Asbestos in Colorado Schools

CYNTHIA A. BALDWIN, MS
HARRY J. BEAULIEU, PhD
ROY M. BUCHAN, DrPH
HANS H. JOHNSON, EdD

ASBESTOS IN SCHOOLS should be of concern to everyone. Exposure to asbestos in the workplace may result in asbestosis or cancer (that is, mesothelioma or lung cancer). However, mesotheliomas (which are closely associated with asbestos exposure) have also resulted from nonoccupational exposures. Such exposures may occur in the home, the neighborhood, or an urban environment (*1*). Extensive exposure to asbestos fibers is not required for the development of mesothelioma. The risk of lung cancer of a person who smokes and is exposed to asbestos may be as much as 30 to 92 times the risk of the nonsmoker who is not exposed to asbestos (*2–5*). All commercial types of asbestos are capable of producing these diseases (*6,7*). Furthermore, no safe level of asbestos exposure has been determined (*8*).

Currently, the exposure of children to asbestos in school building is of great concern. The substance was used extensively in construction from 1946 to 1973. Of primary concern are friable (easily crumbled) materials (especially sprayed-on asbestos) that can easily release fibers to the environment. The possibility that children may be exposed to airborne asbestos fibers is especially worrisome because of the long latency period for the development of lung cancer and mesothelioma. This long period greatly complicates the estimation of the risk involved and identification of where the person was exposed to asbestos (*2*).

Contamination of the school environment by asbestos fibers occurs in three general ways: through fallout, contact or impact, and reentrainment (secondary dispersal). Fallout results in continuous low-level and long-lived fiber dispersal. It may occur without physical disruption of the material and may simply be a function of degradation of the adhesive. Variations in the fallout rate are due to the vibration of the build-

Ms. Baldwin is an industrial hygienist in the Iowa Bureau of Labor, Consultation Division, 307 East 7th, Des Moines, Iowa 50319. Dr. Beaulieu is an assistant professor in the Occupational Health and Safety Section (OHSS) of the Institute of Rural Environmental Health, Department of Microbiology, Colorado State University. Dr. Buchan is an associate professor and chief of the OHSS. Dr. Johnson is deputy chief of the OHSS.

The research described was supported in part by grant No. 1 R18 OH 01053–1 from the National Institute for Occupational Safety and Health and was performed by Ms. Baldwin as partial fulfillment of the requirements for a Master of Science degree. A report on the research was presented at a poster session of the annual American Industrial Hygiene Conference, held May 25–29, 1981, in Portland, Oreg.

Tearsheet requests to Ms. Baldwin.

ing, variations in humidity, air movement from heating and ventilating equipment, and air turbulence and vibration caused by people's activities. Contact contamination may be unavoidable during maintenance work, accidental during routine activities, or deliberate when vandalism occurs. Contamination by contact may result in extremely high levels of asbestos fibers in the air, and material damage may be extensive. Finally, reentrainment results in repeated contamination of the environment by resuspension of fallen fibers and may result in significant exposures of students and school custodians to high levels of airborne asbestos fibers (*9,10*).

Once a fiber is released into the environment, it begins to settle. Its settling rate is generally determined by the size, mass, form, and axis attitude of the fiber. The range of these characteristics also affects the hazard potential of the fiber. Settling velocity is strongly dependent upon the diameter of the fiber, and to a lesser extent, on its length. Its size also determines its respirability. Fibers less than 3.5 μm in diameter are considered to be respirable (*11*). Turbulence prolongs settling and causes reentrainment of fallen fibers. In addition, fibers can move laterally with air currents and contaminate space far from their point of release (*9*).

Widespread use of asbestos-containing materials in schools has been reported in New Jersey (*12*), Rhode Island (*13*), Massachusetts (*14*), New York, Indiana, Kentucky, Oklahoma, and Connecticut (*12,15*).

In 1979, the Environmental Protection Agency (EPA) asked school officials across the country to identify materials in their schools containing asbestos and to take steps to protect students and school personnel from exposure to them. Guidance packages were distributed containing both general and specific information about surveying and testing for asbestos and about its mitigation and removal. Also participating in the program were the Department of Health, Education, and Welfare, the Occupational Safety and Health Administration, and the Consumer Product Safety Commission (*8,16*).

The steps in conducting an asbestos control program, as outlined by the Environmental Protection Agency, are (*8*):

1. Inspect the school building for friable material.
2. If found, take a bulk sample of the material.
3. Have the sample analyzed by a laboratory to determine if asbestos is present.
4. Assess the exposure potential if asbestos is found.
5. Take corrective action.

If a building contains friable materials, and exposure is occurring or will likely occur, corrective action should be considered. In choosing the kind of corrective action, consideration should be given to the location of the material, its condition and function, and the cost of the corrective action. The four control approaches are (*a*) removal, (*b*) encapsulation, (*c*) enclosure, and (*d*) management (no action is taken, but the area is inspected periodically) (*8*).

The analysis of bulk samples to determine if asbestos is present is one of the most costly components of an asbestos detection program. The Environmental Protection Agency recommends that polarized light microscopy be used to determine if asbestos is present in samples. (*8*). The cost of this analysis ranges from \$25 to \$45 per bulk sample. The K^2 Asbestos Screening Test developed by researchers of the National Institute for Occupational Safety and Health (NIOSH) seemed to be a means by which school districts could reduce this cost by avoiding the necessity of laboratory analysis of samples that did not contain asbestos. This test was developed as a quick means of screening bulk samples for asbestos in the field (*17*). If chrysotile asbestos is present in the sample, magnesium is liberated, and a blue-colored complex is formed; or iron is released from amosite or crocidolite, and a red-colored complex is formed. The NIOSH researchers reported that false negatives did not occur, but that false positives were possible. Therefore, samples for which the K^2 test is positive should be analyzed by other methods, such as polarized light microscopy, to confirm the presence of asbestos. The cost of the K^2 test is about \$2.50 per sample, so that the potential savings to school districts could be considerable if it is practical to screen samples with the K^2 test. The magnesium test is performed first. Since calcium will also yield a positive reaction, samples may be washed with glycerin before the test to remove the calcium. If the magnesium test result is negative, the sample should be tested for iron. Use of an acid wash before the test to remove iron from other sources can reduce false positives.

Although it is not known how serious the health effects would be from exposure to airborne asbestos in schools, or how much of the population would be affected by it, the potential for exposure certainly does exist. Even if all asbestos-containing materials cannot be removed from school buildings, such substances should be indentified, and people should be aware of the possible consequences of disturbing them.

To find out how extensively asbestos-containing materials have been used in Colorado schools and the current condition of these materials and to estimate the potential for the release of asbestos fibers from these materials, we undertook a survey of 41 public schools.

Material and Methods

To obtain the sample of 41 schools, we first divided the State into five regions, using the same areas as the five administrative and communications regions of the Colorado Department of Education. Region 1, which has the largest population, was the only basically urban region in our survey; the other regions were basically rural. The second step was to draw, at random, school districts from the five regions. With the total number of schools in each region as a basis, one district was drawn from each region except region 1, from which three districts were drawn. In the third and final step, the study sample of schools was randomly drawn from these seven districts. Each school in the State had an equal chance of being included in the study. The number of schools drawn from each district was in proportion to the total number of schools in the region. In addition, in region 1, the number of schools sampled in each of the three districts was proportional to the total number of schools in the respective district. The 41 schools in the final study sample represented about 3.2 percent of all the public schools in Colorado, as the following table shows.

		Schools sampled	
Region	*Total schools*	*Number*	*Percent*
1	714	23	3.2
2	94	3	3.2
3	157	6	3.8
4	142	4	2.8
5	156	5	3.2
Total	1,263	41	3.2

Once it was determined which schools would comprise the study sample, we made arrangements with the officials of the school districts to conduct asbestos surveys, which consisted of a walk-through and visual inspection. All areas of the school were included: hallways, classrooms, gymnasiums, auditoriums, cafeterias, offices, boiler rooms, storage spaces, and spaces above lower ceilings.

The evaluation criteria used in the survey were based on, and modified from, the Ferris Index used by the Massachusetts Asbestos Commission (*13*) and on the EPA guidelines for exposure assessment (*8*). The exposure potential of asbestos-containing materials was determined by six criteria: condition, accessibility, air movement, activity, friability, and percent asbestos. "Condition" was a reflection of the degree of deterioration damage of the materials. "Accessibility" was the relative ease with which asbestos-containing materials might be reached or disturbed. "Air movement" reflected the degree to which asbestos fibers might accumulate at a site. "Activity" was the potential, because of the room's use, for asbestos-containing materials to be damaged. "Friability" referred to the ease with which the materials could be broken or crumbled. Finally, the "percent asbestos" in the material was obtained later from laboratory analysis of the bulk samples.

Numbers (1–3 for the first five criteria and 1–4 for "percent asbestos") were used to rank the potential asbestos exposure; the highest numbers indicated the greatest exposure potential and the lowest, the least. The total of all assessed values for each criterion reflected the overall exposure potential, with higher values generally representing greater potentials for exposure. Values of 6 to 8 indicated that exposure was negligible or that no potential for exposure existed. In such cases, no action would be necessary beyond continuing inspection to monitor the situation. Higher values, from 9 to 19, indicated that some corrective action (for example, removal, encapsulation, or enclosure of the material) should be considered.

The values for each criterion (except "percent asbestos") were recorded on a form at the time of evaluation. Evaluations were made for each area from which a bulk sample was obtained.

At the time of the survey, additional information about each school was obtained. This information included the number of teachers and staff (full-time and part-time), the building's use (standard curricular use, extracurricular use, and community and other uses), and building construction data (original construction date and dates of additions and remodeling).

Bulk samples were taken from all friable materials that might contain asbestos, including ceiling tiles, pipe lagging, sprayed materials, and jackets on boilers and furnaces. Samples were obtained by removing a portion of the material (including all layers from the outside of the material to the substrate) with a scalpel. The samples were placed in clean, empty 35 mm film canisters and labeled with a code corresponding to that on the evaluation form. The sampling site was noted on the form along with any additional pertinent information. All samples were taken in such a way as to damage the materials as little as possible and from as inconspicuous a place as possible.

The bulk samples were screened for the potential presence of asbestos by the K^2 Asbestos Screening Test. To confirm the presence of asbestos, samples with results positive for either magnesium or iron were sent to an outside laboratory for analysis by polarized light microscopy.

Results and Discussion

One hundred and thirteen samples of friable materials that possibly contained asbestos were collected from the 41 schools. Preliminary screening of those samples with the K² test yielded negative results for only 12 (10.6 percent). This result differs considerably from the results reported by the researchers of the National Institute for Occupational Safety and Health who developed the K² test; they reported that for about 41 percent of the samples tested, the results were negative (*17*). The 101 samples in our study that yielded positive results were sent to a laboratory where the staff was experienced in identifying asbestos by polarized light microscopy. Dispersion staining was used to identify the type of asbestos in the samples. Of those 101 samples, 56 (55 percent) actually contained asbestos. At first glance this result is close to the results reported in the NIOSH study, in which 54 percent of the K² positives were true positives. However, the NIOSH results were achieved before the acid wash step had been added to the iron test. With the acid wash, the NIOSH researchers observed no false positives (*17*). Since all of the Colorado samples that were positive by the K² test for iron were acid-washed, again the results were not comparable.

Part of the discrepancy in results may possibly be attributed to the difficulty in interpreting color variations. The instructions do not mention the wide variety of colors that may be obtained, including various shades of blue (magnesium test) and red (iron test). In addition, the test is described as one that may be used in the field. Use in the field, however, would be difficult because of the strong acids and bases used in the test. A more detailed description of the K² test and the test results will be published in the American Industrial Hygiene Association Journal (*18*).

The types of asbestos we found included chrysotile, actinolite, amosite, and crocidolite. The percentage of chrysotile in sprayed materials ranged from less than 1 percent to 10 percent. Actinolite was frequently found with chrysolite in sprayed materials, but only in small amounts, ranging from less than 1 to 2 percent. In other asbestos-containing materials, the amount of chrysotile varied from less than 1 percent to 95 percent. Amosite content ranged from less than 1 to 60 percent of the materials, and crocidolite was found in very small quantities, from less than 1 to 2 percent. Chrysotile and amosite were found either in combination or singly in these materials. Crocidolite was found with amosite, but never alone. The table shows the number of samples that contained the different forms and combinations of asbestos. Twelve of the 56 samples with positive results for asbestos were from sprayed surfaces on ceilings. All samples of sprayed-on material were taken from areas of the buildings that had been built between 1946 and 1973. Of the remaining samples, 18 came from buildings built before 1946, 22 were from buildings built between 1946 and 1973, and 4 were from buildings built after 1973. These other samples were primarily from pipe lagging.

Number of samples with various percentages of asbestos by type of asbestos

Type of asbestos	Percentage of asbestos [1] 1–10	11–25	26–50	Less than 51	Total
Sprayed samples					
Chrysotile	8	0	2	0	10
Amosite	0	0	0	0	0
Chrysotile and actinolite	2	0	0	0	2
Chrysotile and amosite	0	0	0	0	0
Amosite and crocidolite	0	0	0	0	0
Total	10	0	2	0	12
Other samples					
Chrysotile	5	0	10	14	29
Amosite	3	0	1	0	4
Chrysotile and actinolite	0	0	0	0	0
Chrysotile and amosite	4	2	2	1	9
Amosite and crocidolite	0	0	0	2	2
Total	12	2	13	17	44

[1] Percentage ranges used in the evaluation of potential asbestos exposure.

Thirty-one of the 41 schools surveyed had material containing asbestos in one or more locations. Of these 31 schools, 10 had sprayed-on asbestos ceilings.

Region	*Schools sampled*	*Schools with materials containing asbestos*	*Schools with asbestos-sprayed surfaces*
1	23	16	7
2	3	2	0
3	6	5	2
4	4	4	1
5	5	4	0
Total	41	31	10

Using as a basis the number of schools in the random sample found to have asbestos-containing materials, we estimated that between 63 and 89 percent (95 percent confidence interval) of the public schools in Colorado might have friable materials containing asbestos. Also, we estimated that 10 to 38 percent (95 percent confidence interval) might have sprayed-on materials that contained asbestos.

In evaluating sample sites for the potential for asbestos exposure to occur, each category affecting the likelihood of asbestos fibers being released (activity, accessibility, condition, friability, air movement, and percent asbestos) was assigned a value that indicated the effect of that category on the overall value. These values were intended to represent only the potential for asbestos fibers to be released from the material. This evaluation does not reflect the health risks incurred from exposure to airborne asbestos nor indicate how many fibers might be released. The values and exposure potentials they represented were as follows.

Criteria for determining exposure potential	*Evaluation*
Activity:	
1	Low.
2	Moderate.
3	High.
Accessibility:	
1	Totally enclosed.
2	Generally inaccessible.
3	Accessible.
Condition:	
1	No damage.
2	Slight to moderate damage.
3	Severe damage.
Friability:	
1	Nonfriable.
2	Moderately friable.
3	Very friable.
Air movement:	
1	Air-moving system exhausted to exterior.
2	Limited air movement.
3	No air movement.
Percent asbestos:	
1	1–10.
2	11–25.
3	26–50.
4	50 or more.

The lower numbers represented lower exposure potentials. Activity was broken down into low human activity (for example, offices, boiler rooms, and storage areas), moderate activity (classrooms), and high human activity (gymnasiums, hallways, and all-purpose rooms). For accessibility, materials were identified as totally enclosed or tightly bound and as generally inaccessible to the school population or accessible. The condition of the materials from which a sample was removed was evaluated as showing no damage at all, slight to moderate damage, or severe damage.

Figure 1 shows sprayed materials severely damaged by water, and figure 2, sprayed materials damaged by students scraping their fingers through the soft asbestos material on hallway ceilings. Materials were classified as either moderately friable (for example, ceiling tiles and cementious materials) or very friable (sprayed materials). No samples were taken of nonfriable substances. In each area where a sample was taken, we determined if a mechanical air-moving system was present, if only air movement was possible (by operating doors and windows, for instance), or if there was essentially no air movement. When the results of the polarized light microscopy were received from the laboratory, the percentage of asbestos in the sample was added to the evaluation. Four categories of percentage ranges were used: 1–10, 11–25, 26–50, and more than 51. The values determined for each of these categories were added for each sample that contained asbestos; thus, a total exposure potential value for each area from which a sample was taken was obtained.

Figure 1. Sprayed-on asbestos material damaged by water

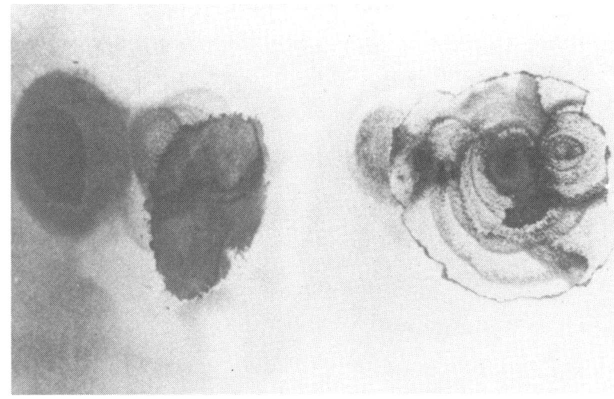
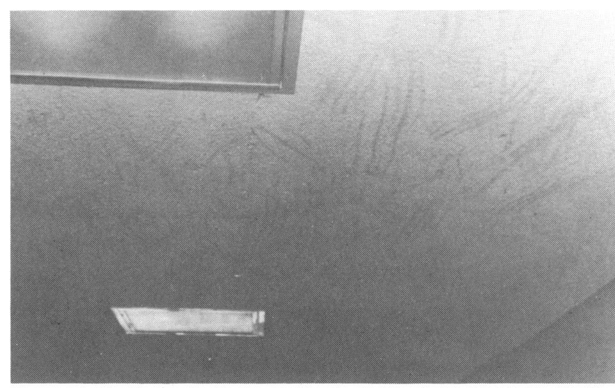
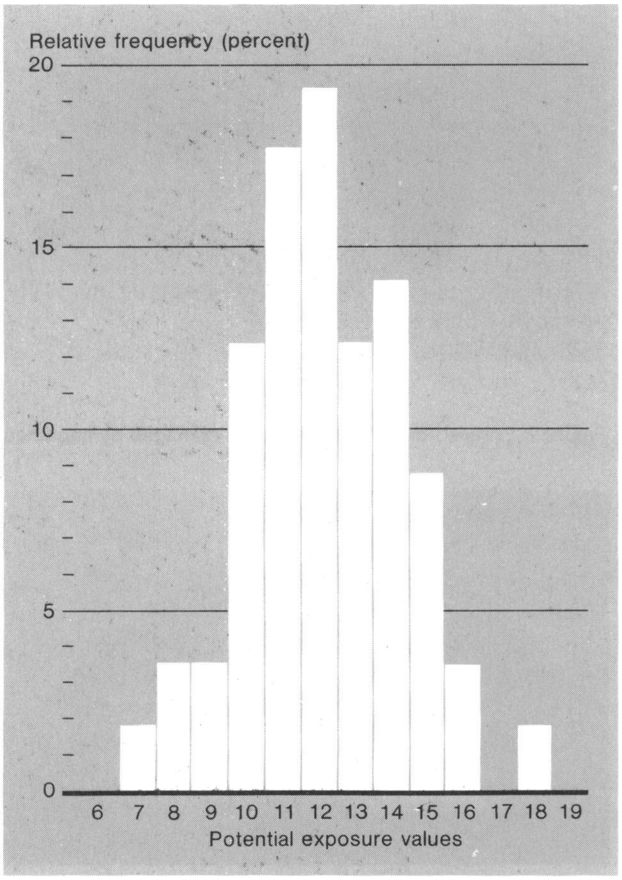


Figure 2. Sprayed-on asbestos material damaged by capricious human contact



The values calculated for the areas where asbestos was found ranged from 7 to 18. The relative frequencies of each potential exposure value for all 56 samples are shown in figure 3. If a potential exposure value from 6 to 18 indicates that no action need be taken and a value from 9 to 19 indicates that some corrective action is required, then action would be required in 43 (95 percent) of the areas sampled in this study. However, the decision to apply some method of control should be carefully considered in each specific situation. Even an area with a high potential exposure value might be controlled by observation to see

Figure 3. Potential exposure value of areas with asbestos-containing materials



that human activity was kept to a minimum and that accessibility to the material was strictly limited. Further, the method of control that is selected (removal, encapsulation, or enclosure) must be appropriate for the type of material involved and its location. As an example, an encapsulant is not appropriate when the sprayed asbestos material is not firmly bonded to its structural support. The added weight of the sealant may cause the asbestos material to separate from its substrate. Also, the corrective action chosen must be properly carried out, or more serious problems could result. Improper removal of asbestos may leave much higher numbers of fibers in the area than before (*9*).

The accumulation of evidence indicating that low levels of asbestos fibers can cause neoplastic disease suggests that the presence of friable asbestos-containing materials in school buildings may present a serious hazard involving a large segment of the population. Not only students and staff members are potentially exposed to asbestos in these buildings; many school buildings are used for community functions as well. Thirty-five of the schools surveyed were used after regular school hours by students and the community, and 26 of these schools were found to contain friable asbestos materials.

All these factors suggest the need for disseminating information about asbestos-containing materials. School administrators should be aware of the potential hazards and know where asbestos-containing substances in their schools may be found. Once the substances are located, each specific area should be dealt with in a way that will reduce the hazard of potential exposure of students, faculty, and staff. In addition, if the asbestos-containing materials are left in place, records need to be kept of their locations so that mishandling during future maintenance, remodeling, or demolition activities can be avoided.

The Environmental Protection Agency is a good place for school administrators to find much of this information. The guidance documents published by this agency in 1979 contain a great deal of information about collecting bulk samples and how they should be analyzed, along with a description of control methods. The regional EPA office staff may be able to provide addresses of laboratories that are experienced in polarized light microscopy and may also have information on contractors in the area who are experienced in dealing with asbestos materials.

Conclusion

Based on our study results, we estimate that as many as 1,124 (89 percent) of the 1,263 public schools in Colorado may have asbestos in friable form, and 380 (38 percent) may have asbestos sprayed on ceilings. If the potential exposure values for the small number of schools we surveyed are typical of the values that might be found in other schools in the State, a serious problem exists that could result in adverse health effects in the future. The cost of dealing with asbestos-containing materials may be high, but this should not be an excuse for ignoring the problem. Simply identifying these materials is an enormous step in the right direction and one that should be taken in the remainder of the public schools in the State and in Colorado's private schools.

References

1. Becklake, M. R.: Asbestos-related disease of the lung and other organs: their epidemiology and implications for clinical practice. Am Rev Respir Dis 114: 187–227 (1976).
2. Spooner, C. M.: Asbestos in schools. A public health problem. N Engl J Med 301: 782–784 (1979).
3. Peters, G. A., and Peters, B. J.: Sourcebook on asbestos diseases: medical, legal and engineering aspects. Garland STPM Press, New York, 1980.
4. Asbestos: an information resource, edited by J. Levine. DHEW Publication No. (NIH) 78–1681. National Institutes of Health, Bethesda, May 1978.

5. Selikoff, I. J., Hammond, E. C., and Churg, J.: Asbestos exposure, smoking and neoplasia. JAMA 204: 106–112 (1968).
6. Nicholson, W. J., Langer, A. M., and Selikoff, I. J.: Epidemiological evidence on asbestos. *In* Workshop on Asbestos: definitions and measurements methods, edited by C.C. Gravatt, P. D. LaFleur, and K. F. J. Heinrich. National Bureau of Standards Special Publication No. 506. Washington, D.C., 1978, pp. 71–94.
7. Copper, W. C.: Epidemiologic evidence of the effect of type of asbestos and fiber dimensions on the production of disease in man. *In* Workshop on asbestos: definitions and measurement methods, edited by C. C. Gravatt, P. D. LaFleur, and K. F. J. Heinrich. National Bureau of Standards Special Publication No. 506. Washington, D.C., 1978, pp. 121–131.
8. Asbestos-containing materials in school buildings: a guidance document. Pt. 1. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C., 1979.
9. Sawyer, R. J., and Spooner, C. M.: Sprayed asbestos-containing materials in school buildings: a guidance document. Pt. 2. Environmental Protection Agency, Washington, D.C., 1979.
10. Sawyer, R. N., and Swoszowski, E. J., Jr.: Asbestos abatement in schools: observations and experience. Ann NY Acad Sci 330: 765–775 (1979).
11. Biologic effects of atmospheric pollutants. Asbestos. The need for and feasibility of air pollution controls. Committee on Biologic Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council. National Academy of Sciences, Washington, D.C., 1971.
12. Nicholson, W. J., et al.: Asbestos contamination in United States schools from use of asbestos surfacing materials. Ann NY Acad Sci 330: 587–596 (1979).
13. Faich, A.: Asbestos hazard evaluation in Rhode Island schools. Am J Public Health 70: 162–164 (1980).
14. Irving, K. F., Alexander, R. G., and Bayley, H.: Asbestos exposures in Massachusetts public schools. Am Ind Hyg Assoc J 41: 270–276 (1980).
15. Lowrey, H.: Growth and development of children. Year Book Medical Publishers, Inc., Chicago, 1973.
16. Robson, R.: Asbestos: what you can do about it. Am Sch Univ 51: 48–55 (1979).
17. Kim, W. S., Carter, J. W. II, and Kupel, R. E.: Quick screening test for asbestos. Am Ind Hyg Assoc J 42: 198–201 (1981).
18. Baldwin, C. A., Beaulieu, H. J., and Buchan, R. M.: Application of the K² Asbestos Screening Test in Colorado Schools. Am Ind Hyg Assoc J. In press.

SYNOPSIS

BALDWIN, CYNTHIA (Iowa Bureau of Labor), BEAULIEU, HARRY J., BUCHAN, ROY M., and JOHNSON, HANS H.: *Asbestos in Colorado Schools, Public Health Reports, Vol. 97, July–August 1982, pp. 325–331.*

Forty-one public schools in Colorado were drawn at random and surveyed for asbestos-containing materials. After bulk samples of possible asbestos materials from the schools were collected and analyzed, the K^2 asbestos screening test was used to eliminate samples that did not contain asbestos. Samples with positive results on the K^2 test were analyzed by an outside laboratory by polarized light microscopy. The risk of potential exposure presented by these materials was then assessed for each site from which a sample was taken.

Of 113 samples collected, results were negative for asbestos for only 10.6 percent by the K^2 test. Of the 101 samples for which results were positive, 56 actually contained 1 or more forms of asbestos. Twelve of these 56 samples were from srayed material; the remaining 44 were from other materials containing asbestos. Of the 41 schools sampled, 31 had asbestos materials in one of more locations. The potential exposure values for these materials ranged from very low to very high, but the majority had high-exposure potentials.

Estimates based on the survey of the 41 schools indicated that 63 to 89 percent of the public schools in Colorado have asbestos materials that present potentially serious hazards, not only to the children, teachers, and staff, but also to members of the community who use the school buildings after regular school hours.