# Prevention of endemic arsenism with selenium

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**Arsenism is a disease with severe damage to human health resulting from long-term exposure to high arsenic levels in the environment. Selenium was used to prevent the accumulation of arsenic in the human body and rectify the damages in the experiment. After the administration of 100–200 μg Se/day for 14 months, 75.0 and 55.0% of the patients served as patients for selenium-therapy group in clinical examination and symptom, and 25.6% and 24.4% as control group. In the Se-therapy group, liver function, hepatic ultrasonotomography, electrocardiogram and electron microscope observation of erythrocyte reversed significantly than the control as 80%, 60%, 72.22%, 84.78% versus 46.15%, 30.7%, 0%, 44.83%, respectively. Arsenic concentration in blood, urine and hair of the Se-group decreased much more than that of the control group.**

INORGANIC arsenic (As) is a documented human carcinogen associated with skin, liver and lung cancers[1–3], and has been classified by WHO's International Agency for Research on Cancer into Group 1 (refs 4–6). Long-term exposure to high arsenic levels in the air, diet and drinking water can also result in permanent and severe damage to human health, including lesions of the skin, rhagades (skin cleft on palm and feet), mucous membranes and digestive, respiratory, circulatory and nervous system damages[7–8]. Such exposures have been found in India[9], Bangladesh[10], Chile[11], Argentina[12], Hungary[13,14], Japan[15] and several other countries. In China, As exposure in humans has been studied at locations in Taiwan[16], Inner Mongolia[17,18], Xinjiang[19], Guizhou[20], Ningxia[21] and the Shanxi[22] Provinces and Autonomous Regions.

Two kinds of endemic arsenism (chronic arsenic poisoning) have been found in China. One is drinking water-type, which is based on ingestion of contaminated food and arsenic 2–40 times higher in drinking water than the state standard of 50 μg/l (ref. 23). Another is coal smoke pollution – inhalation of smoke from combustion of high arsenic coal. More than 17,000 patients in 21 counties of five Provinces or Autonomous Regions have been identified and 2,000,000 people live in disease areas[24].

At present, there is no efficient treatment measurement for endemic arsenism patients. Our study showed that selenium (selenium yeast) could both prevent the accumulation of arsenic in the human body and rectify the damages. Here, we present the results of this experiment.

The most seriously affected area in China is Inner Mongolia with groups of people seriously exposed to high concentrations of As in drinking water that has given rise to arsenism. Nearly 2666 endemic arsenism patients were identified in 12 counties, while more than 300,000 people lived in the affected areas[25] at the end of 1997. The As concentration of most drinking-water wells in the disease areas is approximately 100–2000 μg/l, 2–40 times higher than the Chinese national drinking water standard of 50 μg/l and much higher than the provisional WHO guideline value of 10 μg/l (ref. 26).

BaYinMaoDao Farm is one of the most serious arsenism areas in Inner Mongolia. About 2002 people live in the farm and 1820 are exposed to arsenic-contaminated drinking water (> 50 μg/l). Only 311 arsenism patients had been identified before our experiment.

One hundred patients from BaYinMaoDao Farm were treated with selenium yeast (Beijing Tiancifu Medicine Company). Selenium yeast is a kind of yeast enriched in Se. It is a product found in supermarkets of USA, Europe and China as a nutrient. In our experiment, the selenium tablet was made of selenium yeast (4000 mg Se/g yeast) filled with starch. Each tablet contains 100 μg Se (0.25 mg yeast). 100–200 μg Se/day was given to each patient for 14 months.

Eighty-six patients from the same area who were treated with tablets made of starch containing <1 μg Se per tablet, served as the control (placebo) group.

These people have been exposed to high As drinking water since 1983. During the experiment, arsenic-free water (< 50 μg/l) was supplied simultaneously to both Se-group and control group instead of high As water. Doctors conducted clinical sign examination and symptom examination following the Standard of Chinese Endemic Arsenism Clinical Diagnosis Guidelines[27]. The clinical sign examination includes pigmentation, depigmentation, hyperkeratosis, rhagades (skin cleft), and symptom examination includes headache, dizziness, thoracalgia (chest pain), anesthesia of hand and foot, convulsion, lumbago, etc.

Liver function test, hepatic ultrasonotomography, electrocardiogram and electron microscope observation of erythrocyte were implemented for comparison.

Hair, urine and blood were sampled before the experiment and at the end of 3rd, 6th, 9th and 14th month during the experiment. In this paper, we present the results of arsenic and selenium concentration before and after (14th month) the experiment.

About 5 g new growth hair was cut around the nape of the neck of each adult using stainless steel scissors. Urine was also collected. Drinking water samples from 70 families were collected as well. Hundred ml water was directly taken from each well, stored in acid-washed plastic bottles and acidified with $HNO_3$ at the sample site,

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and kept in a refrigerator (4°C). All the samples were analysed within one week.

Before analysis, the hair samples were dipped in neutral detergent, then washed with running water, distilled water and ion-free water in turn, and dried in an oven for 4 h at 60°C. They were cut into 0.5 cm long pieces for segment digestion.

All the water, hair and urine samples were analysed by hydride generation coupled with ICP–AES. 0.3 g hair or 5 ml water or urine samples were digested with concentrated nitric acid (3 ml) and perchloride acid (1 ml) on electrothermal heating until all the perchloride was removed. After the samples were cooled, 2 ml hydrochloric acid was added and made to standard volume of 8 ml. The samples were analysed by hydride generation inductively coupled with plasma atomic emission spectrometry (ICP2070, Baird Co). ICP2070 has very sensitive detect limit (DL) of 0.8–1.6 ng/ml and relative standard deviation (RSD) of 1.62–2.71%. Usually the instrument has a slightly different DL because of changes in experimental condition. For quality control in chemical analysis, two standard reference materials (Chinese hair, GBW0901, As content: 0.59 ± 0.07 μg/g, Chinese Standard Sample Study Center, Chinese Academy of Measurement Sciences) were randomly analysed with each batch of hair samples[28].

The difference in clinical change rates between the Se-group and the placebo-group was statistically analysed using $\chi^2$ test; the differences in liver function, hepatic ultrasonotomography, electrocardiogram and electron microscope of erythrocyte were analysed by two proportions test method; and As concentration differences were analysed using two samples *t*-test. All the data were analysed using MINITAB (release 13.1, MINITAB INC).

Endemic arsenism can result from As exposure. The incidence of arsenism increases with the arsenic concentration of drinking water (Table 1).

Seventy hair samples and drinking water samples were simultaneously taken from different families. Figure 1 shows that arsenic content in hair samples of adults in arsenism-affected areas has significant positive correlation with arsenic content in drinking water ($r = 0.777$, $n = 70$, $P < 0.05$). Smith[29] studied 1250 hair samples in England. He found that As in 80% of hair samples is lower than 1.0 μg/g, the mean is 0.81 μg/g and the median is 0.51 μg/g. Therefore he concluded that if As in hair is lower than 2.0 μg/g, arsenism will not occur; if it is between 2.0 and 3.0 μg/g, the people should be rechecked; it is abnormal for As in the hair to be higher than 3.0 μg/g. Our work shows that As in the hair is a good indicator for the level of As in both the environment and human body.

The clinical examination was carried out according to the Criteria of Grade for Clinical Manifestation[30]. At the end of the experiment, 75% and 55% of patients served as selenium-therapy group in clinical examination, and 25.6% and 24.4% as control group (Table 2). In contrast, the unvaried cases and deterioration for control group are higher than Se-therapy group.

Before the visible changes on the skin appear, some biophysical–biochemical or physiological–pathological changes such as hepatomegaly (swelling liver), disorder of heart, etc. can be found by liver function test, hepatic ultrasonotomography (ultrasonic equipment for medical diagnosis), electrocardiogram and electron microscope observation of erythrocytes. The erythrocytes of a patient have morphological changes, many target cells, spur cells, echinocytes and spherocytes can be seen. These irregular erythrocytes are in very high ratio. When supplemented with Se, they can be remedied as normal. In selenium-therapy group, liver function, hepatic ultrasonotomography, electrocardiogram and electron microscope observation of erythrocyte reversed significantly than control (Table 3). Thus Se cannot only protect erythrocytes and remedy them from lesions, but it is also important for understanding the mechanism of As-induced lesions.

From Table 4 we can see that As concentration in blood, urine and hair samples in both the control group and Se-therapy group has decreased significantly, but As concentration of Se-therapy group decreases much more than that of control group. The results show that pure drinking water without As contamination can reduce arsenic in the body, but far less than that supplied with selenium.

**Table 1.** Endemic arsenism incidence and As in drinking water

| As in water μg/ml | Population | Patients identified | Percentage of patients identified |
|---|---|---|---|
| < 0.05 | 182 | 0 | 0 |
| 0.05–0.10 | 340 | 33 | 9.71 |
| > 0.10 | 1480 | 278 | 18.78 |
| Total | 2002 | 311 | 15.53 |

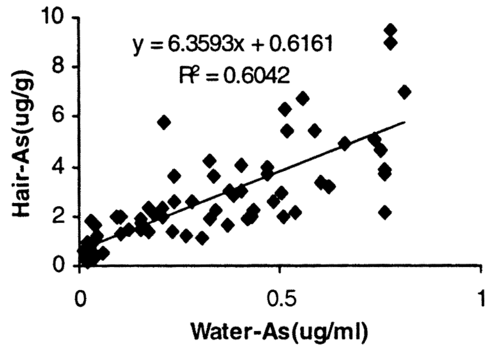


**Figure 1.** Correlation of As concentration in hair with As content in drinking water ($r = 0.777$, $n = 70$, $P < 0.05$).

**Table 2.** Comparison between Se group and control on clinical signs and symptoms

| | Recovery case | (%) | Unvaried case% | (%) | Deterioration case% | (%) |
|---|---|---|---|---|---|---|
| Clinical signs | | | | | | |
| Se-therapy | 75 | 75.0 | 21 | 21.0 | 4 | 4.0 |
| Control group | 22 | 25.6 | 52 | 60.4 | 12 | 14.0 |
| *P*-value | < 0.001 | | | | | |
| Symptoms | | | | | | |
| Se-therapy | 55 | 55.0 | 45 | 45.0 | 10 | 10.0 |
| Control group | 21 | 24.4 | 51 | 59.6 | 14 | 17.0 |
| *P*-value | < 0.001 | | | | | |

Here, recovery means that symptom and signs disappear or relief; unvaried means no significant change in symptom and sign, or change less than one grade; deterioration means getting worse, more than one grade or resulting in Bowen's disease[3,30].

**Table 3.** Comparison of recovery on physical and biochemical test between Se group and control

| | Liver function (%) | UT* (%) | EMOE** (%) | Electrocardiogram (%) |
|---|---|---|---|---|
| Se-therapy group | 80 | 60 | 72.22 | 84.78 |
| Control group | 46.15 | 30.7 | 0 | 44.83 |
| *P*-value | < 0.01 | < 0.01 | < 0.001 | < 0.01 |

*UT, Hepatic ultrasonotomography – ultrasonic equipment for medical diagnosis on liver.
**EMOE, Electron microscope observation of erythrocyte.

**Table 4.** As in blood, urine and hair samples before and after treatment with Se

| | | Before treatment | After treatment |
|---|---|---|---|
| Se-therapy group | Blood As (μg/ml) | 0.049 ± 0.023 (89) | 0.016 ± 0.006 (75)* |
| | Urine As (μg/ml) | 0.190 ± 0.14 (90) | 0.022 ± 0.012 (78)* |
| | Hair As (μg/g) | 2.56 ± 1.17 (90) | 0.718 ± 0.51 (86)* |
| Control group | Blood As (μg/ml) | 0.055 ± 0.031 (83) | 0.025 ± 0.008 (54) |
| | Urine As (μg/ml) | 0.190 ± 0.15 (68) | 0.043 ± 0.024 (52) |
| | Hair As (μg/g) | 2.43 ± 1.79 (86) | 1.23 ± 0.90 (53) |

Figures in parentheses are sample numbers.
*$P < 0.05$ between Se group and control.

Other studies also show that prevention of arsenic exposure can reduce the arsenic concentration in urine[31,32], hair[32,33], and nail[32]. The people who have already developed skin lesions are far from recovering completely[32]. In our study, hair and urinary arsenic concentration in control group also decreased after preventing contamined drinking water exposure, but the amount and rate in Se-therapy group are much more than those in the control group. Furthermore, selenium supplementation can reverse the arsenic-related skin lesions and symptoms.

Selenium is a nutritionally required element. It has been known as an antagonist of arsenic toxicity[34]. Recent studies showed that selenium could form a compound with glutathione and arsenic in rabbit bile after injecting intravenously with sodium selenite followed immediately with intravenous sodium arsenite[35]. Many areas of the world in which chronic arsenic exposure occurs are low in selenium[36]. In a study by Das *et al.*[37], selenium could not be detected in liver tissue of five patients suffering from arsenic toxicity. These results show that selenium supplementation can effectively decrease arsenic concentrations in hair, urine and blood samples, our study shows the prevention of arsenism by oral selenium supplementation. It should be carefully carried out based on evaluation of selenium intake or nutritional status of residents in other areas of the study.

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# Evaluation of various image fusion techniques and imaging scales for forest features interpretation

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**The paper presents an objective evaluation of three image fusion techniques for interpretation of forest features in Pathri Reserve Forest, Hardwar. The three fusion techniques based on principal component substitution (PCS), intensity–hue–saturation transformation (IHS) and Brovey's transformation were performed. The merged images were evaluated on three different scales, i.e. 1 : 50,000, 1 : 25,000 and 1 : 12,500. It was observed that PCS method of fusion presented the most suitable output, followed by Brovey's and IHS, respectively. Further, it was also observed that output from the PCS method contained better information for discrimination of forest stand types. For interpretation of non-forest areas, i.e. grassland, agriculture, water bodies, IHS-based fusion was adjudged to be the best overall and maximum at the scale of 1 : 12,500. The study demonstrates higher capability of merged IRS LISS-III and PAN data products for differentiation and mapping of forest stands.**

REMOTE sensing products are an effective medium for display of spatial information of different land cover features with different spectral characteristics.

Remote sensing data can be obtained in multi-sensor, multi-resolution, multi-frequency, multi-temporal forms, making the fusion or integration of data from various sources and of various kinds, easier. The use of multi-sensor image data is becoming an increasingly important component of digital image processing, since it increases

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