TABLE V-1: SUMMARY OF SELECTED EPIDEMIOLOGIC STUDIES OF LUNG CANCER IN WORKERS EXPOSED TO HEXAVALENT CHROMIUM

Chromate Production

Reference/Exhibit Number	Study Population	Reference Population	Chromium (VI) Exposure	Lung Cancer Risk
Hayes et al. (1979, Ex. 7-14) Braver et al. (1985, Ex. 7-17)	1803 male workers initially employed 3 or more months 1945-1974 at old and new Baltimore MD production facility; follow-up through 1977	Baltimore City mortality	Primarily sodium chromate and dichromate production. Avg Cr(VI) of 21 to 413 $\mu g/m^3$ and avg duration 1.6 yr to 13 yr depending on subcohort, plant, and year employed	-O/E of 2.0 ($p<0.01$) based on 59 lung cancer deaths -Increased risk with duration of employment
Gibb et al. (2000, Ex. 31-22-11)	2357 male workers initially employed 1950-1974 only at new Baltimore MD production facility; follow-up through 1992	U.S. mortality	Primarily sodium chromate and dichromate. Mean cumulative Cr(VI) of 0.070 mg/ m^3 - yr and work duration of 3.1 yr	-O/E of 1.86 ($p<0.01$) based on 71 lung cancer deaths -Significant upward mortality trend with cumulative Cr(VI) exposure
Mancuso (1997, Ex. 23) Mancuso (1975, Ex. 7-11) Mancuso and Heuper (1951, Ex. 7-13) Bourne and Yee (1950, Ex. 7-98)	332 male workers employed at Painesville OH facility 1931-1937; follow-up through 1993	Mortality rate directly calculated using the distribution of person years by age group for the entire exposed population as the standard	Primarily sodium chromate and dichromate production with some calcium chromate as a result of using high lime process. Most cumulative soluble Cr(VI) between 0.25 and 4.0 mg/ m^3 – yr based on 1949 survey	O/E not calculated but significant increase in age-adjusted lung cancer death rate with cumulative chromium exposure based on 66 deaths
Luippold et al. (2003, Ex. 31-18-4)	492 male workers employed one year between 1940 and 1972 at Painesville OH facility; follow-up through 1997	U.S. and Ohio Mortality Rates	Primarily sodium chromate and dichromate production with minor calcium chromate Mean cumulative soluble Cr(VI) of 1.58 mg/ m^3 - yr	-O/E of 2.41($p<0.01$) based on Ohio rates and 51 deaths -Significant upward mortality trend with cumulative Cr(VI) exposure
Davies et al. (1991, Ex. 7-99) Alderson et al. (1981, Ex. 7-22) Bistrup and Case (1956, Ex. 7-20)	2298 male chromate production workers employed for one year between 1950 and 1976 at three different UK plants; follow-up through 1989	Cancer mortality of England, Wales and Scotland and unexposed local workers	Principally sodium chromate and dichromate production with some calcium chromate before switch from high lime to no lime process. Avg soluble Cr(VI) in early 1950s from 2 to 880 $\mu g/m^3$ depending on job.	-O/E of 1.97 ($p<0.01$) pre-process change based on 175 deaths -SMR of 1.02 (NS) post-process change based on 14 deaths - Increased risk for high exposed compared with less exposed
Korallus et al. (1993, Ex. 7-91) Korallus et al. (1982, Ex. 7-26) Birk et al. (2005, Ex. 48-4)	1417 chromate production workers employed for one year between 1948 and 1987 at two different German plants; follow-up through 1988. 901 'post-process change' [to no lime process] workers followed	Mortality rates for North Rhine-Westphalia region of Germany where plants located as well as German national rates	Principally sodium chromate and dichromate production with some calcium chromate before switch from high lime to no lime process. Annual mean Cr(VI) between 6.2 and 38 $\mu g/m^3$ after 1977. Cr(VI) exposure not	-O/E of 2.27($p<0.01$) pre-process change based on 66 deaths -O/E of 1.22 (NS) post-process change based on 22 deaths -O/E of 2.09 ($p<0.05$) post-process change with $\geq$ 200 μg urinary Cr/dl – yr based on 12 deaths

	through 1998.		reported before 1977.	
Pastides et al. (1994, Ex. 7-93)	398 chromate production workers employed for one year between September 4, 1971 and December 31, 1989 at a North Carolina plant; follow-up through 1989	Mortality rates for eight North Carolina counties, state rates (not reported), and U.S. mortality rates	Principally sodium bichromate and chromic acid production with as a result of low lime process. About 50% of personal air monitoring samples < 1 µg/m^3 Cr(VI), 75% < 3 µg/m^3, and 96% < 25 µg/m^3.	-O/E of 127 based on U.S. rates and 2 deaths -O/E of 97 based on North Carolina county rates
Luippold et al. (2005, Ex. 47-24-2)	430 chromate production workers employed for one year at low lime North Carolina plant studied by Pastides et al. (1994); 187 chromate production workers employed for one year at a second plant after switch to low lime process in 1980; follow-up through 1998	State-specific mortality rates and U.S. mortality rates (not reported)	Principally sodium dichromate and chromic acid production as a result of low lime process. Airborne Cr(VI) levels typically < 1.5 µg/m^3; highest recorded levels < 10 µg/m^3.	-O/E of 84 based on state-specific rates and 3 deaths

Observed/Expected (O/E)
Relative Risk (RR)
Not Statistically Significant (NS)
Odds Ratio (OR)

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The basic hexavalent chromate production process involves milling and mixing trivalent chromite ore with soda ash, sometimes in the presence of lime (Exs. 7–103; 35–61). The mixture is 'roasted' at a high temperature, which oxidizes much of the chromite to hexavalent sodium chromate. Depending on the lime content used in the process, the roast also contains other chromate species, especially calcium