Health Impacts of Coal: Facts and Fallacies

INTRODUCTION
Coal has contributed enormously to the advance of civilization by providing an abundant, inexpensive, and convenient source of energy. Concurrent with its contributions, coal has extracted a high cost in terms of environmental damage and human health impacts. Coal will remain a key component of the global energy mix for decades to come as well as a major source of global pollutants. Despite its high media profile, misconceptions about coal abound, especially with regard to its human health impacts. Coal also provides several excellent examples of how a geologic material and human health intersect in a variety of surprising ways. Unfortunately, the links between coal use and human health are distorted by a great deal of ignorance and misinformation. This paper discusses the facts and fallacies of the direct health impacts caused by coal (1, 2). There are a number of important health issues caused by coal that fall outside the scope of this review. The health impacts of particulates emitted from coal combustion have received substantial attention since the groundbreaking work of Wilson et al. (3), and through the recent discussions by Davis (4) and Freese (5). The indirect health impacts of coals through their contributions to global climate change, respirable particulates, acid rain, and acid mine drainage are also beyond the scope of this review. Greb et al. provide an excellent general overview of the environmental impacts of coal (6).

The potential for health impacts caused by exposure to trace elements has received considerable attention for the past quarter of a century. The US Environmental Protection Agency conducted an extensive study of this issue and concluded (7) that, with the possible exception of mercury, there was no compelling evidence of health impacts caused by the emission of trace elements from coal-burning electric generating utilities. Nevertheless, documented examples do exist of health impacts caused by trace elements emitted by coal combustion. Bencok and Symon (8) described hearing problems in children living near a power plant burning high arsenic coal in the former Czechoslovakia. But, perhaps the most significant example of health impacts caused by trace element release from coal use occurs in Guizhou Province, southwest China, where millions of people suffer from dental and skeletal fluorosis and thousands suffer from arsenic poisoning due to mobilization of these elements by burning mineralized coals in unvented or poorly vented stoves (Figs. 1a and b).

Health Impacts of Residential Coal Use
Zheng et al. (9) describe chronic arsenic poisoning, affecting several thousand people in Guizhou Province, PRC. Those affected exhibit typical symptoms of arsenic poisoning including hyperpigmentation (flushed appearance, freckles), hyperkeratosis (scaly lesions on the skin, generally concentrated on the hands and feet: Fig. 1a), Bowen's disease (dark, horny, precancerous lesions of the skin), and squamous cell carcinoma.

Belkin and coworkers (10, 11) conducted detailed chemical and mineralogical characterization of coal samples from this region and found several samples with >30 000 ppm arsenic. This is more than 1000 times the average and 15 times the maximum concentration of arsenic in nearly 10 000 coal samples from throughout the United States (12). The effects of burning these mineralized coals in a residential environment are further exacerated by the practice of drying crops directly over the coal fires.

Zheng et al. have shown that chili peppers dried over open coal-burning stoves may be a principal vehicle for the arsenic poisoning (9). In the autumn it is commonly cool and damp in the higher elevations of Guizhou Province. It is common practice for the residents of this region to dry their corn and chili peppers directly over these coal fires.

Fresh chili peppers have less than 1 part per million (ppm) arsenic. In contrast, chili peppers dried over high-arsenic coal fires can have as much as 500 ppm arsenic. Significant amounts of arsenic may also come from other tainted foods, ingestion of dust (samples of kitchen dust contained as much as 3000 ppm arsenic), and from inhalation of indoor air polluted by arsenic derived from coal combustion. The arsenic content of drinking water samples was not considered to be a significant contributing factor.

The health problems caused by fluorine volatilized during domestic coal use are far more extensive than those caused by arsenic. More than 10 million people in Guizhou Province and surrounding areas suffer from various forms of fluorosis (13), and coal combustion induced fluorosis has also been reported from 13 other provinces, autonomous regions, and municipalities in China (14). Typical signs of fluorosis include mottling of tooth enamel (dental fluorosis: Fig. 1b) and various forms of skeletal fluorosis including osteosclerosis, limited movement of the joints, and outward manifestations such as knock-knees, bowlegs, and spinal curvature.

The cause of this type of fluorosis is similar to that of arsenic poisoning in that the disease is derived from foods dried over coal-burning stoves. Zheng and Huang have demonstrated that adsorption of fluorine by corn dried over unvented ovens burning high-fluorine (>200 ppm) coal is the probable cause of the extensive dental and skeletal fluorosis in southwest China (13). The problem is compounded by the use of clay as a binder for making briquettes. The clay commonly used is a high-fluorine (several hundred parts per million) residue formed by intense leaching of the limestone substrate. Ando et al. estimated that 97% of the fluoride exposure came from food consumption and 2% from direct inhalation (14).

Although there is considerable concern about the health effects of mercury and the proportion of anthropogenic mercury in the environment (15), to date there has been no direct evidence of health problems caused by mercury released from coal, but there are circumstances where poisoning from mercury released from coal combustion may be occurring. In a Guizhou Province village, many elderly villagers exhibit loss of vision. Mineralogical analysis of the coal being used in the homes of people having visual impairment revealed abundant mercury minerals. Chemical analysis of a coal sample being used in this village indicates a mercury concentration of 55 ppm, about 200 times the average mercury concentration in US coals (12). Because mercury acts as a neurotoxin, the loss of vision may be related to the high levels of mercury released from the coal used in this village.

Zheng et al. report nearly 500 cases of human selenosis in southwest China that are attributed to the use of selenium-rich carbonaceous shales known locally as “stone coal” (16). The stone coals may contain as much as several thousand parts per million of selenium. This selenosis is attributed to emission of...