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

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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 Rímac 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.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

An estimated 200 million people worldwide are exposed to arsenic concentrations in drinking water that exceed the recommended limit of 10 µg/l[1] as set out in the guidelines of the World Health Organization (WHO).[2] 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.[3] In Peru, the current national regulatory standards for arsenic in drinking water are based on WHO's recommended limit;[4] 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,[5] as well as with numerous cardiovascular,[6] neurological,[7] skin lesion[8] and respiratory diseases,[9] and with increased all-cause mortality.[10] Chronic exposure to arsenic is also associated with deficits in children's cognitive and motor functions.[11]

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.[12] Peru is also a world leader in gold, silver and copper production.[13] It has been estimated that about 1.6 million people in the country live within 5 km of active or historical mining operations.[14]

A study performed in the Rímac river basin showed that mine tailings resulted in elevated arsenic, copper and lead concentrations in the river and its tributaries.[15] 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.[16] 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)[17–19] 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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Arsenator).[18,19] 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).[19] 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, Chucuito, 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.[14] 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.

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

District	Community	Source type	No. of samples	Mean arsenic concentration, µg/l (range)
Achaya	Achaya	Groundwater	1	4.6
	Calapuja river	River	1	34
	Ramis river	River	3	16.9 (7.1–31.5)
	Chuquillana	Groundwater	2	2.9 (2.1–3.8)
	Lluncha	Groundwater	2	1.7 (0.1–3.4)
Ananea	Ananea	Groundwater	1	0.1
Caracoto	Caracoto	Groundwater	20	67.0 (31.9–113.1)
	Caracoto	Municipal water supply	1	4.25
Chucuito	La Raya	Municipal water supply	1	0.1
Crucero	Crucero	Municipal water supply	1	0.1
Juliaca	Néstor Cáceres Velázquez	Groundwater	27	51.7 (1.6–154.8)
	Sector Palca Pampa	Groundwater	1	150
	Taparachi	Groundwater	48	62.0 (1.2–193.1)
La Oroya	La Oroya	Municipal water supply	1	7.1
	La Oroya	River	5	7.7 (2.2–13.3)
	Yauli	Municipal water supply	2	7.2 (4.3–10.1)
	Yauli	Stream	1	0.1
Lima	Oasis	Municipal water supply	3	2.5 (0.9–4.2)
	Pampas	Municipal water supply	2	3.5 (3.3–3.6)
	Rímac river	River	14	21.7 (14.6–42.5)
Platería	Potojani Chico	Groundwater	1	0.1
Puno	Collacachi	Spring	1	0.9
	Collacachi	River	1	5.8
	Collacachi	Groundwater	2	1.65 (0.3–3.0)
	Mi Perú	Spring	1	0.1
	Mi Perú	Groundwater	1	0.82
San Antón	San Antón	Groundwater	2	52.5 (45.6–59.4)
Taraco	Ramis	Groundwater	3	29.6 (9.6–63.0)
	Ramis	River	2	7.5 (1.4–13.6)

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 (HNO_3) 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% HNO_3 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 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.).[14] Fig. 1 summarizes the location of water sampling sites around the country. Fig. 2 is a map of the water sampling sites in the Rímac river basin, including the section of the river that runs through Lima.[15] Fig. 3 shows the average arsenic concentrations measured in the districts of Achaya, Ananea, Caracoto, Juliaca, La Oroya, Platería, Puno, San Antón and Taraco.

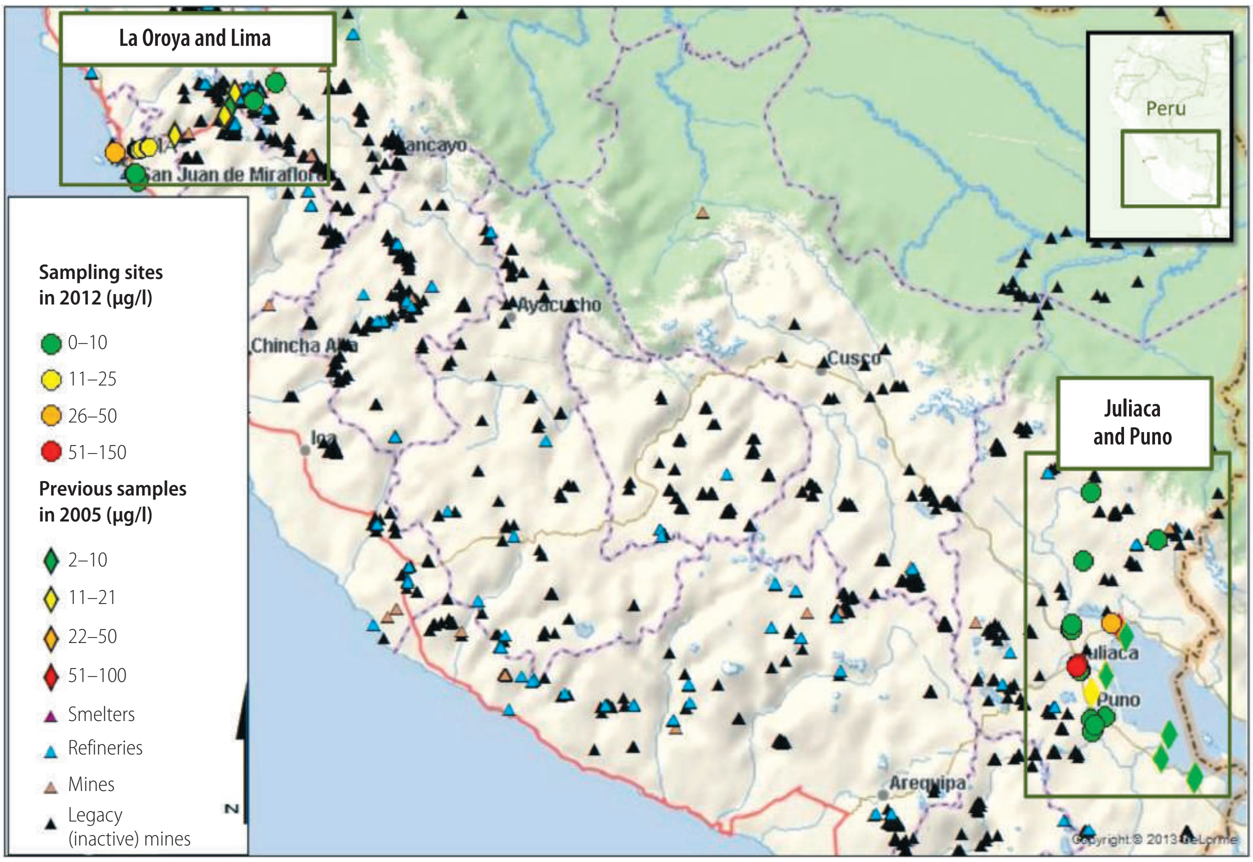
Arsenic concentrations by district

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

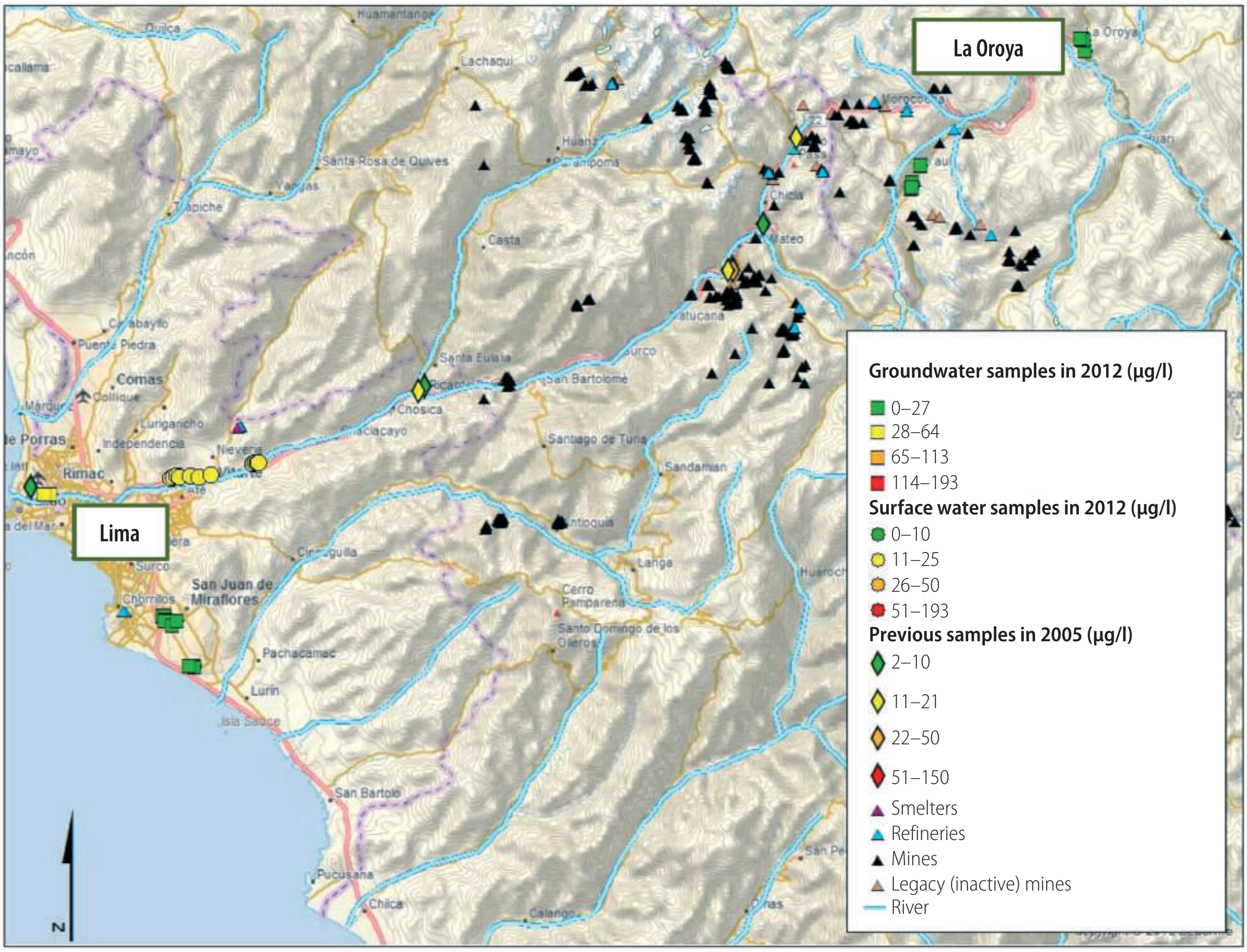
When the results were classified as arsenic concentrations above or below WHO guideline of 10 µg/l, the EQ kit correctly determined 90% (125/139) of the water samples collected compared to ICP-MS measurements as the gold standard. When samples were divided by source

Fig. 1. **Water sampling sites and arsenic concentrations in 2005 and 2012, and mining-related activities in Peru**



Map adapted (including addition of water shapefile map by OpenStreetMaps) and reproduced with permission of DeLorme. © 2014 DeLorme (www.delorme.com) DeLorme World Base Map.

Fig. 2. **Water sampling sites and arsenic concentrations in 2005 and 2012, and mining-related activities for the Rímac river basin in Peru**



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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 of these samples were reported within the 0–10 μg/l range. Relative to the Bangladeshi arsenic standard, 40% of the EQ kit misclassifications below or above this standard were when actual ICP-MS measurements were close to the threshold (49–61 μg/l).

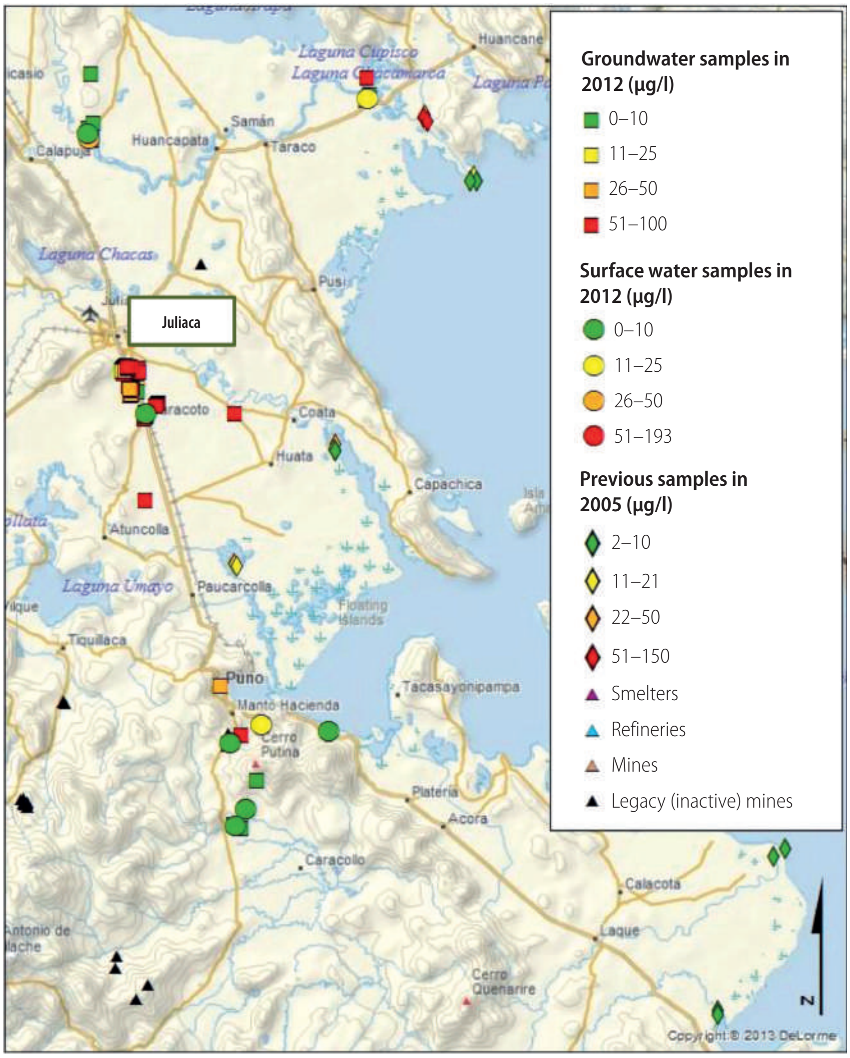
Discussion

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 Rímac 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 Rímac river basin that were adjacent to mine tailings had arsenic levels as high as 31 μg/l.[15] In addition, geographic information systems data indicate that a smelter, a refinery and a legacy mine are located on the Rímac 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 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

Fig. 3. **Water sampling sites and arsenic concentrations in 2005 and 2012, and mining-related activities for Achaya, Ananea, Caracoto, Juliaca, Platería, Puno, San Antón and Taraco districts in Peru**



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above or below WHO's arsenic recommended limit.

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%).[19] 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.[19] 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.[19] 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.[9,20] 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.

This study represents the first evaluation of the EQ kit for measuring arsenic in surface water. The percentage of surface water samples correctly identified against the WHO recommend limit was only 68%, which suggests that this kit cannot be used to accurately measure arsenic in surface water. However, future studies should analyse a larger number of surface water samples in a broader range of arsenic concentrations using the EQ kit.

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.[21] The Pan American Center for Sanitary Engineering and Environmental Sciences, in Peru, has developed a household-level coagulant using aluminium sulfite and ferric chloride, called ALUFLOC, to remove natural arsenic in groundwater.[22,23] 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,[24] 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.[25]

A similar approach should be effective in Peru, at least in the initial phases of the programme. Water should be tested monthly to assess the variability of arsenic concentrations over time. Furthermore, smart phones with a global positioning system application should be used to collect surveillance data. More detailed information should also be collected on well depth, to determine whether there is any correlation with arsenic concentrations in the water. This type of programme may also provide an opportunity for the surveillance of arsenic-induced skin lesions and for information to be disseminated on the health implications of arsenic. All collected information should be compiled into a national water arsenic database that can be used by the government for strategic planning and arsenic mitigation.

Potential mitigation options in Peru could include well switching, arsenic removal devices for household or community use, large-scale surface water treatment and rainwater harvesting. Well switching has been the most commonly used arsenic mitigation strategy in Bangladesh; it might be a good option for Peru as well, because of the heterogeneous distribution of arsenic in well water detected in the present study. However, the social acceptability of using a communal or neighbourhood drinking water source has to be investigated.[26] Barriers to the widespread use of arsenic removal devices in arsenic-affected countries have been related mainly to inadequate equipment maintenance, frequent clogging of the filters, difficult waste disposal, and procedures that are not user friendly.[27]

The present study design has several limitations. First, water sampling was restricted to areas with known current or historical mining. Second, sampling was not equally distributed over the entire study area. Third, budgetary constraints allowed us to collect only a small number of samples. Finally, this study can only point to sites where arsenic contamination exists, but not to the actual sources of the contamination.

Conclusion

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.[28] Equally alarming are the arsenic concentrations found in the section of the Rímac river that flows through Lima. These study findings demonstrate the presence 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.

ملخص

التعرض للزرنيخ في مياه الشرب: تهديد صحي غير معترف به في بيرو

الغرض تقييم حجم تلوث المياه الجوفية والمياه السطحية بالزرنيخ في بيرو، وتقييم دقة مجموعة أدوات Arsenic Econo-Quick™ (EQ)) بغرض قياس تركيزات الزرنيخ في المياه في هذا المجال.

الطريقة تم جمع عينات مياه من 151 مصدراً مائياً في 12 منطقة في بيرو، وتم قياس تركيزات الزرنيخ في المختبر باستخدام قياس طيف كتلة البلازما المقترنة حثياً. وتم التحقق من مجموعة أدوات EQ الميدانية عن طريق مقارنة فئة فرعية من 139 عينة مياه تم تحليلها باستخدام القياسات المختبرية ومجموعة أدوات EQ.

النتائج تجاوز الزرنيخ في 86 ٪ (111/96) من عينات المياه الجوفية القيمة الإرشادية لتركيز الزرنيخ في مياه الشرب المقدمة من منظمة الصحة العالمية وهي 10 ميكروغرام/ لتر. وتجاوز في 56 ٪ (111/62) من العينات عتبة بنغلاديش التي تبلغ 50 ميكروغرام/ لتر؛ وكان متوسط التركيز 54.5 ميكروغرام/ لتر (النطاق: 0.1–93.1). وتجاوز الزرنيخ في 96 ٪ (27/ 28) من عينات المياه الجوفية في منطقتي جولياكا وكاراكوتو، وفي عينات المياه التي تم جمعها من رافد نهر ريماك الذي يمر عبر ليما، القيمة الإرشادية لمنظمة الصحة العالمية، وتجاوزت تركيزات الزرنيخ في كل هذه المناطق الحد المقدم من منظمة الصحة العالمية. وحددت مجموعة أدوات EQ بشكل صحيح تركيزات الزرنيخ ذات الصلة بالقيمة الإرشادية في 95 ٪ (111/106) من عينات المياه الجوفية وفي 68 ٪ (19/ 28) من عينات المياه السطحية عندما تم التحقق منها وفق القيم المختبرية.

الاستنتاج تشير مياه الشرب في العديد من المناطق في بيرو إلى تلوثها بالزرنيخ على نطاق واسع، مع تجاوز القيمة الإرشادية للزرنيخ المقدمة من منظمة الصحة العالمية. ويفرض هذا الأمر تهديداً على الصحة العمومية بما يتطلب بذل المزيد من التحري والعمل. وأثبتت مجموعة أدوات EQ كفاءتها فيما يتصل بحد الزرنيخ المقدم من منظمة الصحة العالمية ومن ثم يمكن أن توفر أداة حيوية لترصد الزرنيخ في المياه.

摘要

饮用水的砷暴露：秘鲁一个不为人知的健康威胁

目的 评估秘鲁地下水和地表水砷污染的程度，评价 Arsenic Econo-Quick ™（EQ）试剂盒测量野外水砷浓度的准确度。

方法 从秘鲁 12 个区的 151 个水源收集水样，在实验室使用电感耦合等离子体质谱法测量砷的浓度。比较由实验室和 EQ 试剂盒分析的 139 份水样的子集，对 EQ 野外试剂盒进行验证。

结果 在 86%（96/111）地下水样本中，砷含量超过世界卫生组织（WHO）规定的饮用水 10 μ g/L 的砷浓度指标。有 56%（62/111）的样本超过孟加拉国 50 μ g/L 的阈值；平均浓度为 54.5 μ g/L（范围：0.1 – 93.1）。在胡利亚卡（Juliaca）和卡拉克土（Caracoto）区，96%（27/28）的地下水样本砷含量超过 WHO 指标；在流经利马的里马克（R í mac）河流域的水样中，所

有砷含量都超过 WHO 限值。在对照实验室值进行验证时，EQ 试剂盒正确地识别 95%（106/111）的地下水和 68%（19/28）的地表水样本相对于指标的砷污染。**结论** 在秘鲁的多个区域，饮用水出现大范围超过 WHO 砷指标的砷污染，这构成了一种公共卫生威胁，需要进一步调查和行动。对于地下水样本，EQ 试剂盒相对于 WHO 砷限值性能良好，因此可以作为水砷监控的重要工具。

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 Juliaca 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 Rímac 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 dans 95% (106/111) 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.

Резюме

Попадание мышьяка в питьевую воду — непризнанная угроза здоровью населения Перу

Цель Оценить масштабы загрязнения мышьяком подземных и поверхностных вод в Перу, а также точность системы Arsenic Econo-Quick ™ TM (EQ), предназначенной для измерения концентрации мышьяка в воде в полевых условиях.

Методы Из 151 источников водоснабжения в 12 районах Перу были отобраны пробы воды для измерения концентрации мышьяка в лаборатории методом масс-спектрометрии с индуктивно связанной плазмой. Точность полевой системы EQ была проверена путем сравнения результатов лабораторного анализа 139 проб воды с измерениями, проведенными с помощью системы EQ.

Результаты В 86% (96/111) проб подземных вод концентрация мышьяка превышала 10 мкг/л — максимально допустимый уровень, установленный Всемирной организацией здравоохранения для питьевой воды. В 56% (62/111) образцов содержание мышьяка превысило 50 мкг/л — максимально допустимый уровень, принятый в Бангладеш; при этом среднее содержание мышьяка составило 54,5 мкг/л (диапазон: 0,1-93,1). В районах Джалиака и Каракото в 96% (27/28) проб подземных вод содержание мышьяка превышало рекомендации ВОЗ. Все пробы воды, отобранные из участка реки Римак в районе Лимы, также содержали концентрации мышьяка, превышающие установленное ВОЗ предельное значение. Результаты сравнения тестов системы EQ с лабораторными исследованиями показали, что прибор правильно определил концентрации мышьяка относительно максимально допустимых в 95% (106/111) проб подземных вод и в 68% (19/28) проб поверхностных вод.

Вывод Анализы питьевой воды в нескольких районах Перу показывают широкое распространение загрязнения мышьяком, превышающее максимально допустимые уровни, установленные ВОЗ. Это создает опасность для здоровья населения, требующую дальнейшего изучения и принятия мер. Система EQ хорошо зарекомендовала себя при контроле максимально допустимых уровней содержания мышьяка, определенных ВОЗ, в пробах подземных вод, и, следовательно, может быть использована в качестве важного инструмента для наблюдения за содержанием мышьяка в воде.

Resumen

Exposición al arsénico en el agua potable: una gran 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 establecido 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 (rango: 0,1 a 93,1). En los distritos de Juliaca y Caracoto, en el 96% (27/28) de las muestras de agua subterránea la concentración de arsénico superaba el límite establecido por la OMS. Asimismo, todas las muestras de agua recogidas en la sección del río Rímac, que atraviesa Lima, tenían concentraciones de arsénico superiores al límite de la OMS. Al validarlo en comparación con los valores de laboratorio, el kit EQ identificó de forma correcta contaminación por arsénico respecto al límite en el 95% (106/111) de las aguas subterráneas y en el 68% (19/28) de las muestras de agua superficiales.

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.

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