February 8, 2002

MEMORANDUM

To: William Maxwell, EPA/OAQPS/ESD/CG

From: Jeffrey Cole, RTI

Subject: Summary and Evaluation of the Recent Studies on Speciated Nickel Emissions from
               Oil-fired Electric Utilities and the Potential Health Risks of Those Emissions

Executive Summary

1.   Industry-sponsored studies find that nickel subsulfide (Ni_3S_2) (and other nickel compounds that
      are currently classified as carcinogenic in the EPA's Integrated Risk Information System
      [IRIS]) form only a small portion (less than 5 percent) of emitted nickel compounds from oil-
      fired electric utilities. These results for Ni_3S_2 are within the range of values used by the U.S.
      Environmental Protection Agency (EPA) in the 1998 "Study of Hazardous Air Pollutant
      Emissions from Electric Utility Steam Generating Units - Final Report to Congress" (RtC). For
      the RtC, EPA estimated (from the data available up to 1998) that from 3 to 26 percent of the
      total nickel concentration in oil-fired electric utility emissions was sulfidic nickel. The EPA
      further concluded that no more than 10 percent of the nickel compounds were likely to be
      Ni_3S_2. This conclusion was largely based on the available data on the percent of total sulfidic
      nickel (including Ni_3S_2, nickel monosulfide, and nickel sulfide) from oil-fired utilities, not on
      Ni_3S_2 alone because EPA had no emissions data specifically for Ni_3S_2.

2.   In 1998, the EPA estimated the potential cancer potency weighting for mixtures of nickel
      compounds emitted from oil-fired utilities to be conservative, but reasonable because some of
      the other nickel compounds (such as nickel oxide [NiO] and nickel hydroxide, which have not
      yet been classified as carcinogenic in EPA's Integrated Risk Information System [IRIS]) could
      be carcinogenic. In fact, these and many other nickel forms are now considered likely
      carcinogens by the National Institute of Environmental Health Sciences (NIEHS). Even if

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Ni_3S_2 is shown to be a small portion of the nickel compounds emitted from oil-fired electric utilities (e.g., less than 5 percent), that low quantity does not preclude the risk of cancer still potentially being as high as 50 percent of that resulting from the cancer potency of Ni_3S_2 alone because of the other nickel compounds that are anticipated to be human carcinogens.

3.   In a 2001 preliminary National-Scale [Urban] Air Toxics Assessment for the year 1996, EPA conservatively postulates that 65 percent of man-made nickel air emissions are insoluble and computes a cancer unit risk estimate (URE) for the insoluble nickel compounds equal to 0.65 times the URE of insoluble Ni_3S_2, a Class A human carcinogen.

4.   Based on newly available speciation data, approximately 50 percent of the nickel emitted from full-scale oil-fired units is in the form of insoluble (crystalline) compounds including Ni_3S_2. As such, the assumptions used earlier appear to be reasonable and consistent with EPA's current URE for nickel compounds.

5.   The State of California has applied health risk level numbers to nickel compounds that had not previously been ranked as to their effect on human health and is moving towards regulating the amount of nickel to which individuals are exposed.

6.   Some oil-fired units have been taken offline in the last 10 years (the exact number is difficult to quantify but there may have been on the order of a 50 percent reduction), but many of those remaining have been made more efficient with extended life spans. These units are not likely to be retired as long as they are profitable.

7.   Depending on the relative price between natural gas and oil, oil consumption for power production is projected to continue to decline over the next decade but will remain a factor in certain geographical locations. If older, uncontrolled oil-fired plants continue in service without particulate-matter controls, significant quantities of carcinogenic compounds may continue to be emitted.

Background

In the EPA's RtC,[1] published in February 1998, nickel emissions from oil-fired utilities were noted as being of potential concern to human health. However, significant uncertainties existed with regards to the chemical composition of nickel forms (species) emitted from oil-fired utilities and the health effects posed by those various forms of nickel.

Since the RtC was published, several research projects have been undertaken to determine the nickel species emitted from utilities and the health effects of those various species. This memorandum summarizes the findings in the RtC and reviews information that has become available since the RtC on

the form (or species) of emissions of nickel from oil-fired electric utility steam generating units, and updated information regarding the health impacts of such emissions.

The RtC Assessment and Findings

At the time emissions data were being gathered for the RtC (1991 - 1994), total nickel was measured at nearly all sites, but only two sites, both oil-fired utilities firing residual oil (No. 6 fuel oil), provided data on speciated nickel emissions. The species measured were:

- soluble nickel (water-soluble salts such as nickel sulfate [$NiSO_4$] and nickel chloride)
- insoluble sulfidic nickel (such as Ni_3S_2, nickel monosulfide, and nickel sulfide)
- insoluble metallic nickel (including alloys)
- insoluble oxidic nickel (including NiO, complex oxides, and silicates)

The average speciation results of the two test sites are presented in Table 1. Additional data from nickel speciation on five test sites submitted to EPA by the Electric Power Research Institute (EPRI) in 1995 are also presented in Table 1.

Table 1. Speciated Nickel Average Values for Full-scale, Oil-fired Utilities

	Average values of two sites (EPRI's "Pisces" Study)[1]	Data ranges of five sites (EPRI additional sites)[2]
Soluble nickel	58 percent	25 to 60 percent
Sulfidic nickel (insoluble)	3 percent	4 to 26 percent
Metallic nickel (insoluble)	0 percent	0 to 4 percent
Oxidic nickel (insoluble)	39 percent	27 to 70 percent
Ratio of soluble nickel compounds to insoluble nickel compounds	58:42	43:58

Note: The 43 percent value in the second column's ratio is rounded from 42.5 percent, which is the average of the sum of 25 and 60 percent for soluble nickel. The 58 percent value is rounded from 57.5 percent, which is the remainder from 100 percent.

Human epidemiologic data available at the time of the data gathering for the RtC indicated that at least some forms of nickel are carcinogenic to humans by inhalation exposure.[3,4] Under EPA's IRIS files on chronic health effects and carcinogenicity of nickel, nickel refinery dust[a] and Ni_3S_2 were

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[a]   Nickel refinery dust is generated only at primary (or secondary) metal process plants.

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classified as human carcinogens (Weight of Evidence [WOE] = A). The cancer potency estimate also known as the inhalation unit risk estimate (IURE) for nickel refinery dust was 2.4 x 10^{-4} per micrograms per cubic meter (: g/m^3). Based on an assumption that Ni_3S_2 constitutes 50 percent of the refinery dust, an IURE of 4.8 x 10^{-4} per : g/m^3 was assigned to Ni_3S_2. Under IRIS, nickel carbonyl was classified as a probable human carcinogen (WOE = B2), but no IURE has been established. These were the only species classified by the EPA as carcinogens as of February 1998. However, even at that time, the International Agency for Research on Cancer (IARC) considered nickel monoxide, nickel hydroxide, and metallic nickel as having sufficient evidence in experimental animals for carcinogenicity.[4] The IARC considered nickel compounds to be carcinogenic to humans and metallic nickel to be possibly carcinogenic. In addition, the State of California had concluded that, "All nickel compounds should be considered potentially carcinogenic to humans by inhalation".[5] Further, in 1995 the American Conference of Governmental Industrial Hygienists (ACGIH) stated that all nickel compounds should be considered carcinogenic for risk management purposes.[6] However, at the time the RtC was being prepared and published, because available data were insufficient to confirm the carcinogenicity of many nickel compounds, there were still significant uncertainties regarding the carcinogenicity of many of these compounds. Therefore, the nickel risk estimates presented in the RtC were based on an assumption that the mix of nickel compounds emitted from utilities were 50 percent as carcinogenic as Ni_3S_2.

In the RtC, cancer IUREs were available only for Ni_3S_2 and nickel refinery dust. The cancer potency of the other potentially-carcinogenic nickel compounds was not known. Results of animal studies suggested that Ni_3S_2 was the most carcinogenic form.[4,4] Based on the limited speciation data presented in Table 1, no more than 10 percent of the nickel compounds are likely to be Ni_3S_2.[1] Therefore, the nickel risk estimates presented in the RtC (where it is assumed the mix of nickel compounds emitted from utilities are 50 percent as carcinogenic as Ni_3S_2) were considered conservative, high-end risk estimates at the time.

For the RtC, the EPA modeled the emissions from all 137 oil-fired plants in the U.S. to estimate off-site air concentrations and potential human inhalation exposures. Based on this modeling, EPA estimated that the maximum annual average air exposure concentration due to emissions from the highest risk plant would be about 0.2 : g/m^3. Maximum air exposure concentrations due to emissions from the second and third highest risk plants were estimated to be 0.08 : g/m^3 and 0.04 : g/m^3, respectively. All other oil-fired plants were estimated to produce lower exposure concentrations.

To estimate cancer risks due to emissions of air toxics (including nickel) from oil-fired utilities, cancer IUREs were applied to the modeled air concentrations (see RtC for details). Based on this risk assessment, EPA estimated, for the majority of the oil-fired plants (125 of the 137 plants), the maximum individual risks (MIR) for cancer by inhalation to be less than 1 x 10^{-6} (i.e., 1 in 1 million). However, up to 11 of the 137 oil-fired plants were estimated potentially to present inhalation MIRs greater than 1 x 10^{-6}. Nickel, arsenic, radionuclides, and chromium were the primary contributors to these cancer risks. For oil-fired utilities, the highest contributions to the MIRs were from nickel. These

risk estimates are summarized in Table 2. As noted above, the risk estimates for 1990 oil-fired electric utility emissions were based on an assumption that the mix of nickel compounds emitted from utilities was 50 percent as carcinogenic as Ni_3S_2.

Table 2. Summary of Cancer Risk Estimates due to Inhalation Exposure to Air Toxics Emissions from the 137 Oil-fired Utilities in U.S. based on Modeling Presented in the RtC

Pollutant	Highest MIR	Estimated population with risk $> 1 \times 10^{-6}$	Number of plants with MIR $> 1 \times 10^{-6}$
Nickel	5×10^{-5}	110,000	11
Arsenic	1×10^{-5}	2,400	2
Cadmium	2×10^{-6}	45	1
Chromium	5×10^{-6}	2,300	1
Total	6×10^{-5}	NA	11

Research Conducted Since the RtC

Since the RTC was published, three research projects have been undertaken to determine the species of nickel emitted from oil-fired power plants. One study (Galbreath) investigated nickel speciation of residual oil combustion fly ash in a laboratory setting.[7] The researchers obtained the different fly ash samples used in the study by combusting low- and high-sulfur (0.33 and 1.80 weight percent, respectively) residual oil in a laboratory-scale (40,000 Btu/hour) combustion system at different excess oxygen (O_2) concentrations (less than or equal to 1 to 3 mol percent). Fly ash samples were collected from the convection pass outlet of the laboratory-scale combustor using Gelman Scientific Type A/E glass-fiber filters. The entire gas stream with its entrained ash was sampled. During sampling, temperatures in the filter enclosure ranged from 290 to 310 °C. Nickel speciation analyses were preformed using X-ray absorption fine-structure (XAFS) spectroscopy and sequential extraction–anodic stripping voltammetry (ASV).

Researchers first analyzed the fly ash samples using XAFS spectroscopy. Comparing the Ni K-edge X-ray adsorption near-edge structure (XANES) spectra for 11 nickel compounds, the researchers found that greater than 95 percent of the total nickel (3 to 9 weight percent) present in the fly ash occurs as divalent nickel (Ni^{2+}) in an oxygen (O^{2-}) coordination environment. Both analysis methods indicate that soluble $NiSO_4$ is the dominant form, although significant portions of insoluble NiO (5 to 24 percent of total nickel) were measured by sequential extraction-ASV. The sequential extraction-ASV method also indicated the presence of very small proportions (less than 2 percent, of

nickel sulfides [Ni_xS_y]). Fuel sulphur content did not significantly affect nickel speciation; however, increasing excess oxygen concentrations promoted nickel sulfation.

The predominance of $NiSO_4$ and relatively low proportions of Ni_xS_y in the experimentally produced fly ashes (Galbreath) were inconsistent with sequential extraction-ASV determinations of nickel speciation in fly ashes collected from full-scale oil-fired utility boilers analyzed in two studies accomplished before the RtC (Bell, Goldstein).[8, 9] The proportions of Ni_xS_y and NiO measured in the fly ash samples produced experimentally are much lower, while the relative proportions of nickel are much higher than from fly ashes collected at full-scale oil-fired utility boilers. Table 3 shows the sampling methods employed and the actual physicochemical properties of fly ashes produced in laboratory-scale versus full-scale combustion systems. Differences in sampling procedures and combustion conditions were to be investigated through further studies to explain this inconsistency.

Table 3. Comparison of Nickel Speciation Investigations

Fly ash source(s)	Full-scale combustion system [8, 9]	Laboratory-scale combustion system [7]
Sampling location	Duct or stack	Convection pass
Sampling method	Isokinetic sampling on a heated quartz thimble filter (EPA Method 5 train)	Entire gas stream on a heated glass-fiber filter
Speciation results	5-26 percent Ni_xS_y, 40-68 percent NiO, 25-44 percent NiX (e.g., X = SO_4, CO_3, Cl_2), and <6 percent Ni^0	1-2 percent Ni_xS_y, 5-24 percent NiO, 79-92 percent $NiSO_4$, 1-3 percent Ni silicate(s) and <1 percent Ni^0

In a second study[10] (UNDEERC), the same researchers as in Galbreath tried to explain the apparent inconsistency of the $NiSO_4$ to Ni_xS_y ratio between their experimentally produced fly ashes and fly ashes collected from full-scale utility boilers. They accomplished this by testing fly ashes produced from intermediate-sulfur (approximately 0.85 weight percent sulfur) residual (No. 6 fuel) oils in the same laboratory-scale (40,000 Btu/hour) combustion system and in a full-scale (400-megawatt [MW]) utility boiler. Fly ash from the 0.86 weight percent sulfur residual oil was produced at 3 mol percent excess oxygen. Fly ash samples, from the laboratory-scale combustor, were collected on heated ($300 °C) glass- and quartz-fiber filters from the convection pass outlet of the combustor. Fly ash samples from the full-scale utility unit were collected from the stack of a 400-MW utility boiler (Unit 4) at the Port Everglades Plant in Fort Lauderdale, Florida. The fly ash samples were captured using a EPA Method 17 sampling train. Nickel speciation analyses were conducted with the same equipment used in the Galbreath study.

The UNDEERC study also estimated that greater than 99 percent of nickel in the experimentally produced fly ash occurs as $NiSO_4$, whereas greater than 95 percent of nickel in the fly ashes sampled from the 400-MW boiler occurs as a $NiSO_4$ and nickel ferric oxide ($NiFe_2O_4$) mixture.

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Particulate matter entering the 400-MW boiler also contains $NiSO_4$ and $NiFe_2O_4$. Results from the UNDEERC and Galbreath investigations indicate that residual oil fly ashes produced in the laboratory-scale (40,000 Btu/hr) combustion system are depleted in nickel and insoluble (crystalline) components but enriched in soluble $NiSO_4$ relative to fly ashes from full-scale oil-fired utility boilers. That is, the laboratory-scale studies do not appear to provide information representative of full-scale oil-fired boiler operation. These differences in fly ash properties are most likely related to the laboratory-scale (40,000 Btu/hr) combustion system's lack of bottom ash/fly ash partitioning, additive injection (e.g., magnesium hydroxide, $Mg[OH]_2$), and residence time present in the full-scale 400-MW boiler combustion system.

In a third study (Wong), a quantitative but indirect separation of nickel phases by sequential extraction was undertaken in conjunction with direct analysis of the sulfidic nickel phase by carbon paste electrode voltammetry (CPEV).[11] Four fly ash samples produced in a laboratory combustion system (provided by the researchers in Galbreath using the same sampling method) by burning high- and low-sulfur residual oil at excess oxygen contents of 1, 2, and 3 mol percent were studied. The extractions yielded five species of nickel. Nickel subsulfide was found to be absent from these fly ash samples. These data indicate that the sulfidic nickel in the experimentally produced fly ash did not contain measurable amounts of Ni_3S_2.

These new data suggest that a slightly higher proportion of the nickel emissions than EPA had estimated for the RtC is composed of the insoluble species (e.g., NiO, sulfidic nickel) which, as noted below, are more likely to be carcinogenic. This finding further validates the range used by the EPA in the RtC.

Updates on Health Risks of Nickel

Several State and Federal government agencies have examined the health effects of nickel compounds since the release of the RtC. The EPA's own IRIS values on chronic health effects and carcinogenicity of nickel and its compounds have not changed since publication of the RtC. [12-15]

In 2001, the EPA released a preliminary draft assessment for review by EPA's Science Advisory Board,[16] fulfilling a portion of its mission to conduct a national-scale assessment of air toxics that present the greatest threat to public health in the largest number of urban areas. Nickel is among the preliminary list of 33 chemicals ranked as air toxics of highest concern. In the preliminary draft assessment, EPA states that, "The IRIS unit risk for nickel inhalation was derived from evidence of the carcinogenic effects of insoluble nickel compounds in crystalline form...Nickel speciation information for some of the largest nickel-emitting sources (including oil combustion, coal combustion, and others) suggests that at least 35 percent of total nickel emissions may be soluble compounds. The remaining insoluble nickel emissions are not well-characterized, however. Consistent with this limited information, this analysis has conservatively assumed that 65 percent of emitted nickel is insoluble, and that all insoluble nickel is crystalline. On this basis, the...URE for nickel subsulfide (representing pure insoluble

crystalline nickel) was multiplied by 0.65 and applied to all nickel compounds" in the urban air toxics ranking assessment to date.[16] Although the SAB panel commented extensively on all aspects of the draft report that it felt could be improved, it did not comment on the nickel discussion, indicating that the members had no additional information that would improve the nickel assessment.

The NIEHS National Toxicology Program found in 1998 sufficient evidence to rate nickel and seven nickel compounds as reasonably anticipated to be human carcinogens.[17] These compounds are:

nickel acetate   (CAS No. 373-02-4),
nickel carbonate   (CAS No. 3333-67-3)
nickel carbonyl (CAS No. 1313-99-1)
nickel hydroxide   (CAS No. 912054-48-7 or 11113-74-9)
nickelocene   (CAS No. 1271-28-9)
nickel oxide   (CAS No. 1313-99-1)
nickel subsulfide   (CAS No. 12035-72-2)

In its 9th Report on Carcinogens (RoC), NIEHS expressed the risk as "reasonably anticipated to be human carcinogens based on sufficient evidence of carcinogenicity" for the compounds listed above (for each nickel compound, the supporting references were unchanged from the 8th RoC).[18] The NIEHS considers this review of nickel and nickel compounds complete. For the 10th RoC, the NIEHS will review metallic nickel and nickel alloys.

The 1997 Agency for Toxic Substances Disease Registry (ATSDR) profile on nickel contains descriptions and evaluations of toxicological studies and epidemiological investigations and provides conclusions, where possible, on the relevance of toxicity and toxicokinetic data to public health.[19] Although ATSDR does not develop health benchmarks for carcinogenic effects, the nickel toxicological profile does comprehensively review its carcinogenic and mutagenic properties.

Several nickel compounds were discussed in the 1997 ATSDR profile. The profile concludes that, generally, the less soluble nickel compounds (i.e., more insoluble or crystalline compounds such as NiO, Ni_3S_2, and other sulfidic nickels) are more likely to be carcinogenic whereas the more soluble nickel compounds (such as nickel chloride, $NiSO_4$, and nickel nitrate) are considered more toxic. Nickel carbonyl, which was identified in the RtC as toxic, was not reported in the 1997 profile because it is believed that the likelihood of exposure is very low. In ambient air, nickel carbonyl is relatively unstable with a half-life of about 100 seconds.

The ATSDR derives Minimum Risk Levels (MRLs) for chemical substances it profiles. In its 1997 profile, ATSDR derived an MRL of 2×10^{-4} milligrams per cubic meter (mg/m^3) for chronic duration inhalation exposure to total nickel and the MRL was based on a 2-year study of $NiSO_4$ in rats.

The ATSDR believes that data are insufficient for derivation of an acute inhalation MRL for nickel because no appropriate lowest observed adverse effect level (LOAEL) could be identified for the most toxic nickel compound, $NiSO_4$. No oral MRLs were derived for nickel.

The IARC's assessment of nickel and its compounds has not been updated since 1990.[20] Nickel as a group is designated as being in Group 1 ("Carcinogenic to humans"). Metallic nickel is designated as being in Group 2B ("Possibly carcinogenic to humans").[21]

The California Environmental Protection Agency (CalEPA) has developed dose-response assessments for many hazardous air pollutants (HAP) based both on carcinogenicity and health effects other than cancer. The process for developing these assessments is similar to that used by EPA to develop IRIS values and incorporates significant external scientific peer review. The non-cancer information includes available inhalation health risk guidance values expressed as chronic inhalation reference exposure levels (RELs). The CalEPA defines the REL as a concentration level at (or below) which no health effects are anticipated, a concept that is substantially similar to EPA's noncancer dose-response assessment perspective based on reference concentrations (RfCs). This assessment uses chronic RELs in the same way as RfCs when neither IRIS nor ATSDR values exist.[16] The CalEPA calculated a chronic inhalation REL of 5×10^{-5} mg/m^3 for total nickel based on respiratory and immune system effects reported in rats exposed to a soluble nickel salt.[22,23]

The CalEPA's quantitative dose-response information on carcinogenicity by inhalation exposure is expressed as a URE, defined similarly to EPA's URE. This assessment uses specific CalEPA UREs in the same way as EPA's when non-IRIS values exist.[16] The CAEPA's inhalation potency factor for all nickel is 2.6×10^{-4} per : g/m^3.[24] This is approximately one-half the EPA URE value, indicating a doubling in the potency.

Assessment of Potential Noncancer Health Effects

In the RtC, the risks of adverse health effects other than cancer (noncancer risks) were not evaluated for nickel compounds. However, as described above, there is an REL and an MRL available to assess potential noncancer risks. To assess the potential for noncancer risks, the exposure concentration is divided by the reference value (MRL or REL) to produce a hazard quotient (HQ). Hazard quotient values at or less than 1 imply that exposures are at or below the reference value and not likely to cause adverse effects. An HQ value exceeding 1 implies that the reference value is exceeded, and the likelihood of adverse effects increases as the amount and frequency of exposures exceeding the reference value increase. A comparison of the exposure concentrations to the REL and MRL are presented in Tables 3 and 4, respectively.

These results indicate that nickel emissions from the large majority of oil-fired utilities are not likely to pose risks of noncancer effects. However, there are one to three plants that may pose some potential risks for noncancer health effects because the exposures exceed the REL. Moreover, this

assessment does not include an evaluation of the contribution of nickel emissions to PM-fine air quality issues and related health impacts.

Table 4. Assessment of Potential Noncancer Risks for 137 Oil-fired Plants Using the REL

Facility	Maximum annual average exposure concentration (ug/m³)	REL (ug/m³)	Hazard quotient
Highest risk plant	0.2	0.05	4
Second highest risk plant	0.08	0.05	1.6
Third highest risk plant	0.04	0.05	0.8
All other plants	< 0.04	0.05	<0.8

Table 5. Assessment of Potential Noncancer Risks for 137 Oil-fired Plants Using the MRL

Facility	Maximum annual average exposure concentration (ug/m³)	MRL (ug/m³)	Hazard quotient
Highest risk plant	0.2	0.2	1
Second highest risk plant	0.08	0.2	0.4
Third highest risk plant	0.04	0.2	0.2
All other plants	< 0.04	0.2	<0.2

Fuel Usage History in the Oil-fired Utility Industry

The Department of Energy/Energy Information Administration (DOE/EIA) reports that in 2000 electric utilities used approximately 4.4 billion gallons of residual oil and just over 1 billion gallons of distillate oil.[25] The use of oil to generate electricity depends in large part on the relative prices of oil and natural gas. During the period 1990 to 2000, DOE/EIA reported that yearly consumption of fuel oil for electricity generation in the United States fluctuated but declined by approximately 23 percent overall.[26] However, oil consumption in the nonutility electricity generation sector has almost doubled since 1990. In addition, the high natural gas prices experienced during 2001 are expected to have resulted in increased oil usage for electricity generation (the 9-month total for 2001 consumption was greater than that for all of 2000). The DOE/EIA projects that, overall, oil will continue to lose its market share to

natural gas for heating and electricity generation in the coming decade.[27] However, the estimate is highly dependent on the assumptions made as to the relative price differential between oil and natural gas, with increased oil consumption being projected under a low oil price case.

Conclusions

Information that has become available since the RtC does not appreciably change the conclusions about the potential risk resulting from the emission of nickel and nickel compounds from oil-fired electric utility units that was presented in the RtC. Since the release of the RtC, new information has become available that indicates that the proportion of nickel that is emitted as Ni_3S_2, a known human carcinogen, is toward the lower end of EPA's estimated range, or less than 5 percent of total nickel emissions. However, this new information does not provide substantial evidence that the portion of insoluble nickel forms is lower than previously estimated. In addition, newer data on the health effects of various nickel species provides additional evidence that the estimates provided in the RtC of the cancer risk from oil-fired utility nickel emissions are reasonable. This new evidence suggests that all of the insoluble species of nickel, now estimated to account for approximately 50 percent of all nickel emissions from these sources, are probable carcinogens. In the 2001 EPA draft national scale assessment[16], it was assumed that these insoluble nickel compounds (other than Ni_3S_2) are as carcinogenic as nickel subsulfide. We think that this is a reasonable assumption based on available data and that it is appropriate to utilize the same assumption for the assessment of carcinogenicity of the insoluble nickel compounds from oil-fired utilities. Hence, the original risk estimates in the RtC (whereby the mix of nickel compounds were assumed to be 50% as carcinogenic as nickel subsulfide) is still considered a reasonable conservative assumption since about 50% of the nickel emissions are judged to be in the insoluble form. Moreover, the RtC did not estimate the risk of non-cancer effects; however, it appears that from one to three plants may pose a risk for non-cancer effects. Only those units that burn No 6 fuel oil are believed to emit significant amounts of nickel. The use of oil to fire electric power boilers is projected to decrease over the next decade.

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