PULMONARY TOXICITY OF ILLITE AND KAOLIN DUSTS

H. DANIEL • L. Le Bouffant • A. Wastiaux • P. Sëbastien
CERCHAR, BP No. 2, 60550 Verneuil en Halatte, France

INTRODUCTION

Clay minerals kaolin and illite are present in some mixed dusts of industrial origin. Kaolin is an industrial mineral with many applications. It is used as a filler in the paper industry, as a filler and extending agent in rubber, paints, inks, plastics and insecticides, in the manufacture of China, refractory bricks, crucibles, saggars and glass, as a mild abrasive in soaps and toothpastes and as stiffener of textile. Dust possibly produced in these industries, but also smoking,[2] can be sources of exposure to fine kaolin particles. It is now accepted that the long term inhalation of high quantities of kaolin dust can lead to the development of a specific type of pneumoconiosis.[11] From the pathological viewpoint, the fibrosis is mainly nodular or massive,[9] with important dust retention.[14]

Sources of exposure to illite and possible related-health effects are much less documented. The interest for illite came essentially from its presence in coal mine dust.[3] It has been suggested that the in-vivo leaching of aluminum from illite particles could reduce the activity of the accompanying quartz particles.[7] To our knowledge, the toxicity of illite particles has been tested in only few in-vitro or in-vivo experiments.[1,5,8]

We have some evidence that both minerals can exhibit acute pulmonary toxicity after a single intratracheal injection.[4] In a previous experiment, two groups of 50 female Wistar rats were injected with 50 mg of fine particles of either illite from Le Puy, or kaolin from Cornwall. Respectively 12% (illite group) and 45% (kaolin group) of the animals died of pulmonary oedema in the first week following the injection.

In this context, we found it useful to conduct long-term experiments to comparatively assess the fibrogenicity of illite and kaolin dust, alone or in combination with quartz.

METHODS

In a first series of experiments, illite (Le Puy), kaolin (Cornwall), quartz (Madagascar) and coal (Courrières low rank) were tested in the rat exposed by inhalation. Wistar female rats were exposed for 3 months (5 h/d, 5 d/w) to 300 mg/m^3 of respirable dust. Aerosol generators and inhalation facilities are described in detail elsewhere.[6]

In a second series, animals received a single intratracheal injection of either quartz (12.5 mg), quartz + illite (12.5 mg + 37.5 mg) and quartz + kaolin (12.5 mg + 37.5 mg). Injected particles were prepared by cyclone separation and were of respirable size.

In both series, the pulmonary response was assessed at month 6, 12, 18 and 24. Animals (10 per subgroup) were killed and the lungs removed. The weight of fresh lung was recorded for each animal.

Left lobes were used for histopathological examination. They were perfused under 25 cm H_2O pressure and fixed in 10% neutral buffered formalin. Sections stained by hematoxylin eosine and Picrosirius were examined at three different locations under crossed polaroid filters. In each group, remaining fragments of lung tissue were pooled, dried and analyzed for collagen, lipids and dust. Collagen was measured by the method of Stegeman.[12] Coal in the lung was measured gravimetrically after extraction by the formamide technique.[13] For quartz and clay, lung dust was extracted by low temperature ashing, ash suspension, and filtration through a polycarbonate membrane filter. Quantity of quartz on the membrane was determined by X-ray diffractometry. Quantity of clay was deduced from aluminum concentration measured by X-ray fluorescence.

RESULTS

Main results of the inhalation experiments are reported in Figure 1. Similar conditions of exposure yielded to different dust retentions in the lung. The highest retention was observed with coal and the lowest with quartz, clay retention being situated in between. For clays, there was no evidence of pulmonary clearance after month 12. At month 6, the mean weight of fresh lung was 5 times above control value in the quartz group; it was only slightly elevated in the other groups. In the following periods, the lung weight increased much more in the quartz group than in the other groups. A similar pattern was observed with pulmonary collagen.

Main results of the intratracheal injection experiments with the quartz and quartz/clay mixtures are reported in Figure 2. At month 6 and 24, respectively 48% and 37% of the injected dose was still present in the lungs of animals exposed to quartz alone. Clay admixture had no clear effect on the clearance of quartz. It seemed, however, that overall quartz retention was somewhat higher in the quartz/illite group and somewhat lower in the quartz/kaolin group. Mean weight of fresh lung was 4–5 times above control value in the quartz group and in the quartz/kaolin group. Interestingly enough, the lung weight was only slightly elevated in the quartz/illite group. In all groups, the lung weight increased in the period 6–24 months. Results of collagen measurement clearly discriminated the three groups. The admixture of illite or kaolin to the injected quartz, respectively reduced or greatly enhanced the production of pulmonary collagen.

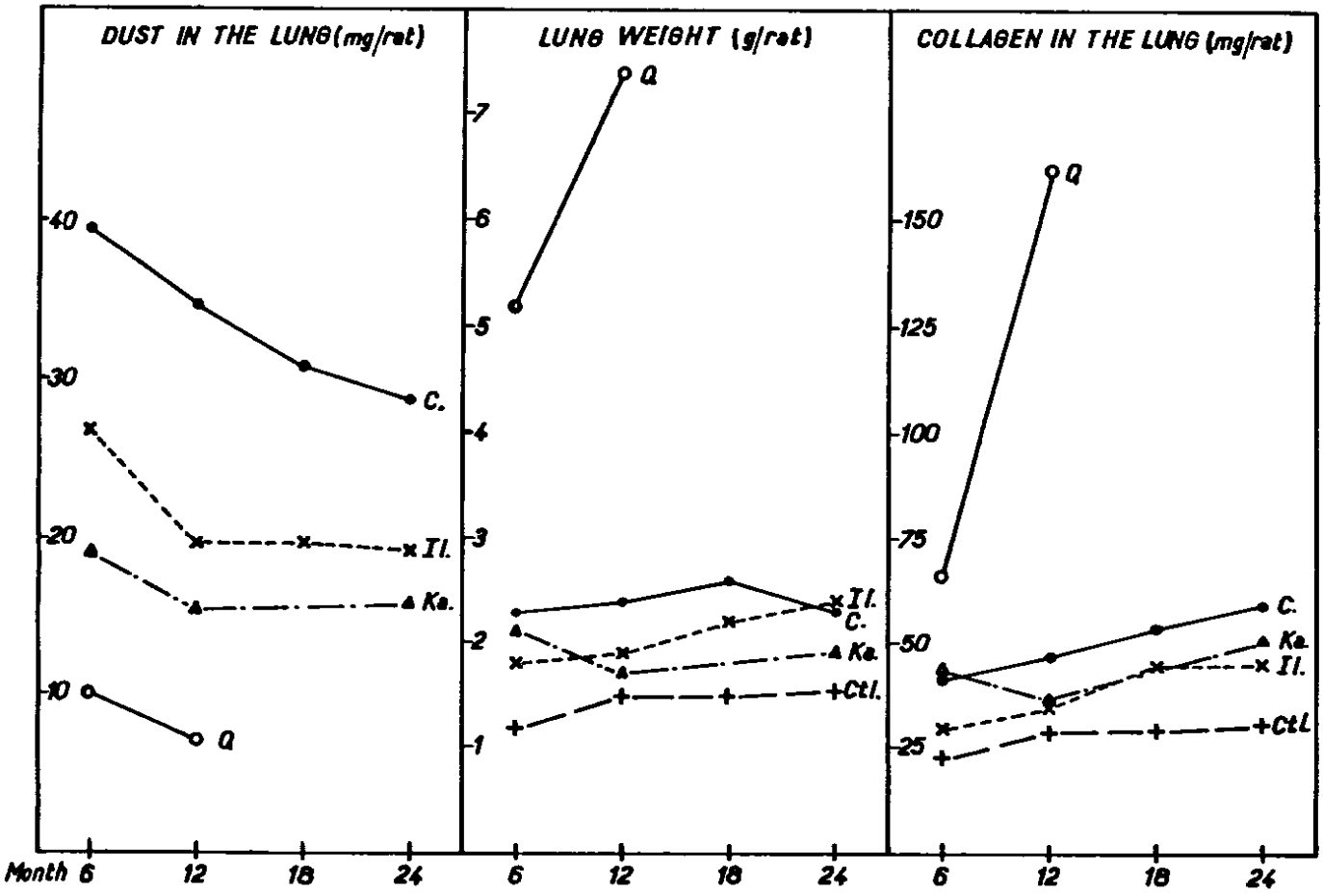

Figure 1. Wistar female rats exposed by inhalation (300 mg/m^3, 3 months) to quartz (Q), kaolin (K), illite (I) and coal (C). Measurement of lung dust, weight of fresh lung and pulmonary collagen at month 6, 12, 18 and 24.

DISCUSSION

In our inhalation experiments kaolin and illite exhibited similar activities. During a two year period they produced very little collagenous fibrosis. These results agree with previous experimental observations.[9] They are also similar to those obtained after inhalation of coal dust by experimental animals. It should not be concluded however, that kaolin, illite and coal dust have similar biological activities. First it must be remembered that results of these experimental tests are poor predictors of the pneumoconiotic risk in humans. Inhalation of coal mine dusts for example, can lead to disabling pneumoconiosis in miners, but these dusts exhibit very moderate activity in most of experimental tests. Secondly, there is some evidence from our experiments by intratracheal injection that clay and coal dust behave differently in the lung.

An interesting observation was the pulmonary response to intratracheal injection of quartz/clay mixtures. Combination of quartz and kaolin gave rise to pronounced collagenous fibrosis, as already noticed.[10] By contrast animals exposed to quartz/illite produced mixtures of less pulmonary collagen than animals exposed to the same dose of quartz alone. This clearly indicates that kaolin and illite behave differently in the lung. But apparently, this difference in behaviour had no detectable effect when the two clay minerals were tested individually. These findings illustrate once more how complex are the mechanisms of action of inhaled coal mine dust, which generally contains quartz, kaolin and illite.

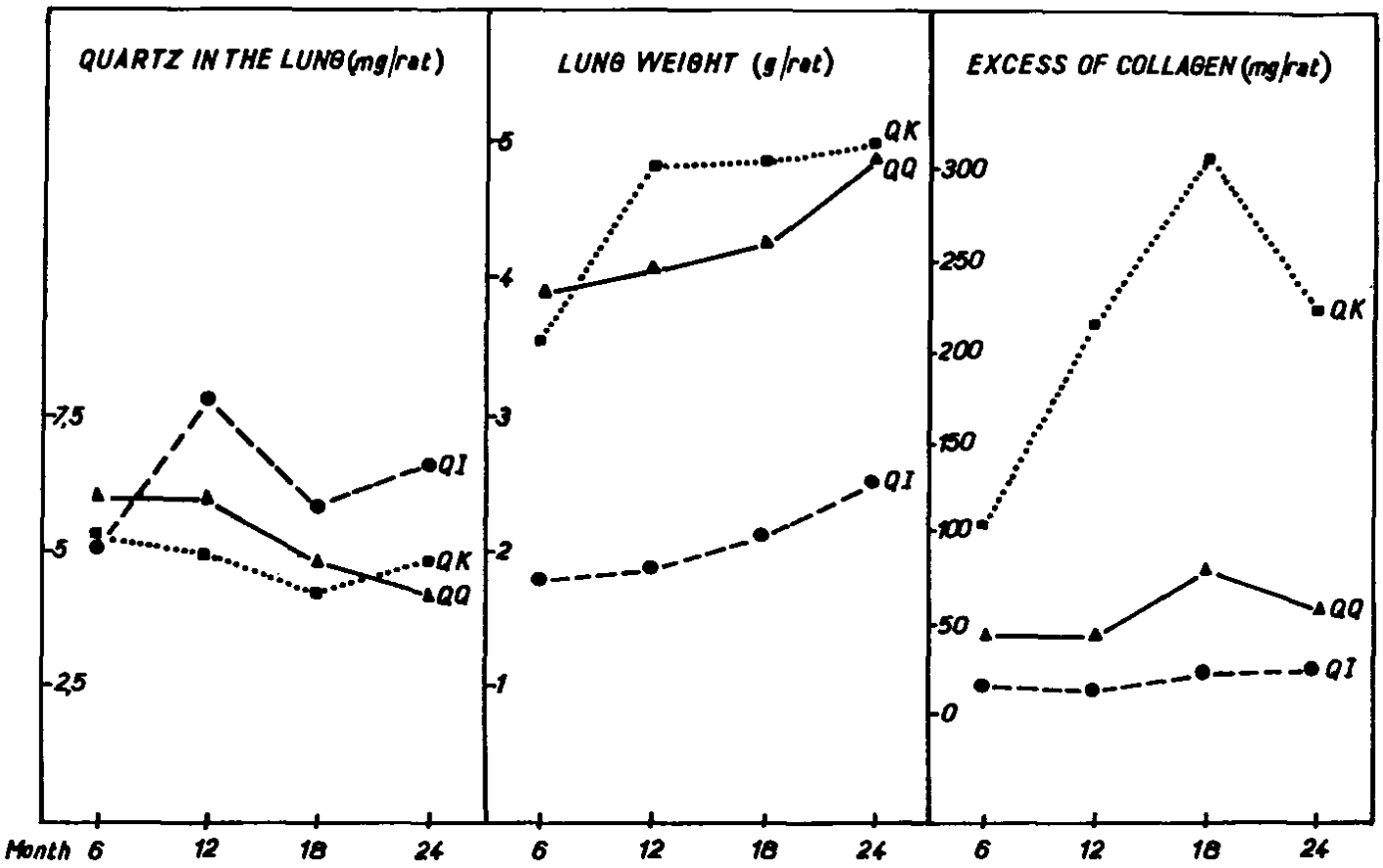

Figure 2. Pulmonary response to quartz/clay mixtures injected intratracheally in Wistar female rats. Measurement of lung quartz, weight of fresh lung and pulmonary collagen at month 6, 12, 18 and 24. Three dusts were injected: QQ 12.5 mg of quartz, QK 12.5 mg of quartz + 37.5 mg of kaolin, QI 12.5 mg of quartz + 37.5 mg of illite.

REFERENCES

1. Adamis, Z., Tatrai, E., Timar, M., Unguary, G.: *In-Vitro Effects of Mineral Dusts*, pp 453-458. Springer-Verlag, Berlin-Heidelberg (1985).
2. Brody, A.R., Craighead, J.E.: Cytoplasmic inclusions in pulmonary macrophages of cigarette smokers. *Lab. Invest.*, 32:125-132 (1975).
3. Bruch, J., Rosmanith, J.: *In-Vitro Effects of mineral dust*, pp 433-440. Springer-Verlag Berlin-Heidelberg (1985).
4. Daniel H. Personal communication (1987).
5. Gormley, I.P., Addison, J.: The in-vitro cytotoxicity of some standard clay mineral dusts of respirable size. *Clay Minerals*, 18:153-163 (1983).
6. Le Bouffant, L. *Inhaled Particles and Vapours*, pp 369-383, Pergamon Press, Oxford, London, New York, Paris, (1961).
7. Le Bouffant, L., Daniel, H., Martin, J.C., Bruyère, S.: Effect of impurities and associated minerals on quartz toxicity. *Ann. Occup. Hyg.*, 26-1-4:625-634 (1982).
8. Martin, J.C., Daniel, H., Le Bouffant, L.: *Inhaled Particles IV*, pp 361-370, Pergamon Press, Oxford (1977).
9. Parkes, W.R.: *Occupational Lung Disorders*, 2nd Ed. pp 310-313 Butterworths, London, Boston, Sydney, Wellington, Durban, Toronto (1982).
10. Schmidt, K.G., Luchtrath, H.: Die Wirkung von frischen und gebranntem kaolin auf die lunge und das Baudchell von vatten. *Beitr. Silikosforsch.*, 58:1-37 (1958).
11. Spannahke, E.W., Menkes, H.A.: Kaolin and the lung. *Am. Rev. Respir. Dis.*, 127:141-142 (1983).
12. Stegeman, H.: Mikrobestimung von hydroxyprolin mit chloramin-t und p-dimethylaminobenzaldehyd. *Hoppe-Sayler's Zeitschrift für Physiologiscge Chemie*, 311:41-45 (1958).
13. Thomas, N., Stegeman H.: Dorstallung der fremsdstaube aus lungen ind ihre ergenschafter. Beitrage Zur Silikose Forschung. Herausgeber Bergbau-Forschunginstitut, Bochum, 28-1-29 (1954).
14. Wagner, J.C., Pooley, F.D., Gibbs, A., Lyons, J., Sheers, G., Moncrieff, C.B.: Inhalation of China stone and China clay dusts: relationship between the mineralogy of dust retained in the lungs and pathological changes. *Thorax* 41:190-196 (1986).

Proceedings of the VIIth International Pneumoconioses Conference *Part*
Transactions de la VIIe Conférence Internationale sur les Pneumoconioses *Tome*
Transaciones de la VIIa Conferencia Internacional sobre las Neumoconiosis *Parte*

II

Pittsburgh, Pennsylvania, USA—August 23–26, 1988
Pittsburgh, Pennsylvanie, Etats-Unis—23–26 aout 1988
Pittsburgh, Pennsylvania EE. UU—23–26 de agosto de 1988

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

CDC
CENTERS FOR DISEASE CONTROL

Sponsors

International Labour Office (ILO)
National Institute for Occupational Safety and Health (NIOSH)
Mine Safety and Health Administration (MSHA)
Occupational Safety and Health Administration (OSHA)
Bureau of Mines (BOM)

November 1990

DISCLAIMER

Sponsorship of this conference and these proceedings by the sponsoring organizations does not constitute endorsement of the views expressed or recommendation for the use of any commercial product, commodity, or service mentioned.

The opinions and conclusions expressed herein are those of the authors and not the sponsoring organizations.

DHHS (NIOSH) Publication No. 90-108 Part II