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Mitigation of Endemic Arsenocosis with Selenium: An Example from China

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Introduction

Endemic arsenocosis (chronic arsenic poisoning) in China comes from two sources of arsenic (As). One source is drinking water, with As concentrations 2–40 times that of the state standard of 0.05 mg/l As. The second is smoke pollution from combustion of coal with high concentrations of As; this can be inhaled or ingested from smoke-contaminated food. Over 2,000,000 people live in areas of high geological As concentrations (Cao 1996), and more than 17,000 arsenocosis patients in 21 counties of five provinces or Autonomous Regions (Fig. 7.1) have been identified.

Long-term exposure to As in air, diet, or drinking water can result in permanent and severe damage to health, including lesions of the skin, mucous membranes of the digestive, respiratory, circulatory, and nervous systems, and rhagades (skin cleft on palm and feet). Elevated As intake is also associated with skin, liver, and lung cancers (Centeno 2000, Liang 1999, Wang Lianfang 54–61 1997).

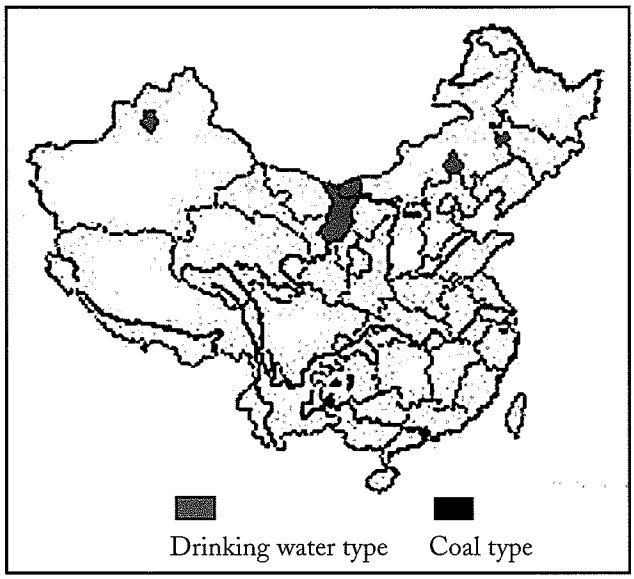

Figure 7.1: Geographic distribution of two sources of As causing endemic arsenocosis in China.

At present, there are few studies of efficient measurement of treatment of endemic arsenocosis patients. Our study demonstrates that treatment of these patients

with dietary selenium (Se) can cause both excretion (elimination) of As accumulated in the human body and remediation of some health damages. We report the results of this experiment.

Methods

Data were collected on 3 test groups of people: 186 patients, from BaYinMaoDao Farm in Inner Mongolia suffering from endemic arsenocosis, were divided into a treatment group (100 patients) and a control group (86 patients). A third group, consisting of 70 families, received no treatment but drank ambient well water, >0.10 mg/l As. All participants had been exposed to high-As drinking water (>0.10 mg/l) since 1983. Throughout the experiment, water containing 0.05 mg/l As was supplied for both treatment and control groups. Of the 186 patients, 100 were treated with Se-enriched yeast* tablets, containing 100 μg Se/tablet. The treatment lasted 14 months. Treated patients received 100–200 μg Se/day.

All patients were examined for clinical criteria of arsenocosis: characteristic pigmentation, depigmentation, hyperkeratosis, rhagades (skin cleft), and incidence of secondary symptoms of headaches, dizziness, thoracalgia (chest pain), numbness of hands or feet, convulsions, or lumbago. Tests on liver function, liver ultrasonotomography, electrocardiography, and electron microscope observation of erythrocytes were performed. Doctors followed the Standard of Chinese Endemic Arsenocosis Clinical Diagnosis Guidelines.

Hair, urine, and blood samples were collected before the experiment and at the end of the 3rd, 6th, 9th, and 14th month. Assay results from the initial and final samples are presented.

Human hair (255 samples) was collected; about 5 g of new growth hair was cut from patients in both the treatment and control groups and the third, ambient well water, group over the 14-month period. Stainless steel scissors were used. Before analysis, the hair samples were dipped in neutral detergent, washed with running water, distilled water, and ion–free water in turn, then oven-dried for 4 hours at 60° C, and cut into 0.5 cm segments for digestion. Urine samples were collected at the same time. Samples of drinking well water for the 70 families in the high-As region were collected; 100 ml water were directly taken from each well, stored in acid-washed plastic bottles and kept refrigerated (4° C). All the samples were analyzed within 1 week.

All water, hair, and urine samples were analyzed by hydride generation coupled with ICP–AES. Samples (0.3 g hair; 5 ml water; 5 ml urine) were digested with concentrated nitric acid (3 ml) and perchloride acid (1 ml) by electrothermal heating until the perchloride acid was almost driven off. After the samples were cooled, 2 ml hydrochloric acid were added and made to standard volume of 8 ml. Samples were analyzed by hydride generation inductively coupled plasma atomic emission spectrometry

Table 7.1: Endemic arsenocosis incidence and As in drinking water

Water As μg/ml	*Population*	*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

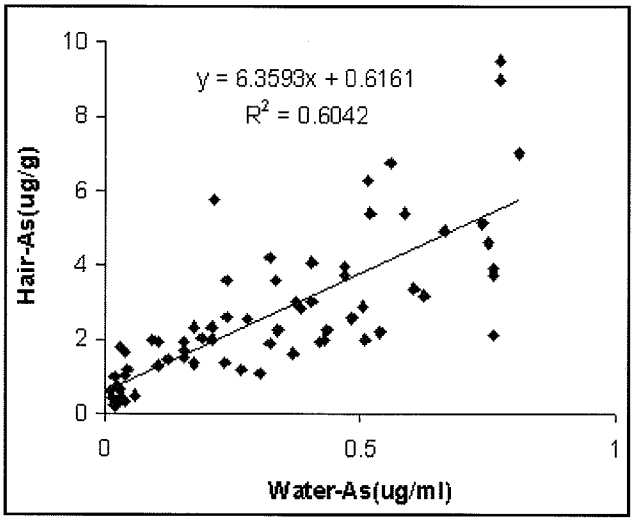

Figure 7.2: Correlations of As concentration in hair with As content in drinking water (r = 0.777, n = 70, p < 0.05)

* Manufactured by the Beijing Tiancifu Medicine Company

(ICP2070, Baird Co.). ICP2070 has a very sensitive DL (detection limit) at 0.8–1.6 mg/ml and RSD (relative standard deviation) of 1.62–2.71%. Instruments may have slightly different DL due to changes in experimental conditions. For quality control in chemical analysis, two standard reference samples (Chinese hair, GBW0901, As content: 0.59±007 μg/g, Chinese Standard Sample Study Center, Chinese Academy of Measurement Sciences) were randomly analyzed with each batch of test hair samples (Wang Lizhen).

Results and Discussion

1. Incidence of arsenocosis increased with As concentration of drinking water (Table 7.1), suggesting endemic arsenocosis can result from exposure to As in drinking water.

2. Hair samples from families drinking ambient well water shows that hair-As content of adults in arsenocosis-affected regions has a significant positive correlation with As content in drinking water ($r = 0.777, n = 70, p < 0.05$) (Fig. 7.2). Smith (Smith 1064) studied 1250 hair-As samples in England. He determined that if As in 80% of hair samples was less than 1.0 μg/g, the mean was 0.81 μg/g and the median was 0.51 μg/g. He concluded that if hair-As is lower than 2.0 μg/g, arsenocosis has not occurred; if hair-As is 2.0–3.0 μg/g, the people should be evaluated; if hair–As is higher than 3.0 μg/g it is abnormally high and an indication of possible arsenocosis. Our work shows that hair-As is a good indicator of As levels in both the human body and the environment.

3. A preliminary clinical examination was carried out according to the Criteria for Clinical Manifestations for Arsenocosis (Table 7.2) (Wang Lianfang 184–191, 1997).

(Note: Symptoms in nerve-blood vessels include three syndromes: neurasthenia, peripheral neuritis, and Raynaud's disease. These medical terms indicate abnormalities in the nervous system. Keratosis is a general term indicating keratinization and abnormal squamous cell development.)

Results indicate that after 14 months, 75.0% of Se-treated patients recovered clinically to some extent and 55.0% had decreased secondary symptoms, but only about 25.6% and 21.4%, respectively, of the control group (Table 7.3). In contrast, the unvaried cases and deterioration for the control group are higher than Se-treated group.

4. Before visible changes on the skin appear, some biophysical–biochemical or/and physiological–patho-

Table 7.2: Chinese clinical criteria for arsenocosis

	Grade I	*Grade II*	*Grade III*
Keratosis			
	Mild hyper-pigmentation	Papular eruptions	Lesions on palms metatarses, backs of hands and feet
Pigmentation			
	Grayish or black, or brown spots	Brown–gray with increased brown spots	Grayish black or dense brown spots
Depigmentation			
	Scattered	More spots	Densely clustered spots
Nerve-blood vessel symptoms			
	1 item	2 items	3 items

Table 7.3: Comparison between Se-therapy group and control group by the clinical exam for arsenocosis

	Recovery Case %	*Unvaried Case %*	*Deterioration Case %*
Se-therapy group			
Clinical exam	75 75.0	21 21.0	1 1.0
Symptom	55 55.0	45 45.0	0 0
Control group			
Clinical exam	22 25.58	52 60.47	12 13.96
Symptom	21 21.41	51 59.30	14 16.24

Recovery = symptoms and signs disappear or are alleviated.
Unvaried = no significant change for symptoms and signs, or the change <one grade.
Deterioration = worsening more than one grade or results in Bowen's disease (7,4).
Clinical exam, see Table 7.2.
Symptom = secondary symptoms, e.g., headache.

logical changes can be detected such as hepatomegaly (liver swelling); disorder of heart and other disorders that can be detected by a check of liver function; liver ultrasonotomography (ultrasonic equipment for medical diagnosis); electrocardiography; and electron microscope observation of erythrocytes. Patients' erythrocytes change morphologically; target cells, spur cells, echinocytes, and spherocytes can be seen in very high ratio. With supplemental Se, these abnormalities can be remedied to normal. In the Se-therapy group, liver function, liver supersonic tomography, electrocardiography, and electron microscope observation of erythrocytes reversed significantly compared to the control (Table 7.4). This means that not only can Se protect erythrocytes and remediate them from lesions, but also that this information provides an important contribution toward understanding the mechanism of As-induced lesions.

5. Data from Table 7.5 indicate that both the Se-therapy group and the control group have a significant decrease of As concentration in blood, urine and hair, but As concentrations of Se-therapy group decrease much more than that of control group.

Selenium is a nutritionally required element. It has been known as an antagonist of arsenic toxicity for many years (Levander 1966). 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 (Aposhian 1999).

Cessation of chronic As exposure can reduce the As concentration in urine, but longer periods are required to restore to normal background urinary excretion (Buchetet al. 1999). In our study, urinary As concentration in the control group decreased after exposure to elevated As in drinking water ceased.

Cessation of elevated As exposure can also reduce As in hair. But As concentration in hair persists even after use of the polluted well water ceased for 2–4 months (Maki-Paakkanen 1998), and even after 2.5 years (Li Yong 1998). However, the differences in our study of the decreasing concentration and decreasing rate between the Se-therapy group and control group show that Se has an efficient effect on the binding of As in hair.

Many areas of the world where chronic arsenic exposure occurs are low in selenium (Aposhian 1998), and the results in this study show that selenium supplementation can effectively decrease arsenic concentrations in hair, urine, and blood. This study is among the first indicating the mitigation of arsenocosis by dietary selenium supplementation. Tests should be carefully carried out on the basis of evaluation of selenium intakes or nutritional status of residents in other areas.

Table 7.4: Comparison of physical and chemical test on Se group and control

	Liver Function	*Liver UT* (a)	*EMOE*(b)	*Electro–cardiography*
Se–therapy Group	80.00%	60.0%	72.22%	84.78%
Control group	46.15%	30.7%	0	44.83%

(a) Liver ultrasonotomorgraphy: ultrasonic equipment for medical diagnosis on liver.
(b) Electron microscope observation of erythrocyte.

Table 7.5: As in blood, urine and hair before and after treatment with Se

		Before treatment	After treatment
Se–therapy group	Blood As μg/ml	0.070±0.099 (98) (a)	0.016±0.006(88) (b)
	Urine As μg/ml	0.255±0.306 (99)	0.030±0.030 (85) (b)
	Hair As μg/g	2.970±1.627 (99)	0.798±0.603 (88) (b)

(a) Data in bracket is sample number.
(b) P <0.05 between Se–therapy group and control

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