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Comparative Carcinogenic Potencies of Particulates from Diesel Engine Exhausts, Coke Oven Emissions, Roofing Tar Aerosols and Cigarette Smoke

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Mammalian cell mutagenesis, transformation and skin tumorigenesis assays show similar results in comparing the potencies of diesel, coke oven, roofing tar and cigarette smoke particulates. These assay results are reasonably consistent with the comparative carcinogenic potencies of coke oven and roofing tar emissions as determined by epidemiological studies. The bacterial mutagenesis assay tends to show disproportionately high potencies, particularly with diesel particulates.

Results to date encourage the approach to the assessment for carcinogenic risks from diesel emissions based on the use of epidemiological data on cancer induced by coke oven emissions, roofing tar particulates and cigarette smoke with the comparative potencies of these materials determined by *in vivo* and *in vitro* bioassays.

In 1978 the EPA Carcinogen Assessment Group (CAG) was asked by the EPA Office of Mobile Sources to do an assessment of the carcinogenic risks to the general public of diesel exhausts on the assumption that 25% of the automobile fleet in the USA was equipped with diesel engines. Given the lack of animal or epidemiological data, the approach taken by the CAG was to base the risk assessment on human carcinogenic risks from exposure to organic combustion products (coke oven workers, roofing tar applicators and cigarette smokers) with the comparative potency of diesel particulates and the other materials to be established by short-term bioassays. This approach launched a substantial research program in the EPA. The purpose of this paper is to evaluate the comparative potency data acquired thus far.

The study design, sample generation, collection and preparation are presented elsewhere (*1*). The diesel, coke oven and roofing tar particulates were Soxhlet-extracted with dichloromethane. The cigarette smoke tar was removed from the smoke condenser with acetone and adjusted to the appropriate concentrations.

The *in vitro* and skin tumor bioassay methodology and results have been described elsewhere (*2,3*). Tests not used in this evaluation because of poor dose-response data include sister chromatid exchange in Chinese hamster ovary and the BALB/c 3T3 cell mutagenesis and transformation studies.

Tests used here include: (1) the Ames *Salmonella typhimurium* (TA98) reverse mutation test (Ames TA 98), expressed as revertants/μg (maximum linear slope); (2) gene mutation in L5178Y mouse lymphoma cells (L5178Y mutagenesis), expressed as mutation frequency per 10^6 surviving cells per μg/mL; (3) viral enhancement of chemical transformation in Syrian hamster embryo cells (cell transformation), expressed as transformation frequency per μg/mL; and (4) Sencar mouse skin tumor initiation (skin initiation), expressed as papillomas per mouse/mg. There was also some preliminary mouse skin carcinogenesis data at one year.

Table 1 shows the comparative potencies of the indicated materials. From left to right, the tests are placed in probable order of relevance to lung cancer induction. The blanks in the table are tests that were either not done or not done adequately.

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Table 1. Comparative potencies for the indicated materials for each of the bioassay tests.

	Skin initiation papillomas per mouse/mg	Cell transformation, frequency per μg/mL	L5178Y mutagenesis frequency per 10^6 surviving cells per μg/mL	Ames, revertants/μg
Coke oven topside	1.8	1.2	12.2	1.8
Roofing tar	*0.6*	*0.6*	*17.0*	*0.7*
Cigarette tar	—	0.4	0.8	0.6
Nissan diesel	0.5	0.3	2.9	13.6
Oldsmobile diesel	0.14	—	1.3	1.4
Volkswagon diesel	—	—	0.7	3.0
Mustang gasoline	0.08	—	1.1	3.4

Table 2. Comparative potencies of indicated materials in relation to coke oven topside particulates.

	Skin initiation	Skin cancer[a]	Cell transformation	L5178Y mutagenesis	Ames TA 98	Plausible potency
Coke oven topside	1.0	1.0	1.0	1.0	1.0	1.0
Roofing tar	0.3	0.3	0.5	*1.4*[b]	0.4	0.3
Cigarette tar	—	—	0.3	0.1	0.3	0.3
Nissan diesel	0.3	0.15	0.3	0.2	*7.6*[b]	0.2
Oldsmobile diesel	0.1	—	—	0.1	*0.8*[b]	0.1

[a]Roofing tar is twice as potent as Nissan diesel for skin cancer induction (*3*). Coke oven topside was not assayed by skin carcinogenesis. This column assumes that the relative potency of coke oven topside with respect to roofing tar is the same for skin initiation and skin cancer induction.

[b]*Italic numbers are out of line with other data.*

Table 2 shows the comparative potencies for each test normalized to the coke oven topside samples. Except for the underlined values, particularly from the Ames tests, which given high values for the potency of diesel particulates, there is reasonably good consistency in the comparative potencies. A tabulation of plausible values for the comparative potencies are given in the right-hand column.

It has been suggested that the coke oven topside sample was adulterated with urban particulates (*1*); if so, the true potency would likely approach that of the coke oven mains, which, as shown in Table 3, probably has a potency about twice that obtained at the top of the coke ovens. Again, the Ames test appears to read high. The epidemiological data indicate that coke oven and roofing tar particulates have the same carcinogenic potencies (*4*) which is within a factor of three of bioassay results.

Table 3. Comparison of potencies of coke oven topside and coke oven mains sample.

	Skin cancer[a]	L5178Y mutagenesis	Ames TA 98
Topside	1.0	1.0	1.0
Main	2.4	2.2	*8.5*[b]

[a]The coke oven mains sample is 8× more potent than roofing tar for skin carcinogenesis. Since coke oven topside by skin initiation is 3× more potent than roofing tar, it is estimated that the coke oven mains sample is 8/3.3 = 2.4 times more potent than the coke oven topside particulates.

[b]Italic numbers are out of line with other data.

Summary

The mammalian cell mutagenesis, transformation and skin tumorigenesis assays show similar results in comparing the potencies of diesel, coke oven, roofing tar and cigarette smoke particulates. These assay results are reasonably consistent with the comparative carcinogenic potencies of coke oven and roofing tar emissions as determined by epidemiological studies. The bacterial mutagenesis assay tends to show disproportionately high potencies particularly with diesel particulates.

The results to date encourage the approach to the assessment for carcinogenic risks from diesel emissions based on the use of epidemiological data on cancer induced by coke oven emissions, roofing tar particulates and cigarette smoke with the comparative potencies of these materials determined by *in vitro* and *in vivo* bioassays.

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