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Screening high-fluoride and high-arsenic drinking waters and surveying endemic fluorosis and arsenism in Shaanxi province in western China

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ABSTRACT

The objectives of this study were to screen high-fluoride and high-arsenic drinking waters, to evaluate the effectiveness of fluoride-reducing projects and to assess the present condition of endemic fluorosis and arsenism in Shaanxi province in western China. For screening high-fluoride drinking waters, five water samples were collected from each selected village where dental fluorosis patients were detected in 8–12 year-old children. For evaluating the effectiveness of fluoride-reducing projects, four water samples were collected from each project at end-user level. Fluoride concentrations in water samples were measured by fluoride-selective electrode method or spectrophotometry. Dental fluorosis in children aging 8–12 years was examined according to Horowitz's Tooth Surface Index of Fluorosis. Skeletal fluorosis in adults was detected clinically and radiologically according to Chinese Criteria of Clinical Diagnosis of Skeletal Fluorosis. For screening high-arsenic waters, 20 water samples were collected from each village which was selected from areas characterized by the geographic features to induce high-arsenic underground water, i.e., alluvial plains, ore mining or smelting areas, geothermal artesians, and thermal springs. Arsenic concentrations in water samples were determined by spectrophotometry or arsine generation atomic fluorospectrophotometry. Arsenism in adults aging 40–89 years was examined in villages with arsenic concentrations in drinking water above 0.05 mg/l according to Chinese Criteria for Classification of Endemic Arsenism Areas and Clinical Diagnoses of Endemic Arsenism. The results showed that the fluoride level of 7144 water samples was 1.17 ± 0.93 mg/l. There were 3396 (47.6%) high-fluoride waters (fluoride level was above 1.0 mg/l) distributing in 786 (45.1%) villages, where about 0.8 million (50.0%) people inhabited. Additionally, the 1315 fluoride-reducing projects were studied. The fluoride level of the projects was 2.79 ± 1.09 and 0.98 ± 0.47 mg/l before and after building the projects, which remained at relatively lower level (1.03 ± 0.47 mg/l). But there were still 58.0% of the projects providing drinking waters with fluoride concentrations beyond 1.0 mg/l. The rates of dental fluorosis and skeletal fluorosis were 38.2% and 11.8%, respectively. The arsenic level of 1732 water samples was 0.010 ± 0.082 mg/l. There were 174 (14.9%) high-arsenic waters (arsenic level was above 0.010 mg/l) being detected, distributing in 41 (38.7%) villages. The arsenic level in 53 (4.5%) water samples was beyond 0.025 mg/l. There were 3 villages with arsenic level in drinking water beyond Chinese National Permissible Limits (0.050 mg/l), and the prevalence rate of arsenism reached 37.0% in these three villages, 3.7%, 22.2%, and 11.1% of subjects suffering from mild, moderate, and severe arsenism, respectively. Conclusively, the wide distribution of high-fluoride drinking waters con-

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tributes to the prevalence of dental and skeletal fluorosis in Shaanxi province and the quality of fluoride-reducing projects should be further improved. Ore mining and smelting induces high-arsenic drinking waters, resulting in arsenism prevalence in Shang-luo city. Proper measures should be taken to deal with water pollution in the ore mining and smelting areas in order to solve the high-arsenic water problem in Shaanxi province.

1. Introduction

Endemic fluorosis is prevalent in 29 provinces, municipalities or autonomous regions in China. The endemically affected areas can be divided, according to the sources of fluoride, into three types: high fluoride water, pollution from coal burning (Ando et al., 2001; Cao et al., 2003a, b), and drinking brick tea (Cao et al., 2003a, b). Shaanxi province is situated in the west of China. The area of Shaanxi is 201 thousands km^2, where 36 million people inhabits. Shaanxi province is one of the severe endemic fluorosis provinces in China. According to the general survey conducted in 1980, there were approximately 2 and 0.22 million people suffering from dental fluorosis and skeletal fluorosis, respectively (Zhu et al., 1982). In Shaanxi province, many measures have been implemented to reduce fluoride level in drinking water since 1980, such as construction of pits to collect rain, changing water sources from deep wells into surface water, etc. The preferred option is to find supplies of safe drinking water with safe fluoride level. In the circumstances as the access to safe water is limited, pits for collection of rain are built. Other methods of defluoridation including bone charcoal or activated alumina absorption were also employed years ago, but they have been replaced gradually due to the difficulty of implementation for end-users (Huo, 2003). The incidence of the fluorosis has been reduced with some patients making a complete recovery owing to the construction of such projects (Wang and Huang, 1995; Bai et al., 1995; Chen et al., 1997). On the other hand, there were still inhabitants to consume high-fluoride water due to the shortage of funds to construct such projects (Liu et al., 2005). Additionally, fluoride level remains higher in some drinking waters from some fluoride-reducing projects (Chen et al., 1997). Unlike fluorosis, water-induced endemic arsenism has never been reported in Shaanxi province before. This study was performed to screen high-fluoride and high-arsenic drinking waters, to evaluate the effectiveness of fluoride-reducing projects and to assess the present condition of endemic fluorosis and arsenism in Shaanxi province in western China.

2. Materials and methods

2.1. Study areas

The province of Shaanxi is situated between 31°42′ N and 39°35′ N latitude and 105°29′ E and 111°15′ E longitude. There are 10 cities in Shaanxi province. The study was implemented in eight endemic fluorosis cities, i.e., Wei-nan, Xi-an, Bao-ji, Xian-yang, Yu-lin, Yan-an, Shang-luo, and Han-zhong. Among the 8 cities investigated, Wei-nan, Xi-an, Bao-ji, and Xian-yang are located in Guan-zhong plain, Yu-lin and Yan-an in Shaan-bei loess plateau, and Shang-luo and Han-zhong in Shaan-nan mountainous area.

2.2. Interlaboratory quality control

To evaluate the participant laboratory's performances in order to select qualified laboratories in this study, 2 reference samples of fluoride (1.00 and 2.00 mg/l, respectively) and arsenic (0.100 and 0.200 mg/l, respectively) were sent to each laboratory. Participant laboratories determined concentration of fluoride and arsenic in the 2 reference samples. Laboratories whose given values were within the ranges of $\bar{x} \pm 2s$ for both reference samples were considered as qualified. Only qualified laboratories could participate in this study.

2.3. Screening high-fluoride drinking waters

For screening high-fluoride drinking waters, villages were selected for study where dental fluorosis patients were detected in 8–12 year-old children. Five samples were collected from the east, west, south, north, and middle parts of each village and stored in precleaned plastic bottles at 4 °C before being analyzed. A total of 7144 water samples were sampled.

2.4. Evaluating the effectiveness of fluoride-reducing projects

For evaluating the effectiveness of fluoride-reducing projects, four samples were collected from each project at end-user level and stored in precleaned plastic bottles at 4 °C before being analyzed. A total of 1315 projects were investigated.

2.5. Examination of the dental and skeletal fluorosis

Twenty counties in Shaanxi province were sampled randomly. The villages in each selected county were divided into four strata, i.e. normal, mild, moderate, or severe endemic fluorosis areas according to historic records. One village was sampled from each stratum as one study area. A total of 9030 children, aging 8–12 years were sampled. Dental fluorosis in the sampled children was examined according to Horowitz's Tooth Surface Index of Fluorosis (Horowitz et al., 1984), which is a modification of Dean's method. In Horowitz's standard, there are seven grades of severity (1–3, mild; 4, moderate; 5–7, severe). Each child's teeth were examined under natural light by two dentists, recommended by WHO. A total of 17427 adults, aging 16–66 years were selected. Clinical symptoms