

found in the cohort with the shortest mean duration of employment. Therefore we conclude that, based on epidemiology studies, the evidence for an association between dioxin and excess total cancer in humans is mixed, at best.

771 ASSESSMENT OF BENZENE CARCINOGENIC POTENTIAL IN HUMANS.

K. W. Chan, L. A. Beyer and B. D. Beck. *Gradient Corporation, Cambridge, MA.*

Benzene is currently classified as a human carcinogen based primarily on increased risks of leukemia, with acute myeloid leukemia as the predominant form. Recently, some researchers have suggested that benzene also causes other types of cancer such as, lymphoma, non-Hodgkin's lymphoma, multiple myeloma, brain, lung, and kidney cancers. It is therefore of interest to assess the evidence for the carcinogenicity of benzene with respect to these other tumor sites. We selected seven epidemiological studies determined to be of sufficient quality, based on analysis of specific cancer outcomes, assessment of benzene exposure, and cohort size of more than 300 workers. These studies involved cohort studies of workers in painting, printing, paint-and shoe-manufacturing, chemical production, oil refinery, and workers as car and mobile equipment mechanics, and filling station managers in China, Italy, Sweden, United Kingdom, and United States. While excess lymphoma, non-Hodgkin's lymphoma, and lung cancer were observed in a group of benzene-exposed Chinese workers, five other studies did not demonstrate any significant increase in risks among other workers exposed to benzene or benzene-containing petroleum products. Findings in multiple myeloma, brain and kidney cancers in workers were also inconclusive, for example, there was significant increased risk of brain cancer in small service filling stations, but not in large service filling stations, and two other studies did not demonstrate any significant increased risk of brain cancer in workers exposed to benzene. Therefore, we conclude that there is no convincing evidence for an association between benzene and the tumor types noted above.

772 AN ASSESSMENT OF THE HUMAN RISKS ASSOCIATED WITH RADIOFREQUENCY EXPOSURE.

A. L. Lavin and J. M. DeSesso. *Mitretek Systems, McLean, VA.*

Many emerging technologies depend on radiofrequency (RF) electromagnetic (EM) energy; consequently, public concern regarding potential hazards associated with RF exposure is high. To assess the human health effects of low-level RF exposure, 80 epidemiology studies published since 1965 related to EM radiation exposure were identified; these were categorized according to EM frequency ranges (0-300 kHz, 0.3-30 MHz, and 0.03-300 GHz). The majority of studies identified dealt with cancer endpoints. Within each EM frequency category, studies were further classified according to study design (cohort, ecological, case-control, etc). Studies of exposures in the 0.03-300 GHz range (the RF range) were given greatest weight in assessing potential health risks; these included eight cohort studies, four ecological analyses, twelve case-control studies, and one cross-sectional report. Overall, the individual epidemiology studies related to EM frequency exposures are deficient for risk assessment purposes; they suffer from methodological flaws, design biases, and inadequate exposure measurements. Analyzed as a whole using the Hill criteria for causation, these studies do not provide evidence of adverse health outcomes related to low-level RF exposure. Those studies that reported potentially increased health risks associated with RF exposure (primarily brain and hematopoietic cancers) failed to demonstrate consistent exposure-response relationships and showed disparate findings that were not confirmed in other studies. The studies related to the 0-300 kHz and 0.3-30 MHz frequency ranges also reported discordant findings with no consistent exposure-response data. The lack of epidemiological evidence for potentially adverse human health outcomes related to RF exposure is supported by animal data and mechanistic studies which demonstrate that temperature increases in exposed tissues (which do not occur at exposure levels below current US regulatory limits) are required to cause biological effects. In summary, the available epidemiology data suggest that exposure to low-level RF is not associated with adverse human health effects.

773 LUNG CANCER MORTALITY AMONG WORKERS EXPOSED TO AIRBORNE HEXAVALENT CHROMIUM.

R. S. Luippold¹, K. A. Mundt¹, J. M. Panko³, E. W. Liebig², C. Crump³, K. S. Crump⁴, D. J. Paustenbach⁵ and D. M. Proctor⁵. ¹*Applied Epidemiology, Amherst, MA*, ²*AMEC Earth and Environmental, Pittsburgh, PA*, ³*ICF Consulting, Ruston, LA*, ⁴*Environ, Ruston, LA* and ⁵*Exponent, Irvine, CA.*

This study assesses mortality through 1997 for 492 persons who worked at a chromate production plant for at least one year between 1940 and 1972. Cumulative airborne Cr(VI) exposures were quantified for each worker and, together with this mortality assessment, provide new data for use in cancer risk assessment. Cohort

members were followed for mortality through 1997, and standardized mortality ratios (SMRs) were estimated. Lung cancer mortality was investigated further by calculating SMRs stratified by duration of employment, time since hire, year of hire, and categories of cumulative exposure to Cr(VI). Including 51 deaths due to lung cancer, 303 deaths occurred. SMRs were significantly elevated for all causes (SMR=129, 95% CI 115-144), all cancers (SMR=155, 95% CI 125-191), and lung cancer (SMR=241, 95% CI 180-317). Lung cancer mortality was significantly elevated for the highest two cumulative exposure groups—>1.05 to <2.70 mg/m³-years, SMR=365, 95% CI 208-592; and >2.71 to <29.0 mg/m³-years, SMR=463, 95% CI 283-716—but not for the lowest three exposure groups. Significantly elevated SMRs were also found for those hired before 1960, with 20 or more years of employment, and with latency of 20 or more years. No excess lung cancer was found among workers first employed after 1960, which may reflect the conversion to a lower-lime process and lower exposures due to improved industrial hygiene. The stratified analysis of lung cancer mortality by cumulative exposure suggests a threshold effect, because risk is statistically significantly elevated only at exposure levels over 1.05 mg/m³-years. Although a threshold is consistent with recently published toxicological studies, this finding must be interpreted cautiously, because the data are also consistent with a linear Dose-Response, perhaps due to the small numbers of lung cancer deaths in the lowest exposure groups.

774 DOSE-RESPONSE ASSESSMENT FOR LUNG CANCER MORTALITY OF AN OCCUPATIONAL COHORT EXPOSED TO AIRBORNE HEXAVALENT CHROMIUM.

C. Crump¹, E. Hack¹, K. S. Crump², J. M. Panko³, E. W. Liebig³, D. J. Paustenbach⁴ and D. M. Proctor⁵. ¹*ICF Consulting, Ruston, LA*, ²*Environ, Ruston, LA*, ³*AMEC Earth and Environmental, Pittsburgh, PA* and ⁴*Exponent, Irvine, CA.*

The dose-response relationship for inhalation exposure to hexavalent chromium [Cr(VI)] and lung cancer mortality is assessed for persons who worked at a chromate production facility from 1940 through 1972. Dose metrics of maximum 8-hour time-weighted-average (TWA) exposure, defined as the highest TWA exposure estimated for each worker, and lifetime cumulative exposure (e.g., mg/m³-years) were evaluated. Poisson and Cox regression models were used to estimate a benchmark dose for 10% additional lifetime risk and unit risks (risk from exposure to 1 µg/m³) for occupational and continuous (e.g., environmental) exposure scenarios. Trend analyses were performed to identify the highest exposure level for which there is statistical evidence of an increased risk of lung cancer. Cumulative exposure to Cr(VI) ranged from 0 to 29 mg/m³-years, and the maximum TWA exposures ranged from 3 µg/m³ to 5,518 µg/m³. A linear dose-response was observed in both of these exposure ranges. The benchmark dose for continuous exposures was 10 µg/m³, and the maximum likelihood estimate of unit risk was 0.011 µg/m³. However, the dose-response was also consistent with a threshold for both dose metrics. There was no statistical evidence of an increased cancer risk at maximum occupational TWA exposures of 116 µg/m³, or cumulative exposures of 0.8 mg/m³-years, corresponding to a 40-year occupational exposure level of 20 µg/m³. The estimated unit risks are approximately equal to those developed by the USEPA in 1984, and are two to six times lower than those proposed by OSHA in 1995. The absence of a linear trend below certain doses suggests a threshold effect although a non-threshold dose-response cannot be ruled out. The lack of an increased cancer risk at low exposure levels is consistent with mechanistic data suggesting that at low exposure levels, Cr(VI) is reduced to and detoxified by extra- and inter-cellular components of the lung.

775 USING QSAR IN THE SELECTION OF SURROGATE TOXICITY VALUE.

C. J. Moudgal, R. M. Bruce and H. Choudhury. *NCEA/ORD, USEPA, Cincinnati, OH.*

The National Center for Environmental Assessment, Cincinnati (NCEA-Cin), through its Superfund Technical Support Center (STSC), provides rapid-turn-around technical support to Regional staff and others for time-critical decision making under the Superfund program. A key element of this support is the development of provisional toxicity values, such as oral Reference Doses (RfDs), Inhalation Reference Concentrations (RfCs), oral cancer slope factors (SFOs), or inhalation cancer unit risks (URIs). When the published data are inadequate for the development of toxicity values, the Center makes an attempt to identify an appropriate surrogate using a quantitative structure activity relationship (QSAR) approach. A commercial QSAR model, TOPKAT[®], is utilized to establish a degree of structural similarity between the query chemical (chemical under examination) and the compounds in the models database. The two models utilized in the selection process are the Oral Rat Chronic LOAEL and the Rat Oral LD₅₀ models. The