... of most of the elements in the center ... the periodic table, such as the transition elements. Finally, when the ionic potential is high (> 10) the positive ion appropriates one or more oxygen ion, freeing the hydrogen and forming an oxyanion, which is generally soluble; this is characteristic of the nonmetals in the upper right corner of the periodic table.

If life began in the primitive terrestrial oceans, elements whose abundances in the aqueous phase are high should have a high representation in living material. In Fig. 1, the enrichment factor for a number of elements—that is, the ratio of the concentration of the element in an organism to its concentration in the earth's crust (*7*)—is plotted against ionic potential. A similar curve is seen for all major groups of organisms, as we proceed up the evolutionary scale from bacteria to fungi to plants to land animals, and for the ocean (Fig. 2).

A general pattern is observed for all living organisms: (i) For elements of low ionic potential values ($IP < 3$) the log of the enrichment factor (EF) is in the range of -1 to $+1$ indicating small enrichment or small depletion relative to the crust. (ii) For intermediate IP values ($3 < IP < 10$) log EF is -3 to -4 indicating large depletion in living organisms. (iii) For large IP values ($IP > 10$) log EF increases as the ionic potential increases and varies from -4 to $+4$. It should be noted that the elements mentioned by Crick and Orgel as showing anomalous distribution patterns—Mo, Ni, and Cr—also follow this general pattern. Specifically, Mo does not show any significant enrichment in living organisms as compared to the earth's crust. Obviously, taking each element and each group of organisms separately, we may expect many exceptions to the rules; still, the general pattern is strikingly similar for all the groups of organisms investigated.

According to Oparin (*8*), some combinations of biochemical reactions are characteristic of all contemporary organisms. These are combinations of patterns acquired by the emerging living matter in its very early stages of development, before further specialization and differentiation took place. Thus the basic similarity of the elemental composition pattern of all groups of living organisms (Fig. 1) indicates that the pattern was determined at the initial steps of the development of life.

It should be noted that in the range of ionic potentials higher than 10, where the major biochemical elements sulfur, carbon, and nitrogen are found, organisms have a very significant enrichment of 10 to most 10,000 relative to the ocean. This

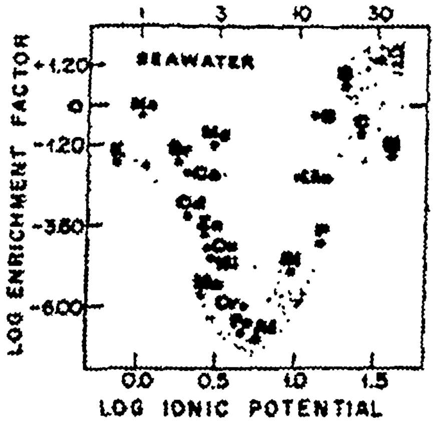

Fig. 2. Elemental enrichment factors in seawater, related to the ionic potential of the elements.

may be taken as a clue to a more exact location for the origin of life. It can be speculated that life began at the interface of the primitive atmosphere and the ocean, in the thin microlayers at the surface of the ocean where large enrichments of the atmospheric constituents (mainly nitrogen and carbon at that stage) may occur. Various other elements may also be concentrated in these microlayers because of the effects of surface-active materials, surface tension, and the transfer processes between the liquid and the gaseous phase. In any event, it is evident that a chemical environment similar to the earth's ocean is sufficient to explain the elemental abundance relationships in living materials. A nonterrestrial explanation, especially one that has in... as being advantageous to the rapid development of life, is not justified.

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11 March 1975

Exposure to Asbestos in the Use of Consumer Spackling, Patching, and Taping Compounds

Abstract. *Analysis of representative samples of spackling, patching, and jointing compounds, purchased at retail stores in the New York City area, has shown that some contain asbestos minerals as well as other biologically active substances. Measurements suggest that home repair work involving the use of such materials may result in exposure to dust at concentrations sufficient to produce disease.*

Spackling and drywall taping compounds consist of extremely fine-grained white powders or premixed pastes. Plaster of Paris is supposedly the major constituent, but other light-colored materials including clays, micas, quartz, talc, and ground limestone, supplement or replace the plaster in many formulations. Chrysotile is added to some products, apparently because these minute fibers act as reinforcing agents. The presence of amphibole asbestos in some products results from its natural occurrence in talc, carbonates, and other rocks used as raw materials (*1*).

Fifteen samples of consumer spackling and patching compounds were purchased at hardware stores in the New York City area, four in 1972 or earlier and the remainder in January 1974. We analyzed the samples for mineral phases by polarized light microscopy, x-ray powder diffraction, and transmission electron microscopy, with particular attention to quantitative determination of asbestos minerals. The spackling and taping compounds consist mainly of particles smaller than 3 μm in average diameter or length (Fig. 1). Particles of this size are generally too small to

Table 1. Mineral content of consumer spackling and patching compounds and industrial drywall taping compounds.

Mineral phase	Frequency of occurrence of mineral phases: In 15 consumer spackling and patching compounds	In 10 industrial drywall taping compounds
Chrysotile	3 (5–10%)	9 (5–12%)
Tremolite	1 (4– 6%)	1 (5– 7%)
Anthophyllite	1 (10–12%)	
Talc	2	2
Quartz	9 (5–70%)	6 (10–30%)
Feldspar	1	
Pyrophyllite	2	
Mica	8	9
Kaolinite	5	7
Calcite	11	4
Dolomite	3	4
Plaster of Paris	7	6

be individually studied by polarized light microscopy, and identification is further confounded because these compounds commonly are mixtures of four or more different materials. The analytical use of the optical microscope with its limited resolution allows large numbers of fibers to go undetected. The asbestos minerals, in particular, are usually too fine-grained to identify. In such circumstances, x-ray powder diffraction may be used to identify and quantify the individual crystalline phases present in the mixtures.

In this investigation the amounts of asbestos present in spackling compounds was determined by comparison with dilution standards (*2*). Binary systems of chrysotile, tremolite, and anthophyllite asbestos in plaster of Paris ($CaSO \cdot \frac{1}{2}H_2O$) were prepared at varying dilutions on a weight-to-weight basis. Diagnostic reflections for each of the asbestos minerals were selected. These reflections were step-scanned by x-ray diffraction at increments of 0.02° 2θ, where θ is the dispersion angle, over a goniometric interval sufficient to define a peak-to-background ratio for the diagnostic reflections. A digital printout of elapsed time in a fixed-count determination was used to prepare precise positions and profiles of the diagnostic reflections. The area above background, determined with a compensating polar planimeter, was taken to be proportional to the concentration. Details of the method have been presented elsewhere (*2*). Samples of spackling and taping compounds were prepared, analyzed, and measured under the same conditions as the dilution standards. Comparison of the results of known dilution standards with the samples permitted the amounts of asbestos to be estimated with approximately 20 percent reproducibility.

The presence of certain minerals may interfere with the detection or quantitation of chrysotile in spackling and taping compounds. For example, chrysotile and kaolinite have similar crystal structures and consequently similar x-ray diffraction patterns (*3*). However, electron microscopy can be used to corroborate the results of x-ray diffraction and to directly estimate the asbestos content of materials, since each mineral type has a characteristic morphology and electron diffraction pattern.

The results of the analyses of 15 consumer spackling and patching compounds are given in Table 1. Three of the samples were found to contain chrysotile asbestos, and two others contained tremolite and anthophyllite asbestos. Talc was a major con-

Fig. 1 Electron photomicrograph of a cons. :n spackling product. Large numbers of chrysot fibers and fiber bundles are present. Granul. particulates are clay, mica, and carbonate mi· erals.

stituent in two samples and pyrophyllite i two. The crystal structure and physic properties of pryrophyllite are almo: identical to those of talc; pyrophyllite ma be considered the aluminum analog of tal. Its biological activity is presently ur known. Quartz was a major constituent i seven of the samples, and it was present : two others in lesser concentrations. On tl basis of the x-ray intensities of several m: jor quartz reflections, including those . 4.26, 3.34, and 1.817 Å, the amount ‹ quartz present is estimated to be greate than 10 percent in the seven samples. Opt cal and transmission electron microscor have shown essentially all the quartz to ' of respirable size (< 5 μm). Both qua· and talc can produce pulmonary fibros (silicosis, talcosis) (*4*). One sample co: sisted largely of quartz with lesser amoun of feldspar and anthophyllite. This may ii dicate that the source material for th product was an anthophyllite schist. Tl combination of talc with some tremoli and quartz in another sample represents common mineral association typical commercial talc ore bodies.

Both optical and electron microsco: analyses showed that the asbestos fibe present in the samples ranged in len; from 0.25 to 8.0 μm. Most were shor than 5 μm in length, which is respirat size, yet they were not generally detec: by optical microscopy.

The possibility of asbestos exposure d ing home construction and repair is dicated by the fact that drywall constr tion workers are exposed to signific· concentrations of asbestos air c tamination. Mineralogical analyses of industrial drywall taping compounds s! that nine contain chrysotile, in concen tions ranging from 5 to 12 percent weight) (Table 1).

Table 2. Asbestos fiber concentrations during use of taping compounds containing asbestos minerals. Multiplication of the number of fibers per milliliter by 10^6 gives the number of fibers per cubic meter of air, an amount which may be inhaled during 1 hour. An unstudied proportion of these fibers is retained and others are exhaled. Current (interim) regulations of the OSHA prohibit concentrations of 5 fibers per milliliter or more, longer than 5 μm, as a time-weighted average for workers. Concentrations above 2 fibers per milliliter will be illegal after 1976. Current regulations set a ceiling concentration of 10 fibers, longer than 5 μm, per milliliter of air.

Operations	Number of samples	Peak fiber concentration (fibers per milliliter): Mean	Range
Pole-sanding (1 to 1.5 m)	10	10.0	1.2 to 19.3
Background (2.5 m), same room	3	8.6	3.5 to 19.8
Background (7.5 m), adjacent room	2	4.8	0.7 to 8.8
Hand-sanding (1 to 1.5 m)	11	5.3	1.3 to 16.9
Background (2.5 m), same room	2	2.3	2.1 to 2.5
Background (4.5 m), adjacent room	2	4.3	1.5 to 7.1
Dry mixing (1 to 1.5 m)	2	47.2	35.4 to 59.0
Background (3 to 6 m), same room	3	5.8	0.5 to 13.1
Background (5 to 10 m), adjacent room	2	2.6	2.1 to 3.1
Sweeping floor (3 to 15 m)			
15 Minutes after sweeping	1	41.4	
35 Minutes after sweeping	1	26.4	

The chemistry and physical characteristics of these minerals vary appreciably and it is with a knowledge of such physical and chemical characteristics that single particles of the minerals can be identified with considerable confidence.

The considerable industrial importance of asbestos minerals depends upon the very fine fibrous nature of the materials and their chemical inertness. Fibres formed from the varying minerals which are released and inhaled are mainly submicroscopic in size so that it is only with sophisticated equipment such as the transmission electron microscope that they can be seen.

With modern developments in electron optical and X-ray analytical equipment it is now possible to chemically analyse these submicroscopic fibres and identify them positively. This enables assays of diseased tissue to be made for their mineral content down to the single particle level. Particles from very well defined areas of tissue can also be isolated and determined with relative ease. Previous techniques of tissue analysis relied mainly on bulk extraction together with bulk analysis for identification purposes, with the modern analysis techniques now available the various chemical phases are readily separated.

C. THE PHYSICIST'S APPROACH TO ASBESTOS CANCERS

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For inhaled particles to penetrate deeply into the lungs, they must be of small aerodynamic size. In the case of a fibre, this is roughly proportional to the diameter and virtually independent of length. The fact that amphibole asbestos from different geographical areas vary in their diameter distributions indicates that they differ in the extent to which they penetrate to the pulmonary regions associated with asbestosis, lung carcinoma and pleural mesothelioma. Substantial fibre length militates against deep penetration, as also does the curly shape of chrysotile fibres. The fibres most likely to penetrate to the pleura are short, thin, straight fibres. Crocidolite from the N.W. Cape is particularly rich in such fibres and has been the asbestos most associated with the formation of pleural mesotheliomas.

These aerodynamic considerations do not apply to intrapleural injection experiments. The mesotheliomas produced in these studies appear to be related primarily to the fineness of the fibre. Chrysotile asbestos, which produces extremely fine fibrils by fragmentation in lung fluids, is particularly carcinogenic in this situation. Chemical composition seems to be of secondary importance in the formation of these mesotheliomas, and other types of fibre, including fibre glass, produce these cancers when the fibres are as fine as those of asbestos.

D. EXPERIMENTAL AND FUTURE STUDIES

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Using experimental methods, we have tried to answer some of the questions posed by the epidemiologists, physicists and chemists. It has been possible to produce asbestosis, mesotheliomas, and carcinomas of the lung by using caesarian derived barrier protected rats. We have also been able to confirm that it is the fineness of the fibres that is important and that this not only applies to asbestos but to other fibrous dusts. By using standard reference samples prepared by the physicists we have been able to study and compare the effects of the different types of asbestos on this model.

Our future concern is towards the early diagnosis and treatment of the mesotheliomas which in certain heavily exposed populations have reached epidemic proportions. It is hoped that by developing a system of immunological surveillance we will be able to recognize those among the populations at high risk who are most likely to develop these tumours. It is considered that if effective immunotherapy can be applied at this stage, it may at least be possible to delay the development of these appalling tumours, for which no known treatment is effective.

COMMUNICATIONS

1. ALLERGIC ASPECTS OF ASTHMA IN THE HIGHLANDS OF PAPUA NEW GUINEA

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(Introduced by J. E. COTES)

Asthma in the highlands of Papua New Guinea has a lower prevalence and later age at onset than in Western countries. Of forty-eight patients, all showed cutaneous sensitivity to *D. pteronyssinus*: multiple sensitivity to allergens appeared more common with increasing age at onset. Among 335 unselected controls, 19% were sensitive to allergens, 14% of them to *D. pteronyssinus* (Anderson, 1974, *Clinical Allergy*, in press).

The levels of IgE antibody have been determined in these subjects and although asthmatics have higher levels than controls, there is considerable overlap and both groups have higher levels than their counterparts in an Australian community. IgE levels in controls were positively correlated with egg counts of intestinal parasites particularly hookworm: this

CINE
August 1974

Clinical Science and Molecular Medicine