ONTARIO AIR STANDARDS
FOR
MINERAL SPIRITS

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Executive Summary

The Ontario Ministry of the Environment (MOE) has identified the need to develop and/or update air quality standards for priority contaminants. The Ministry's Standards Plan, which was released in October, 1996 and revised in October, 1999, identified candidate substances for which current air standards will be reviewed over the next several years. Mineral spirits, particularly Stoddard solvent, were identified as priority compounds for review based on their patterns of use in Ontario. A review of scientific and technical information relevant to setting air quality standard for mineral spirits has previously been provided to stakeholders for their comments. A document providing the rationale for recommending an Ambient Air Quality Criterion (AAQC) and a half-hour Point of Impingement (POI) standard for mineral spirits has also been provided to stakeholders for their comments. This document summarizes comments from stakeholders on the proposed criteria and the responses provided by the Ministry. This document also provides the rationale for the decision on the air quality standards for mineral spirits.

Mineral spirits, also called petroleum distillates, are liquid mixtures of at least 200 different hydrocarbons, primarily consisting of C_7-C_{12} alkanes (paraffins) and cycloalkanes (naphthenes), with 15-20 % aromatic hydrocarbon content, of which less than 0.1 % is benzene. Due to the complex variable composition of mineral spirits, these solvent mixtures are often recognized using the names of the most commonly used commercial mixtures, including Stoddard solvent, VM & P naphtha, Varsol and white spirits. All are obtained by distillation of crude oil. These solvents have similar compositions and properties and are widely used in dry-cleaning fluids, paint thinners, varnishes, photocopy toners, inks, adhesives, and as general purpose cleaners and degreasers.

The major source of mineral spirits in ambient air are dry-cleaning facilities, spills, and waste sites. There is no information regarding releases or ambient air concentrations of these solvents in Ontario, nor was any other information in the literature about the ambient air levels. Since these solvents are complex and variable mixtures, their concentrations cannot be measured accurately and specifically in air. Information on their atmospheric levels may be estimated using dispersion modelling through the presence of individual volatile chemical components. Using the modelling method the US Environmental Protection Agency (EPA) estimated that in the Chicago area the maximum exposure level to Stoddard solvent, due to potential industrial waste streams, is 103 $\mu g/m^3$. Standardized methods of measurement (concentration and adsorption on a solid sorbent) have been developed for the workplace with a percentage recovery of all components of up to 90 %. The detection limit for mineral spirits ranges from 2,500 to 5,000 $\mu g/m^3$.

When mineral spirits are released in air from a point source, all chemical components are differentially evaporated and dispersed in the surrounding ambient air according to their individual physical and chemical properties. The initial concentration ratios of all components of the solvent mixture at the point of emission will not be expected to space away from the point

source. This makes the positive identification of a particular hydrocarbon mixture in ambient air very difficult. Additionally, many components of these solvents are commonly released by other sources such as automobile exhaust and oil, and can easily be confused with background levels. In the context of diffuse sources of emissions, such as waste sites, the task of identifying and quantifying hydrocarbon solvents over the background level is even more complex.

Mineral spirits are expected to induce primarily non-cancer effects. Mineral spirits cause adverse health effects such as eye, throat, respiratory tract, reproductive, and neurological problems. The major threat posed by these solvents is from long-term or chronic exposures. Data on cancer development related to Stoddard solvent is inconclusive, but concerns have been raised over the probable carcinogenicity and genotoxicity of other petroleum distillates like machining/cutting oils in the workplace following chronic exposure to much higher doses.

In revising the air quality standards for Ontario, the MOE reviewed risk assessments, standards, and guidelines developed by the US EPA, the States of California, New York, New Jersey, Michigan, the Commonwealth of Massachusetts, the World Health Organization, The Netherlands, the Swedish Institute of Environmental Medicine and the Canadian Federal Government. Only the State of Michigan has a recommended guideline (ITSL, Initial Threshold Screening Level) for the combined impact of all petroleum hydrocarbon solvent mixtures of 3,500 $\mu g/m^3$ and is based on an 8-hour average. Some specific components of the mixture are designated with annual average guidelines which were derived from available NOAEL or LD_{50}. The lack of established guidelines for mineral spirits from the above mentioned agencies prompted the examination of guidelines from several other additional State agencies. Most of the guidelines of these agencies were derived from occupational exposure limits, although the values and averaging times are different.

For protection of human health, guidelines have been derived from occupational exposure levels. The odour detection thresholds of mineral spirits (including Stoddard solvent) range from 500 to 5250 $\mu g/m^3$ which indicate that odour may also be a concern with mineral spirits.

Of the criteria reviewed from other agencies, the Ministry has evaluated and agreed with the State of Michigan and accepted the rationale supporting the ITSL of this agency. The ITSL considers the scientific studies which support the development of the occupational exposure limit of 350,000 $\mu g/m^3$ from the National Institute for Occupational Safety & Health. After reviewing additional toxicological information, the Ministry has decided to derive air quality standards for mineral spirits based on the rationale for this occupational exposure limit. Applying an exposure time conversion factor and appropriate uncertainty factors to the Threshold Limit Value -Time-weight Average of 350,000 $\mu g/m^3$ result in a 24-hour AAQC of 2,600 $\mu g/m^3$. In addition, the Ministry has also considered the odour effect of mineral spirits in deriving its air quality standards. The odour thresholds of mineral spirits (including Stoddard solvent) range from 500 to

5,250 µg/m^3. In the absence of a geometric mean for odour thresholds, the arithmetic mean of values at the two ends of the range is used to derive a POI of 3,000 µg/m^3, based on odour.

In summary, based on the information reviewed from leading agencies, the assessment of toxicological information, the odour nuisance of mineral spirits, and the stakeholder comments, the Ministry has determined the following Ambient Air Quality Criterion and interim Point Of Impingement standard for mineral spirits:

- **2,600 µg/m^3 (micrograms per cubic metre of air; 24-hour average) based on the adverse health effects;**

- **7,800 µg/m^3 (half-hour average interim POI standard) based on the health effects.**

The health-based interim POI standard of 7,800 µg/m^3 (half-hour average) has been determined for mineral spirits from the proposed range of 3,000 µg/m^3 to 30,000 µg/m^3. The Ministry will initiate consultation with stakeholders to develop an implementation plan to achieve the final odour-based POI of 3,000 µg/m^3, pending the outcome of all consultation on a risk management framework, the introduction of new air dispersion models in Ontario, and proposed amendments to O. Reg. 346 to incorporate effects-based air standards with appropriate averaging times.

The interim POI standard will take effect 6 months from the date of this Environmental Registry decision posting to provide some implementation flexibility in respect to the stakeholder comments and our current limited knowledge of emitters.

The Ministry is currently undergoing stakeholder consultation in the discussion paper "A Proposed Risk Management Framework for the Air Standard Setting Process in Ontario". The risk management framework addresses implementation timeframes for adopting final effects-based air standards (POI and AAQCs) as well as technology and economic issues linked to the introduction of new or revised air quality standards and the introduction of new dispersion models into Ontario's regulatory framework. Consultation is also underway in the discussion paper entitled: "Updating Ontario's Air Dispersion Models".

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1.0 Introduction

Ontario regulates air emissions in order to achieve and maintain air quality which is protective of human health and the environment. The *Environmental Protection Act* (Section 9) requires that all stationary sources that emit, or have the potential to emit, a contaminant obtain a Certificate of Approval which outlines the conditions under which the facility can operate.

The Ministry of the Environment uses a combination of regulated point of impingement (POI) standards and point of impingement guidelines in reviewing Certificates of Approval (MOEE, 1994a), each of which is derived by mathematical scaling, from an ambient air quality criterion (AAQC). Ambient Air Quality Criterion (AAQCs) represent human health or environmental effect-based values, and are normally set at a level not expected to cause adverse effects based on continuous exposure. As such, economic factors, such as technical feasibility and costs, are not explicitly considered when establishing AAQCs.

All sources are required to comply with the Point of Impingement standards that are included in the schedule of Regulation 346. The regulation (Section 5(3)) specifies that a source cannot, "cause or permit the concentration of a contaminant at a point of impingement to exceed the standard prescribed in Schedule 1". All sources are required to comply with the standards in Regulation 346 unless they are specifically exempt. The concentration of a contaminant at a POI may be calculated in accordance with the Appendix of Regulation 346 (Air Dispersion Models).

In addition to POI standards established under Regulation 346, the Ministry also has a large number of POI guidelines. These are used by the Ministry to assess general air quality, and the *likelihood* of causing adverse effect (MOEE, 1994a). Like the POI standards specified in Regulation 346, POI guidelines are used in reviewing applications for Certificates of Approval, to approve new and modified emission sources. Once incorporated into a legal instrument such as a Certificate of Approval, POI guidelines are legally binding.

The Ontario Ministry of the Environment has identified the need to develop and/or update air guidelines/standards for priority toxic contaminants. The Ministry's Standards Plan, which was released in October, 1996 and revised in October, 1999 (MOEE, 1996; MOE, 1999a), identified 70 high priority substances for which current air standards will be reviewed, over the next several years. Factors used by the Ministry to determine which contaminants require priority include potential degree of exposure, volume of use, toxicity, Federal/Provincial commitments and sensitive sub-populations, including children.

In March 1998, following the 1996 initiative, the Ministry proposed a multi-step process for developing air quality standards (MOE, 1998). Initially, risk assessment and risk management information, relevant to establishing a standard for a particular compound, is documented (an Information Draft) and made available for stakeholder review through direct mail-out and posting

on the Environmental Registry. This provides stakeholders with the opportunity to critically review the information and provide any additional information they feel should be considered by the Ministry in setting an air quality standard for a particular compound. The Ministry considers comments received on the Information Draft and recommends proposed standards (a Rationale Document) and again solicits comments through direct mail-out and posting on the Environmental Registry for another public comment period. After assessing comments on the Rationale Document the Ministry finalizes its work by making a decision on the air quality standards by posting a Decision Notice onto the Environmental Registry.

Mineral spirits, including Stoddard solvent, were identified as a priority for review based on their pattern of use in Ontario. The Information Draft (MOEE, 1999b) and the Rationale Document (MOE, 2000) with recommended Ambient Air Quality Criteria (AAQC) and half-hour Point of Impingement (POI) standard for mineral spirits have also been provided to stakeholders for their comments. This document summarizes comments from stakeholders on the proposed criteria and the responses provided by the Ministry. This document also provides the rationale for the decision on the air quality standards for mineral spirits.

2.0 General Information

2.1 Physical/chemical Properties

Mineral spirits are colourless petroleum distillate mixtures of C_7-C_{12} hydrocarbons (generally >65% C_{10} and higher), with boiling points ranging from 130-220°C and flash points ranging from 21-60°C. These solvent mixtures have been identified by various names and synonyms, including Stoddard solvent, dry cleaning safety solvent, petroleum solvent, varnoline, spotting naphtha, white spirits, petroleum distillates, petroleum spirits, ligroine, VM & P naphtha, benzine and trade named products such as Varsol, Solvesso and Petrosol. The Chemical Abstracts Service (CAS) identification numbers for some of these solvents are as follows:

Naphtha	8030-30-6
Ligroine	8032-32-4
Stoddard solvent	8052-41-3
Heavy hydrotreated petroleum naphtha	64742-48-9
Medium aliphatic solvent petroleum naphtha	64742-88-7
Light aliphatic solvent petroleum naphtha	64742-89-8

All of these are liquid mixtures, which are primarily composed of 30-50% linear and branched alkanes, 30-40% cycloalkanes and 5-20% aromatic hydrocarbons (<0.1% benzene; mainly alkylbenzenes particularly trimethylbenzene), formed in the standard production of petroleum. More specifically, all of the mineral spirit formulations are comprised of three classes of

compounds: the alkanes (*n*-nonane, –decane, methylnonanes, 2,6-dimethyloctane, *n*-undecane, dodecanes, tridecanes), the cycloalkanes (monocycloparaffins, dicycloparaffins, tricycloparaffins, acenaphthenes) and aromatic compounds. The latter include alkylbenzenes (dimethylbenzenes, *n*-propylbenzene, ethyltoluenes, 1,2,4-trimethylbenzene, toluene, xylenes), other benzenes, indans/tetralins, indenes, naphthalenes, acenaphthalenes, and tricyclic aromatics. Alkylbenzenes account for most of the contribution of the aromatics to the total chemical composition of these solvents while the rest of the aromatics account for no more than 4.6% of the total; each chemical species rarely contributing more than 1% individually. Very few of the aromatics are individually classifiable as human carcinogens except for benzene.

Mineral spirits have a sweet odour similar to kerosene. The odour detection threshold is reported to range from 2,000 to 5,250 $\mu g/m^3$ (ATSDR, 1995; Ruth, 1986), and is expected to vary because of the variable chemical composition of these mixtures. The odour irritation concentration of Stoddard solvent is 2,100,000 $\mu g/m^3$ (Ruth, 1986). Odour thresholds, which have been reported in some human volunteers, for Stoddard solvent range between 500 to 5,000 $\mu g/m^3$ (Carpenter *et al.*, 1975 as cited in NIOSH, 1977a). These solvents are considered hazardous materials for which transportation and management is regulated. Disposal of these compounds is recommended through controlled incineration. Disposal to domestic sewage drains is prohibited.

2.2 Uses of Mineral Spirits

Mineral spirits are industrial multipurpose organic solvents widely used in dry-cleaning products, inks, paints and thinning agents for paints, coatings, waxes, varnishes, adhesives, photocopy toners, machine shop and automotive repair applications, and as cleaners and degreasers. The major industries most commonly associated with these solvents are electroplating, metal degreasing, paint stripping, semiconductors and dry-cleaning. Although one type of mineral spirit, Stoddard solvent, was introduced in the 1920's specifically for use in dry-cleaning, most dry-cleaners today use chlorinated hydrocarbon solvents such as perchloroethylene rather than mineral spirits.

2.3 Sources and Levels

Mineral spirits are detected in the air through their individual components. There are standardized methods for measuring their concentration in air. These methods are approved by the National Institute for Occupational Health and Safety, method 1550 (NIOSH, 1984), and by the Occupational Safety and Health Administration (OSHA), method 48. For these methods, the analytical precision is good but not all of the components present in the air are easily recovered (i.e., less than 90% are recovered) and the detection limit of the equipment is poor (i.e., requires 5,000 $\mu g/m^3$ as a total concentration). Other methods need to be developed for a better recovery of all the components. At present, knowledge on the exact hydrocarbon components and their

ratios in various hydrocarbon mixtures in air (e.g. Stoddard solvent versus paint thinners) is scarce.

Mineral spirits are mainly released to the atmosphere from industrial facilities, waste sites, and as a result of large spills into soil and water. Volatilization along with subsequent rapid photooxidation in the atmosphere is expected to be an important fate of mineral spirit releases. An experiment designed to determine the potential hazard to operators of landfill sites by comparing the volatilization of Stoddard solvent on a simulated waste site and a nearby lagoon, reported a rate of evaporation six times greater from the solid waste site. Mineral spirits are not listed as candidate pollutants on Environment Canada's National Pollutant Release Inventory for environmental release reporting by industry (NPRI, 1997). In the US, based on information in the 1990 Toxics Release Inventory, reporting releases of Stoddard solvent was not mandatory. However, the total volume of production was estimated to have dropped by 51%, from 74.9 million pounds in 1986 to 38.3 million pounds in 1990. The average concentration of Stoddard solvent emitted from one dry-cleaning plant was determined to be in the order of 12,033,000 $\mu g/m^3$ measured as propane (ATSDR, 1995).

The MOE has not measured, or estimated, ambient air levels of mineral spirits in Ontario (MOEE, 1997). Given the difficulty in measuring mineral spirits *per se* in ambient air, no data on these levels could be located in the literature. Some estimation of population exposure was established by the US EPA, in the Chicago area, using air dispersion models for five combustion scenarios at the emission source. The highest concentration of Stoddard solvent to which people would be exposed to in ambient air, expressed as a total concentration, was predicted to be 103 $\mu g/m^3$ (ATSDR, 1995). In comparison, indoor air levels of Stoddard solvent in paint booths was found to be in the range of 412,000 to 707,000 $\mu g/m^3$ (Bradley and Bodsworth 1983). The occupational exposure would then appear to be thousands of times more than values predicted by dispersion models for ambient air. However, with a detection limit of 5,000 $\mu g/m^3$, the current standard methods of measurement for mineral spirits used for indoor air levels would not appear to be sensitive enough for detecting the anticipated lower ambient air levels even if "mineral spirits" *per se* could be measured with certainty.

From an analysis of recent applications for Certificates of Approval in Ontario, a sample of 74 facilities with emissions of mineral spirits covered by a Certificate was identified. These approvals were for emissions from manufacturers of plastic products, transportation equipment, forest product and metal and mining industries and chemical plants. The median Ground Level Concentration estimated by Regulation 346 dispersion modelling for all 74 sources was approximately 59.35 $\mu g/m^3$. The maximum and minimum were 5854 and 0.002 $\mu g/m^3$, respectively.

2.4 Environmental Fate

The environmental fate of mineral spirits will depend on the physico-chemical and biological properties of the constituents. The lower molecular weight alkanes and aromatics tend to volatilize and undergo photodegradation in the atmosphere. Higher molecular weight compounds tend to adsorb to organic matter in soil or water. Biodegradation of C_7 to C_{12} hydrocarbons is expected to be significant under conditions favourable for microbial oxidation. Mineral spirits have a moderate potential for bioaccumulation based on octanol-water partitioning coefficients of 3.5 to 6.4, however, the likelihood of bioconcentration in the environment is reduced by degradation and reduced bioavailability resulting from sorption to organic matter (WHO, 1996).

3.0 Toxicology of Mineral Spirits

Contact with mineral spirits generally occurs as a result of inhalation or through the skin. Exposure to mineral spirits can cause skin, eye and throat irritation, and dermatitis. No studies were found on the effects of solvents following ingestion. The inhalation and dermal routes are the most predominant routes of exposure, but it is still unclear which one is the most significant. Once the solvent enters the body, it quickly enters the bloodstream. At present there is no reliable information regarding doses of mineral spirits that could lead to death in humans (ATSDR, 1995).

3.1 Acute Toxicity

Inhalation of mineral spirits causes dizziness and headaches. Studies have been performed on human volunteers to investigate short-term or acute toxicological effects and biochemical changes following inhalation of white spirits (Shellsoll TS: 99% paraffins; Exsol D 40: 52% paraffins and 48% naphthenes; Varnolene: 57% paraffins, 25% naphthenes and 18% aromatics) for 6 or 48 hours. Inhalation of any of the three white spirits at a concentration of approximately 102 ppm (605 - 610 mg/m^3) or to Exsol D 40 at 0, 51, 102 and 205 ppm (0, 304, 611 and 1228 mg/m^3) did not induce the symptoms reported at higher concentrations such as dryness of the mucous membranes, loss of appetite, nausea, vomiting, diarrhoea, and fatigue during and after exposure. No symptoms were found which are usually associated with organic solvent poisoning such as headache, dizziness, feeling of inebriation, visual disturbances, tremour, muscle weakness, coordination impairment, or paraesthesia of the skin. The only biochemical changes observed were significant decreases in serum α-amylase 6 hours after exposure and in S-urate 48 hours following exposure to white spirit with high naphthalene content at 200 ppm (1228 mg/m^3) (Pedersen and Cohr, 1984). This concentration was approximately equivalent to the TLV level of 100 ppm for light or moderate work, as explained by the authors.

A NOAEL of 140,000 µg/m^3 for a 15-min average and of 600,000 µg/m^3 for a 30-min average exposure were found for ocular effects, probably due to the direct contact of the concentrated vapours with the eyes (ATSDR, 1995).

3.2 Subchronic/chronic Toxicity

Long-term exposure studies on human volunteers suggested that the most sensitive indicator of chronic effects relates to neurological problems. In painters for example, a relationship was found between long-term hydrocarbon solvent exposure and a higher frequency of early disability pension due to neuropsychological disorders (Soren *et al.*, 1996).

Inhalation studies on animals showed that the hydrocarbons, which compose mineral spirits, may be stored in body fats and can enter the brain days after exposure to induce delayed effects. Stoddard solvent has been shown to cause seizures in rats, cats, and dogs, and bronchitis in guinea pigs. It has also been shown to cause kidney damage only in male rats. This is thought to be due to a specific protein, $\alpha_{2\mu}$-globulin, which is synthesized in large amounts by male rats as a urinary pheromone carrier and is reabsorbed in the proximal tubules. Stoddard solvent may bind to this protein and accumulate in lysosomes in the proximal tubules where it causes nephropathy (ATSDR, 1995). No studies established a possible link between exposure to Stoddard solvent and immunological or lymphoreticular effects (ATSDR, 1995).

3.3 Developmental/Reproductive Toxicity

Stoddard solvent was not found to cause maternal toxicity, structural teratogenesis, or decreased foetal weight when administered during organogenesis in the rat. No studies have established a possible link between exposure to Stoddard solvent and birth defects, reproductive effects, and/or infertility (ATSDR, 1995).

3.4 Genotoxicity

The lack of mutagenic activity of white spirits was reported by Gochet *et al.* (1984) with different strains of *Salmonella typhimurium* as well as in *in vivo* animal studies. However, the available data is much too limited to allow definitive conclusions regarding the genotoxicity of mineral spirits in humans. There is some concern regarding the genotoxicity of some components of mineral spirits. As mentioned above, *n*-decane will increase the frequency of mutations in V79 Chinese hamster cells in the presence of methylazoxymethanol, although it does not cause mutagenesis on its own. This suggests that *n*-decane may be a cancer promoter. It is not certain whether some of the carcinogenic and genotoxic effects observed with some of the individual components of these solvents would also occur with the complete mixture.

3.5 Carcinogenicity

Few studies were conducted on the carcinogenic effects of mineral spirits in humans and animals. The International Agency for Research on Cancer (IARC) classifies "petroleum distillates" as probable human carcinogens. However, these mixtures have not been classified as carcinogenic by the American Department of Health and Human Services (DHHS), the US EPA, or any other national or international agencies in any exposure situation (ATSDR, 1995). A limited case-referent study using cases of Hodgkin's and non-Hodgkin's lymphoma among Swedish workers exposed to white spirits implied a slight increase in crude odds ratios (ORs), but was limited by an insufficient number of cases (Persson *et al.*, 1993). Some human data were obtained from a case-control study of 32-100 individuals who had cancer and were questioned on their exposure to unknown levels of petroleum products (Siemiatycki *et al.*, 1987). Statistically significant ORs were found for mineral spirits and prostate cancer. Non-significant but positive ORs were reported for Hodgkin's lymphoma and squamous cell carcinoma of the lung.

It has been estimated that 75% of dry cleaners world-wide now use tetrachloroethylene; the remaining 25% use petroleum-based solvents. The carcinogenic risk for people working in dry cleaning facilities and exposed to Stoddard solvent, trichloroethylene, and carbon tetrachloride was evaluated (McGregor *et al*., 1995). The relationship between employment in dry cleaning and cancer incidence was assessed in studies of proportionate mortality in case-referent studies and in cohort studies. Risks were evaluated for urinary, bladder and oesophageal cancer. It was found that dry cleaning entails exposures that are possibly carcinogenic to humans. However, none of these studies provide conclusive results on the carcinogenic potential of mineral spirits for humans exposed at ambient air levels, such as at hazardous waste sites.

There was only one chronic dermal (skin-painting) study in mice that was suggestive of possible carcinogenic effects of mineral spirits, although the results were considered ambiguous as the test substance was a rust-preventative compound containing not only Stoddard solvent (90%) but also calcium petroleum sulphonate (7%) and ethylene glycol monobutyl ether (3%). Several other studies have shown that carcinogenesis cannot be attributed to any particular component of mineral spirits, however, *n*-alkanes may be one of the promoters of carcinogenicity or co-carcinogenic elements. An *in vitro* study on V79 Chinese hamster cells showed that *n*-decane, a component of mineral spirits, may be a tumour promoter since the frequency of mutations caused by methylazoxymethanol, a complete carcinogen in several species, increased in the presence of *n*-decane (ATSDR, 1995). In contrast, some other components of mineral spirits, such as the alkylbenzenes, are believed not to be carcinogenic (ATSDR, 1995).

3.6 Environmental Effects

There have been very few studies on the toxicity of mineral spirits to wildlife. The application of Stoddard solvent (1,123 L/ha) to the excised root tips of various species of pine seedlings

resulted in an increase in oxygen uptake ranging from 19% to 39% (Voigt, 1953). Aquatic organisms exposed to mineral spirits have demonstrated LC_{50} values ranging from 0.5 to 5 mg/L (WHO, 1996).

4.0 Existing Ambient Air Quality Criteria

4.1 Overview

In revising the air quality standards for Ontario, the MOE reviewed risk assessments, standards, and guidelines developed by the US EPA, the States of California, New York, New Jersey and Michigan, The Commonwealth of Massachusetts, the World Health Organization, The Netherlands, the Swedish Institute of Environmental Medicine and the Canadian Federal Government. Agency-specific summaries of guidelines for mineral spirits are presented in Section 10.0. A brief summary of available criteria is presented in Table 1.

In reviewing the air quality guidelines and exposure limits presented in Table 1, it should be noted that the MOE typically uses a factor of **15** to convert from guidelines based on annual average concentrations to half-hour point-of-impingement limits, and a factor of **3** to convert from guidelines based on 24-hour average concentrations. These factors are derived from empirical measurements and are selected to ensure that if the short-term limit is met, air quality guidelines based on longer-term exposures will not be exceeded (MOE, 1987; MOEE, 1994b). However, depending on the health end-point being considered, other conversion factors may also be employed.

Of all the agencies reviewed, only Michigan refers to specific petroleum hydrocarbon solvent mixtures. Their 8-hour guideline (ITSL) of 3500 $\mu g/m^3$ is for the combined ambient impact of all petroleum hydrocarbons other than mineral oils. In addition, Michigan has set different annual-average limits (e.g. 2 - 24 $\mu g/m^3$) for some specific hydrocarbon solvent mixtures for which applicable NOAEL or LD_{50} were available to derive specific effect-based criteria. These values were applied to hydrotreated middle distillate, hydro-desulphurized middle distillate, sweetened middle distillate, hydrotreated heavy naphthenic distillate, and hydrotreated light distillate. The State of New York plans to set a guideline for Stoddard solvent in the near future which will be based on the occupational limit of 350,000 $\mu g/m^3$ of the US National Institute for Occupational Safety and Health (NIOSH), using a method similar to that of Michigan. The State of New York also intends to establish an equivalent concentration to set a guideline for mineral spirits which refers implicitly to the total concentration of all hydrocarbon constituents of the mixture. The Netherlands refers to emission levels of organic hydrocarbon compounds which may include solvent mixtures.

Table 1. Summary of Existing Air Quality Guidelines[1] for Mineral Spirits

Agency	Guideline Value[2]	Basis of Guideline	Date[3]	Comments
Michigan	3,500 µg/m^3 ITSL (8-hour average), total refined petroleum hydrocarbons (not including mineral oils); in addition, there are longer-term guidelines for specific solvent types:	Occupational levels 1% of NIOSH REL	1992	Initial threshold screening level (ITSL) of 3,500 µg/m^3 for all hydrocarbon materials excluding mineral oils. NIOSH REL 350,000 µg/m^3
	• hydrotreated middle distillate, hydro-desulphurized middle distillate, sweetened middle distillate: 2 µg/m^3 ITSL (annual average)	NOAEL from unpublished API 4-wk rat inhalation study, 24 mg/m^3		Based on study on hydrodesulphurized middle distillate, others have similar composition
	• hydrotreated heavy naphthenic distillate: 16 µg/m^3 ITSL (annual average)	Surrogate acute oral LD_{50} from 14-day rat gavage study, greater than 5 g/kg body weight		
	• hydrotreated light distillate: 24 µg/m^3 ITSL (annual average)	NOAEL for deodourized kerosine from rat subchronic inhalation study, 98 mg/m^3		Composition similar to deodourized kerosine, similar toxicity expected.
The Netherlands	none	emission standard of 100,000 µg/m^3 HC for flows of 2.0 kg per hour or more	1987	hydrocarbons (HC) in general
Canada (CEPA)	none		1997	Not in PSL1 or PSL2
Ontario	(Note: see comments for replaced air quality standards)		1994	Previous Ontario air quality standards which have been replaced with the current air quality standards.
	AAQC for mineral spirits 10,000 µg/m^3 (24-hour average)	Health		AAQC (Ambient Air Quality Criteria)
	30,000 µg/m^3 (half-hour POI)	Odour		Point Of Impingement guideline.

1. Guidelines in this table can refer to: guidelines, risk-specific concentrations based on cancer potencies, and non-cancer-based reference concentrations.
2. As different jurisdictions use different units to express concentration, an air concentration conversion factor of 1ppm = 5682 µg/m^3 has been used whenever a conversion to µg/m^3 was necessary to maintain a consistent unit of measure within this document (ATSDR, 1995).
3. Date here refers to when the health-based guideline background report or original legislative initiative was issued. The sources were the respective agency documents.

Considering that only the state of Michigan has a guideline for hydrocarbon solvent mixtures among the listed agencies, guidelines in nine other State agencies (Connecticut, Florida-Pinellas, Florida-Ft. Lauderdale, Nevada, North Dakota, Oklahoma, Texas, Vermont and Virginia) were also reviewed (ATSDR, 1995; US EPA 1993). The guidelines from these states are based on similar occupational exposure limits but there are considerable variations among their air quality criteria. The recommended 8-hour average criteria vary between 3,500 $\mu g/m^3$ and 7,000 $\mu g/m^3$, the 24-hour average limits vary between 1,260 and 8,800 $\mu g/m^3$, and the annual average guidelines vary between 350 and 12,500 $\mu g/m^3$. The scientific rationales for these guidelines are not available for evaluation.

In addition to agency guidelines, occupational exposure limits were also examined. Occupational safety and health agencies recommend workplace exposure limits by considering human health effects regarding the central nervous system (dizziness, headaches), the eyes, skin, throat, and odour irritations caused by mineral spirits. The OSHA set the maximum allowable concentration of refined petroleum solvents at 2,900,000 $\mu g/m^3$ for its PEL-TWA (Permissible Exposure Level during an 8-hour workday and 40-hour work week). The ACGIH (American Conference of of Government Industrial Hygienists) set a TLV–TWA at 525,000 $\mu g/m^3$. The NIOSH set a recommended exposure level (REL-TWA time weighted average) at 350,000 $\mu g/m^3$ for an 8-hour average for refined petroleum solvents including mineral spirits, Stoddard solvent, petroleum ether, rubber solvent, Varnish Makers' and Painters' naphtha and kerosene (NIOSH, 1977a).

4.2 Evaluation of Existing Criteria

Existing air quality criteria from various agencies (Table 1) appears to focus on the health concerns of mineral spirits on the central nervous system following inhalation exposure. Despite some concerns regarding the potential carcinogenic effects of Stoddard solvent in the workplace, none of the agencies reviewed assessed mineral spirits on the basis of carcinogenicity. The evidence of carcinogenicity of Stoddard solvent in the human and animal database is currently ambiguous and any observed carcinogenic effect may be due to the presence of small amounts of aromatic carcinogenic components in the solvent mixture, e.g. benzene which is specifically regulated in Ontario.

4.2.1 Discussion Based on the Adverse Effects of Mineral Spirits

Most agencies do not have guidelines for the specific types of mineral spirits due to the unresolved issue of their compositional variability and the complexity of their mixtures in ambient air. Only a Michigan guideline refers specifically to hydrocarbon solvent mixtures for permitting purposes and does not contain any actual measurements. Michigan's 8-hour average guideline of 3500 $\mu g/m^3$ is set for a combined ambient impact for all petroleum hydrocarbons with hydrocarbon profiles similar to mineral spirits, i.e. refined petroleum hydrocarbon mixtures

excluding aromatic hydrocarbon solvent mixtures and mineral oil-based solvent mixtures (Butterfield, 1993). The guideline was derived from an occupational exposure limit, 1% of the NIOSH's REL of 350,000 $\mu g/m^3$, determined from human epidemiological, volunteers, and animal toxicological data. In addition to this, Michigan has different 24-hour or annual average guidelines for specific mineral spirits for which NOAELs or LD_{50}s were available (see Table 1). The ambient air quality guidelines from other US states did not provide sufficient information to examine the scientific basis for their criteria.

Most of the exposure to mineral spirits in ambient air occurs through inhalation. Unfortunately, due to the complex nature of mineral spirits and the lack of adequate detection methods for determining the ambient concentrations of these mixtures, the majority of toxicological studies have focussed on indoor inhalation exposures of a completely vaporized mixture. Meanwhile human exposure scenarios in ambient air are likely to result in greater exposure to the more volatile fractions (e.g. aromatics) than the less volatile fractions. Indoor inhalation studies may overemphasise the effects of the less volatile aliphatic fractions, which are associated with acute effects e.g. irritation and narcosis. However, in the absence of other data, it may be considered reasonable to extrapolate human risks from the indoor inhalation studies to ambient air situations. This extrapolation would only be fully valid assuming that all components of mineral spirits could be maintained together as the predominant mixture in ambient air, which is typically not the case.

All studies conducted on mineral spirits have been based on indoor exposure as a whole (integrative approach), where the mixture maintains its chemical integrity. Previous studies have not considered toxic components individually (dissective approach) (Mauderly, 1993). The integrative approach is favoured by the US EPA and would probably be more appropriate for ambient air. However, this approach is better suited for simple mixtures rather than for complex mixtures (Seed *et al.*, 1995). It necessitates the calculation of a hazard index, which is the summation of the hazard quotient of each compound in the mixture being equal to the current dose divided by the maximum acceptable dose for that compound.

Adverse effects on the central nervous system-mediated motor coordination are common following acute exposure to mineral spirits. Cerebral atrophy, discoordination, dementia, headaches, memory deficits, and fatigue were reported in humans suffering from chronic exposure to solvents including white spirits. This implies that the central nervous system (CNS) effects may become more severe with prolonged exposure time. Mineral spirits may also compound the effects of other chemicals that cause central nervous system depression, such as alcohol, barbiturates, and medical anaesthetics (ATSDR, 1995). Few inhalation studies have been performed in animals to describe the effects of prolonged exposure to mineral spirits.

Mineral spirits are commonly used in Ontario. Residents in the vicinity of facilities producing or using these solvents may be at risk as a result of chronic air exposure. These solvents also have

multimedia impacts. They contribute to the environmental impact of volatile organic compounds as ozone precursors. Alkylbenzenes, and the aromatics in general, are persistent in water and soil and have the potential to bioaccumulate in biota.

4.2.2 Discussion on Methods for Criteria Development

The evaluation of mineral spirits must take into consideration their significant toxicity, the difficulty in identifying their individual components in mixtures, the difficulty in monitoring specific individual mixture components, and the limited availability of documented guidelines available from other agencies and jurisdictions. Some methods for setting a guideline for a hydrocarbon mixture are discussed below.

Regulations have tended to focus on single air contaminants and not on mixtures which reflects the difficulty of accurately estimating personal exposures to multiple pollutants and assessing multiple health outcomes. To compound the difficulty of assessing the toxic effects of complex mixtures as a whole in ambient air, the complexity and components may vary as human activities influence the sources, as meteorology continuously alters the distribution and dilution of the pollutants, as components undergo chemical transformation (Samet and Speizer, 1993), and as background levels significantly interfere with the main chemicals. Even if the exact chemical contents of a particular petroleum hydrocarbon solvent were known at the point of emission, once it enters ambient air it would not be realistic to look for the mixture as its initial chemical signature.

Understanding the health effects of complex mixtures, in ambient air would require much more multi-disciplinary research. Even in indoor environments ATSDR, in conjunction with the US Department of Human and Health Services through the NTP (National Toxicology Program), have recognized that further data are needed to reduce or eliminate the uncertainties inherent to the current database on the human health assessment of Stoddard solvent (ATSDR, 1995). For example, many chronic studies on neurotoxicity in humans related to mixed solvent exposures do not measure the concentration levels of the solvents.

None of the agencies reviewed considered the risk of individual components of mineral spirits. At low doses the toxic effects of mixtures may be evaluated with the dose-additive approach. This assumes that all components dispersed in the air will induce the same toxic effect in the same organ system, through the same mechanism of action, as if they were alone. In a regulatory context only the main toxic compounds are considered therefore eliminating those at levels well below their respective thresholds. In the case of mineral spirits, the major components (alkanes and cycloalkanes) cause the mixture's primary neurological effects via a common mechanism of action, nonpolar narcosis, with potency proportionate to molecular weight. A narcosis-carbon chain length relationship has been observed and discussed for short-chain aliphatic alkanes of C_5 to C_8 (NIOSH, 1977b). It would therefore appear reasonable to evaluate the potential effects of a

mineral spirit hydrocarbon mixture as an aggregate based on total mg hydrocarbon /m^3. Another approach, referred to as the "reciprocal calculation procedure" (ECETOC, 1997), is a way to estimate occupational exposure levels (OELs) for various components of a hydrocarbon mixture according to their fraction (relative proportions in the mixture), i.e.:

$$\frac{1}{OEL_{HC\,mixture}} = \frac{f_a}{OEL_a} + \frac{f_b}{OEL_b} + \ldots + \frac{f_n}{OEL_n}$$

This appears to be a reasonable approach provided that OELs are available for the majority of hydrocarbons in the mixture and provided that their relative proportions in the mixture are known and anticipated to remain reasonably stable from batch to batch. The Health & Safety Executive of the United Kingdom employed the reciprocal calculation procedure to derive a solvent mixture OEL of 553 mg/m^3 for white spirit. This was based on a hydrocarbon composition of 52% alkanes $\geq C_7$, 27% cycloalkanes $\geq C_7$, 10% aromatics, 1% C_8 aromatics (xylenes) and 10% trimethylbenzenes (HSE, 1998). It would be possible to derive an environmental criterion for mineral spirits from this aggregate OEL, if this particular "white spirits" composition is acceptable as a surrogate for mineral spirits in general.

5.0 Responses of Stakeholders to the Information Draft

In January 1999, the Ministry posted information draft documents for eighteen chemicals, including mineral spirits, for air quality standards development under the Standards Plan (MOEE, 1996; MOE 1999). The Ministry requested input regarding: the completeness of inhalation toxicological information examined by the Ministry; the rationales of the agency guidelines which the Ministry has considered appropriate for the development of air quality standards, specifically, the rationale supporting the occupational exposure limit of NIOSH from which the air quality guidelines of the State of Michigan based; as well as technical and economic impacts that may be anticipated as a consequence of the revision of the air quality standards.

During the consultation period the Ministry received four submissions from various stakeholders regarding the draft document for mineral spirits. Comments from the vehicles manufacturing stakeholders suggested that the odour-based POI for mineral spirits be maintained at its current level until more relevant information is available for an in-depth revision, for example, the report on risk assessment of total petroleum hydrocarbons produced by the TPH Criteria Working group in the U.S.A. One automotive equipment and parts manufacturing stakeholder explained that it would be technically difficult to monitor the emissions of subfractions of mineral spirits based on the guidelines developed by the State of Michigan and therefore recommended the current POI be maintained. A rubber industry stakeholder expressed concerns over the basis of the

TLV-TWA for air quality standards derivation. The petroleum products stakeholders indicated that a full risk management process would be required if the Ministry intended to introduce a substantial decrease in the air quality standards for mineral spirits.

6.0 Responses of Stakeholders to the Rationale Document

On February 21, 2000, the Ministry posted to the Environmental Registry a document titled "Rationale for the Development of Ontario Air Quality Standards for Mineral Spirits" (MOE, 2000) and requested public comments over a period of 90 days. Five submissions were received and the concerns of stakeholders are summarized below.

Comments Specific to Mineral Spirits:

Comment: In developing the proposed limits for mineral spirits, the Ministry apparently ignored information submitted during the Information Draft stage of the standard setting process. The proposed POI limit for mineral spirits is based on odour as an end-point and this fails to recognize the widespread availability and use of de-odourized mineral spirits. The Ministry should review the full range of toxicological information on mineral spirits and examine the approach recommended by the Total Petroleum Hydrocarbon Criteria Working Group of the U.S.A. for assessing the health risk of complex mixtures of hydrocarbons. Given the technical difficulties of measuring mineral spirits in ambient air, it is not clear that the Ministry has the ability to enforce the standard it has proposed.

Response: The Ministry does not reckon that “de-odourized” mineral spirits are used on a province-wide basis in Ontario. The Ministry did not refer to the RfC recommended by the TPH Criteria working Group for air quality standards development for the following reasons: a) the TPH Criteria Working Group does not represent an agency whose main responsibility is for the protection of human health and the environment; b) the studies selected in the fraction RfC developed for surrogate fractional hydrocarbons may not be extensive; c) Ontario has air quality standards development for some of the surrogate fractional hydrocarbons already and in fact, the RfC developed by this Working Group ranged from 200 - 1,300 $\mu g/m^3$, which were more conservative than the interim POI standard of 7,800 $\mu g/m^3$.

In order to address issues regarding the use of odour versus health-based standards, the Ministry is consulting on proposed amendments to O. Reg. 346 to incorporate air standards with appropriate effects-based averaging times. The proposed new air dispersion models allow for the effects of a contaminant to be assessed using modelled exposure concentrations over the most appropriate averaging time for that contaminant (e.g. 24-hour average standard for chronic effects and short-term average standards for acute effects such as odour). This approach may assist in distinguishing between health versus odour impacts. The proposed introduction of

effects-based standards with appropriate averaging times is currently out for consultation in the discussion paper entitled: “Updating Ontario’s Air Dispersion Models”.

Comments of a General Nature:

Four submissions included general comments applicable to any of the proposed air standards. The comments are summarized below with the Ministry's response.

Comment: The proposed standards are not based on the latest scientific information.

Response: The Ministry considers the most credible science when revising existing air standards or developing new air standards. During the Information Draft stage of the air standard setting process, stakeholders are encouraged to provide any additional scientific information that they feel the Ministry should consider when developing or revising air standards. In some instances, new and credible scientific information has been published following the posting of the Rationale Document to the Environmental Registry. In these instances, the Ministry assesses the new information in detail before making a decision on the proposed air standard.

Comment: The proposed standards do not integrate socio-economic considerations.

Response: The proposed standards are set at effects-based levels. Socio-economic considerations are taken into account during the implementation phase (risk management) of the standards setting process. The Ministry is consulting with stakeholders on a risk management framework to ensure fair and equitable implementation of new air standards and integration of socio-economic considerations.

Comment: It is not clear how stakeholder input was incorporated into the decision-making process.

Response: The Ministry accepts this comment from stakeholders. We are improving our air standards documentation to better explain how stakeholder comments were considered in the decision making process. A summary of comments and responses is included in this document.

Comment: The proposed standards, the introduction of new dispersion models, and the assessment of compliance are all linked.

Response: The Ministry acknowledges that these issues are all linked and will be having joint consultation sessions with stakeholders on a risk management framework and on the introduction of new dispersion models for use in Ontario.

Comment: An appropriate phase-in period is required for both the proposed standards and the introduction of new dispersion models.

Response: The Ministry agrees that an appropriate phase-in period is important. The Ministry is consulting with stakeholders on an appropriate phase-in period for new standards and on the introduction of new dispersion models for use in Ontario.

Comment: There is concern about the ability to meet the proposed standards and that the potential costs to comply will make Ontario industries uncompetitive.

Response: The Ministry is consulting with stakeholders to address these risk management issues. A risk management framework will help companies determine their options to achieve compliance.

Comment: The Ministry of the Environment is adopting exposure guidelines used in other jurisdictions as regulatory limits in Ontario.

Response: The Ministry reviews the science supporting the exposure guidelines of other jurisdictions. If Ministry experts concur with the scientific assessment of other jurisdictions, the published exposure guideline is used as a basis for proposing a regulatory limit in Ontario.

Comment: The use of 30 minute screening limits (i.e. 30 minute Point of Impingement) may be an unrealistic estimate of causing an adverse effect.

Response: Use of the proposed new dispersion models would allow for a more representative assessment of environmental and health impacts by using the most appropriate averaging time for exposure. The effects of a contaminant could then be assessed using modelled exposure concentrations over the most appropriate averaging time for that contaminant. For example, the effects-based averaging time for health-based air standards is 24 hours (or daily) exposure. These concepts are currently out for consultation in the Discussion Paper entitled: “Updating Ontario’s Air Dispersion Models”.

Comment: The proposed use of US EPA Reference Concentrations (RfC) as 24-hour criteria yields standards 5 times more stringent than necessary.

Response: The Reference Concentration is defined by the US EPA as "...an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious non-cancer effects during a lifetime". The RfC is calculated on the basis of a daily exposure over a 70 year lifetime. Jurisdictions apply Reference Concentrations in a manner consistent with their policies and regulations. Ontario considers the 24-hour AAQC a daily limit

for long-term exposures. This approach is also used by some other jurisdictions in North America.

Comment: The use of a risk level of one-in-one million is a policy decision which needs to be discussed in the broader context of managing environmental health risks.

Response: For carcinogens, the Ministry proposals are within the range of risk levels recommended by the US EPA. The one-in-one million risk level is also used as the 'de minimus' limit in many jurisdictions (i.e. a level below which no action needs to be taken). The discussion paper entitled: "Proposed Risk Management Framework for the Air Standard Setting Process in Ontario" outlines options for those who cannot attain the one-in-one million risk level for any new proposed effects-based air standards.

Comment: Regulatory standards in O. Reg. 346 should not be established on the basis of odour impacts but should be used as screening tools only.

Response: Consistent with the intent of Section 14 of the Environmental Protection Act (i.e., prohibition of causing an adverse effect, including nuisance impacts such as odour) and Section 6 of O. Reg. 346, the Ministry believes that it is reasonable to establish regulatory standards on the basis of odour impacts.

Summary: An Ambient air quality criterion (AAQC) has been set for mineral spirits at 2,600 µg/m^3(micrograms per cubic metre of air): 24-hour average based on health effects. The Ministry has set an interim POI standard of 7,800 µg/m^3, based on health, in anticipation of implementation issues that arise by lowering the final effects-based standard and proposing to adopt the new models. The Ministry is currently consulting with stakeholders on the introduction of new dispersion models and a proposed risk management framework that will, among other things, propose an appropriate timeframe for complying with the new proposed final effects-based air quality standard of 3,000 µg/m^3, based on odour.

7.0 Considerations in the Development of Air Quality Standards for Mineral spirits

For the MOE air quality standards, mineral spirits are represented by the CAS Registry number for Stoddard solvent (CAS # 8052-41-3).

The odour detection thresholds for Stoddard solvent have been reported to be in the range of 500 to 5,000 µg/m^3, whereas for mineral spirits they are in the range of 2000 to 5250 µg/m^3. These values are at least one order of magnitude lower than the current POI. The aesthetic effect (odour) of mineral spirits is a critical effect to be considered in the development of air quality standards for Ontario.

The toxic effects of mineral spirits appear to be predominated by the adverse neurological effects of their major components such as alkanes and cycloalkanes. Brief exposure to levels above 140,000 µg/m^3 may induce irritation of the eyes. Exposure to higher concentrations may result in adverse effects ranging from ocular and nasal irritations to headache, dizziness, nausea, narcosis and discoordination. Loss of appetite, aplastic anaemia, liver and kidney damage have also been reported. In light of the adverse neurological effects of mineral spirits, the NIOSH has established 8-hour TWA value (350,000 µg/m^3) for refined petroleum solvents, including mineral spirits and Stoddard solvent, as well as for aliphatic alkanes (C_5 - C_8). Most jurisdictions have used occupational exposure levels to derive their guidelines for mineral spirits or related hydrocarbon mixtures.

8.0 Decision

Of the criteria reviewed from other agencies, the Ministry has evaluated and agreed with the State of Michigan and accepted the rationale supporting the ITSL of this agency. The ITSL considers the scientific studies which support the development of the occupational exposure limit of 350,000 µg/m^3 from the National Institute for Occupational Safety & Health. After reviewing additional toxicological information, the Ministry has decided to derive air quality standards for mineral spirits based on the rationale for this occupational exposure limit. The TLV-TWA of 350,000 µg/m^3 is divided by a factor of 1.5 to convert from an 8-hour work day exposure to a 24-hour equivalent averaging time (MOE, 1987). A total uncertainty factor of 90 is applied which includes 3 for the insufficient database for mineral spirits, 3 for the exposure limit which is based on a mixture of hydrocarbons including alkanes, in which the neuropathological *n*-hexane may be a component and a factor 10 for protecting the sensitive individuals. Applying the exposure time conversion factor and the uncertainty factors to the Threshold Limit Value - Time-weight Average of 350,000 µg/m^3 results in a 24-hour AAQC of 2,600 µg/m^3. In addition, the Ministry has also considered the odour effect of mineral spirits in deriving its air quality standards. The odour thresholds for Stoddard solvent and mineral spirits range from 500 to 5,250 µg/m^3. In the absence of a geometric mean for odour thresholds, the arithmetic mean of values at the two ends of the range is used to derive a POI of 3,000 µg/m^3, based on odour.

In summary, based on the information reviewed from leading agencies, the assessment of toxicological information, the odour nuisance of mineral spirits, and the stakeholder comments, the Ministry has determined the following Ambient Air Quality Criterion and interim Point Of Impingement standard for mineral spirits:

- **2,600 µg/m^3 (micrograms per cubic metre of air; 24-hour average) based on the adverse health effects;**

- **7,800 µg/m^3 (half-hour average interim POI standard) based on the adverse health effects.**

The health-based interim POI standard of 7,800 µg/m^3 (half-hour average) has been determined for mineral spirits from the proposed range of 3,000 µg/m^3 to 30,000 µg/m^3. The Ministry will initiate consultation with stakeholders to develop an implementation plan to achieve the final odour-based POI of 3,000 µg/m^3, pending the outcome of all consultation on a risk management framework, the introduction of new air dispersion models in Ontario, and proposed amendments to O. Reg. 346 to incorporate effects-based air standards with appropriate averaging times.

The interim POI standard will take effect 6 months from the date of this Environmental Registry decision posting to provide some implementation flexibility in respect to the stakeholder comments and our current limited knowledge of emitters.

The Ministry is currently undergoing stakeholder consultation in the discussion paper "A Proposed Risk Management Framework for the Air Standard Setting Process in Ontario". The risk management framework addresses implementation timeframes for adopting final effects-based air standards (POI and AAQCs) as well as technology and economic issues linked to the introduction of new or revised air quality standards and the introduction of new dispersion models into Ontario's regulatory framework. Consultation is also underway in the discussion paper entitled: "Updating Ontario's Air Dispersion Models".

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10.0 Appendix: Agency-Specific Reviews of Air Quality Guidelines

10.1 Agency-Specific Summary: Federal Government of the United States

1. *Name of Chemical:* Mineral spirits

2. *Agency: US Environmental Protection Agency*

3. *Guideline Value(s):*
There is no reference in the US Environmental Protection Agency (EPA) database IRIS (Integrated Risk Information System).

4. *Application:*
IRIS contains health risk assessment information on over 300 chemicals. IRIS supports regulatory actions on a given compound but does not constitute a standard or guideline by itself. Since Stoddard solvent does not appear on the list of IRIS compounds, there is no application for Stoddard solvent. However, the DOT (Department of Transportation, Code of Federal Regulations, puts Stoddard solvent among the list of hazardous materials of 1989.

5. *Documentation Available:*
US EPA, 1995. Integrated Risk Information System (IRIS) Database. US Environmental Protection Agency, Washington, D.C.

6. *Peer Review Process and Public Consultation:*
In its assessment, US EPA makes use of peer-reviewed scientific research data, analyses, and evaluations from various sources, including a variety of public and government agencies from around the world and the published scientific literature. Both the general assessment methodologies and the chemical-specific information found in IRIS undergo extensive scientific and policy reviews, both within the EPA and within other science-based US regulatory agencies. Information is put on IRIS after results of the public review and comments on draft documents/information have been addressed. The National Toxicology Program on which IRIS bases its information, in conjunction with ATSDR (1995) has identified the need for further information on Stoddard solvent.

7. *Status of Guideline:*
No guideline. However, mineral spirits contain hydrocarbons (volatile organic compounds) which are regulated under the Clean Air Act guidelines for the reduction of VOC emissions from solvents (Clean Air Act 1990).

8. *Key Risk Assessment Considerations:*
No risk assessment considerations available.

9. *Key Risk Management Considerations:*
None, since no guidelines for ambient air exist.

10. *Multimedia Considerations of Guidelines:*
None are reported.

11. *Other Relevant Factors:*
None.

10.2 Agency-Specific Summary: State of California

1. *Name of Chemical:* Mineral spirits

2. *Agency:* State of California (Office of Environmental Health Hazard)

3. *Guideline Value(s):*
There is no reference in CAPCOA (1996).

4. *Application:*
?The intent of the Committee in developing the guideline was to provide risk assessment procedures for use in the Air Toxics ‹Hot Spots' program." (CAPCOA, 1993). This program is based on a California State Law, the Air Toxics ‹Hot Spots' Information and Assessment Act of 1987 (Health and Safety Code Section 44360 *et Seq*.). The act specifies how local Air Pollution Control Districts determine which facilities in the area will prepare a health risk assessment, how such health risk assessments should be prepared, and how the results have to be prioritized. These Guidelines were prepared to provide consistent risk assessment methods and report presentation to: 1) compare one facility against another, 2) expedite the review of risk assessments by reviewing agencies, and 3) minimize revisions and resubmission of risk assessments. The various health-based exposure levels developed for and employed in this program should not be used outside the framework of the program. Therefore, the State of California does not consider them to be general, independent, legally enforceable air quality guidelines or limit values at this time.

5. *Documentation Available:*
CAPCOA, 1993. CAPCOA Air Toxics "Hot Spots" Program. Revised 1992 Risk Assessment Guidelines. Toxics Committee of the California Air Pollution Control Officers Association (CAPCOA).

Key reference(s):
CAPCOA, 1996. A Review of the California Environmental Protection Agency's Risk Assessment Practices, Policies, and Guidelines. Report of the Risk Assessment Advisory Committee, 179 pp. + Appendices.

6. *Peer Review Process and Public Consultation:*
Cancer potency slope factors, and acute and chronic reference levels were prepared by the California Office of Environmental Health Hazard Assessment (OEHHA) using peer-reviewed scientific data for hundreds of compounds other than mineral spirits but comprising some components of mineral spirits. Both the exposure and health assessments have undergone public review and comment prior to finalization. Under the CAPCOA risk assessment process, each assessment is site specific and public notice to all exposed individuals is required when the

assessment concludes that a significant health risk is associated with emissions from a facility. Public input is obtained in identifying and ranking areas and facilities for risk assessment screening. Further input is expected as the process moves forward.

7. *Status of Guideline:*
No information.

8. *Key Risk Assessment Considerations:*
CAPCOA "Hot Spots" information does not include information for mineral spirits in ambient air. However, for some of its components, there are existing values which were developed in order to protect against perceptible occurrence of observable effects among an exposed human population for one-hour.

9. *Key Risk Management Considerations:*
The exposure guidelines were prepared for both non-cancer and cancer-based endpoints. The cancer-based value is used in a screening risk assessment to determine the maximum offsite cancer risk for exposed human population. The process is not readily comparable to the air quality guideline approach to non carcinogens. The non-cancer guidelines are based on the most sensitive adverse health effect reported in the scientific literature and are designed to protect the most sensitive individuals in the population.

The State of California allows local options to address the possible economic impacts of emission control of volatile organic compounds, which are mineral spirit components. It appears that the options are under local control and are based on local risk, socioeconomic analyses and feedback from public workshops and hearings. The enforcement mechanism is via operating permits. Thus, the process is primarily directed towards site-specific evaluations and development of further regulatory tools rather than towards enforceable levels in themselves.

10. *Multimedia Considerations of Guidelines:*
No information.

11. *Other Relevant Factors:*
No information.

10.3 Agency-Specific Summary: State of Massachusetts

1. *Name of Chemical:* Mineral spirits

2. *Agency:* Commonwealth of Massachusetts, Department of Environmental Protection (DEP)

3. *Guideline Value(s):*
There are no specified Allowable Ambient Limits (AAL) or Threshold Exposure Limits (TEL) for mineral spirits by the DEP.

4. *Application:*
The guidelines are to be used mostly to assist in awarding permits, to verify compliance and enforcement and to be used as reference for regulatory actions. The guidelines consider the protection of public health and welfare irrespective of technological, economic and enforcement limitations. The selected chemicals were chosen as a representative sample in order to test and develop the proposed evaluation system. Health assessment of new chemicals is made on a case-by-case basis and using a standardized approach.

5. *Documentation Available:*
Commonwealth of Massachusetts, 1990. The Chemical Health Effects Assessment Methodology and the Method to Derive Allowable Ambient Limits, Volumes I and II. Commonwealth of Massachusetts, Department of Environmental Protection, Boston, MA.

Key Reference(s):
Massachusetts Department of Environmental Protection (DEP), 1995. Updated list of 24-hour average Threshold Effects Exposure Limit (TEL) values and annual average Allowable Ambient Limit (AAL) values.

Office of Research and Standards (ORS), 1994. 1) Revisions to Massachusetts allowable ambient air limits for compounds with inhalation reference concentrations, 2) publication of updated list of Massachusetts AALs and TELs, 3) incorporation of inhalation reference concentrations into the CHEM/AAL process and 4) Decisions made by ORS regarding some discrepancies observed in the RfC methodology. Letter from the ORS to the DEP, October 1994, 10 pp.

6. *Peer Review Process and Public Consultation:*
The guidelines are not systematically peer-reviewed but are updated and modified by the DEP at a rate of 25 to 40 AALs per year and when revision is warranted. However, public consultation is solicited in public meetings and peer-reviews are organised.

7. *Status of Guideline:*
Mineral spirits is not on the list of chemicals to be evaluated.

8. *Key Risk Assessment Considerations:*
The Massachusetts system uses hazard assessment only and does not use the number of exposed individuals as a criterion for regulatory action except for prioritizing regulatory activities.

9. *Key Risk Management Considerations:*
The Department of Environmental protection believes that the evaluation system of AALS can minimize risks effectively while maintaining a practical regulatory approach to air toxics.

10. *Multimedia Considerations of Guidelines:*
The Massachusetts guidelines cover only ambient air but include a contribution factor of 20% in the establishment of Threshold Effect Exposure Limits (TEL). This factor assumes that 20% of the exposure is due to air for any given compound.

11. *Other Relevant Factors:*
None.

10.4 Agency-Specific Summary: State of Michigan

1. *Name of Chemical:* Mineral spirits. Specified as petroleum hydrocarbon materials: mineral spirits, heavy naphtha, hydrotreated heavy naphtha, hydrotreated middle distillate, hydrodesulfurized middle distillate, sweetened middle distillate, hydrotreated heavy naphthenic distillate, hydrotreated light distillate, naphtha heavy straight-run, naptha, solvent naphtha light aliphatic, solvent naphtha medium aliphatic, stoddard solvent, VM & P naphtha.

2. *Agency:* Michigan State, Department of Environmental Quality (current) and Department of Natural Resources (previously)

3. *Guideline Value(s):*
The ambient impact of all petroleum hydrocarbon materials in this class must be below the initial threshold screening level (ITSL) of 3,500 $\mu g/m^3$ developed by the Air Quality Division (AQD) of the Michigan Department of Environmental Quality, based on an 8 hour averaging time. This guideline originates from the NIOSH REL of 350,000 $\mu g/m^3$ multiplied by a safety factor of 1%.

In addition, there are annual average ITSLs for several specific petroleum hydrocarbon solvent mixtures for which mixture-specific toxicological data were available, i.e.: 2 $\mu g/m^3$ ITSL (annual average) for hydrotreated middle distillate, hydro-desulphurized middle distillate, sweetened middle distillate; 16 $\mu g/m^3$ ITSL (annual average) for hydrotreated heavy naphthenic distillate; and 24 $\mu g/m^3$ ITSL (annual average) for hydrotreated light distillate.

4. *Application:*
The guidelines are developed by the Toxics Unit of the Michigan Department of Environmental Quality for implementation of the Michigan's air toxic rules no. 230 and 232. The rules apply to new and modified processes for which an application for a permit is required and which emits toxic air contaminants.

5. *Documentation Available:*
Michigan Department of Environmental Quality, 1995/1997. Air Toxics Screening levels. Air Quality Division. 6 pp. + Appendices.

Key Reference(s):
Carpenter, C.P., et al., 1976. Petroleum hydrocarbon toxicity studies, XI. Animal and human response to vapors of deodorized kerosine. Toxicol. Appl. Pharmacol. **36**:433-456.

IRDC, 1986. Four week subchronic inhalation toxicity study in rats: API 81-07 hydrodesulfurized kerosine, API 81-09 hydrodesulfurized middle distillate, and API 81-10 hydrodesulfurized middle distillate. Study conducted for American Petroleum Institute (API), API Report # 33-32724 (unpublished).

NIOSH, 1992. NIOSH Recommendations for Occupational Safety and Health: Compendium of Policy Documents and Statements. Cincinnati, OH: National Institute for Occupational Safety and Health. DHHS, NIOSH publication no. 92-100.

Vernot, E.H., Drew, R.T., Kane, M.L., 1990. Acute toxicological evaluation of hydrotreated naphthenic distillate. J. Amer. Coll. Toxicol., **1**(2):133-134.

6. *Peer Review Process and Public Consultation:*
The guidelines are reviewed by the Toxics Unit upon requests for permits for certain compounds and information is based on latest review of the literature.

7. *Status of Guideline:*
Current and updated information according to Air Toxics Unit.

8. *Key Risk Assessment Considerations:*
The 8-hour ITSL value for aliphatic petroleum hydrocarbon solvents was developed based on the occupational limits specified by NIOSH and evaluation by the Air Quality Division.

9. *Key Risk Management Considerations:*
Risk assessment considers that for each source, the best available control technology should be used.

10. *Multimedia Considerations of Guidelines:*
No information.

11. *Other Relevant Factors:*
None.

10.5 Agency-Specific Summary: State of New Jersey

1. *Name of Chemical:* Mineral spirits

2. *Agency:* New Jersey Department of Environmental Protection

3. *Guideline Value(s):*
There is no recommended level in the New Jersey information document.

4. *Application:*
Not applicable.

5. *Documentation Available:*
New Jersey Department of Environmental Protection (NJDEP), 1994. Guidance on Preparing a Risk Assessment for Air Contaminant Emissions, Technical manual 1003. Air Quality Permitting Program, Bureau of Air Quality Evaluation, 20 pp. + 7 Appendices.

Key Reference(s):
US EPA, 1993. Integrated Risk Information System (IRIS) Database. US ENVIRONMENTAL Protection Agency, Washington, DC.

6. *Peer Review Process and Public Consultation:*
The information is provided by New Jersey Department of Environmental Protection and Federal Standards and new evaluations are conducted by the risk management committee that evaluates the application ro determine wether the sources's permit should be approved.

7. *Status of Guideline:*
No guideline.

8. *Key Risk Assessment Considerations:*
Not applicable.

9. *Key Risk Management Considerations:*
Not applicable.

10. *Multimedia Considerations of Guidelines:*
Not applicable.

11. *Other Relevant Factors:*
Not applicable.

10.6 Agency-Specific Summary: State of New York

1. *Name of Chemical:* Mineral spirits

2. *Agency:* New York State Department of Environmental Conservation

3. *Guideline Value(s):*
Mineral spirits are not currently specifically addressed under the guidelines from the New York State Air Guide (AG-1). However, New York State is considering adopting a Short-term Guideline Concentration (SGC; 1-h average air concentration) of 83,000 $\mu g/m^3$ and an annual Guideline Concentration (AGC) of 830 $\mu g/m^3$ (de Santis, 1997) . The NIOSH value of 350,000 $\mu g/m^3$ is divided by 4.2 to obtain the AGC. The factor of 4.2 converts 40 hour work week to a continuous exposure. The general population is then no more exposed than workers.
Under section iv.A.2.c.1., for contaminants without numerical guidance, the contaminant must be limited to 0.1 $\mu g/m^3$ for moderate toxicity compounds and 1.0 $\mu g/m^3$ for low toxicity compounds. Stoddard solvent is a mixture and each component may have different effects. It cannot be classified directly in either of these categories, but is not a high toxicity compound because it is not listed as a carcinogen.

4. *Application:*
"... The guidelines ... are primarily intended for use in conjunction with the permitting authority and regulatory concerns found in 6NYCRR Parts 200, 201, 212, 257." (NY DEC, 1991, p. 1). These guidelines are not established as ambient air quality standards but they are intended to protect the general public from adverse effects that may be induced by exposure to ambient air contaminants. These regulations refer specifically to construction and operation (Certificate to Operate) permits for any sources of air contamination. The guidelines are used to aid in the regulatory decision-making process. This process includes the classification of chemicals into groups of high, moderate and low toxicity. The regulatory screening process considers the toxicity classification and the emission rate potential from a facility. An air emission dispersion model is also specified in the process to guide regulators in their assessment of chemical emissions from sources of interest. Both long-term and short-term effects are considered.

5. *Documentation Available:*
De Santis, S., 1997. Personal communication. New York State Department of Environmental Conservation (DEC)

New York State Department of Environmental Conservation (DEC), 1991. New York Air Guideline-1. Guidelines for the Control of Toxic Ambient Air Contaminants. Draft. New York State Department of Environmental Conservation., Albany, New York NY, 20 pp. + Appendices.

Key Reference(s):
None.

6. *Peer Review Process and Public Consultation:*
The guidelines do not constitute a standard and are not peer-reviewed. The guidelines are updated by the NY Department of Environmental Conservation as new toxicological data are available and most guidelines are also updated based on changes in the occupational values. New chemicals are evaluated by the NY DEC on demand by the public.

7. *Status of Guideline:*
None yet. Annual and hourly guidelines will likely be set in April-May 1997.

8. *Key Risk Assessment Considerations:*
Chemical compounds are evaluated on whether they are of high, low, or moderate toxicity or high toxicity (carcinogens). But no risk assessment considerations for mineral spirits.

9. *Key Risk Management Considerations:*
Risk management is performed by monitoring by the source owner or his authorized agent and during selected sampling by DEC staff. Impact screening analyses used in the permitting process include a guide and a computer model described in the NY State guide.

10. *Multimedia Considerations of Guidelines:*
The NY guidelines cover only ambient air.

11. *Other Relevant Factors:*
Most of the values are based on the occupational exposure limits existing for a given compound.

10.7 Agency-Specific Summary: World Health Organization (WHO)

1. *Name of Chemical:* Mineral spirits.

2. *Agency:* World Health Organisation.

3. *Guideline Value(s):*
No guideline.

4. *Application:*
No guideline applicable.

5. *Documentation Available:*
WHO, 1987. Air Quality Guidelines for Europe. WHO Regional Publications, European Series No. 23. World Health Organisation, Regional Office for Europe, Copenhagen, Denmark, 426 pp.

Key Reference(s):
WHO/Nordic Council of Ministers, 1985. Environmental Health Series No. 5: Chronic effects of organic solvents on the central nervous system and diagnostic criteria. WHO Regional Office for Europe, Copenhagen, Denmark, 274 pp.

6. *Peer Review Process and Public Consultation:*
None.

7. *Status of Guideline:*
No guideline.

8. *Key Risk Assessment Considerations:*
No risk assessment considerations, however, there has been some environmental criteria developed for the exposure to multiple organic solvents including white spirits (WHO, 1985).

9. *Key Risk Management Considerations:*
None.

10. *Multimedia Considerations of Guidelines:*
No information.

11. *Other Relevant Factors:*
No information.

10.8 Agency-Specific Summary: The Netherlands

1. *Name of Chemical:* Mineral spirits

2. *Agency:* Netherlands Ministry of Housing, Spatial Planning and the Environment

3. *Guideline Value(s):*
Netherlands references comprise emission standards (1992) and environmental quality objectives (1994) or guidelines. The emission standard (1992) for mineral spirits falls under the emission standards for organic substances. Because mineral spirits are petroleum solvents containing hydrocarbons, they can be classified either under organic substances of class gO.2 or gO.3 for emissions in gaseous or vaporous form. For class gO.2, emissions standard is 100,000 $\mu g/m^3$ for emissions with a mass flow of 2.0 kilograms per hour or more. For class gO.3, emissions standard is 150,000 $\mu g/m^3$ for emissions with a mass flow of 3.0 kilograms per hour or more.

4. *Application:*
None.

5. *Documentation Available:*
NeR Staff Office, 1992. Netherlands Emission Regulations - Air. Netherlands Emission Regulation Staff Office, Bilthoven, The Netherlands. 81 p. + Appendices.

The Netherlands MHSPE, 1994. Environmental Quality Objectives in the Netherlands. A review of environmental quality objectives and their policy framework in the Netherlands. Risk Assessment and Environmental Quality Division, Ministry of Housing, Spatial Planning and the Environment (MHSPE), The Hague, The Netherlands. 465 pp.

Key Reference(s):
None.

6. *Peer Review Process and Public Consultation:*
None.

7. *Status of Guideline:*
No information.

8. *Key Risk Assessment Considerations:*
None.

9. *Key Risk Management Considerations:*
Although it is said to largely occur in the case of probable carcinogenic substance, MAC (Maximum Acceptable Concentration at the workplace) values are not solely based on health consideration. In fact, national limit values include consideration of environmental, economic and social interests as well as technical options. Specific information on such details was not presented in the available documentation.

10. *Multimedia Considerations of Guidelines:*
No considerations for mineral spirits. However, multimedia exposure was not considered in the development of the current air limits for hydrocarbons. Inter-compartmental criteria which address this problem are being developed. A specific schedule for revisions based on this process has not been announced.

11. *Other Relevant Factors:*
No information.

10.9 Agency-Specific Summary: Swedish Institute of Environmental Medicine

1. *Name of Chemical:* Mineral spirits

2. *Agency:*Swedish Institute of Environmental Medicine

3. *Guideline Value(s):*
None. According to Dr. K. Victorin (1997), no official Swedish air quality guideline was promulgated or will be in a near future for mineral spirits/Stoddard solvent.

4. *Application:*
Not applicable.

5. *Documentation Available:*
Victorin, K., 1993. Health effects of urban air pollutants: guideline values and conditions in Sweden. Chemosphere 27: 1691-1706.

Key Reference(s):
Victorin, K., 1997. Personal communication.

6. *Peer Review Process and Public Consultation:*
No information.

7. *Status of Guideline:*
No official status but has been used as ad hoc basis by Swedish Regulators along with WHO guidelines.

8. *Key Risk Assessment Considerations:*
Not applicable.

9. *Key Risk Management Considerations:*
Not applicable.

10. *Multimedia Considerations of Guidelines:*
Not applicable.

11. Other Relevant Factors:
Not applicable.

10.10 Agency-Specific Summary: Federal of Government of Canada (CEPA)

1. *Name of Chemical:* Mineral spirits

2. *Agency:* Environment Canada and Health Canada

3. *Guideline Value(s):*
A revision is underway (PSL 2). However, mineral spirits is not on the list of substances under examination.

4. *Application:*
None.

5. *Documentation Available:*
Canadian Environmental Protection Act (CEPA), 1993-94. CEPA Priority Substance List (PSL 1). Environment and Health Canada.

Key Reference(s):
None.

6. *Peer Review Process and Public Consultation:*
No information.

7. *Status of Guideline:*
No information.

8. *Key Risk Assessment Considerations:*
No information.

9. *Key Risk Management Considerations:*
No Information.

10. *Multimedia Considerations of Guidelines:*
No Information.

11. *Other Relevant Factors:*
No information.

11.0 Acronyms, Abbreviations and Definitions

AAL *Allowable Ambient Level* (Massachusetts)

AAQC *Ambient Air Quality Criteria* - used by the Ontario Ministry of the Environment to define the potential for causing an adverse effect

ACGIH *American Conference of Governmental Industrial Hygienists* - a non-governmental organization which establishes occupational safety exposure limits for workers

AGC *Annual guideline Concentration* (New York State)

ATSDR *Agency for Toxic Substances and Disease Registry* - an agency of the US Department of Health & Human Services

CAPCOA *California Air Pollution Control Officers Association*

CAS *Chemical Abstracts Service* - ascribes a unique, identification (registry) number to each chemical to help clarify multiple listings for the same chemical structure

CEPA *Canadian Environmental Protection Act*

GLC *Ground Level Concentration* - the concentration of contaminant predicted by dispersion modelling

HEAST *Health Effects Assessment Summary Tables* - prepared by US EPA's Office of Health and Environmental Assessment. HEAST contains risk assessment information on chemicals that have undergone reviews, although generally not as extensive as the reviews conduced under IRIS

HEC *Human Equivalent Concentration*

IARC *International Agency for Research on Cancer*

IRIS *Integrated Risk Information System* - a database published by the US EPA containing risk assessment information on a wide range of chemicals

IRSL *Initial Risk Screening Level* - a limit corresponding to a one in a million lifetime risk of cancer used by Michigan for screening new sources of emissions

ITSL *Interim Threshold Screening Level* - similar to the IRSL, however, derived from the RfC for non-carcinogens

LC_{50} The concentration of a substance in the medium (eg., air, water, soil) to which a test species is exposed, that will kill 50% of the population of that given species

LD_{50} The dose of a substance given to a test species, that will kill 50% of the population of that given species

LOAEL *Lowest-Observed-Adverse-Effect Level*

LOEL *Lowest-Observed-Effect Level*

MAC *Maximum Acceptable Concentration*

MACT *Maximum Achievable Control Technology*

µg a microgram, one millionth of a gram

mg a milligram, one thousandth of a gram

MRL *Minimal Risk Level* - a term used by ATSDR, which defines a daily exposure [either from an inhalation or oral route] not likely to induce adverse non-carcinogenic effects within a given time period, ie., acute, intermediate, or chronic

MOE *Ontario Ministry of the Environment*; between 1993 and 1997 known as **MOEE** or Ontario Ministry of Environment and Energy

ng a nanogram, one billionth of a gram

NIEHS *National Institute of Environmental Health Sciences* (USA)

NIOSH *National Institute for Occupational Safety and Health* (an agency of the US Department of Health & Human Services)

NOAEL *No-Observed-Adverse-Effect Level*

NOEL *No-Observed-Effect Level*

NPRI *National Pollutant Release Inventory*

NTP *National Toxicology Program* (USA)

OEHHA *Office of Environmental Health Hazard Assessment* (California EPA)

OEL *Occupational Exposure Level*

OSHA *Occupational Safety and Health Administration* - a branch of the US Dept of Labour

PEL *Permissible Exposure Limit* (OSHA air standard)

POI *Point of Impingement* - used in conjunction with dispersion modelling to define the area in which the maximum ground level concentration (GLC) of a contaminant is predicted to occur

ppb parts per billion

ppm parts per million

REL **Either**'*Reference Exposure Level*' as used by the California EPA which defines the concentration at or below which no adverse health effects are expected in the general population **or** '*Recommended Exposure Limit***'** used by both NIOSH and ATSDR

RfC *Reference Concentration* - an estimate of a daily inhalation exposure not likely to induce deleterious non-cancer health effects during a lifetime

RfD *Reference Dose* - an estimate of a daily exposure dose not likely to induce adverse health effects during a lifetime

RTECS *Registry of Toxic Effects of Chemical Substances* - database maintained by NIOSH

SGC *Short-term Guideline Concentration* (New York State)

STEL *Short-term Exposure Limit*

TC *Tolerable Concentration* - used by Health Canada to define the airborne concentration to which a person can be exposed for a lifetime without deleterious effects (for non-carcinogens)

TC_{05} *Tumorigenic concentration* - the concentration of a contaminant in air generally associated with a 5% increase in incidence or mortality due to tumours

TD_{05} *Tumorigenic dose* - the total intake of a contaminant generally associated with a 5% increase in incidence or mortality due to tumours

TLV *Threshold Limit Value* - an exposure concentration that should not induce an adverse effect in a work environment

TWA *Time-Weighted-Average* - allowable exposure averaged over an 8-hour workday or 40-hour work week

US EPA *United States Environmental Protection Agency*

WHO *World Health Organization*