2

Natural Dust and Pneumoconiosis in High Asia

EDWARD DERBYSHIRE
Centre for Quaternary Research, Department of Geography
Royal Holloway, University of London, Egham, Surrey, United Kingdom

High Asia, defined here as that great tract of land from the Himalaya-Karakoram in the south to the Tian Shan in the north and the Pamir in the west to the Qinling Mountains in the east, is a very dusty place. Whole communities of people in this region are exposed to the adverse effects of natural (aerosolic) dusts at exposure levels reaching those encountered in some high-risk industries. Outdooor workers are at particular risk. However, few data are available on the magnitude of the dust impact on human health. The effect of such far-travelled particles on the health of the human population in the Loess Plateau, and including major Chinese cities, has received relatively little attention to date.

A combination of the highest known uplift rates, rapid river incision (up to 12 mm/yr: Burbank et al. 1996), unstable slopes, glaciation and widespread rock breakup by crystal growth during freezing (frost action), and by hydration of salts (salt weathering) makes the High Asia region the world's most efficient producer of silty (defined as between 2 and 63 μm) debris.

The earliest written records of the dust hazard come from China, most notably in the "Yu Gong" by Gu Ban (ca 200 BC) (Wang and Song 1983). Here, deposits of wind-blown silt (known as 'loess') cover the landscape in a drape that is locally 500 m thick. In North China, the loess covers an area of over 600,000 km^2, most of it in the Loess Plateau, situated in the middle reaches of the Huang He (Yellow River).

The characteristic properties of loess include high porosity and collapsibility on wetting (Derbyshire et al. 1995, Derbyshire and Meng 2000). Thus, it is readily reworked and redistributed by water. This process concentrates silts in large alluvial fans (up to 50 x 50 km) in the piedmont zones of 6,000 m high glacier- and snow-covered mountain ranges of western China, including the Altai Shan ('shan' = mountains), Tian Shan, Kunlun Shan, Qilian Shan, and Karakoram. These zones are loci for human populations, and also a major source of wind-blown dust.

The Chinese loess has a simple mineralogy consisting of angular, blade-shaped quartz grains (~60–65%), with minor feldspars, micas, and carbonates. Clay minerals rarely total more than 12–15% in the loess units, although they may reach 40% in the intercalated soils (palaeosols). The air-fall nature of deposition results in high to very high porosities and low bulk densities (> 40% and ~1400 kg/m^3, respectively, in the most recent loess). Considerable convergence of cold and dry westerly airflows leeward of the Tibetan Plateau, driven by the Mongolian 'high' and orographically enhanced, is characteristic of the winter/spring circulation pattern. The 30-year mean annual incidence of dust storm days exceeds 35 in the Taklamakan Desert, the Hexi Corridor, and the western Loess Plateau (Fig. 2.1). Substantial dust falls (0.02–0.08 mm/yr, equivalent to ~32–108 tons/km^2/ yr) occur in at least 6 months of the year at several sites in this region (Derbyshire et al. 1998).

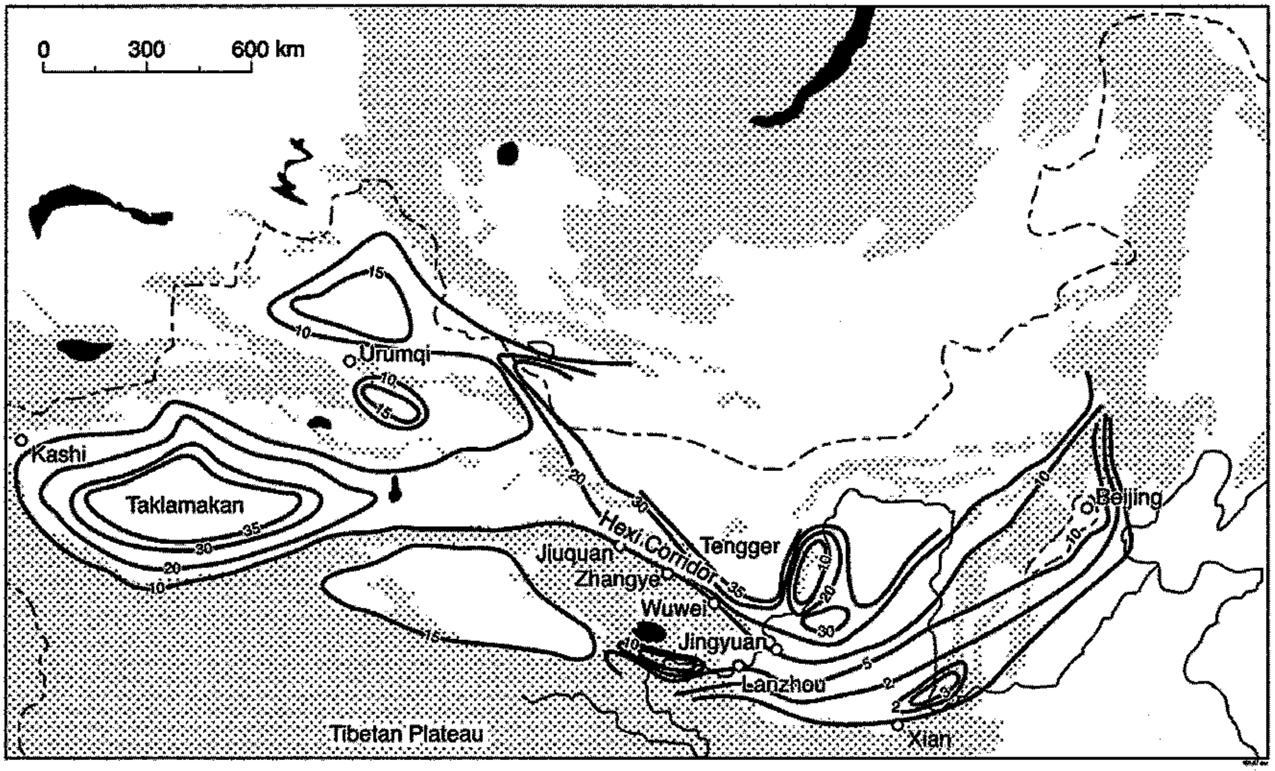

Figure 2.1: Annual number of sand and dust storm days (30–year mean) in North and West China. Shaded areas are mountains and plateaux. Lakes are shown in black (after Derbyshire et al. 1998).

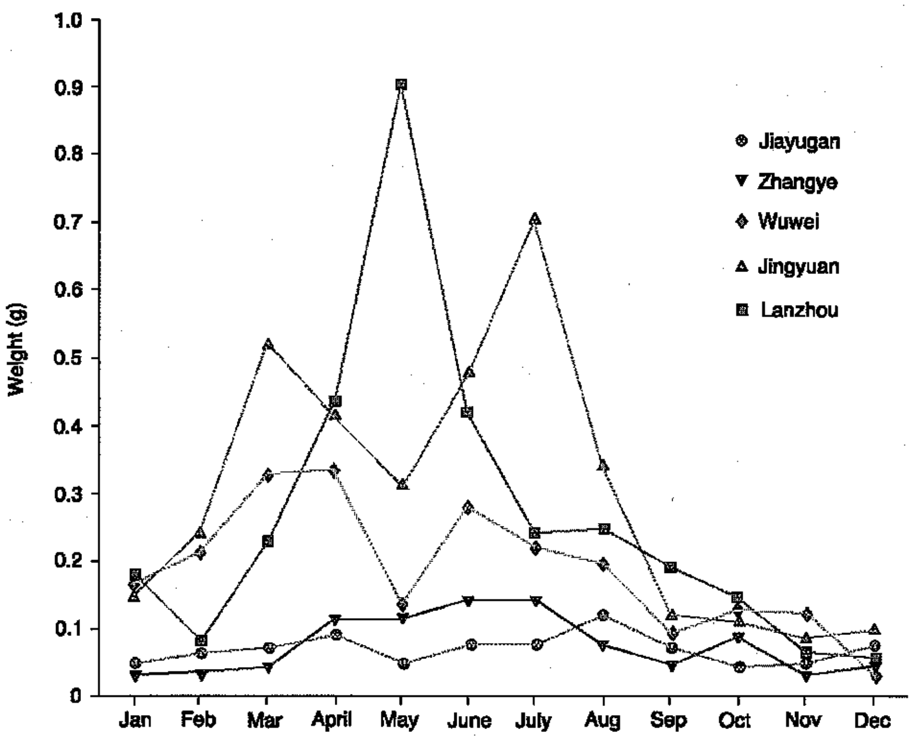

Figure 2.2: Mean monthly rate of dust deposition (1988–1991) at five stations along the Hexi Corridor, western Gansu province, China (after Derbyshire et al. 1998). Weight values x 30 = g per m².

Dust-fall sampling along the Hexi Corridor shows that while it is traditionally believed that dust storm activity peaks in spring to early summer, the pattern is more complex (Figure 2.2). Moreover, there is increased complexity down-wind along the length of the Hexi Corridor and across the Loess Plateau, a function of proximity to the dust sources and progressive increase in dust deposition leeward of the sources. For example, dust deposition amounts are relatively small and the spring and summer peaks only weakly developed in Jiayuguan (ca. 20 km WNW of Jiuquan) and Zhangye in the narrowest part of the western Hexi Corridor. However, dust accumulation rates rise significantly where the Corridor begins to widen just west of Wuwei, with resultant divergent airflow reaching highest values outside the Corridor on the western Loess Plateau at Jingyuan and Lanzhou. The double peak (March–April and June–July) is a clear feature of the dust deposition regime at Wuwei and Jingyuan (Fig. 2.2). Both lie adjacent to a complex of sources including the Hexi Corridor and the Tengger Desert, as well as the ice- and snow-fed Shiyang River (Wuwei) and the highly seasonal Yellow River (Jingyuan), but a full explanation of the double accumulation maximum requires more work. The curve for Lanzhou is dominated by a single substantial but broad maximum extending from March to August but with a clear peak in early summer (May). The location of Lanzhou toward the right (south) margin of the fan-shaped zone of dust deposition to leeward (east) of the outlet of the Hexi Corridor (see Fig. 4 in Derbyshire et al. 1998), and the possibility of additional dust sources in the northeastern Tibetan Plateau (as suggested by equivalent rates of loessic silt accumulation in the Xining Basin, about 200 km WNW of Lanzhou) may form part of the explanation of such a distinctive pattern. The reasons for such variations in accumulation patterns need to be better understood before a sound platform can be provided for the work of health scientists. The research required includes improved and longer-term dust-fall sampling, improved knowledge of ground-surface conditions in the source areas, and a fuller characterization of the meteorological controls, especially the wind-flow dynamics.

Dust suspended in the lower atmosphere is overwhelmingly of silt size. Minerogenic dusts sampled along the 1200-km long Hexi Corridor consist of finer silts derived from re-entrainment of loess, reworked silts, and loessic soils. There is no marked difference between summer and winter dusts. Both contain a mixture of fine to medium silts and silt-size aggregates of very fine silts and clay-size particles. Aggregates rich in clay-size (<2 μm) angular quartz are common. The finer respirable dust particles associated with the incidence of silicosis (<5 μm: Pendergrass 1958, <3 μm: Policard and Collet 1952) do not occur as discrete suspended grains in North China, but as silt-sized aggregates 5–50 μm in diameter, a notable proportion being 5–15 μm. The exposed population in China's semi-arid northwest is estimated to number 24 million people, although exposure data are limited. The highest rates of dust accretion appear to coincide with the thickest loess, indicating a dynamic relationship. Pilot measurements by medical staff of the Lanzhou Military Hospital (1982–1984) found outdoor and indoor dust concentrations of 4.2 mg/m^3 and 20 mg/m^3, respectively, within which free silica reached 61%. These very high dust loads occurred during storms, with analysis of the deposits showing important contributions from coarser fractions. In 1980, annual means of total suspended particulates (TSP) in Lanzhou of 1.14 mg/m^3 were reported for outdoor sites. Indoor/outdoor comparisons in Lanzhou in 1988 yielded TSP values of 0.94 and 0.76, respectively. Inhalable particulate levels of 3.02 mg/m^3 were reported in a rural home in Gansu Province in which dung was used as a cooking fuel. In the Minghai and Lianghua communes of the Hexi Corridor, the "average dust concentration" during 3 days in April 1991 (windy season) ranged from 8.25 to 22.0 mg/m^3 (15–26% free silica), according to Xu et al. (1993). We have identified only two surveys of silicosis in NW China, and these appear to be incomplete. In the study by Xu et al. (1993), radiographs were taken of 395 residents in a desert area, with a reported prevalence of 7% silicosis, rising to 21% among subjects over 40 years old. Such prevalences are comparable to those found in surveys of silicosis in industrial settings of which many have been published over the years both in developed and, now increasingly, in developing countries (Wagner 1997).

Radiological examination of the chest X-rays of 9591 residents, undertaken in Gansu province, showed a silicosis prevalence of 1.03%, rising to 10% in subjects over 70 years old [Personal communication, Changqi Zhou (Beijing)]. In addition, there are case reports of silicosis and silico-tuberculosis in farmers in the same province [Personal communication, Zhang Shi Fan (Lanzhou)]. There is thus some evidence that silicosis may be a public health problem in north China, although degree and extent cannot be quantified in the absence of statistics on morbidity levels across this extensive region. It should not be forgotten that these respiratory disease risks add to the substantial risk of nonsilicotic respiratory disease, the prevalence of cigarette smoking in Chinese adult males (over 15 years old) having exceeded 60% in 1984, with the figure of 7% for women smokers set to rise (World Health Organization 1997).

Wind-blown loessic dust, including aggregates of the finest fractions, is also known to be a health hazard in the Ladakh region of NW India. Chest X-ray surveys here, supported by analysis of limited necroptic lung tissue samples, suggest an incidence, among a randomly selected group of adults from two villages in the age range 50–62, of up to 45%, including three cases of progressive massive fibrosis (Norboo et al. 1991, Saiyed et al. 1991). Bulk chemical analysis of lung tissue showed that over 54% of the inorganic dust proved to be elemental silica (by X-ray diffraction) indicating that quartz constituted 16–21% of the extracted inorganic dust). Only 20% of men and none of the women were cigarette smokers, and silicosis was clearly shown to be of higher incidence in the village with the higher incidence of dust storms, suggesting an important link between the environment and the incidence of silicosis. Women's daily work is such that they are more exposed than men to fine dusts, and this is reflected in the greater incidence of advanced fibrotic lung disease in women in this region.

Finally, measures designed to reduce exposure to fine atmospheric dust have yet to be considered in High Asia, a region with a population inured to the difficulties of living for millennia in a generally harsh environment. Certain measures, such as the wearing of facemasks of doubtful efficacy, have been adopted by some sections of the population in some of the larger Chinese cities, but these are largely a response to perceived human-induced conditions ('pollution') rather than to natural phenomena.

Acknowledgments:

This summary owes much to the research of Dr. Tony Fletcher (London School of Hygiene and Tropical Medicine, U.K.), and Dr. Keith Ball (Middlesex Hospital, U.K.). I am also grateful for the help of my Chinese colleagues, Dr. Xingmin Meng (University of London, U.K.), Professor Shi Fan Zhang (Lanzhou, China) and Professor Changqi Zhou (Beijing, China). Dr. Tony Fletcher is also thanked for suggestions that improved an earlier draft.

References

Burbank, D.W., Leland, J., Fielding, E., Anderson, R.S., Brozovic, N., Reid, M.R. and Duncan, C. 1996. Bedrock incision, rock uplift and threshold hillslopes in the northwestern Himalayas. Nature, v.379, p.505–510.

Derbyshire, E., T.A. Dijkstra and I.J. Smalley (eds.) 1995. Genesis and Properties of Collapsible Soils. NATO ASI Series C: Mathematical and Physical Sciences, Vol. 468, Kluwer, Dordrecht, 413p.

Derbyshire, E. and Meng, X.M. 2000. Loess as a geological material. Chapter 3 in: Derbyshire, E., Meng, X.M. and Dijkstra, T.A. (eds.) 2000, Landslides in the thick loess terrain of Northwest China. John Wiley & Sons, Chichester and New York, p.47–90.

Derbyshire, E., Meng, X.M. and Kemp, R.A. 1998. Provenance, transport and characteristics of modern aeolian dust in western Gansu Province, China, and interpretation of the Quaternary loess record. Journal of Arid Environments, v.39, p.497–516.

Norboo, T. Angchuk, P.T. and Yahya, M. 1991. Silicosis in a Himalayan village population: role of environmental dust. Thorax, v.46, p.341–343.

Pendergrass, E.P. 1958 Silicosis and a few other pneumoconiosis: observations on certain aspects of the problems with emphasis on the role of the radiologist. J. of Roentgenology, v.80, p.1–41.

Policard, A. and Collet, A. (1952)Deposition of silicosis dust in the lungs of the inhabitants of the Saharan Regions, Arch. Industrial Hygienne and Occupational Med., v.5, p.527–534.

Saiyed, H.N., Sharma, Y.K. and Sadhus, H.G. 1991. Non-occupational pneumoconiosis at high altitude villages in central Ladakh. British Journal of Industrial Medicine , v.48, p.825–829.

Wagner, G.R. 1997. Asbestosis and silicosis. Lancet, v.349 (9061), p.1311–15.

Wang, Y.Y. and Song, H.L. (Eds) 1983 Rock Desert, Gravel Desert, Sand Desert Loess. Xi'an , Shaanxi People's Art Publishing House, N.P. World Health Organization 1997. Tobacco or Health: a Global Status Report. WHO.

Xu, X.-Z., Cai, X.-G., Men, X.-S. et al. 1993. A study of siliceous pneumoconiosis in a desert area off Sunan County, Gansu Province, China. Biomedical and Environmental Sciences, v.6, p.21–222.