were observed at temperatures above 200°C and 300°C, respectively. For the three bacterial strains studied, ± S-9, no mutagenic activity was observed for filtrates from fly ash heated to 350°C.

Our studies of physical factors affecting the mutagenic activity of coal fly ash extracts provide insight into the chemical properties of fly ash mutagens. The finding that the greatest activity is associated with the finest fractions of stack-collected ash is consistent with the observations of Natusch (*13*) that PAH are adsorbed on particle surfaces during cooling of the effluent stream. The observation that ESP-collected fly ash was not mutagenic (whether size-classified or not) suggests that condensation of mutagens on fly ash particles occurred after passage through the ESP but before or within the stack sampling system. Natusch and Tomkins (*14*) have predicted that a temperature near 100°C is critical for the adsorption of PAH onto fly ash. Our observations of the complete loss of mutagenic activity with experimental heating to 350°C are consistent with the hypothesis that the bulk of the mutagenic activity of the fly ash samples is associated with organic compounds. This loss of activity from stack-collected fly ash appears to begin at temperatures greater than the operating temperatures of the ESP. The temperature difference probably reflects the fact that organic compounds are chemisorbed to fly ash surfaces and therefore require higher temperatures for desorption. This hypothesis is supported by our observations that the mutagens in fly ash are resistant to photochemical decomposition upon UV- or x-ray irradiation. Similarly, Natusch and his co-workers (*8*, *15*) have observed that PAH adsorbed from the vapor phase on fly ash surfaces may be stabilized against photochemical decomposition at solar radiation wavelengths; photodecomposition occurred with irradiation of PAH as dry powders, in solution, or adsorbed onto silica, alumina, or glass.

These studies demonstrate that (i) the most respirable stack-collected fly ash samples are the most mutagenic, (ii) the ESP-collected fly ash from the same power plant is not mutagenic, (iii) the surface-associated mutagens are resistant to photodecomposition with UV- or x-ray irradiation, and (iv) the mutagenicity of fly ash is completely removed by heating to 350°C. The observation that mutagens were associated with fly ash particles when collected at temperatures below 100°C suggests a possible improvement in control technology. Fly ash could be collected at lower temperatures than normally present in ESP's. However, if such an approach were used, the industry would be confronted in 1980 with a predicted 100 million tons (*1*) of weakly mutagenic solid waste. A reasonable strategy, therefore, would consist of high-temperature, high-efficiency collection of particulate matter from the flue stream, followed by subsequent condensation and in-plant collection of volatilized organic matter.

G. L. FISHER
C. E. CHRISP
O. G. RAABE

Radiobiology Laboratory, University of California, Davis 95616

References and Notes

1. *Chem. Eng. News* (6 November 1978), p. 26.
2. A. E. Vandegrift, L. J. Shannon, P. G. Gorman, *Chem. Eng. (N.Y.)* **80**, 107 (1973).
3. C. E. Chrisp, G. L. Fisher, J. E. Lammert, *Science* **199**, 73 (1978).
4. B. N. Ames, J. McCann, E. Yamasaki, *Mutat. Res.* **31**, 347 (1975).
5. A. R. McFarland, G. L. Fisher, B. A. Prentice, R. W. Bertch, *Environ. Sci. Technol.* **11**, 781 (1977).
6. We collected 3000 kg of fly ash from the dry discharge of the ESP collection hoppers. The size classification of this material, based on use of the model C24 Donaldson Acucut production classifier (Majac Division, Donaldson Company, Minneapolis, Minn.), yielded 75 kg of respirable particles.
7. G. L. Fisher, B. A. Prentice, D. Silberman, J. M. Ondov, A. H. Biermann, R. C. Ragaini, A. R. McFarland, *Environ. Sci. Technol.* **12**, 447 (1978); J. M. Ondov, R. C. Ragaini, R. E. Heft, G. L. Fisher, D. Silberman, B. A. Prentice, in *Proceedings of the Eighth Materials Research Symposium, Methods and Standards for Environmental Measurement* (Special Publication 464, National Bureau of Standards, Gaithersburg, Md., 1977), pp. 565–572; W. G. Jennings, L. Sucre, G. L. Fisher, O. G. Raabe, *Radiobiology Laboratory Annual Report UCD 472–124* (National Technical Information Service, Springfield, Va., 1977), p. 24.
8. D. F. S. Natusch, J. R. Wallace, C. A. Evans, Jr., *Science* **183**, 202 (1974).
9. M. Jacobs, T. S. Matney, A. C. Griffin, *Cancer Lett.* **2**, 319 (1977); L. W. Wattenberg, *Adv. Cancer Res.* **26**, 197 (1978).
10. T. L. Gibson, V. B. Smart, L. L. Smith, *Mutat. Res.* **49**, 153 (1978).
11. We carried out the UV-irradiation with a 15-W mercury-vapor lamp (General Electric G15T8). We measured the radiant flux with a ferrioxalate actinometer [J. G. Calvert and J. N. Pitts, *Photochemistry* (Wiley, New York, 1966), pp. 783–786]; the results were in good agreement with the manufacturer's specifications, which also indicated that 85 percent of the flux was in the range from 240 to 260 nm. The period of irradiation with ambient sunlight consisted of four foggy days and four clear days. An estimated cumulative near-UV (295 to 385 nm) exposure of 2200 J was calculated from concurrent measurements at a nearby field station (data supplied by L. O. Myrup and C. Whan).
12. Since our earlier studies (*3*), we have demonstrated that fraction 4 of the stack-collected fly ash is weakly mutagenic to the base pair-substitution tester strain, TA 100.
13. D. F. S. Natusch, *Environ. Health Perspect.* **22**, 78 (1978).
14. _____ and B. A. Tomkins, *Carcinogenesis 3*, P. W. Jones and A. I. Freudenthal, Eds. (Raven, New York, 1978), pp. 145–153.
15. D. F. S. Natusch, personal communication.
16. We gratefully acknowledge the technical support of J. E. Lammert, D. Silberman, and B. A. Prentice and the critical review of the manuscript by S. A. Book, C. P. Nash, and L. S. Rosenblatt. This research was supported by the Office of Environmental Research of the U.S. Department of Energy under contract EY-76-C-03-0472 with the University of California, Davis.

29 January 1979; revised 9 March 1979

Estimating Fatness

Part of the controversy between Frisch and Trussell (*1*) hinges on the manner in which Frisch has estimated fatness as a linear function of height and weight rather than measuring it physiologically. It appears that the random variability of the estimator has an impact on the arguments which has not been fully appreciated heretofore. Rather than actual measurements of fatness, Frisch uses the Mellits and Cheek equation (*1*):

$$\hat{TW} = -10.313 + 0.252WT\ (\text{kg}) + 0.154HT\ (\text{cm})$$

to predict a girl's total body water (TW) (assumed proportional to fatness) from her height (HT) and weight (WT) at menarche. Since this regression line has a multiple $r^2 = .97$, one might be tempted to suppose that the random variability is negligible, but this is not the case. Examination of the Mellits and Cheek data (*2*) shows that one needs to provide a band of 3.03 liters to either side of the line to cover 90 percent of the individuals in the Mellits and Cheek study. With this error band one has:

$$\hat{TW} = -10.313 + 0.252WT + 0.154HT \pm 3.03$$

and thus,

$$WT = \frac{-10.313 + 0.154HT \pm 3.03}{\hat{TW}/WT - 0.252}$$

Now, according to Frisch, the minimum required weight for the onset of menarche is given by the 10th percentile fatness line, where $\hat{TW}/WT = 0.598$, and thus we have,

$$\text{Minimum required weight} = \frac{-10.313 + 0.154HT \pm 3.03}{0.598 - 0.252}$$

From this it can be seen that about 9 kg of uncertainty is added to or subtracted from the predicted minimum required weight by the error bands. Clearly, this 9-kg variability in estimated minimum weight occurs for all heights and weights involved, rendering this procedure for determining fatness rather questionable and undermining any support these data might be thought to give to a critical fatness hypothesis.

JAXK REEVES

Statistics Department, University of California, Berkeley 94720

References

1. J. Trussell, *Science* **200**, 1506 (1978); R. E. Frisch, *ibid.*, p. 1509.
2. E. D. Mellits and D. B. Cheek, *Monogr. Soc. Res. Child Dev.* **35**, 12 (1970).

14 September 1978; revised 11 January 1979

0036-8075/79/0525-0881$00.50/0