à la limite fixée par l’OMS. Lorsque les kits EQ ont été validés avec les valeurs obtenues en laboratoire, ils ont correctement identifié la contamination par l’arsenic par rapport à la recommandation des échantillons d’eau souterraine et dans 68% (19/28) des échantillons d’eau de surface.

Conclusion Dans plusieurs districts du Pérou, l’eau potable présente une contamination généralisée par l’arsenic, supérieure à la recommandation de l’OMS en ce qui concerne l’arsenic. Cela constitue une menace pour la santé publique, nécessitant des études approfondies et des mesures supplémentaires. Le kit EQ a obtenu de bons résultats pour les échantillons d’eau souterraine par rapport aux limites pour l’arsenic fixées par l’OMS, et il pourrait donc fournir un outil vital pour surveiller la présence d’arsenic dans l’eau.
muestras de agua recogidas en la sección del río Rímac, que atraviesa Lima, tenían concentraciones de arsénico superiores al límite establecido por la OMS y supone una amenaza para la salud pública que requiere mayor investigación y acción. Para las muestras de agua subterránea, el kit EQ ofreció buenos resultados en relación con el límite de arsénico de la OMS y, por tanto, podría ser una herramienta esencial para el control del arsénico en el agua.

**Conclusión** En varios distritos de Perú, el agua potable muestra una contaminación por arsénico generalizada que supera el límite de arsénico establecido por la OMS y supone una amenaza para la salud pública que requiere mayor investigación y acción. Para las muestras de agua subterránea, el kit EQ ofreció buenos resultados en relación con el límite de arsénico de la OMS y, por tanto, podría ser una herramienta esencial para el control del arsénico en el agua.

**Referencias**


