

## **POISONING BY COAL SMOKE CONTAINING ARSENIC AND FLUORIDE**

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**SUMMARY:** An investigation was made into a disease involving skin pigmentation, keratosis of the hands and feet, dental discoloration, and generalized bone and joint pain, stiffness and rigidity, in the village of Bazhi, Zhijin County, Guizhou Province, People's Republic of China. Measurements were made of the arsenic and fluoride levels of coal, water, air, food, urine and hair in Bazhi and a control village, Xinzhai, in which coal with a low arsenic content was used. Up to 188 persons, including children, in Bazhi and 752 in Xinzhai, were examined for the presence of chronic arsenism, skeletal fluorosis, dental fluorosis and electrocardiogram abnormalities. The coal in Bazhi was found to contain high levels of arsenic and fluoride resulting, after burning in homes without an adequate chimney system for the removal of smoke, in pollution of air and food with arsenic and fluoride. The coal in Xinzhai did not cause arsenic pollution but did produce a higher level of fluoride pollution. Chronic arsenism was found to affect 30% of the persons in Bazhi but none in Xinzhai. In both villages 100% of the children aged 8-15 years had dental fluorosis. Skeletal fluorosis was present in 47.5% of the adults in Bazhi and 56.1% of those in Xinzhai (difference not significant). It was concluded that the endemic disease in Bazhi was caused by pollution by coal smoke containing arsenic and fluoride. It is suggested that arsenic may act synergistically with fluoride so that a lower level of fluoride may produce fluoride toxicity with dental and skeletal fluorosis.

Key Words: Arsenic; Bazhi; Coal smoke; Dental fluorosis; Skeletal fluorosis; Xinzhai.

### **INTRODUCTION**

Chronic fluoride toxicity or fluorosis caused by burning coal is an endemic disease in 12 provinces of China including Guizhou, Sichuan, Hubei, Yunnan, Hunan, and Shanxi. Zhijin county in Guizhou province is one of the areas most severely affected. The fluorosis is caused by air and food pollution from coal-smoke with high levels of fluoride produced by the burning of coal in indoor stoves which do not have a chimney to take the smoke to the outside.<sup>1</sup>

Arsenic poisoning or arsenism may occur with pollution of the environment by arsenic. Poisoning from arsenic contaminating water has been reported from Chile,<sup>2</sup> India<sup>3</sup> and other areas<sup>4</sup>.

In this paper we report the finding, in 1988, of poisoning by coal-smoke containing fluoride and arsenic.

### **MATERIALS AND METHODS**

The residents of the village of Bazhi, population 190, situated 40 km from Zhijin in Zhijin county of Guizhou, were studied, with residents of the village of Xinzhai, population 977, situated 7 km from Zhijin, being used as a control. In both villages the staple diet was of maize and chilli. Coal was burnt indoors, in a stove without a chimney, for cooking, heating and the drying of food. A door-to-door survey was made in the two villages with all residents being examined for arsenism.

Dental fluorosis was examined for in children aged 8-15 years, and fluorosis symptoms were assessed in adults aged 16-65 years. One third of the adults, chosen randomly, in each village were examined radiologically with radiographs of the forearm and hand, and the pelvis, knee joint and leg. The arsenic and fluoride levels were measured in the indoor air, water, food and coal, and the urine of some persons selected at random. The arsenic levels in hair were also measured in the latter group. Arsenic levels were measured by the silver diethyl dithiocarbamate method, and fluoride analyses were performed with the fluoride ion-selective electrode method.

## RESULTS

The arsenic content of the coal and indoor air were significantly higher in Bazhi than in Xinzhai (Table 1). In both villages the fluoride content of the coal and indoor air were high, and the arsenic and fluoride content of the drinking water low.

In both villages the arsenic and fluoride content of fresh food was low but food polluted by coal smoke had a high fluoride content (Table 2). The arsenic content of food polluted by coal smoke in Bazhi was significantly higher than that in Xinzhai (Table 2).

The estimated mean daily intakes per person of food, water and air were: rice 100 g, maize 400 g, chilli 15 g, water 2 L, and air 15 m<sup>3</sup>. Residents of Bazhi had high arsenic and fluoride intakes, while residents of Xinzhai had significantly higher fluoride intakes (Table 3).

None of 646 persons examined in Xinzhai were found to have chronic arsenism, while 56 out of 188 persons, 29.8%, in Bazhi were found on physical examination to have chronic arsenism (Table 4).

Dental fluorosis was found by, physical examination, on all 49 children, aged 8-15 years, examined in Bazhi, and symptoms and signs of fluorosis were found in 57 of 120, 47.5%, of the adults examined in Bazhi. Some patients in Bazhi had both fluorosis and chronic arsenism. In Xinzhai, dental fluorosis was found in 207 of 208, 99.5%, of the children aged 8-15 years, while fluorosis was found in 305 of 544, 56.1%, of the adults. No significant difference was present between Bazhi and Xinzhai in the rates of dental fluorosis in children (Fisher's Exact Test, one-sided P value 0.35, n.s.) or skeletal fluorosis in adults (Chi-square with Yates correction 2.57, n.s.).

No significant difference was found in the urinary fluoride level in the two villages, but the urine and hair arsenic levels were higher in Bazhi than in Xinzhai (Table 5).

Skeletal fluorosis was found by X-ray examination in 16 of 20 adults, 80.0%, in Bazhi, and in 103 of 113 adults, 91.2%, in Xinzhai (difference not significant).

Seven skin lesions in patients with chronic arsenism were examined histopathologically with excessive keratosis being found in all of them and cancrroid in one. Cancer cells were found in one specimen of ascitic fluid and in a breast tumour.

Significantly more abnormalities were found in the electrocardiogram in adults in Bazhi, in 27 of 31, 87.1%, than in adults in Xinzhai where abnormalities were found in 12 of 21, 57.1%.

**TABLE 1.** The arsenic and fluoride content of coal, air and water in the two villages

Specimen	N	Village of Bazhi	N	Village of Xinzhai
Coal mg arsenic/kg coal	4	2166.67±57.74*	3	2.50±0.70
mg fluoride/kg coal	4	125.41±9.12	3	131.29±11.45
Air mg arsenic/M <sup>3</sup> air	12	0.1105±0.0532*	12	0.0003±0.0001
mg fluoride/M <sup>3</sup> air	11	0.022±0.011	10	0.020±0.013
Water mg arsenic/L	7	0.0052±0.0043	6	0.0024±0.0011
mg fluoride/L	5	0.17±0.0098	5	0.13±0.0052

Values are mean ± S.D.

\* Compared to Xinzhai p&lt;0.001

**TABLE 2.** Arsenic and fluoride content of freshly harvested food and food polluted by coal smoke for six months in Bazhi and Xinzhai

Specimen	N	Village of Bazhi	N	Village of Xinzhai
rice (fresh) arsenic mg/L	9	0.26 ± 0.16	5	0.14 ± 0.16
rice (polluted) arsenic mg/L	10	7.43 ± 2.28*	9	0.52 ± 0.29
rice (fresh) fluoride mg/L	13	0.68 ± 0.15	15	0.76 ± 0.16
rice (polluted) fluoride mg/L	15	1.15 ± 0.45	11	1.40 ± 0.67
maize (fresh) arsenic mg/L	9	0.44 ± 0.25	6	0.17 ± 0.15
maize (polluted) arsenic mg/L	12	48.58±16.23*	10	0.22 ± 0.06
maize (fresh) fluoride mg/L	15	0.65 ± 0.14	17	0.66 ± 0.15
maize (polluted) fluoride mg/L	17	22.63±13.07	19	69.76±24.19
chilli (fresh) arsenic mg/L	9	1.62 ± 0.83	7	1.41 ± 0.63
chilli (polluted) arsenic mg/L	12	610.83±76.94*	9	1.04 ± 0.58
chilli (fresh) fluoride mg/L	14	1.70 ± 0.54	16	1.64 ± 0.86
chilli (polluted) fluoride mg/L	15	589.01±243.25	15	1126.03±603.86

Values are mean ± S.D.

\* Compared to Xinzhai p&lt;0.001

**TABLE 3.** Mean daily intakes per person in Bazhi and Xinzhai of arsenic and fluoride

Substance	Village of Bazhi	Village of Xinzhai
arsenic mg/day/person	31	1.34
fluoride mg/day/person	18.75	45*

\* Significantly higher than that for Bazhi

**TABLE 4.** Clinical symptoms and signs in 56 persons with chronic (endemic) arsenism in Bazhi

Symptoms and signs	N	%
Keratosis of hands and feet	44	78.6
Peripheral neuritis	38	67.9
Verrucae keratosis on skin	34	60.7
Pigmentation of skin	32	57.1
Abdominal pain	12	21.4
Hepatomegaly	5	8.9
Cutaneous ulceration	3	5.4
Ascites	1	1.8
Breast tumour	1	1.8

**TABLE 5.** Urinary fluoride and urinary and hair arsenic levels in Bazhi and Xinzhai

Specimen	N	Village of Bazhi	N	Village of Xinzhai
Urine fluoride mg/L	73	6.12±1.64	154	5.74 ± 1.93
Urine arsenic mg/L	38	0.137±0.100*	35	0.023±0.028
Hair arsenic mg/L	27	3.08±2.04*	20	0.97 ± 1.40

Values are mean ± S.D.

\* Compared to Xinzhai p&lt; 0.001

## DISCUSSION

The study showed that although the arsenic and fluoride content of the drinking water in Bazhi were low, the values for the coal burnt in residences were very high. As the coal is burnt directly in the open living area of the homes all year around, without the use of a stove to enclose the fire and chimney to conduct away the smoke, there is a continuing release into the living area of smoke containing arsenic and fluoride leading to very heavy pollution of the indoor air, and the food and vegetables stored indoors. This resulted in the residents having high intake of arsenic and fluoride from the contaminated air and food. All the children, aged 8-15 years, examined in Bazhi were found to have dental fluorosis, 80.0% of the adults examined had skeletal fluorosis, and 29.8% of the adults had chronic arsenism. Some patients had both fluorosis and arsenism.

Similarly the residents of Xinzhai used water which was low in arsenic and fluoride but suffered pollution of their air and food from fluoride-rich coal burnt in the living areas of the homes without adequate chimney systems to remove the smoke. The result was a higher intake of fluoride in the residents of Xinzhai than in those of Bazhi. However although the fluoride intake was higher in Xinzhai than in Bazhi there was no significant differences in the prevalence of dental fluorosis in children aged 8-15 years, or, in adults, in the prevalence of skeletal fluorosis or the urinary fluoride levels. A significantly higher rate of electrocardiogram abnormalities was found in the residents of Bazhi compared to those of Xinzhai.

The results thus suggest that fluoride may be able to act synergistically with arsenic in humans so that a lower dose of fluoride, when combined with arsenic, is able to produce signs of fluoride toxicity, such as dental and skeletal fluorosis, normally seen only with a higher intake level of fluoride.

It was concluded that the endemic disease involving skin pigmentation, keratosis of the hands and feet, dental discolouration, and generalized bone and joint pain, stiffness and rigidity in the village of Bazhi was caused by pollution by coal smoke containing arsenic and fluoride.

## REFERENCES

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