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METHYLENE CHLORIDE EXPOSURE EVALUATION DURING ACTIVE PHARMACEUTICAL INGREDIENT MANUFACTURING

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by

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Abstract

A manufacturer utilizes methylene chloride (CH_2Cl_2) (CAS 75-09-2), also known as dichloromethane, to manufacture active pharmaceutical ingredients. Methylene chloride is specifically regulated by the Occupational Safety and Health Administration (OSHA) under 29 Code of Federal Regulation (CFR) 1910.1052. Evaluation and documentation of employee exposure to methylene chloride is required to comply with OSHA regulations. In addition to OSHA compliance, it is also important to evaluate employee exposure levels to determine if respiratory protection, regulation of the work area, and medical monitoring are necessary.

This industrial hygiene report describes an investigation into the risks of exposure to methylene chloride. This report includes evaluation of employee exposure to methylene chloride during the manufacture of active pharmaceutical ingredients. During the manufacture of active pharmaceutical ingredients, employees transfer methylene chloride from small containers to a large reactor. After the desired reaction has taken place and allowed to separate, different layers of the solution which contains methylene chloride are drained from the reactor into small containers. Employees have the potential for exposure to methylene chloride during the transfer and collection processes.

The results of the occupational exposure sampling indicate employees are exposed to levels of methylene chloride above the permissible exposure limit (PEL) and the action limit (AL). The regulatory standard requires medical monitoring when employees are exposure above the AL. Regulation of the work area and respiratory protection is required at the PEL.

Recommendations to reduce exposure include identifying a substitute solvent that is less hazardous. To control exposure through an engineering control, an evaluation of the current localized ventilation system would be valuable in determining existing capabilities for reducing exposure to methylene chloride vapors. If this is not possible with the current ventilation system, other ventilation options could be explored. An engineering control to reduce exposure during methylene chloride transfer from pails to the reactor may be achieved by applying nitrogen pressure to the bucket to force methylene chloride from one container to the reactor vessel from a remote location. Reduction of exposure during transfer from the bottom of the reactor to collection pails may be achieved by attaching a hose to the bottom of the reactor and channeling discharge into a closed top container. The implementation of either of these controls would necessitate additional exposure monitoring to evaluate the effectiveness.

Keywords:

Methylene chloride, dichloromethane, exposure monitoring, active pharmaceutical ingredient manufacturing

Dedication

I would like to acknowledge the love and support of my husband throughout my career including the pursuit of an advanced degree.

I would like to thank my parents for being sympathetic listeners and helping me to keep up with day-to-day life issues.

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Glossary of Terms

Term	Definition
29 CFR 1910.1052	29 Code of Federal Regulation (CFR) 1910.1052 is known as the methylene chloride standard
AIHA	American Industrial Hygiene Association
AL	Action Level is established by OSHA as the 8-hour time-weighted average exposure level at which exposure regulatory requirements are applicable
ATSDR	Agency for Toxic Substances and Disease Registry
PEL	Permissible Exposure Limit established by OSHA to protect workers from adverse exposure effects based on an 8-hour time-weighted average
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
TWA	Time-weighted average; the average exposure over a given period of time

1. Introduction

A manufacturer utilizes methylene chloride (CH_2Cl_2) (CAS 75-09-2), also known as dichloromethane, to manufacture active pharmaceutical ingredients. Methylene chloride is specifically regulated by the Occupational Safety and Health Administration (OSHA) under 29 Code of Federal Regulation (CFR) 1910.1052. To comply with this regulation, it is necessary to conduct an initial exposure determination to determine employees' exposure levels. The manufacturer indicated exposure monitoring had been conducted and exposure limits were below the action level (AL) and permissible exposure limit (PEL). However, documentation pertaining to the exposure monitoring, including the calculated exposure levels, was unavailable.

Evaluation and documentation of employee exposures to methylene chloride is required to comply with the OSHA methylene chloride standard. It is also important to evaluate employee exposure levels to determine if respiratory protection, regulation of the work area, and medical monitoring are necessary.

This industrial hygiene report will include a review of the risks of exposure to methylene chloride. This project will also include evaluation of employee exposure to methylene chloride during the manufacture of active pharmaceutical ingredients. The results of the exposure evaluation provided in this report were used to recommend appropriate actions (e.g., regulatory compliance, engineering controls, additional monitoring).

1.1. Process Description

The process of manufacturing active pharmaceutical ingredients is a multi-step process. Chemicals used in the manufacturing process are transferred from the suppliers' containers (e.g., drums, 4-liter bottles, pails) to properly labeled 5-gallon pails which are then weighed and staged

in the work area (see Figure 1). These transfer activities are performed the day prior to initiating manufacturing activities and were not included in this evaluation.

Figure 1: Pails containing chemicals staged in the work area.

As the manufacturing process begins, the first step includes charging the reactor (i.e., pouring materials into the reactor) with a proprietary compound, methylene chloride and additional chemicals to facilitate a reaction. To accomplish this step, Employee 1 climbs steps to an elevated platform that is staged near the reactor (see Figure 2). Employee 2 carries the pails to the elevated platform. Employee 1 then opens the containers and pours the contents into the reactor. At this time, localized ventilation (i.e., a snorkel, trunk exhaust duct or extraction arm) is positioned near the opening of the reactor (see Figure 3). The localized ventilation is provided by a Plymovent extraction arm which is intended to capture chemical vapors. The employees wear supplied-air, full-faced respirators, laboratory coats and chemical-compatible gloves. This portion of the manufacturing process occurs intermittently over an approximate four hour period as dictated by the desired reaction and quenching of the reaction.

Figure 2: View of the elevated platform with reactor in the background

Figure 3: Movable ventilation duct.

After allowing time for the phases of the solution to separate, the aqueous layer of the material is then released from the reactor through a drain at the bottom of the reactor into appropriately labeled 5-gallon pails (see Figure 4). After additional stirring, the material is

allowed time to separate again. The methylene chloride layer (i.e., the halogenated waste layer) is then collected in to appropriately labeled 5-gallon pails. At this time, localized ventilation (i.e., extraction arm) is positioned near the discharge location at the bottom of the reactor. The employees wear supplied-air, full-faced respirators, laboratory coats and chemical-compatible gloves. This activity occurs intermittently over an approximate four hour period.

Figure 4: Bucket staged below reactor to capture separated layers.

The remaining material is then filtered as it is removed. The liquid potion is captured in pails while the solids are captured on a filtering cloth. The employees wear supplied-air, full-faced respirators, laboratory coats and chemical-compatible gloves. This typically occurs the next day over an approximate 15 minute period.

2. Hypotheses

As the methylene chloride exposure level was not established, it was unknown if respiratory protection, regulation of the work area, and medical monitoring are necessary to meet

the requirements of 1910.1052. This evaluation is important to determine regulatory compliance responsibilities.

Information about the toxicology of methylene chloride and background information as to the risks of methylene chloride exposure are provided in Section 4 which emphasizes the importance of evaluating methylene chloride exposure levels.

This research was designed and implemented with the intention of answering the following question: "what is the methylene chloride exposure level for employees manufacturing active pharmaceutical ingredients?" From this question, the following hypotheses were developed:

Null 1: Employee exposure to methylene chloride will be equal to or less than the OSHA PEL.

R 1: Employee exposure to methylene chloride will be greater than the OSHA PEL.

Null 2: Employee exposure to methylene chloride will be equal to or less than the OSHA AL.

R 2: Employee exposure to methylene chloride will be greater than the OSHA AL.

To reject or not reject the null hypotheses, exposure monitoring was conducted to determine the exposure level.

The final portion of the industrial hygiene report includes a discussion of the findings, conclusions, and recommendations. If either null hypothesis 1 or null hypothesis 2 are rejected, medical surveillance is required in accordance with 29 CFR 1910.1052. Further if null hypothesis 1 is rejected, regulation of the work area and engineering controls, administrative

controls, or personal protective equipment such as full-faced, supplied-air respirators are required to reduce employee exposure below the PEL.

3. Background

Methylene chloride, a chlorinated hydrocarbon, is a colorless liquid with high vapor pressure and a sweet odor (Agency for Toxic Substances and Disease Registry (ATSDR), 2000). It is easily evaporated, but does not readily burn (ATSDR, 2000). Methylene chloride is not naturally occurring; rather it is made from methane gas or wood alcohol (ATSDR, 2000). The chemical and physical properties of methylene chloride are presented in Table I.

Table I: Chemical/Physical Data

Parameter	Methylene Chloride Properties
Molecular Weight	84.9
Boiling Point	39.8°C (104°F)
Specific Gravity (water = 1)	1.3
Vapor Density (air = 1)	2.9
Vapor Pressure at 20°C (68°F)	350 millimeters mercury (mm Hg)
Solubility in Water (grams/100 grams water at 20°C (68°F))	1.32
Appearance and Odor	Colorless liquid, chloroform-like odor

(NIOSH, 2011 and ECSA, 2007)

3.1. Toxicology

The primary route of exposure to methylene chloride, a volatile organic compound, is through inhalation. As methylene chlorine is inhaled, over seventy percent is absorbed by the bloodstream and reaches a steady state in the blood within one to two hours of continuous exposure (Klaasen, 2008 and ATSDR, 2000). In the bloodstream, methylene chloride is distributed throughout the body with most of it going to the liver, kidney, brain, lungs and fatty tissue (ATSDR, 2000). Of the absorbed dose, less than five percent is exhaled as unchanged methylene chloride, while 25 to 34 percent is exhaled as carbon monoxide, an end metabolite of

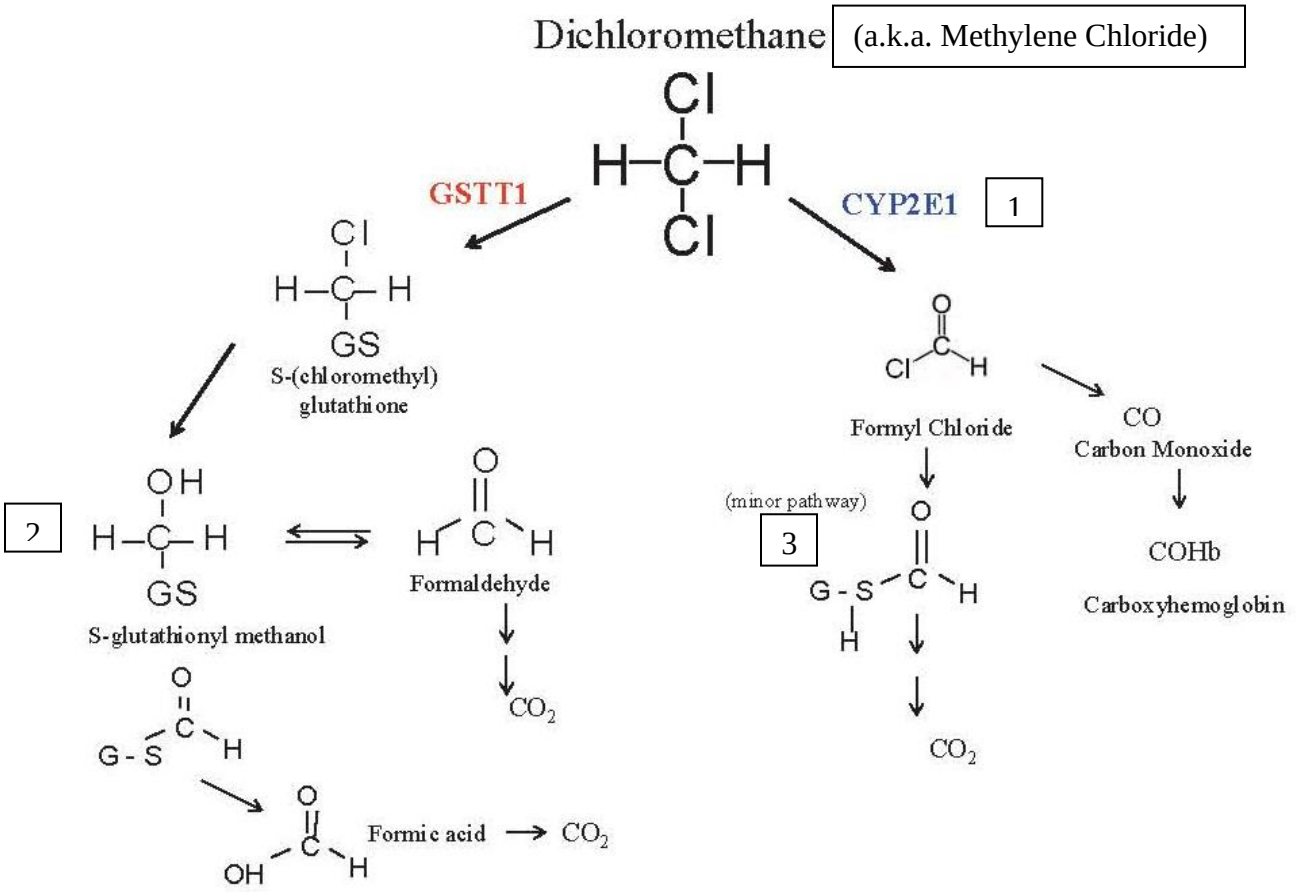
methylene chloride (Klaasen, 2008). A small amount of methylene chloride leaves the body in urine (ATSDR, 2000). Methylene chloride is quickly eliminated from the body and was not shown to accumulate over a five day exposure regimen (Klaasen, 2008).

A small amount of methylene chloride can be absorbed by the skin; however, when trapped against the skin by clothing or gloves, skin absorption can be greater and result in potential chemical burns (ATSDR, 2000).

Absorption of methylene chloride through dermal exposure is relatively slow in comparison to inhalation. In scenarios where employees are wearing supplied-air, full face respirators and the skin is not protected (i.e., the employees are not wearing gloves), a sufficient amount of methylene chloride may be absorbed through the skin over an 8-hour work period to result in an internal concentration which would exceed that of employees exposed to methylene chloride by inhalation of 25 ppm for eight hours (OSHA, 2012). Employees at risk of hand contact with methylene chloride must wear impermeable gloves to prevent this route of exposure (OSHA, 2012).

Methylene chloride is believed to be metabolized via three pathways as illustrated in Figure 5 (EPA, 2011).

Figure 5: Proposed pathways for methylene chloride metabolism



1 – Mixed function oxidase pathway
2 – Glutathione transferase pathway
3 – Nucleophile pathway

One of the pathways involves cytochrome P450 2E1 (CYP2E1)-catalyzed oxidation of methylene chloride to carbon monoxide via the reactive intermediate formyl chloride and is referred to as the mixed function oxidase (MFO) pathway (see Figure 5) (Klaasen, 2008 and ATSDR, 2000). This pathway is a high-affinity, low-capacity pathway and is the main pathway of methylene chloride metabolism for occupational exposure (Klaasen, 2008). It is suggested that this is the preferred pathway for the metabolism of inhaled methylene chloride (ATSDR, 2000).

As shown in Figure 5, the second pathway (i.e., the glutathione transferase pathway) is a glutathione (GSH)-mediated pathway involving the theta-class glutathione transferase (GST), GSTT1-1 (Klaasen, 2008 and ATSDR, 2000). The conjugation of GSH and methylene chloride results in the formation of reactive intermediates (i.e., S-(chloromethyl)glutathione and formaldehyde) which are eventually metabolized to carbon dioxide. The GST pathway is a low-affinity, high-capacity pathway which is operative at high exposure levels (Klaasen, 2008).

The suggested third pathway includes the formation of carbon dioxide via the MFO pathway due to the reaction of intermediate, proposed to be formyl chloride, with a nucleophile, such as glutathione (GSH), prior to the elimination of the chlorine ion (Klaasen, 2008 and ATSDR, 2000).

3.2. Exposure Standards

The OSHA regulation 29 CFR 1910.1052 establishes an AL of 12.5 ppm as an 8-hour time-weighted average (TWA) and a PEL of 25 ppm as an 8-hour TWA (OSHA, 2012). OSHA has also established a short-term exposure limit (STEL) of 125 ppm as measured over a fifteen minute exposure period (OSHA, 2012).

In accordance with the regulatory standard, the employer must establish regulated areas (i.e., restricted area that is demarcated) when the PEL or the STEL are expected to be exceeded. In addition, when the PEL or STEL may be exceeded, the employer must provide respiratory protection. Only full face, supplied-air respirators are acceptable for methylene chloride exposure. Medical surveillance is required when employees are exposed at or above the AL for 30 or more days per year or exceedances of the PEL or STEL for ten or more days per year. In addition, medical surveillance is also required if an employee is at risk from cardiac disease or other methylene chloride-related health condition.

When feasible, the employer must institute and maintain engineering controls and work practices to reduce employee exposure to below the PEL and STEL. Respiratory protection is then used to supplement engineering controls and work practices after the lowest level of exposure is achieved.

The National Institute of Occupational Safety and Health (NIOSH) has not established a recommended exposure limit (REL) as measured for up to a 10-hour exposure period during a 40-hour work week for methylene chloride (NIOSH, 2011). NIOSH identifies methylene chloride as a potential carcinogen and, therefore, recommends a "no exposure detectable levels for proven carcinogenic substances". NIOSH intends to provide a REL based on human and/or animal data (NIOSH, 2011). NIOSH has identified an immediately dangerous to life and health (IDLH) level of 2,300 ppm (NIOSH, 2011). If the IDLH level is reached, the work area should be immediately evacuated.

The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value (TLV) for methylene chloride of 50 ppm as measured over an 8-hour period during a 40-hour work week.

The German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission) has classified methylene chloride as a Category 3A carcinogen (i.e., a suspected carcinogen for which additional data is needed for further classification). (Greim, 2001). The MAK occupational exposure limit (OEL) is 100 ppm as measured over an 8-hour TWA (ECSA, 2007).

The Netherland, the United Kingdom and Switzerland have established an 8-hour TWA OEL for methylene chloride of 100 ppm (ECSA, 2007). Sweden and France have also

established 8-hour TWA OELs for methylene chloride of 35 ppm and 50 ppm, respectively (ECSA, 2007).

3.3. Site Evaluated

The process evaluated is detailed in section 1.1 Process Description. The work activities are restricted to one room of the manufacturer's facility. Employees return to their office while waiting for the reaction to take place or the solution in the reactor to separate.

4. Effects of Exposure

4.1. Target Organs

Methylene chloride is considered a potential human carcinogen and is a confirmed carcinogen in rodents (Klaasen, 2008 and OSHA, 1997). Studies to date show little evidence of methylene chloride carcinogenicity in humans (Klaasen, 2008). OSHA concluded that a positive association between human exposure to methylene chloride and cancer incidence exists, but that the dose response relationship is not clear (OSHA, 1997) Additional research may clarify if methylene chloride is a human carcinogen.

Other toxic effects of methylene chloride exposure include effects to the central nervous system, cardiac toxicity, hepatic toxicity, and reproductive toxicity (OSHA, 1997).

Relatively mild, but reversible central nervous system depression is seen in humans when inhaled at low levels including levels as low as 200 ppm (OSHA, 1997). Depression of the central nervous system as a result of methylene chloride exposure is characterized by tiredness and a decrease in attentiveness (OSHA, 1997). It has been suggested that repeated exposure to high levels of methylene chloride could result in irreversible central nervous system depression, however, a review of the studies by OSHA concluded that the results of these studies is not

supported (OSHA, 1997). Monitoring of future research by OSHA will continue due to concern about potential central nervous system effects at low levels (OSHA, 1997).

Cardiac health effects are anticipated due to exposure to methylene chloride, or more specifically, the metabolite, carbon monoxide (OSHA, 1997). Carbon monoxide competes with oxygen and binds to hemoglobin producing carboxyhemoglobin (COHb) (OSHA, 1997). The reduction in oxygen delivery to tissues can result in myocardial infarction (OSHA, 1997). Animal studies have shown no evidence of direct toxic effects on cardiac tissue as the result of methylene chloride exposure (OSHA, 1997). In human studies, methylene chloride exposure resulted in increased blood COHb (OSHA, 1997). Human baseline levels of COHb are typically less than 1% (OSHA, 1997). Measurements of COHb of 24% and 30% were reported by one human study, but were believed to only occur at high levels of exposure to methylene chloride (i.e., greater than 500 ppm) (OSHA, 1997). OSHA, while concerned about the metabolism of methylene chloride to carbon monoxide, has determined that the risk for cardiac health effects is low (OSHA, 1997). OSHA will continue evaluate new research on this health effect (OSHA, 1997).

It is suspected that methylene chloride could be toxic to the liver as are other chlorinated hydrocarbons (e.g., carbon tetrachloride and chloroform) (OSHA, 1997). Mild liver effects (i.e., mild inflammatory response) were noted in rats and mice exposed to methylene chloride (OSHA, 1997). In studies evaluating the chronic exposure of rats, mice and hamsters to methylene chloride, increased fatty liver, cytoplasic vacuolization and increased number of multinucleated hepatocytes were noted hepatic effects. OSHA's review of these animal studies concluded that rodent livers are sensitive to chronic effects, but not acute effects of methylene chloride exposure (OSHA, 1997). Human studies provided mixed results. A study of acetate fiber production plant

workers was suggestive of a hepatotoxic response (i.e., increases in serum bilirubin and alanine aminotransferase) (OSHA, 1997). Hepatotoxic effects (i.e., liver function and enlarged liver) were also suggested of floor tile setters which were chronically exposed to methylene chloride at concentrations between 400 and 5,300 ppm. Case studies were not conclusive that methylene chloride was the causative agent of alteration of liver enzymes or hepatitis (OSHA). As a result of the review of studies in animals and humans and case reports, OSHA concluded that human heptotoxicity is not likely (OSHA, 1997).

Animal studies have shown the fetus is sensitive to the methylene chloride metabolite, carbon monoxide producing central nervous system damage or reduced fetal growth. Limited data is available regarding teratogenicity effects in humans (OSHA, 1997). Carbon monoxide, a metabolite of methylene chloride, which reduces the amount of oxygen available to tissues, has been shown to have resulted in fetal or infant death (OSHA, 1997). OSHA concluded that it is aware of the reproductive effects of carbon monoxide and, therefore, there is still concern about the potential for methylene chloride teratogenicity. OSHA will continue to monitor research as it becomes available (OSHA, 1997).

Ultimately, the exposure limits established by OSHA are based on carcinogenic and central nervous system effects (OSHA, 1997).

4.2. Occupational Exposure Review

No studies specific to methylene chloride exposure during the manufacture of active pharmaceutical ingredients were found with the exception of one which studied the risk for spontaneous abortion for females working in the pharmaceutical industry (Taskinen, 1986). The study supported there is increased risk of harmful effects on the pregnancy of female pharmaceutical workers using methylene chloride (Taskinen, 1986). Other factors (e.g., use of

four or more other solvents and heavy lifting) also increased the risk for spontaneous abortion (Taskinen, 1986). The study did not document exposure levels or other potential risk factors. This study was included in the human studies reviewed by OSHA for reproductive toxicity. OSHA concluded more research is necessary to evaluate the effects of methylene chloride exposure on potential pregnancy outcome (OSHA, 1997).

A study of the effects of occupational exposure to methylene chloride and the subsequent production of COHb through metabolism in cellulose diacetate and triacetate fiber production workers in Rock Hill, South Carolina suggested no excess mortality was observed for ischemic heart disease (OSHA, 1997). NIOSH suggested that the study did not follow appropriate analytical techniques and additional studies are needed to evaluate the cardiac disease risks associated with methylene chloride exposure (OSHA, 1997). In an update to this study, bilary/liver cancer mortality was considered. While observed, it was not considered significantly significant (OSHA, 1997).

A study of cellulose diacetate and triacetate fiber production workers in Cumberland, Maryland evaluated the relationship between exposure to methylene chloride and bilary/liver cancer (OSHA, 1997). In this study, incidents of bilary/liver cancer were observed, but no statistically significant elevated incidence was found (OSHA, 1997). Statistically significant mortality was observed from prostate, uterine and cervical cancers and is considered to be suggestive, but not conclusive evidence of the human carcinogenic effect (OSHA, 1997).

Studies including a proportional mortality study and a retrospective mortality cohort study of film production workers exposed to methylene chloride were conducted (OSHA, 1997). No statistical significance was noted for these workers for ischemic heart disease or liver cancer in the proportional mortality study (OSHA, 1997). The cohort mortality study did identify

differences when compared with an external population, but it was not significantly significant (OSHA, 1997).

An epidemiological study of employees exposed to methylene chloride during the manufacture of paint or varnish did identify cancers of the digestive organs, including the pancreas and peritoneum, but these were not considered to be statistically significant (OSHA, 1997).

A case-control study for astrocytic brain cancer among workers exposed to methylene chloride while producing or repairing electronic equipment suggests an association between methylene chloride exposure and brain cancer (OSHA, 1997). This study specifically looked at the potential association between brain cancer and exposure to chlorinated aliphatic hydrocarbons including methylene chloride. Duration of employment for occupations or industries with exposure, a cumulative exposure score and "average" intensity of exposure were used as surrogate measures of exposure (OSHA, 1997). Exposure intensity categories were used for calculating odds ratios. As the probability of exposure to organic solvents, particularly methylene chloride, increased so did the risk for brain cancer (OSHA, 1997).

5. Research Design and Methods

The results of exposure sampling data were evaluated and compared to the OSHA PEL and AL. OSHA requires exposure monitoring to be accurate at the 95% confidence interval to within plus or minus 25% at concentrations above 25 ppm and within plus or minus 35% at concentrations between 12.5 and 25 ppm.

For the manufacturer of active pharmaceutical ingredients, exposure to methylene chloride occurs during the transfer of the methylene chloride from pails into the reactor. After the liquid is contained within the reactor vessel, the process operates in a closed system during

which there is no exposure. Exposure may also occur when fractions are then extracted from the reactor by draining the contents from the bottom of the reactor.

Established OSHA methylene chloride sampling methods (i.e., OSHA 80 and OSHA 59) are established for 5-minute sampling periods (OSHA, no date provided). Due to the Class I Division 2 requirements of the room, passive badges were selected over utilizing charcoal tubes with air sampling pumps. Exposure monitoring was conducted utilizing 3M Organic Vapor Monitors Badge 3520 (3520 Monitor). Sampling for methylene chloride using the 3520 Monitor is shown to meet the OSHA accuracy requirements for methylene chloride (OSHA, 1997).

The badges contain a charcoal adsorbent pad and operate on the principle of diffusion. Temperature affects will not be significant between 50 and 104 degrees Fahrenheit (°F). The temperature of the building is controlled to be within this range. Relative humidity levels can affect sampler accuracy. High relative humidity during sampling may result in decreased recovery (3M, 1997). Uptake of methylene chloride can be affected at relative humidity rates exceeding 50% at which the capacity may be significantly reduced (3M, 1997). Relative humidity was measured and recorded at the time exposure monitoring was initiated. All relative humidity readings were below 50%.

Occupational exposure sampling was conducted during three client campaigns in February and March 2014. The campaigns follow similar work procedures and each included approximately 100 kilograms (i.e., between 80 and 100 kilograms) of methylene chloride. Each of the campaigns followed the same process detailed in section 1.1 Process Description. The difference between the campaigns would have included the proprietary active ingredient and slight variations in the volume of chemicals used.

The employee anticipated to have the greatest exposure to methylene chloride (i.e., the employee that was responsible for transferring methylene chloride from pails into the reactor) was selected to wear the 3520 Monitor for the initial sampling event. After the initial exposure monitoring indicated the AL was exceeded, both employees involved with the process wore monitoring badges in subsequent sampling events. Manufacturing events do not occur on a regular schedule. Rather the events are sporadic, occurring with client demand. Two sampling events occurred in February 2014 and one sampling event occurred in March 2014.

The badges were distributed at the beginning of the monitoring period. The badge is clipped to the laboratory coat collar to take a personal breathing zone air sample and be representative of the employee's exposure. The badges were worn by employees for the full duration of the manufacturing process. Upon completion of the monitoring, the plastic ring and white film were removed from the monitor and caps secured to each portion of the monitor in preparation for shipment to the analytical lab.

After observing work activities during the initial campaign, a 3520 Monitor was issued to two employees performing these activities during the second and third campaigns. This allowed for the exposure of the employee transferring the liquid as well as a support employee that would transport closed containers. These are the only two employees within the room during these procedures.

The samples were analyzed by ALS Environmental, a laboratory accredited by the American Industrial Hygiene Association (AIHA) as an industrial hygiene laboratory.

As detailed in Section 1.1 Process Description, during work activities both employees wear supplied-air, full-faced respirators, laboratory coats and chemical-compatible gloves. In addition, localized ventilation (i.e., extraction arm) is positioned near the opening of the reactor.

6. Results

The occupational exposure sampling was conducted in accordance with a method that will provide an initial exposure determination in accordance with 29 CFR 1910.1052. Conducting 8-hour methylene chloride sampling with the 3M 3520 badge meets the OSHA accuracy requirements (3M, 1997).

An 8-hour work shift is composed of 480 minutes. Exposure during the time period not monitored would have occurred outside the laboratory as office time and would not have had any methylene chloride exposure. The typical work shift is 8-hours, but may vary with the time needed for the solution to separate. Employees would wear the badges for the duration of their work in the laboratory. The employees continued to wear the badges during breaks or office time (i.e., the badges were not left in the laboratory). In the event the employee's work in the laboratory was completed for the day and they would not be returning, the badge was collected. To calculate the methylene chloride exposure for an 8-hour time-weighted average (TWA), equation (1) shown below was utilized.

$$TWA = \frac{(Concentration_1 * Time_1) + (Concentration_2 * Time_2)}{Time} \quad (1)$$

The calculated analytical results and calculated 8-hour TWA are presented below in Table II.

Table II: Analytical Results and 8-Hour TWA

Sample	Campaign	Location	Relative Humidity (%)	Exposure Time (minutes)	Analytical Results (ppm)	8-Hour TWA (ppm)
NG5160	1	Employee 1	7.1	361	22	16.65
NG5155	2	Employee 2	20.5	568	15	17.75
NW6944	2	Employee 1	29.1	413	22	18.93
NW7307	3	Employee 2	24.6	180	110	41.25
NG6937	3	Employee 1	25.0	510	38	40.38
NW7305	NA	Blank	NA	NA	ND	ND
NW7307	NA	Blank	NA	NA	ND	ND

NA = not applicable
ND = non-detect

The American Industrial Hygiene Association's (AIHA's) Industrial Hygiene Statistic (IHSTAT) tool to perform statistical calculations of industrial hygiene data was utilized to interpret these results (AIHA, 1998). The spreadsheet is presented in Appendix C.

The W-test value indicates the rejection of the normal distribution and the lognormal distribution is not rejected.

The Logprobability Plot and Least Squares Best Fit Line indicates an excellent fit as the data (i.e., the white circles) are near the line. The Linear Probability Plot and Least Squares Best Fit Line does not fit as indicated by the data point not being visible on the graph.

Based on this information, the data set is lognormally distributed. Therefore, the lognormal statistics are used to interpret the results.

The arithmetic mean is estimated to be 26.91 ppm. The Upper Confidence Limit (UCL), indicated by the cell labeled UCL1, 95% %>OEL, indicates that the PEL is exceeded 76.33% of the time. Based on this analysis, the exposure level is unacceptable when compared with the established PEL.

7. Discussion

The OSHA regulation 29 CFR 1910.1052 establishes an AL of 12.5 ppm as an 8-hour TWA and a PEL of 25 ppm as an 8-hour TWA.

Null hypothesis 1, employee exposure to methylene chloride will be equal to or less than the OSHA PEL, is rejected.

Null hypothesis 2, employee exposure to methylene chloride will be equal to or less than the OSHA AL, is rejected.

A short-term exposure limit (STEL), established by OSHA to be 125 ppm for methylene chloride as determined over a sampling period of 15 minutes, was not conducted as part of this assessment. It is recommended that additional monitoring be conducted to determine the short-term exposure of employees for comparison to the STEL.

As the exposure levels exceed the AL and the PEL, the continued monitoring should occur at the frequency shown in Table 1 of the OSHA standard (OSHA, 2012) (see Table III). This table indicates sampling should e conducted for the PEL and the STEL every three months.

Table IIII: Initial Determination Exposure Scenarios and Their Associated Monitoring Frequencies

Exposure scenario	Required monitoring activity
Below the action level and at or below the STEL.	No 8-hour TWA or STEL monitoring required.
Below the action level and above the STEL	No 8-hour TWA monitoring required; monitor STEL exposures every three months.
At or above the action level, at or below the TWA, and at or below the STEL.	Monitor 8-hour TWA exposures every six months.
At or above the action level, at or below the TWA, and above the STEL.	Monitor 8-hour TWA exposures every six months and monitor STEL exposures every three months.
Above the TWA and at or below the STEL	Monitor 8-hour TWA exposures every three months. In addition, without regard to the last sentence of the note to paragraph (d)(3), the following employers must monitor STEL exposures every three months until either the date by which they must achieve the 8-hour TWA PEL under paragraph (n) of this section or the date by which they in fact achieve the 8-hour TWA PEL, whichever comes first: employers engaged in polyurethane foam manufacturing; foam fabrication; furniture refinishing; general aviation aircraft stripping; product formulation; use of MC-based adhesives for boat building and repair, recreational vehicle manufacture, van conversion, or upholstery; and use of MC in construction work for restoration and preservation of buildings, painting and paint removal, cabinet making, or floor refinishing and resurfacing.
Above the TWA and above the STEL	Monitor 8-hour TWA exposures and STEL exposures every three months.

(OSHA, 2012)

While this project been adequate to reject or not reject the hypotheses, additional monitoring to assess short-term exposure is necessary.

8. Conclusions

Methylene chloride is a suspect human carcinogen and may result in central nervous system effects, cardiac toxicity, hepatic toxicity, and reproductive toxicity. Due to these risks, it is important to evaluate exposure levels. Based on the results, it has been determined that employees are exposed to methylene chloride above the OSHA PEL and AL.

The results of the occupational exposure sampling indicate employees are exposed to levels of methylene chloride above the PEL and the AL. The regulatory standard requires respiratory protection and regulation of the work area when employees are exposure above the PEL. Medical monitoring is required for employees exposed to levels above the AL or the PEL.

Recommendations to reduce exposure include identifying a substitute solvent that is less hazardous. Substitution is considered the ideal method for reducing employee exposure to methylene chloride.

To control exposure through an engineering control, an evaluation of the current localized ventilation system would be valuable in determining existing capabilities for reducing exposure to methylene chloride vapors. If this is not possible with the current ventilation system, other ventilation options could be explored.

An engineering control to reduce exposure during methylene chloride transfer from pails to the reactor may be achieved by applying nitrogen pressure to the bucket to force methylene chloride from one container to the reactor vessel from a remote location.

Reduction of exposure during transfer from the bottom of the reactor to collection pails may be achieved by attaching a hose to the bottom of the reactor and channeling discharge into a closed top container.

The implementation of any of these controls would necessitate additional exposure monitoring to evaluate the effectiveness.

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Appendix A: Laboratory Results

06-Mar-2014

Janet Rullman
Nitto Denko Avecia
8560 Reading Road
Cincinnati, OH 45215

Tel: (513) 771-3667
Fax: (508) 482-7510

Re: NOA Work Order: **1402645**

Dear Janet,

ALS Environmental received 4 samples on 27-Feb-2014 01:30 PM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 7.

If you have any questions regarding this report, please feel free to contact me.

Sincerely,

Chris Gibson

Electronically approved by: Rob Nieman

Chris Gibson
Project Manager

ALS Environmental

Date: 06-Mar-14

Client: Nitto Denko Avecia
Project: NOA
Work Order: **1402645**

Work Order Sample Summary

Lab Samp ID	Client Sample ID	Matrix	Tag Number	Collection Date	Date Received	Hold
1402645-01	NG5160	Air		2/27/2014	2/27/2014 13:30	☐
1402645-02	NG5155	Air		2/27/2014	2/27/2014 13:30	☐
1402645-03	NW6944	Air		2/27/2014	2/27/2014 13:30	☐
1402645-04	NW7305	Air		2/27/2014	2/27/2014 13:30	☐

Client: Nitto Denko Avecia
Project: NOA
Work Order: 1402645

Case Narrative

The sample condition upon receipt was acceptable except where noted.

Results relate only to the items tested and are not blank corrected unless indicated.

ALS Environmental

Date: *06-Mar-14*

Client: Nitto Denko Avecia
Project: NOA

Work Order: 1402645

Analytical Results

Lab ID: 1402645-01A
Client Sample ID: NG5160
Collection Date: 2/27/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **361**	Analyst: **TSA**
Date Analyzed: 3/6/2014		Reporting Limit		
	µg/sample	µg/sample	**ppm**	
Methylene Chloride	**890**	**10**	**22**	

Lab ID: 1402645-02A
Client Sample ID: NG5155
Collection Date: 2/27/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **568**	Analyst: **TSA**
Date Analyzed: 3/6/2014		Reporting Limit		
	µg/sample	µg/sample	**ppm**	
Methylene Chloride	**970**	**10**	**15**	

Lab ID: 1402645-03A
Client Sample ID: NW6944
Collection Date: 2/27/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **413**	Analyst: **TSA**
Date Analyzed: 3/6/2014		Reporting Limit		
	µg/sample	µg/sample	**ppm**	
Methylene Chloride	**1,000**	**10**	**22**	

Lab ID: 1402645-04A
Client Sample ID: NW7305
Collection Date: 2/27/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **0**	Analyst: **TSA**
Date Analyzed: 3/6/2014		Reporting Limit		
	µg/sample	µg/sample	ppm	
Methylene Chloride	ND	10	NA	

Note:

ALS Environmental

Date: 06-Mar-14

Client: Nitto Denko Avecia

Work Order: 1402645

Project: NOA

QC BATCH REPORT

Batch ID: **21206** Instrument ID: **GC4** Method: **3M**

MBLK Sample ID: **MBLK-21206-21206** Units: **µg/sample** Analysis Date: **3/6/2014**

Client ID: Run ID: **GC4_140306A** SeqNo: **775248** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	ND	10								

LCS Sample ID: **LCS-21206-21206** Units: **µg/sample** Analysis Date: **3/6/2014**

Client ID: Run ID: **GC4_140306A** SeqNo: **775249** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	144.4	10	132.5	0	109	70-130	0			

LCSD Sample ID: **LCSD-21206-21206** Units: **µg/sample** Analysis Date: **3/6/2014**

Client ID: Run ID: **GC4_140306A** SeqNo: **775254** Prep Date: DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	161.9	10	132.5	0	122	70-130	144.4	11.4	20	

The following samples were analyzed in this batch:

1402645-01A 1402645-02A 1402645-03A
1402645-04A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: Nitto Denko Avecia
Project: NOA
WorkOrder: **1402645**

QUALIFIERS, ACRONYMS, UNITS

Qualifier	Description
*	Value exceeds Regulatory Limit
a	Not accredited
B	Analyte detected in the associated Method Blank above the Reporting Limit
E	Value above quantitation range
H	Analyzed outside of Holding Time
J	Analyte detected below quantitation limit
n	Not offered for accreditation
ND	Not Detected at the Reporting Limit
O	Sample amount is > 4 times amount spiked
P	Dual Column results percent difference > 40%
R	RPD above laboratory control limit
S	Spike Recovery outside laboratory control limits
U	Analyzed but not detected above the MDL

Acronym	Description
DUP	Method Duplicate
E	EPA Method
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MBLK	Method Blank
MDL	Method Detection Limit
MQL	Method Quantitation Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PDS	Post Digestion Spike
PQL	Practical Quantitaion Limit
SDL	Sample Detection Limit
SW	SW-846 Method

Units Reported	Description
µg/sample	

ALS Environmental

Sample Receipt Checklist

Client Name: **NITTODENKOAVECIA-CINCINN** Date/Time Received: **27-Feb-14 13:30**

Work Order: **1402645** Received by: **RDN**

Checklist completed by: Shannon Darling 27-Feb-14 Reviewed by: Rob Nieman 04-Mar-14

eSignature | Date | eSignature | Date

Matrices:

Carrier name: Client

Shipping container/cooler in good condition?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☑	No ☐	
Container/Temp Blank temperature in compliance?	Yes ☑	No ☐	
Temperature(s)/Thermometer(s):			
Cooler(s)/Kit(s):			
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☐
Water - pH acceptable upon receipt?	Yes ☐	No ☐	N/A ☐
pH adjusted?	Yes ☐	No ☐	N/A ☐
pH adjusted by:			

Login Notes:

Client Contacted: Date Contacted: Person Contacted:

Contacted By: Regarding:

Comments:

CorrectiveAction:

1402645

ANALYTICAL REQUEST FORM

3455

☒ **REGULAR Status**

☐ **RUSH Status Required - ADDITIONAL CHARGE**

RESULTS REQUIRED BY _____ DATE

CONTACT ALS LABORATORY GROUP PRIOR TO SENDING SAMPLES

Date 02/27/2014 Purchase Order No. _____

Company Name Nitto Denko Avecia

Address 8560 Reading Road

Cincinnati OH 45215
City State Zip

Send Report To Janet Rullman / Chris Garner

Email Address jrullman@apexcos.com chris.garner@apexcos.com

Telephone (513) 771-3667 513-301-8058

Fax Telephone (513) 771-3723

Billing Address (if different)

Quote No. email from Ben Dressman

Sampling Site NDA

Date/Time of Collection 02/24 and 02/26/2014

Project No. MC

Lab Use Only	Client Sample Number	Media Type	Sample Volume (Liters)	ANALYSES REQUESTED - Use Method Number if Known
01	NG5160	3M 3520 Badge	361 minutes	Methylene Chloride
02	NG5155	3M 3520 Badge	568 minutes	Methylene Chloride
03	NW6944	3M 3528 Badge	413 minutes	Methylene chloride
04	NW7305	3M 3520 Badge	NA	Methylene chloride

Failure to complete all portions of this form may delay analysis. Please fill in this form *LEGIBLY.*

CHAIN OF CUSTODY

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Date / Time
Janet Rullman	02/27/2014 13:30		1330 2/27/14
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Date / Time

14-Mar-2014

Janet Rullman
Nitto Denko Avecia
8560 Reading Road
Cincinnati, OH 45215

Tel: (513) 301-8058
Fax: (508) 482-7510

Re: DCM/MC; NDA Work Order: **1403271**

Dear Janet,

ALS Environmental received 3 samples on 11-Mar-2014 12:32 PM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 6.

If you have any questions regarding this report, please feel free to contact me.

Sincerely,

Chris Gibson

Electronically approved by: Chris Gibson

Chris Gibson
Project Manager

ALS Environmental

Date: 14-Mar-14

Client: Nitto Denko Avecia
Project: DCM/MC; NDA
Work Order: **1403271**

Work Order Sample Summary

Lab Samp ID	Client Sample ID	Matrix	Tag Number	Collection Date	Date Received	Hold
1403271-01	NW 6937	Air		3/4/2014	3/11/2014 12:32	☐
1403271-02	NW 7306	Air		3/4/2014	3/11/2014 12:32	☐
1403271-03	NW 7307	Air		3/4/2014	3/11/2014 12:32	☐

ALS Environmental

Date: *14-Mar-14*

Client: Nitto Denko Avecia
Project: DCM/MC; NDA

Work Order: 1403271

Analytical Results

Lab ID: 1403271-01A
Client Sample ID: NW 6937

Collection Date: 3/4/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **510**	Analyst: **TSA**
Date Analyzed: 3/12/2014		Reporting Limit		
	µg/sample	µg/sample	**ppm**	
Methylene Chloride	**2,200**	**10**	**38**	

Lab ID: 1403271-02A
Client Sample ID: NW 7306

Collection Date: 3/4/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **180**	Analyst: **TSA**
Date Analyzed: 3/12/2014		Reporting Limit		
	µg/sample	µg/sample	**ppm**	
Methylene Chloride	**2,300**	**10**	**110**	

Lab ID: 1403271-03A
Client Sample ID: NW 7307

Collection Date: 3/4/2014
Matrix: AIR

Analyses

ANALYTE(S) BY 3M OVM ANALYSIS GUIDE		Method: **3M**	Time (Min): **0**	Analyst: **TSA**
Date Analyzed: 3/12/2014		Reporting Limit		
	µg/sample	µg/sample	ppm	
Methylene Chloride	ND	10	NA	

Note:

ALS Environmental

Date: 14-Mar-14

Client: Nitto Denko Avecia

Work Order: 1403271

Project: DCM/MC; NDA

QC BATCH REPORT

Batch ID: **21358** Instrument ID **GC4** Method: **3M**

MBLK Sample ID **MBLK-21358-21358** Units: **µg/sample** Analysis Date: **3/12/2014**

Client ID: Run ID: **GC4_140312A** SeqNo: **780720** Prep Date: **3/12/2014** DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	ND	10								

LCS Sample ID **LCS-21358-21358** Units: **µg/sample** Analysis Date: **3/12/2014**

Client ID: Run ID: **GC4_140312A** SeqNo: **780721** Prep Date: **3/12/2014** DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	134.6	10	132.5	0	102	70-130	0			

LCSD Sample ID **LCSD-21358-21358** Units: **µg/sample** Analysis Date: **3/12/2014**

Client ID: Run ID: **GC4_140312A** SeqNo: **780725** Prep Date: **3/12/2014** DF: **1**

Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
Methylene Chloride	130.8	10	132.5	0	98.7	70-130	134.6	2.86	20	

The following samples were analyzed in this batch: 1403271-01A 1403271-02A 1403271-03A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

ALS Environmental

Date: 14-Mar-14

Client: Nitto Denko Avecia
Project: DCM/MC; NDA
WorkOrder: **1403271**

QUALIFIERS, ACRONYMS, UNITS

Qualifier	Description
*	Value exceeds Regulatory Limit
a	Not accredited
B	Analyte detected in the associated Method Blank above the Reporting Limit
E	Value above quantitation range
H	Analyzed outside of Holding Time
J	Analyte detected below quantitation limit
n	Not offered for accreditation
ND	Not Detected at the Reporting Limit
O	Sample amount is > 4 times amount spiked
P	Dual Column results percent difference > 40%
R	RPD above laboratory control limit
S	Spike Recovery outside laboratory control limits
U	Analyzed but not detected above the MDL

Acronym	Description
DUP	Method Duplicate
E	EPA Method
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MBLK	Method Blank
MDL	Method Detection Limit
MQL	Method Quantitation Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PDS	Post Digestion Spike
PQL	Practical Quantitaion Limit
SDL	Sample Detection Limit
SW	SW-846 Method

Units Reported	Description
µg/sample	

ALS Environmental

Sample Receipt Checklist

Client Name: **NITTODENKOAVECIA-CINCINNA** Date/Time Received: **11-Mar-14 12:32**

Work Order: **1403271** Received by: **JNW**

Checklist completed by Rob Nieman 11-Mar-14 Reviewed by:

eSignature | Date | eSignature | Date

Matrices:

Carrier name: Client

Shipping container/cooler in good condition?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☑	No ☐	
Container/Temp Blank temperature in compliance?	Yes ☑	No ☐	
Temperature(s)/Thermometer(s):			
Cooler(s)/Kit(s):			
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☐
Water - pH acceptable upon receipt?	Yes ☐	No ☐	N/A ☐
pH adjusted?	Yes ☐	No ☐	N/A ☐
pH adjusted by:			

Login Notes:

Client Contacted: Date Contacted: Person Contacted:

Contacted By: Regarding:

Comments:

CorrectiveAction:

ANALYTICAL REQUEST FORM

6009

☒ **REGULAR** Status

☐ **RUSH** Status Required - ADDITIONAL CHARGE

RESULTS REQUIRED BY _____ DATE

CONTACT ALS LABORATORY GROUP PRIOR TO SENDING SAMPLES

Date 3/11/14 Purchase Order No. _____

Company Name Nitto Denko Avecia

Address 8560 Reading Road

Cincinnati (City) OH (State) 45215 (Zip)

Send Report To Janet Rullman / Chris Garner

Email Address jrullman@apexcos.com chris.garner@avecia.com

Telephone (513) 771-3617 513-301-8058

Fax Telephone (513) 771-3723

Billing Address (if different)

Quote No. email from Ben Dressman

Sampling Site NBA

Date/Time of Collection 03/04/2014 -- 03/11/2014

Project No. DCM/MC

1403271

Lab Use Only	Client Sample Number	Media Type	Sample Volume (Liters)	ANALYSES REQUESTED - Use Method Number if Known
01	NW 6937	3M3520 Badge	510 mins	Methylene chloride
02	NW 7306	3M3520 Badge	180 mins.	Methylene chloride
03	NW 7307	3M3520 Badge	NA	Methylene chloride

Failure to complete all portions of this form may delay analysis. Please fill in this form *LEGIBLY.*

CHAIN OF CUSTODY

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Date / Time
[signature]	03/04/14	[signature] ALS	3/11/14 1232
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Date / Time

Appendix B: Calculations

Using equation (1) and the laboratory analytical results, the 8-hour TWA for each sample was calculated.

$$TWA_{(Campaign\ 1 - Employee\ 1)} = \frac{(22\ ppm * 361\ minutes) + (0\ ppm * 119\ minutes)}{480\ minutes} = 16.55\ ppm$$

$$TWA_{(Campaign\ 2 - Employee\ 2)} = \frac{(15\ ppm * 568\ minutes)}{480\ minutes} = 17.75\ ppm$$

$$TWA_{(Campaign\ 2 - Employee\ 1)} = \frac{(22\ ppm * 413\ minutes) + (0\ ppm * 67\ minutes)}{480\ minutes} = 18.93\ ppm$$

$$TWA_{(Campaign\ 3 - Employee\ 2)} = \frac{(110\ ppm * 180\ minutes) + (0\ ppm * 300\ minutes)}{480\ minutes} = 41.25\ ppm$$

$$TWA_{(Campaign\ 3 - Employee\ 1)} = \frac{(38\ ppm * 510\ minutes)}{480\ minutes} = 40.38\ ppm$$

Appendix C: IHSTAT

Industrial Hygiene Statistics

OEL
25

Sample data
16.65
17.75
18.93
41.25
40.38

Descriptive statistics

Number of samples (n)	5
Maximum (max)	41.25
Minimum (min)	16.65
Range	24.6
Mean	26.992
Median	18.930
Standard deviation (s)	12.648
Geometric mean	24.767
Geometric standard deviation	1.581
Percent above OEL	40.0%

Test for distribution fit

W-test of log-transformed data	0.764	
Lognormal (α = 0.05) ?	**Yes**	
W-test of data	0.743	
Normal (α = 0.05) ?	No	

Lognormal parametric statistics

Estimated Arithmetic Mean - AM est.	26.907
LCL1,95% - Land's "Exact"	19.079
UCL1,95% - Land's "Exact"	52.435
95th Percentile	52.635
UTL95%,95%	169.899
Percent above OEL	49.2%
LCL1,95% %>OEL	22.505
UCL1,95% %>OEL	76.327

Normal parametric statistics

Mean	26.992
LCL1,95% - t statistics	14.933
UCL1,95% - t statistics	39.051
95th Percentile - Z	47.798
UTL95%,95%	80.14
Percent above OEL	56.26