

#### IV. ENVIRONMENTAL DATA

##### Environmental Concentrations

In 1940, Case and Castrop [17] measured the oxides of nitrogen (reported as nitrogen dioxide) at various distances from welding arcs under different conditions of ventilation. Thirteen samples were collected in a large unventilated room. Measurements were made 3 inches from the electric arc. Results indicated concentrations of nitrogen dioxide ranging from 30 to 70 ppm. However, they reported finding no nitrogen dioxide at a distance of 18 inches from the arc. Samples of a variety of mechanically ventilated electric welding operations involved in automobile manufacturing were also collected. Most of these showed 1 ppm or less of nitrogen dioxide. Two samples taken 12 inches from the arc showed 4 ppm, and one, 18 inches from the arc, showed 11 ppm. Five samples collected between 2 and 6 inches from an acetylene welding flame produced nitrogen dioxide concentrations ranging from 6 to 40 ppm. Only traces were found 18 inches from the flame. In the opinion of the authors, none of the methods then available for estimating nitrogen dioxide in air were entirely satisfactory. They used the alpha-naphthylamine and sulfanilic acid method (see Environmental Sampling and Analytical Methods in this chapter).

Adley, in 1946, [11] reported on nitrogen oxides produced by oxyacetylene torch shrinking operations in ship construction. Nitrogen oxides at an average of 196 ppm with a maximum of 480 ppm were obtained from eight samples collected over a 23-minute period in a 600-cu ft unventilated compartment. The torch had a rated capacity of 125 cu ft of acetylene/hour. Further tests showed that the rate of nitrogen oxides

production was directly related to the rate of acetylene consumption. An average of 38 ppm of nitrogen oxides was produced in a 700-cu ft compartment with an acetylene consumption of 15.9 cu ft/hour. There was a consistent increase up to 352 ppm of nitrogen oxides when acetylene consumption reached 175 cu ft/hour. Adley also made measurements in large, ventilated compartments with areas ranging from 7,200 to 10,000 cu ft. Concentrations found in 28 samples varied from 4 to 89 ppm. The phenoldisulfonic acid method was used for sample analysis. [169] Details of Adley's findings are given in Tables XIII-12 and XIII-13.

Dreessen et al [13] reported results of over 2,000 samples collected at a variety of welding operations in seven shipyards. Approximately 43% of the samples exceeded 4 ppm. Analysis was by the phenoldisulfonic acid method. Further data are presented in Table XIII-14.

Mangold and Beckett in 1971 [18] presented data on samples collected at silver brazing operations. Measurements were made following the hospitalization of 2 silver brazers from a naval shipyard. Exposure to cadmium oxide fumes was suspected as the principal cause of their acute pulmonary distress; however, tests revealed that no cadmium-bearing solders were used. Samples of nitrogen dioxide indicated that concentrations quickly reached a level of 50 ppm and increased to 122 ppm in 30 minutes.

Surveys on plasma torch operations by various investigators [12, 21,170,171] reported nitrogen oxides concentrations from "not detected" to more than 50 ppm.

Kosmider et al, [71] in a study of men from a chemical works, reported that these workers were exposed daily at nitrogen oxides concentrations fluctuating between 0.4 and 2.7 ppm as nitrogen dioxide over 6-

8 hours. No details were given as to the nature of the operations or to the methods employed in determining the air levels.

#### Formation of N-nitroso Compounds

The oxides of nitrogen have the intrinsic chemical property of reacting with primary and secondary amines which are present in body tissues, [172] foods, [173] tobacco, [173] water, [174] and in workplace air of some occupational environments [175] to form N-nitroso compounds. The nitrosation of primary amines produces unstable compounds which can decompose to form diazonium salt derivatives while the nitrosation of secondary amines produces secondary nitrosamines. [176] The metabolic dealkylation of secondary nitrosamines can lead to the formation of unstable diazonium salt derivatives. [176] Alkylated derivatives of proteins, nucleic acids, and other cellular constituents have been isolated following the in vivo treatment of mammals with secondary nitrosamines or the in vitro treatment with diazonium salt derivatives. [176] Subcutaneous, intravenous, intraperitoneal, percutaneous, and oral administration of secondary nitrosamines in experimental animals has resulted in the formation of tumors in several different organs. [176] The rate of tumor formation in rats following administration of secondary dialkyl nitrosamines has been extensively investigated by Druckrey [177] who reported a linear-logarithmic relationship between the daily dose and the induction time for several dialkyl nitrosamines.

The reaction between secondary amines and the oxides of nitrogen is catalyzed under acidic conditions [178] as may be found in human gastric fluids or in the presence of acidic atmospheric contaminants. Although the

optimum pH for this reaction lies in the range 2.0 to 3.4, [178] formation of nitroso compounds can occur under neutral conditions. [174] Data on the in vivo formation of nitrosamines have been extensively reviewed by Mirvish [178] in 1975. For the most part, these studies have been limited to the investigation of intragastric formation of nitrosamines in animals who ingest oxides of nitrogen and secondary amines or in animals given the two compounds by gavage. The formation of nitrosamines is dependent upon a number of factors including the structure of amine, pH, order of administration of the two compounds, absorption of nitrite in the stomach, dose, and the presence of nitrite-competing compounds such as ascorbate which deplete the supply of available nitrites. [178] Experimental data on the in vivo formation of nitrosamines following inhalation of the oxides of nitrogen have not been found in the literature. The observations of Henschler and Ross [160] and Kuschner and Laskin [162] do not indicate production of carcinomas in mice, rats, and guinea pigs intermittently exposed to nitrogen dioxide for 1 1/2 to 2 years at 40 ppm and 25 ppm, respectively. However, further research should be conducted to determine the rate of in vivo formation of secondary nitrosamines following inhalation of oxides of nitrogen at low concentrations, and the possible effect of such in vivo formation on the induction of neoplastic changes.

Of particular concern is the airborne formation of secondary nitrosamines in the occupational environment. In 1973, Bretschneider and Matz [175] reported measuring secondary nitrosamines in the workplace air of plants involved in the production of dimethyl- and diethylamines. Samples, collected on activated charcoal, were eluted by diethyl ether and analyzed by gas chromatography. Levels of dimethylnitrosamine (DMN)

measured in one plant manufacturing dimethylamine ranged from 0.001 to 0.43 parts per billion (ppb). Samples collected over a period of 3 days indicated a decline in the airborne concentration of DMN to nondetectable levels by the third day. Airborne levels of nitrogen dioxide were found to decrease to 1/2 of the initial concentration over the same sampling period. The correlation between the airborne concentrations of DMN and nitrogen dioxide is interesting in light of data reported by Mirvish [179] indicating that the rate of DMN formation in buffered aqueous solutions was proportional to the concentration of dimethylamine and to the square of the nitrite concentration. However, the unexplained finding that the DMN could not be detected in the workplace air on the third day of measurement despite of 10-fold increase in the concentration of dimethylamine raises serious questions about the reliability of the sampling method.

Fine et al [180] reported data indicating the presence of N-nitroso compounds in the air near chemical plants in two urban communities. Air was sampled through three successive cold traps at a rate of 1.8 liters/min. for 2 hours. Analysis was by means of a gas and liquid chromatograph interfaced with an N-nitroso specific Thermal Energy Analyzer. Of five urban areas selected for analysis, two had detectable levels of dimethylnitrosamine. Concentrations of DMN near a dimethylhydrazine plant in Baltimore ranged between 0.033 ppb and 0.96 ppb. Only trace levels of DMN were detected in samples taken during nighttime operations. [Fine, as cited in 181] This finding is surprising since the concentration of N-nitroso compounds is presumably higher under low ultraviolet light exposure. [175,177] Since DMN is a precursor for dimethylhydrazine, the levels measured in Baltimore could represent leakage of DMN

into the atmosphere rather than in airborne formation of the compound. However, airborne formation is suggested by the results of measurements made near a dimethylamine plant in Belle, West Virginia where concentrations of DMN ranged between 0.014 ppb and 0.051 ppb. Collectively, the work of Bretschneider and Matz [175] and Fine et al [180] suggests that N-nitroso compounds may be formed in the workplace air or in the sampling train. However, extensive research will be required to validate sampling and analytic methods for measuring volatile N-nitroso compounds. Additional research should be conducted to: (1) measure and verify the levels of N-nitroso compounds in the air of occupational environments where secondary amines are produced, (2) determine the rate of formation of secondary nitrosamines in the workplace air, and (3) identify the environmental factors influencing the formation and decomposition of secondary nitrosamines in the occupational environment.

Isolated experimental studies indicate that the inhalation of secondary nitrosamines is acutely toxic in laboratory animals. Jacobson et al [182] exposed groups of rats, mice, and beagle hounds for 4 hours to nitrosodimethylamine vapor at various concentrations between 16 and 188 ppm. The LC50 values for rats and mice exposed to nitrosodimethylamine for 4 hours and observed for 14 days were 78 ppm and 57 ppm, respectively. Although the LC50 for beagle dogs was not determined, the dogs appeared to succumb at lower concentrations than did the rats and mice. Effects noted included polydipsia, loss of appetite, ascites, hyperacute liver necrosis, leukopenia, disruption of normal blood coagulation, and hemorrhage into the wall of the gastrointestinal tract, the abdominal cavity, and other tissues. Analogous effects have been noted in humans accidentally exposed

to nitrosodimethylamine at unknown concentrations. [183] Druckrey et al [184] studied neoplastic changes occurring in rats exposed either once or intermittently (1/2 hour/week) to dimethylnitrosamine or methyl vinyl nitrosamine. The 1-hour LC50's for dimethylnitrosamine and methyl vinyl nitrosamine were 506 ppm and 203 ppm, respectively. Of 12 rats exposed once/week for 1/2 hour to 50 ppm of dimethylnitrosamine, 9 died of carcinomas which developed from the ethmoid cells after 260-450 days of exposure. Similar exposure to methyl vinyl nitrosamine resulted in the death of 6 out of 12 rats after 230-330 days of exposure. Unlike dimethylnitrosamine, exposure to methyl vinyl nitrosamine produced carcinomas of the epithelium in the anterior nasal cavity. Dontenwill et al ([185] observed the development of tumors in the trachea and lungs of golden hamsters exposed to diethylnitrosamine aerosol (1-2mg) twice weekly. After 5 months of exposure, 18 out of 33 experimental animals had carcinomas of the trachea, lungs, or of both. The remaining 15 animals showed metaplastic changes in these areas. Similar exposures in 10 rats did not result in tumors after 3 months of exposure. However, the concentration of exposure in the rat experiments was not given.

In summary, experimental animal studies indicate that inhalation of relatively high concentrations of secondary nitrosamines for short periods of time can result in liver damage and severe hematologic changes as well as in carcinomas of the nasal cavity, trachea, and lungs. Jacobson et al [182] and Dontenwill et al [185] have observed widely varying sensitivities in nonprimate species exposed to airborne nitrosamines. Except for the ill-defined exposure used by Dontenwill et al, [185] the animal studies which have been reviewed have used exposures at concentrations which are

approximately 1 million times greater than that reported in the occupational environment. No animal data have been found on the chronic effects of long-term exposure at low airborne levels of nitrosamines, or on the in vivo formation of N-nitroso compounds from inhalation of the oxides of nitrogen. Furthermore, no epidemiologic data have been found indicating chronic effects in humans exposed to airborne secondary nitrosamines. Serious questions yet remain on the reliability of sampling techniques used to monitor nitrosamine levels in the working environment. Therefore, although a potential human health hazard exists from the airborne or in vivo formation of N-nitroso compounds, the currently available data base is insufficient to establish the degree of risk to occupationally exposed workers.

#### Control of Exposures

Since nitrogen oxides can be produced under a variety of situations, the appropriate engineering controls will vary. For welding and related types of operations, local exhaust ventilation, located as close as practicable to the source of heat, is needed. Because the nature of the work may require the welder to be frequently changing the location of operations, the exhaust system must be mobile. This may necessitate the use of flexible exhaust ducts or other arrangements which would place the hood or duct opening at the most effective location. [186,187]

Operations, such as bright dipping of metals with nitric acid, conducted in stationary tanks lend themselves to conventional local exhaust ventilation practices. [186,188] Exhaust systems must be resistant to acid gases. In a laboratory pilot study, Kerns [189] observed that the release



of nitrogen oxides from bright dipping and similar operations can be effectively suppressed by the addition of urea to the acid in the tank; however, the practice has not gained general acceptance in operational procedures.

Control of nitrogen oxides from indoor vehicular operations is usually dependent upon provision of sufficient general ventilation. Where work is being done upon stationary vehicles as in repair garages, local exhaust systems should be attached to or located close to the vehicle tail-pipes to limit exposure not only to nitrogen dioxide, but to other contaminants as well, particularly carbon monoxide. Similar considerations are applicable to gas and diesel engines operated in enclosed areas, such as mines and tunnels.

Design principles contained in publications on ventilation systems [186,187,188] should be followed if exhaust ventilation is needed for the control of nitrogen oxides.

Where blasting is done in tunnels or mines, workers should not be permitted back into the area until the ventilation system has had time to clear out the blasting gases.

The hazard from oxides of nitrogen in agricultural silos is greatest during the first week to 10 days after green ensilage has begun fermenting. [29,190,191,192] Workers should not enter silos which have not been properly ventilated. Wherever there is a possibility that the concentrations of oxides of nitrogen, of other contaminants, or of oxygen are not safe, workers should enter a silo with an acceptable respirator which should be, and if oxygen is deficient must be, an air-supplied type.

Additional personnel should be available for rescue operations.

#### Environmental Sampling and Analytical Methods

Several instrumental methods for measuring nitrogen dioxide have been suggested. Morrison et al [193] and Morrison and Corcoran [194] have reported on nitrogen dioxide determinations by electron-capture detection in gas chromatography. Techniques for obtaining breathing zone samples in the occupational environment and for the transport and preparation of samples for analysis by such a procedure remain to be worked out. Coulometric instruments [195] also represent a possible measurement method. This method is based on the reduction of nitrogen dioxide by bromide or iodide with the release of bromine or iodine, respectively. Bromine and iodine produce a current which may then be measured by a microammeter. Alternatively, voltage drop may be measured. Guicherit [196] observed that the efficiency of a specific coulometric instrument is low and the reactions not specific for nitrogen dioxide. In 1972, he reported a chemiluminescent method for measuring nitric oxide for application to air pollution studies. Commercially produced instruments are now available. Nitrogen dioxide may be determined by a chemiluminescent reaction between oxygen atoms and nitrogen dioxide, or by indirect means. In the latter method, ozone, produced by nitrogen dioxide photolysis, is measured utilizing a chemiluminescent reaction between ozone and an organic compound. Size and portability factors make the use of such equipment unsuitable for measuring breathing zone exposures. The method probably could be used for area monitoring. The equipment cost is considerable, and the complexity of the method requires highly trained personnel for

operation and maintenance.

Early industrial hygiene studies of total nitrogen oxides exposures employed the phenoldisulfonic acid method. [169] The procedure consists essentially of the absorption of nitrogen oxides in an acid solution to form nitrous and nitric acids, followed by oxidation with hydrogen peroxide of the nitrous acid to nitric acid. Potassium hydroxide is added, and following evaporation to dryness, the nitrates are treated with phenoldisulfonic acid, forming a yellow color. The intensity of the color is proportional to the concentration. Presumably, the method can be made specific for nitrogen dioxide by passing the air sample through silica gel, which absorbs the nitrogen dioxide, but not for nitric oxide. [197] However, Wade et al [5] found that nitrogen dioxide is not absorbed by silica gel but is converted to nitric acid. Although the phenoldisulfonic acid method is exacting and time-consuming, it is very sensitive. [198,4]

Patty and Petty [199] developed a field technique using sulfanilic acid and alpha-naphthylamine (Greiss-Ilosvay reagent). This technique uses a 50-ml hypodermic syringe into which the reagent is placed before the sample is collected. The color developed is compared with standards. A kit employing this procedure is commercially available. However, since the procedure is for nitrites, [199] it is nonspecific for nitrogen dioxide or nitric oxide.

In 1954, Saltzman [4] reported on screening tests for absorption efficiency performed on a number of reagents. He developed a modification of the Greiss-Ilosvay reagent which is specific for nitrogen dioxide. The method, which has been widely used for both community air pollution (40 CFR Part 50) and occupational exposure studies, [18,19,29] uses sulfanilic acid

and N-(1-naphthyl)-ethylenediamine dihydrochloride. Automatic continuous recording equipment, as well as grab sampling devices such as evacuated bottles or syringes, are used with the Saltzman reagent. [200] Length-of-stain detector tubes using this reagent have also been developed. [197,201,202] Detector tubes, while only semiquantitative, [201] can be valuable adjuncts to the compliance method, especially for the determination of exposure areas and for special purposes of identification of hazardous conditions. The use of detector tubes, while not as sensitive or precise as the compliance method described in Appendix I, does have the advantage of simplicity and of giving results immediately. A description of the use of detector tubes is given in Appendix III.

Most analytical procedures for nitric oxide involve oxidizing it to nitrogen dioxide and subsequently determining the concentration of that compound. [5,201,203,204,205,206,207] Consideration must be given to the fact that some nitrogen dioxide is also present in occupational or environmental exposures. [198,4,5, 6,9,14,16,23,10,208] In most published investigations of occupational exposures, all of the mixtures of oxides have been oxidized to nitrogen dioxide, and only the totals reported. If each is to be reported separately, one of two basic approaches is usually employed. The nitrogen dioxide portion of the sample may be separated out and measured, with the nitric oxide in the remainder then being oxidized to nitrogen dioxide and determined by the same procedure. The alternative approach is to collect two samples simultaneously at the same location (or to split one sample into two portions). One is analyzed for nitrogen dioxide, the other for total nitrogen oxides, with the nitric oxide being

the difference. [204,205,207,209]

Extensive work has been done to improve methods for precise determinations of airborne concentrations of nitric oxide. [204,205,206,209] Much of this work has been incorporated into a tentative method for nitric oxide recommended by a chemical standards setting group, known as the Intersociety Committee. [207] In this method, nitrogen dioxide is first removed by a solid adsorbent containing triethanolamine. After adjustment of the humidity of the remaining sample, it is passed through an oxidizer made of chromium trioxide deposited on a solid material. The nitric oxide is then converted to nitrogen dioxide, after which it enters a bubbler containing Saltzman reagent. The absorbance is then read at 550 nm. The Saltzman method is a sensitive colorimetric procedure. All of the reagents are incorporated in one solution, which is an efficient collection medium for nitrogen dioxide. The color is partially developed during sampling, which is advantageous since the sampling time can be adjusted to provide adequate color for accurate photometric measurement. [210]

Blacker [211] reported on a field method to sample nitrogen dioxide in the range of concentrations encountered in the work environment. The sample is collected on a triethanolamine-impregnated molecular sieve surface, [212] using the principle described by the Intersociety Committee. The solid-type adsorber is simpler to use and avoids other disadvantages encountered in trying to perform personal sampling with a liquid-type collector. In addition, Blacker reported that samples collected on the solid adsorber have a high degree of stability for at least 2 weeks. This

is important in the event that analyses cannot be performed promptly.

If a second solid-type adsorber is substituted for the bubbler in the sampling train described by the Intersociety Committee, a personal sampling device for measuring both nitrogen dioxide and nitric oxide is produced. Such a device, described in Appendix I, represents the recommended method for sampling the oxides of nitrogen. The method is recommended because of its simplicity, suitability for personal sampling, and because samples remain stable during shipment to the laboratory.

The samples may then be analyzed by the procedure described by Blacker [211] and by Levaggi et al. [212]. This procedure is described in Appendix II. Since, in the sampling procedure, the nitric oxide is converted to nitrogen dioxide, the same analytical procedure serves to determine both substances.

Tests of the recommended sampling train by NIOSH [213] indicated that recovery rates for nitrogen dioxide were greater than 90% for samples generated at concentrations of between 0.8 and 5.6 ppm. The average recoveries for nitric oxide were 97.4, 106, 84, and 67% for sample concentrations at 8.6, 11.0, 24.0, and 50.0 ppm, respectively. The total coefficient of variation was 7.2% for nitrogen dioxide and 5.5% for nitric oxide.