12-2006

Indoor Air Quality: Determination of VOC's in a Reproductive Clinic.

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Indoor Air Quality:
Determination of VOCs in a Reproductive Clinic

A thesis

presented to

the faculty of the Department of Environmental Health

East Tennessee State University

In partial fulfillment

of the requirements for the degree

Master of Science in Environmental Health

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by

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December 2006

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Keywords: Indoor Air Quality, Carbon Dioxide, Reproductive Clinic, *In Vitro*, Ventilation

ABSTRACT

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The purpose of this study was to perform an indoor air quality (IAQ) investigation at the Center for Applied Reproductive Science (CARS) to assess whether VOCs exist at levels dangerous to embryo. Formaldehyde, n-hexane, benzene, and styrene concentrations were measured at six locations. Formaldehyde concentrations were comparable to office and residential indoor air. N-hexane, benzene, and styrene were not detected. In addition, acetaldehyde, ethanol, and isopropyl alcohol were detected. IAQ parameters (carbon dioxide, temperature, humidity, pressure, and particulates) were measured at 22 sites monthly for one year. Temperature and humidity readings were within Environmental Protection Agency recommendations. Particulate concentrations were below Occupational Safety and Health Administration standards. Pressure readings indicated the facility was under a negative pressure. Carbon dioxide concentrations exceeded recommendations established by American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). Recommendations include assessing air intakes to assure dampers are adjusted to allow 15 ft^3/min/person of fresh air established by ASHRAE.

DEDICATION

I would like to like to dedicate this thesis to my two wonderful children, Allen and Shannon. They have been ever so patient and understanding during these times in my attempt to make a better life for them. It is because of them that I have strived so hard to succeed. I would also like to thank my boyfriend, Jeff. He has stayed by my side and supported me (both financially and emotionally) and even encouraged me to further my education.

ACKNOWLEDGMENTS

I would like to thank my committee members Dr. Phillip Scheuerman, Dr. Creg Bishop, and Dr. John Kalbfleisch for all of their help and support. I would also like to thank Dr. William Garside of the Center for Applied Reproductive Science for his patience and advice during this project. I would also like to thank my colleagues, Douglas Dulaney, Maria Floresguerra, Josh Culver, and Travis Holt, for their help during sampling and Chuck Patton for all his help behind the scenes. Special thanks go to my daughter, Shannon, for her assistance in sampling.

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CHAPTER 1

INTRODUCTION

In urban areas outdoor air pollution because of a higher volume of traffic, construction, adjacent buildings, and industry can lead to an increase in indoor air pollution. Because a great portion of indoor air comes from outdoors, there is an increased risk of bringing pollution into the indoor environment. Kukadia and Palmer (1996) have shown that outdoor air quality has a proportional impact on indoor air quality. When pollutant concentrations are high outside, the indoor concentration tends to also be higher (Kukadia and Palmer 1996).

According to Cohen et al., (1998) the air quality in reproductive clinics is far less suitable for humans than air quality in homes, businesses, and schools. There have been a limited number of studies investigating the indoor air quality of human fertility clinics. These studies, along with experimental data performed by Jacques Cohen, PhD, Scientific Director of Assisted Reproduction at The Institute of Reproductive Medicine and Science at Saint Barnabas, Livingston, New Jersey are being used by Dr. Cohen to further substantiate that indoor air quality at reproductive clinics is somewhat lower than other public and private environments (i.e., homes, businesses, schools). This may be because of the substances used in the clinics. Because reproductive clinics are typically laboratory facilities, they often contain compressed gases, cleaning supplies, sterilizing agents, and plastics. Such substances may contribute to the overall air quality and ultimately affect embryos stored at these facilities. The effects of outdoor pollution and

other factors that contribute to indoor air pollution may be detrimental to embryos *in vitro*.

During the *in vitro* fertilization process, the sperm and egg are exposed to any environmental contaminants that may be in the laboratory. The resulting embryos exposed to these environmental contaminants may succumb to concentrations much lower than the most sensitive populations (children, the elderly, or the immune compromised). Cohen et al. (1997) have shown that common occurrences such as spraying for insects can lead to decreased implantation success rates of mouse embryos. In their 10-month study, Cohen et al. (1997) observed decreased success rates that correlate with fumigation for insects and remodeling activities such as painting, installing floor tiles, and installing a bench-top.

Cohen et al. (1998) concluded that Volatile Organic Chemicals (VOCs) associated with resurfacing a parking lot near The Institute for Reproductive Medicine and Science of Saint Barnabas, in Livingston, New Jersey was responsible for a decrease in embryo survival. Significant concentrations of compounds used in the resurfacing, such as acrolein, hexanal, decanal, and pentanal, were detected in the facility. The conclusion that the VOCs were responsible for the decrease in success rates was determined by exposing mouse embryos to various concentrations (some in the ppb range) of acrolein (Cohen et al. 1998). As a result of these studies, I think it is important *in vitro* fertilization facilities are monitored for contaminants that may decrease the success rates of pregnancy.

Background

Doctors at the Center for Applied Reproductive Science (CARS) in Johnson City, Tennessee requested an air quality investigation to determine the concentration of VOCs. Concerns were related to decreased fertility rates at other fertility clinics because of elevated concentrations of VOCs from construction activities. The objective for sampling was to determine if there were VOCs present in concentrations that would cause a decrease in fertility rates. The concern was that fertility rates might be consistently lower than optimal because of the continuing presence of contaminants. According to information obtained from the Center for Disease Control and Prevention's (CDC) annual Assisted Reproductive Technology Report (ART), the fertility rates for CARS were slightly below industry averages for the years 2002 and 2003 (U.S. Department of Health and Human Services 2004; U.S. Department of Health and Human Services 2005). No fertility rate data for the clinic were available at the CDC before 2002 for comparing previous fertility rates.

The Center for Applied Reproductive Science (CARS) was established in January 1996. The office suite was renovated from January 1996 until December 31, 1996 to accommodate the needs of the doctors and patients for *in vitro* fertilization. During this time, the office was not open for business. The CARS location in Johnson City, TN was officially opened on January 1, 1997.

The CARS is located on the third floor of the medical center office building directly behind the Johnson City Medical Center Hospital. It is a facility that performs *in vitro* fertilization. All fertilization and implantation procedures are performed in the

clinic. Because of the nature of the procedure, the fertilized embryo must be stored in incubators before implantation.

The fertilized embryos are stored in 5 incubators that are supplied with 6 % Carbon dioxide (CO_2) and 94% ambient air. The ambient air is introduced to the incubators after it has been filtered through a charcoal filtration system located in the back of the unit.

Objectives

1. To determine if concentrations of VOCs are elevated within the fertility clinic compared to other fertility clinics.
2. To perform an assessment of general indoor air quality (i.e. temperature, humidity, carbon dioxide, carbon monoxide, pressure, particulates).
3. To do a detailed investigation to determine if there are any contributing factors affecting indoor air quality.
4. To investigate ambient CO_2 concentrations and determine if they are elevated.

Limitations of the Study

Limitations of this study include the lack of data about the concentration of indoor pollutants, such as VOCs (benzene, formaldehyde, styrene, etc.), that harm developing embryos. Because there have been few studies on the impact of indoor pollutants on embryos, and those that have been done were for specific compounds, establishing harmful concentrations is not feasible for this study.

CHAPTER 2

LITERATURE REVIEW

Indoor air quality (IAQ) has become an increasingly significant issue. In the last two decades, stricter building standards and the desire to improve energy efficiency has led to the construction of airtight buildings. This has created an indoor air quality problem. Because most buildings are no longer "well ventilated", chemicals that are used in construction and everyday use accumulate or are re-circulated throughout the building (Harrison 1997). Contaminants of concern include building materials such as wood, paints, resins, carpeting, sealants, and fiberglass. There can also be adverse health effects from common everyday products, which may include cleaning solutions, perfumes, and insecticides (Zummo and Karol 1996). These compounds are major contributors to building related illness (BRI) and sick building syndrome (SBS). The causes of BRI and SBS can be attributed to the lack of adequate amounts of outdoor air introduced into the building, the presence of various combinations of chemical and microbiological contaminants, and insufficient temperature and relative humidity (Lynch and Kipen 1998).

Total Volatile Organic Compounds (TVOCs)

Although VOCs are often associated with adverse health effects such as allergies, sensory irritation, and chemical sensitivities, the source and specific effects can be difficult to determine. Because there are so many compounds that make up TVOCs, using them as a risk indicator has been questioned. This is because of the different effects that

individual VOCs have on people. One of the limitations of trying to use TVOCs as an indicator of air quality is that the effect of TVOCs on human health depends on the individual compounds and what affect each compound has on human health. Because TVOCs are uncertain of mixtures, the overall health effects for different individuals (young, elderly, immune compromised, etc.) may vary. Therefore, to use TVOCs as a measure of exposure does not account for which compounds are present or their varying concentrations and, more importantly, which compounds are responsible for any adverse health effects (Andersson 1997).

Formaldehyde

Formaldehyde is an organic compound that is commonly used in building materials and industrial processes. It is classified as a class B carcinogen. Scientific evidence shows that formaldehyde can cause nasal cancer in rats (U.S. EPA 1991). Although there is insufficient evidence that it causes cancer in humans, there are other health effects caused by formaldehyde. Health effects in humans include, but are not limited to, respiratory, eye, and skin irritation (U.S. EPA 1991).

Formaldehyde is commonly found indoors, especially during construction or remodeling. The increase in concentrations in indoor environments is caused by the use of formaldehyde in building materials (Wolkoff and Nielsen 2001). Construction of airtight buildings prevents formaldehyde from escaping the indoor environment. Although there is a background concentration of formaldehyde, proper ventilation can alleviate an increase, and with time, concentrations of formaldehyde will decrease (Wolkoff and Nielsen 2001).

Indoor and outdoor background concentrations of formaldehyde are typically <0.03 ppm. The OSHA permissible exposure limit (PEL) for an 8-hour time weighted average (TWA) of formaldehyde is 0.75 ppm. NIOSH recommends an exposure limit for an 8-hour TWA not to exceed 0.016 ppm (ATSDR 1999a).

Aerosol concentrations of formaldehyde depend on temperature and humidity (Possanzini et al. 2002). As temperature and humidity increase, concentrations of formaldehyde increase. Likewise, as temperature and humidity decrease, concentrations of formaldehyde decrease (Possanzini et al. 2002).

Benzene

Benzene is an aromatic hydrocarbon that is found in many common products. It is found in paints, adhesives, tobacco smoke, laser printers, building materials, petroleum products, and many other products. Tobacco smoke and gasoline fumes are probably the most common non-occupational exposures to benzene.

Benzene is classified by the U.S. EPA as a Class A carcinogen or known human carcinogen. Long-term exposure to high concentrations of benzene can lead to acute myeloid leukemia (AML) (ATSDR 1997). Acute exposures to high concentrations of benzene (700-3000 ppm) can cause dizziness, headaches, tremors, confusion, drowsiness, rapid heart rate, and even unconsciousness. Because benzene is a known human carcinogen, the OSHA standard for workers is 1 ppm as an eight hour TWA. Respiratory protection should be used if there is exposure to benzene (ATSDR 1997).

Acute exposures to benzene may cause toxicity in embryos *in vitro* (ATSDR 1997). Brown-Woodman et al. (1994) showed that embryo toxicity occurred in rat

embryos exposed *in vitro* for 2 days to 1.56 μmole benzene/mL. The effects of the exposure of 10-day-old embryos included a decrease in the yolk sac diameter and protein content (Brown-Woodman et al. 1994). Although it is unlikely that human embryos will be exposed to this concentration (1.56 μmole benzene/mL), Brown-Woodman et al. (1994) demonstrated that this concentration is toxic *in vitro* to rat embryos.

Styrene

Styrene (also known as ethylbenzene) is an aromatic hydrocarbon that is commonly used as an intermediate in the production of products such as styrene butadiene rubber, which is used in carpet backing (ATSDR 1992). Other uses for styrene include the manufacture of building materials, plastics, insulation, and resins. Styrene can also be found in tobacco smoke and automobile exhaust and occurs naturally in some fruits, vegetables, nuts, meats, and beverages (ATSDR 1992).

According to the United States Environmental Protection Agency (EPA), styrene is classified as a known toxicant and possible human carcinogen. Studies designed to determine the carcinogenicity of styrene are inconclusive. Although it is classified as a human carcinogen in the U.S. EPA Toxic Release Inventory, there is insufficient evidence that styrene causes cancer (U.S. EPA 1993).

Animal studies indicate that styrene can have reproductive and developmental effects (ATSDR 1992). Brown-Woodman et al. (1994) demonstrated that embryo toxicity occurs *in vitro* in rat embryos exposed for 2 days to 1.0 μmole styrene/mL. The styrene metabolite styrene oxide is more toxic with a lower toxicity threshold of 0.038 μmole styrene/mL.

Volatile Organic Compound Sampling Methods

Volatile organic compounds, whether they originate outdoors or indoors, are a major source of indoor air pollution. Although it is hard to quantify the compounds that contribute to health problems, there are methods that can be used to identify what compounds may be present in the air.

Sampling indoor air quality can be accomplished using several methods. For sampling indoor air quality in an occupant building (e.g., office building, school, tenant complex, and non industrial building) with low concentrations of organic chemicals, passive sampling is an effective method. Although the sampling rate is low and sampling time is long, passive sampling methods are effective for determining time-weighted average (TWA) concentrations (Zabiegala et al. 2002). Other advantages of passive sampling include the reduced cost of labor because of minimal set up time and low maintenance. Passive sampling is also less intrusive for the employee. A disadvantage of passive samplers is the high costs of sampling badges. They are also not as sensitive as other methods because of the lower sampling rate (Nothstein et al. 2000). Although there are some disadvantages, Nothstein et al. (2000) provided evidence based on material, labor, and validation costs, that passive sampling was more cost effective than active sampling methods. Zabiegala et al. (2002) compared active and passive sampling and concluded that there were no significant differences in the results obtained using these methods.

Active sampling offers short or long (15 min. to 24 hours) sampling times to provide a TWA, but the equipment (pumps, flow meters, chargers, battery packs, etc.)

can be expensive and cumbersome for employees (Zabiegala et al. 2002). Active sampling methods for evaluating indoor air quality include sorption tubes (e.g., charcoal tubes, Tenax TA tubes, silica gel, etc.), impingers, and cassettes with filters. The disadvantage of this type of sampling is the initial cost of purchasing the equipment necessary to operate active samplers. There is the constant added expense of sorbent tubes, cassettes, and filters. There is also an added expense of industrial hygiene (IH) personnel to maintain and calibrate the equipment. Other disadvantages include the possibility of a sampling error because of a pump failure or loss of calibration (Nothstein et al. 2000). However, when samples are properly collected, the results are comparable to passive sampling methods (Zabiegala et al. 2002).

Photo ionization detectors (PID) are useful tools for detecting VOCs. PIDs are direct reading instruments that use a 10.6 eV lamp and Ultraviolet (UV) light to ionize compounds that can be counted by a detector (RAE Systems, Inc. 2001). The PID offers instantaneous results and can be used for both short and long-term sampling (up to 10 hours) and can detect a wide variety of volatile organic compounds. Most PIDs are equipped with data logging capabilities that provide exposure concentration over time (Coy et al. 2000). This capability allows the industrial hygienist to determine the exposure rates at different times of the day. The disadvantage of the PID is the underestimated readings of high concentrations of compounds. Coy et al. (2000) showed that the PID would result in underestimated hydrocarbon concentrations. However, the PID is a cost effective and accurate method for detecting low concentrations of VOCs.

IAQ of Reproductive Clinics

The presence of the highly sensitive embryos in reproductive clinics requires superb indoor air quality to insure survival and successful development. Because standards for air quality do not take into account this population, it is the responsibility of the clinic to assure that air quality is adequate for *in vitro* embryos.

Most studies involving toxicological effects of VOCs on embryos are done on *in vivo* animal and human embryos. Once an embryo has been implanted, it is partially protected from environmental contaminants by the mother's defense system. The EPA and United States Food and Drug Administration (FDA) only require toxicological studies on post implantation embryos and offspring (Cohen et al. 1997). This does not take into account the toxicological effects of VOCs on a pre-implantation embryo that is unprotected and exposed to ambient air. Embryos *in vitro* lack necessary defenses, such as a functional liver, to battle harmful VOCs and detoxify contaminants. They don't have developed immune systems and are defenseless against VOCs. They also lack physical barriers, such as an epithelium, excretory mechanisms, and pulmonary function to fight off contamination (Hall et al. 1998).

Embryos that are stored in incubators are at risk of contamination. The supplied CO_2 required to sustain the embryo (6% or 60,000 ppm) is often from deteriorated bottles that contain low concentrations of organic compounds. Medical grade CO_2 is reported to contain compounds such as benzene, alcohols, and chlorinated organics, such as freon (Cohen et al. 1997). The other 94% of the air supplied to incubators comes from ambient air. Any contamination found outside the incubators will likely be present inside the incubator (Cohen et al. 1997). Most incubators are equipped with filters to lower

contaminants from the ambient air. Often incubators are opened and embryos are exposed to ambient air without the benefit of filtration. Despite the use of filtration and extreme caution, embryos are commonly in contact with VOCs from petri dishes, test tubes, culture media flasks, and the ambient air (Cohen et al. 1997).

Cleanrooms can be constructed to lower the probability of contamination to embryos. A cleanroom is equipped with its own ventilation system containing ultra low penetrating air (ULPA) filters and UV free fluorescent lighting (Boone et al. 1998). An anteroom that leads to the cleanroom houses a UV light to eliminate any microbial contamination and ULPA filters to reduce particulates and contaminants. The cleanroom and anteroom operate under positive air pressure. Cleanrooms designed for fertility clinics typically have high air exchange rates (~20.5 air exchanges per hour) and are constructed from non-shedding materials (Boone et al. 1998). Boone et al. (1998) showed an increase in pregnancy rates after the construction of a cleanroom. Before construction of the cleanroom, pregnancy rates decreased from 35% in 1993 to 16% in 1994 reportedly because of VOCs emitted during remodeling of a lab. After construction of the cleanroom, pregnancy rates gradually increased to a rate of 59% by 1997 (Boone et al. 1998). This increase provides clear evidence of the importance of indoor air quality in a reproductive setting.

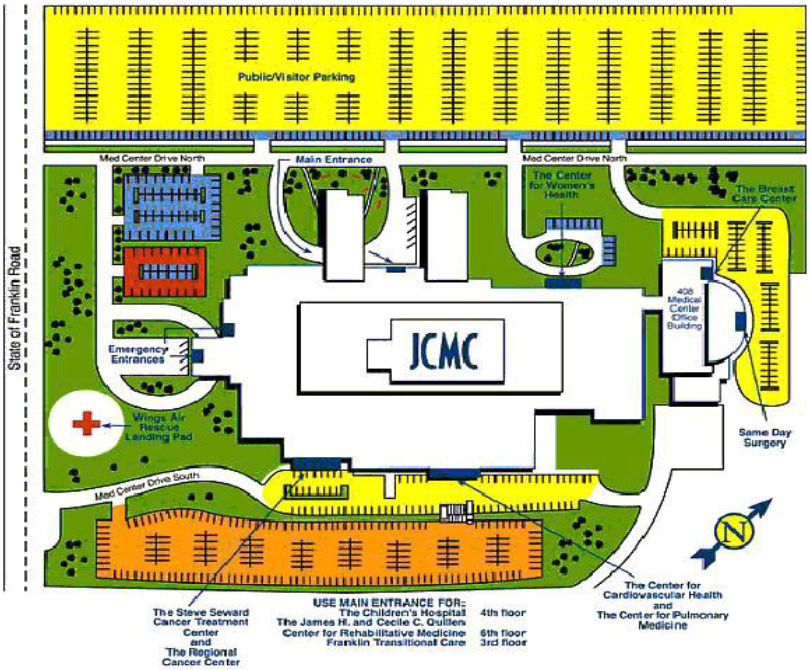
Based on information in these studies and a request from the doctors at the Center for Applied Reproductive Science (CARS), an indoor air quality investigation of predetermined VOCs (benzene, styrene, n-hexane, and formaldehyde) was initiated. Because of the surrounding activities at the CARS facility, VOCs related to automobiles, storage of styrene containing products, building materials from the recent remodeling of

the facility, and cleaning products (i.e., floor wax, bathroom cleaners, etc.) was investigated. The selected VOCs were sampled to determine if the chemicals present in the ambient air could be associated with a decrease in fertility rates. Although there are several factors involved in the success of implantation and full term pregnancy, this investigation only focuses on the localized air quality of the exposed embryos before implantation and how that air may affect an embryo.

CHAPTER 3

METHODOLOGY

The Center for Applied Reproductive Science is located on the third floor of the medical center office building directly behind the Johnson City Medical Center Hospital (Figure 1). The study area covers approximately 6000 sq. ft. There are 30 offices and patient areas in the clinic. Of these 30 offices, 21 were chosen for sampling of air quality baseline parameters (CO_2, CO, temperature, humidity, pressure, and particulates). These 21 sample sites were measured once a month for one year at approximately the same time of day (1:00 pm – 2:00 pm). These times were requested by the clinic because of the patient load and sample site availability. A site could not be sampled if a patient occupied it.



Source: The Center for Applied Reproductive Science

Figure 1 Aerial representation of the Johnson City Medical Center Hospital (CARS 2003). The Center for Applied Reproductive Science is located on the 3rd floor of the Medical Center Office Building located behind the JCMCH

In indoor environments, elevated CO_2 concentrations are often the result of human activity. An experiment was performed to determine if the increased concentrations that were consistently found at the clinic in late afternoon were the result of human activity or because of the CO_2 tanks used in the clinic. The experiment involved taking CO_2 measurements early in the morning, midday, and late afternoon during business hours. To further evaluate whether the elevated concentrations were the result of human occupancy, measurements were taken on a day where there was no human occupancy. This was done for two independent sites: at the fertility clinic and in a classroom at East Tennessee State University.

For short term monitoring of VOCs, nine sites within the facility were chosen. They were chosen based on an initial walk through and an inventory of the facility. The sites are described in Table 1. Each site was sampled for benzene, styrene, n-hexane, and formaldehyde. Benzene and n-hexane were chosen because of the constant flow of vehicle traffic through the area. High concentrations of these compounds could be indicators that exhaust fumes from vehicles (cars, trucks, buses, helicopters, etc.) are entering the ventilation system.

Styrene was chosen because of the use of styrene products in the clinic. The clinic has dedicated a closet (approximately 6' by 8') to store and off-gas styrene from these products. The problem is that the ventilation system in this closet is part of the same system as the in-vitro laboratories.

Formaldehyde is a compound that is commonly used in building materials and carpeting. Because the clinic has been remodeled and new carpeting was installed, there was potential for increased formaldehyde concentrations.

Table 1 Sample Site Locations. Sample locations at The Center for Applied Reproductive Science for Detection of Volatile Organic Compounds (VOCs) using a Portable Photo Ionization Detector (MiniRAE 2000)

Sample Site ID	Sample Location
Site 1	Room 349-With H_2O Faucet on-Near Incubators
Site 2	Room 349-Near Incubators-Embryo Storage
Site 3	Room 347-Cryo Laboratory-Sperm Storage
Site 4	Room 342-Tank Storage (CO_2 and N_2)
Site 5	Room 339-Styrene Storage Closet
Site 6	Room 338-Doctors Office (Near window)
Site 7	Room 321-Endocrine Laboratory
Site 8	Room 319-Cleaning Closet
Site 9	Room 303-Copy Machine/Receptionist Area
Site 10	Hospital-2nd Floor-Control
Site 11	Outside- Under Fresh Air Intake

VOCs (benzene, n-hexane, styrene, and formaldehyde) were measured using a portable photo ionization detector (PID) the MiniRAE 2000, (RAE Systems, San Jose, CA). The PID is a "real time" monitoring instrument that can also be used for long-term measurements. For this study, it was only used for "real time" measurements. Long-term measurements were collected using seven diffusive organic vapor-monitoring badges. One badge was placed in each area (total of six areas) and one badge was placed outside.

Industrial Hygiene Air Sampling Methods

This study used a combination of "real time" and long term monitoring of the ambient indoor air within the clinic. Air quality parameters were measured using several real time instruments (CO_2 and CO monitor, particulate counter, velocity meter, and PID). One measurement per site was taken in the designated sample sites within the breathing zone. The results were then recorded on a data sheet.

Q-TRAK™ IAQ Monitor

The Q-TRAK™ IAQ Monitor, Model 8551 (TSI inc., St. Paul, MN) is a hand held instrument equipped with a single probe to measure carbon dioxide (ppm), carbon monoxide (ppm), temperature (°F/°C), and % relative humidity. To measure CO_2, the Q-TRAK™ is equipped with a non-dispersive infrared sensor (TSI, Inc. 2001). This instrument can measure a range of CO_2 concentrations from 0 to 5000 ppm with an accuracy of 63% of reading or 650 ppm (TSI, Inc. 2001). For measuring CO, the Q-TRAK™ is equipped with an electrochemical sensor; can measure a range of CO concentrations from 0 to 500 ppm; and has an accuracy of 63% of reading or 3 ppm, whichever is greater (TSI, Inc. 2001).

DUSTTRAK™ Aerosol Monitor

The DUSTTRAK™ Aerosol Monitor, Model 8520 (TSI, inc., St. Paul, MN) is a portable laser photometer that is used to detect particulate matter (TSI, Inc. 2000). It provides instantaneous measurements in mg/m^3 and measures a range from 0.001 mg/m^3 to 100 mg/m^3 (TSI, Inc. 2000). The DUSTTRAK™ is also capable of measuring particulates that range from 0.1 microns to 10 microns. There are two sizes of particulates of concern at the clinic, total particulates ($\leq$10 μm) and respirable particulates (<2.5 μm). The DUSTTRAK™ is equipped with interchangeable adaptors to change the particulate size measured. For each site, the instrument automatically calculates and records the average concentration of a 20-second measurement.

Velocicalc® Ventilation Meter

The VelociCalc® Plus Multi-Parameter Ventilation Meter, Model 8386 (TSI, inc., St. Paul, MN) is a real time instrument that was used to measure static pressure readings. The Velocicalc® measures several parameters using a probe with multiple sensors. Parameters include: velocity, volumetric flow rate, temperature, differential pressure, humidity, and heat flow.

MiniRAE 2000 - Organic Vapor Monitor

Initial measurements of VOCs were conducted using the MiniRAE 2000 Portable VOC Meter, Model PGM-7600 (RAE Systems, Inc., Sunnyvale, CA). The MiniRAE 2000 organic vapor monitor is a hand-held photo ionization detector (PID) that houses a 10.6 eV lamp. The PID is calibrated using isobutylene gas (100 ppm) and has correction factors for 102 VOCs. It has a detection limit of 0.1 ppm and was used for detecting benzene, styrene, formaldehyde and n-hexane. The MiniRAE 2000 organic vapor monitor complies with EPA Method 21 (RAE Systems, Inc. 2001).

Organic Vapor Diffusive Monitoring Badges

The diffusive monitors that were used for benzene, styrene, and total hydrocarbons as n-hexane are the full scan organic vapor monitors (OV-00) manufactured by Advanced Chemical Sensors, Inc., Boca Raton, FL. The price of the monitors included analysis for 50 compounds and a second monitor that was used as a quality assurance standard. Sample analyses were performed at the Advanced Chemical

Sensors, Inc. AIHA accredited laboratory in Boca Raton, FL. Compounds measured using the badges are listed in Table 2.

Table 2 List of 50 chemicals measured. Chemicals were measured using the OV-00 diffusive monitoring badges, by the Advanced Chemical Sensors, Inc. AIHA accredited laboratory

50 Chemicals analyzed with the OV-00 diffusive monitoring badges				
Acetone	Cellosolve	Dipropylene Glycol	Hexone (MIBK)	Pentane
Acetonitrile	Chlorobenzene	Ethyl Acetate	Isobutyl Alcohol	Perchloroethylene
Acrylonitrile	Chloroform	Ethyl Alcohol	Isopropyl Alcohol	Pyridine
Allyl Chloride	Cyclohexane	Ethyl Benzene	Isooctane	Styrene
Benzene	Cyclohexanol	Ethyl Ether	Methyl Acrylate	Tetrahydrofuran
2-Butanone (MEK)	Cyclohexanone	Ethoxyethanol	Methyl Chloroform	Toluene
Butyl Cellosolve	1,2 Dichloroethane	2-Ethoxyethyl Ether	Methyl Ether	Trichloroethane
Butyl Acetate	Dimethyl Formamide	Formamide	Methyl Methacrylate	Trichloroethylene
Butyl Carbitol	Dimethyl Sulfoxide	Heptane	Methyl-t-butyl-Ether	Vinyl Acetate
Carbon Tetrachloride	Dioxane	Hexane	Methylene Chloride	Xylene

One diffusive organic vapor monitor (OV-00) was hung in the breathing zone in each sample area. Six badges were placed in sites within the clinic. A badge was hung outside to detect any compounds that may affect the indoor air quality. Because the fresh air intake provides outdoor air into the indoor environment, it was essential to determine if there were any harmful contaminants being pulled into the ventilation system.

Formaldehyde was measured using the formaldehyde vapor monitor (F-50), also manufactured by Advanced Chemical Sensors, Inc. These monitors also included a prepaid analysis and report. Sample analyses was performed at the Advanced Chemical Sensors, Inc. AIHA accredited laboratory.

The formaldehyde monitors were also used to analyze acetaldehyde. The formaldehyde/acetaldehyde badges were placed in three locations. One badge was placed near the incubators, another was placed in the lobby of the clinic, and a third badge was hung outside on a tree between the parking lot and the entrance of the building.

Quality Assurance/Quality Control

The quality assurance and control program (QA/QC) included a factory calibration of the Q-TRAK™ before starting the 12-month sampling of air quality parameters (CO, CO_2, temperature, and % relative humidity). The results of the calibration stated that CO_2 and % relative humidity accuracy were within 63% of reading. For temperature, accuracy was within 61% of reading. The Q-TRAK™ was also cleaned and calibrated (with calibration gases obtained from TSI, Inc.) before each sampling event. Calibration gases included one zero air standard containing contamination ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO with oxygen content between 18-21% vol. and one standard with 35 ppm CO and 1000 ppm CO_2. Calibration of the equipment was followed according to manufacturers' instructions.

The DUSTTRAK™ was calibrated for proper flow rates before sampling. The flow rate was calibrated at 1.7 L/min and was checked before each sampling event to assure accuracy. The instrument's internal housing was cleaned and the internal filter was replaced before initial sampling. A thorough cleaning with isopropanol was performed on the interchangeable particulate adapters and nozzle before each sampling event. Isopropanol is the recommended cleaning solvent (TSI, Inc. 2000).

Before initial sampling for VOCs, the organic vapor monitor (MiniRAE 2000) was calibrated using a calibration kit obtained from RAE Systems, Inc. The calibration kit included a charcoal filter for the fresh air calibration and a 100-ppm isobutylene gas cylinder. Calibration of the MiniRAE 2000 was performed according to manufacturer's instructions. The results of the fresh air and isobutylene gas calibration assure an accuracy of 62%.

Control sites were used for QA/QC of air quality parameters (CO_2, CO, temperature, humidity, particulates, and pressure). Included was an outside control, positioned away from the front entrance and beneath a fresh air intake located between the second and third floor. There were three inside controls: one on the first floor, one on the second floor, and one on the fourth floor. All three of these control sites were located in front of the elevators (lobby area). The last control site was the ventilation control. This site was located on the third floor in front of the elevators. This site was chosen because it was part of the same ventilation system but was not within the enclosed area of the clinic.

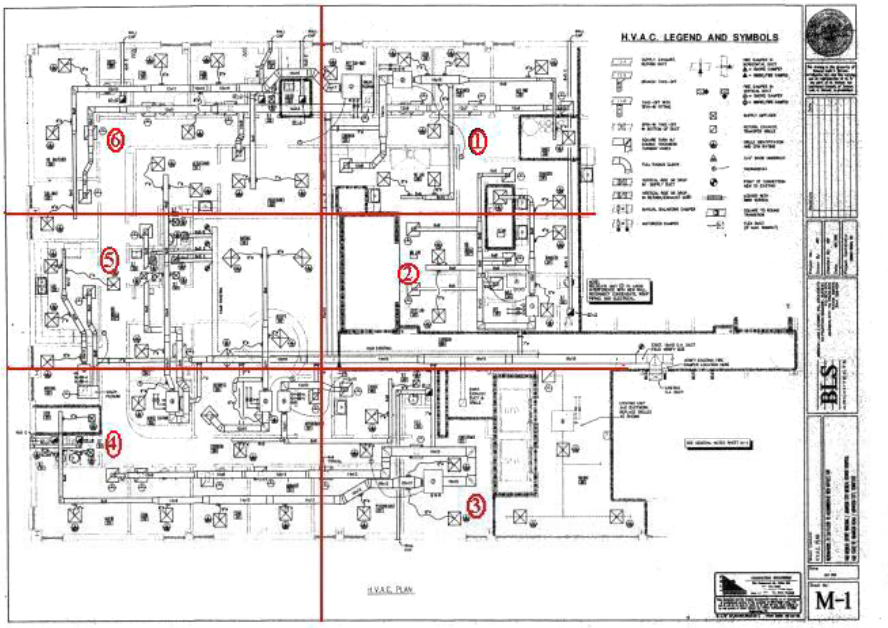
Data Analysis

The air parameters measured were CO_2, air pressure, humidity, temperature, and particulates (respirable and total). Air parameters were measured once a month for one year (April 2002-March 2003). For statistical analysis, the clinic was also subdivided into a grid of six equal areas of 1000 sq. ft. per area (Figure 2). Areas 1 and 2 include doctors' offices and laboratories where embryos and sperm are stored and where the in vitro fertilization process is performed. Area 3 is the lunchroom/conference room and kitchen

section. Area 4 includes nurses' stations and laboratories. Area 5 includes patient examination rooms and a lobby/waiting room. Area 6 includes patient examination rooms and doctors' offices (Table 3).

Table 3 Clinic areas. The clinic was divided into six areas. Each area has distinct sections associated with it

Area	Location
1	Doctors' offices and in vitro laboratories
2	Doctors' offices and in vitro laboratories
3	Lunchroom/conference room and kitchen area
4	Nurses' stations and laboratories
5	Patient examination rooms and lobby/waiting room
6	Patient examination rooms and doctors' offices



Source: Meca PC

Figure 2 Illustration of the fertility clinic subdivided into six areas (Meca Engineering, PC 1996).

Statistical analyses were performed using Minitab® Release 12.21(Minitab Inc., State College, PA). Descriptive statistics were calculated and recorded from the raw data for all sample sites (Appendix A). This was done for each parameter. Frequency

distributions were then graphed for each variable using Minitab® Release 12.21. This was done to provide an overall visual representation of all the data points.

The Anderson Darling test for normality and the homogeneity of variance was performed on the air parameters (CO_2, temperature, particulate concentrations, and humidity) to determine normality. Next, a preliminary statistical analysis was performed on the data using an Analysis of Variance (ANOVA) complex model, the General Linear Model (GLM) (Appendix A). Statistical significance for the analysis was established at $\alpha = 0.05$. Means were compared to determine statistically significant means between areas and between months and interactions between the months, areas, and individual sites. For multiple comparisons, Tukey's procedure was used (Appendix A). To determine statistical significance, $p \leq 0.05$ was used.

Boxplot and line graphs for each parameter, generated using Microcal™ Origin® Version 6.0 (OriginLab Corp., Northampton, Massachusetts), were used to visualize seasonal variation in the measured parameters. Interaction plots were used to compare areas by month.

Statistical analysis could not be performed on the VOC data because of a lack of statistical power, as there were not sufficient data for the PID results or VOC badges. For the VOC badges, there was only one data point for each of the six areas. The results of the badges will be reported and compared with previous data of other fertility clinic studies.

CHAPTER 4

RESULTS

Indoor Air Quality Parameters

Particulate loadings in the fertility clinic were one to two magnitudes lower than National Ambient Air Quality Standards (NAAQS) for respirable (NAAQS = 0.015 mg/m^3) and total (NAAQS = 0.05 mg/m^3) particulates. The lowest average yearly total particulate concentrations were in the doctors' offices/*in vitro* laboratory (Area 1) and patient examination rooms/doctors' offices (Area 6). Both areas had a yearly average concentration of 0.0028 mg/m^3. All other areas had yearly average concentrations between 0.0043 mg/m^3 and 0.0049 mg/m^3. Monthly and yearly ranges of concentrations of measured indoor air quality parameters are included in Table 4.

There were five control sites (one outside, four inside) that were measured once a month. Respirable particulates for the outside controls ranged from 0.010 mg/m^3 to 0.053 mg/m^3. Inside controls ranged from <0.001 mg/m^3 to 0.012 mg/m^3. Total particulates for the outside controls ranged from 0.012 mg/m^3 to 0.056 mg/m^3. Inside controls ranged from 0.001 mg/m^3 to 0.033 mg/m^3.

Table 4 Monthly and yearly range of concentrations of indoor air quality parameters. Monthly range refers to all samples in a given month averaged with the lowest monthly average and the highest monthly average. Yearly range refers to the average lowest and highest range for a given year

Parameter	Monthly Range		Yearly Range	
	Minimum	Maximum	Minimum	Maximum
Temperature (° C)	22.7	23.8	23.2	23.3
Relative Humidity (%)	29.7	46.2	38.6	39.7
Air Pressure (cm H_2O)	–0.00254	–0.14478	–0.10668	–0.10922
Respirable Particulates (mg/m^3)	0.0002	0.0012	0.00036	0.00075
Total Particulates (mg/m^3)	0.0019	0.0095	0.0028	0.0049
Carbon Dioxide (ppm)	933	1694	802	2043

Carbon Dioxide

All carbon dioxide concentrations for April 2002 to March 2003 were graphed using a frequency distribution to show individual data points (Figure 3). Carbon dioxide concentrations in the clinic ranged from 802 ppm to 2043 ppm with the yearly average of 1281 ppm. The CO_2 concentrations for the control data ranged from 333 ppm to 1049 ppm with a yearly average of 612 ppm.

There were five control sites (one outside, four inside) that were measured once a month. Carbon dioxide concentrations for the outside controls ranged from 333 ppm to 386 ppm with a yearly average of 366 ppm. The CO_2 concentrations for the inside controls (1^{st}, 2^{nd}, and 4^{th} floor) ranged from 493 ppm to 794 ppm with a yearly average of 594 ppm. The ventilation control (3^{rd} floor) CO_2 concentrations ranged from 707 ppm to 1049 ppm with a yearly average of 912 ppm. The raw data and the control data for CO_2 concentrations are in Appendix B.

The Anderson Darling Normality test performed on the monthly CO_2 concentrations did not follow a normal distribution ($p<0.001$) (Appendix A). The result of the normality test was used to determine the statistical analysis to be performed.

Monthly Distribution of CO_2 Concentrations

Average monthly carbon dioxide concentrations during April 2002 to March 2003 ranged from 933 ppm (July 2002) to 1694 ppm (September 2002). The CO_2 concentrations varied seasonally with concentrations higher during the fall (Figure 4). Statistical analysis of the data was performed using the ANOVA GLM to detect

differences between the months, interactions between months and areas, and sites within each area (Table 5). Based on the ANOVA GLM, CO_2 concentrations varied significantly ($p<0.001$) between months. A post hoc test of multiple comparisons using Tukey's procedure shows specifically where the significant differences occurred between months. The months of July and March resulted in the lowest mean CO_2 concentrations (933 ppm and 954 ppm, respectively) compared to the highest mean CO_2 concentration (1535 ppm and 1586 ppm) in August and September, respectively (Figure 5).

Table 5 F-Statistic results of the ANOVA. Results of ANOVA comparing months and areas of each parameter and the interactions between months, areas, and sites of those parameters

Study Effect	CO_2 (ppm)	Pressure (in. H_2O)	Temp (ºF)	Humidity (%)	Total Particulates (mg/m^3)	Respirable Particulates (mg/m^3)
Area	4.95	2.91	0.16	1.50	1.15	1.07
Site(Area)	*11.72	NA	*4.48	*2.40	1.00	NA
Month	*244.80	NA	*10.30	*298.03	*3.04	NA
Area*Month	*5.20	NA	*2.92	*2.04	0.99	NA

NA – analysis not feasible
* $p<0.01$

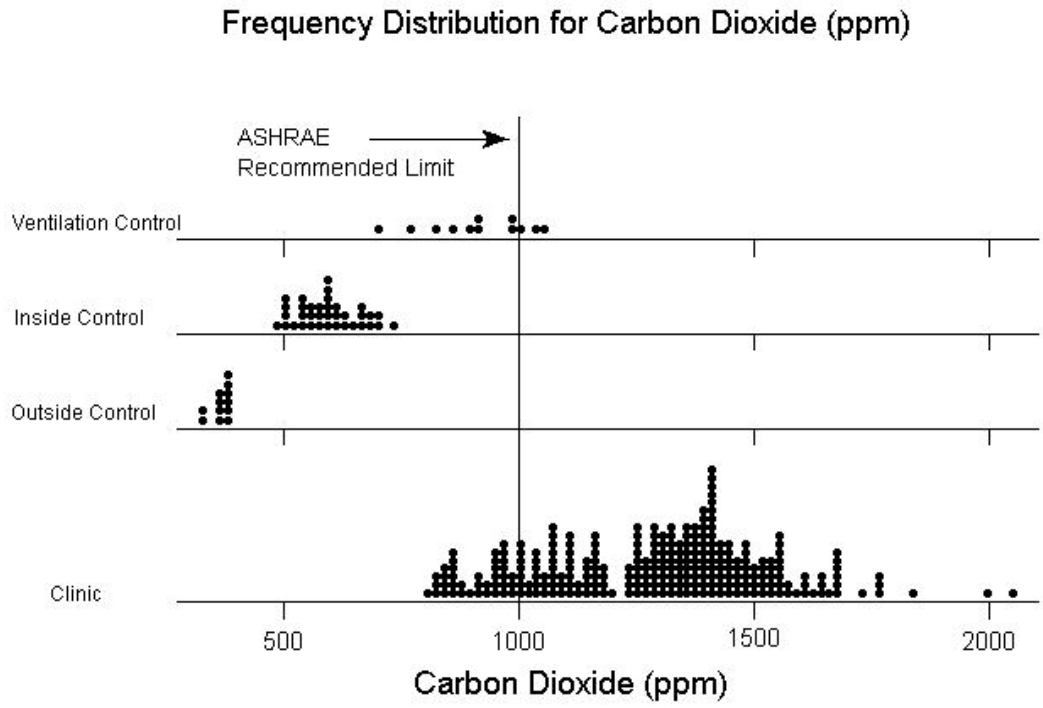


Figure 3 Frequency Distribution of CO_2 Concentrations. Frequency distribution of all carbon dioxide data points for one year (April '02 through March '03). Each dot represents one measurement. Ventilation control is part of the clinic ventilation system but not within the enclosed area of the clinic. The inside controls were located on the 1st, 2nd, and 4th floor lobby area. The outside control was located under the fresh air intake

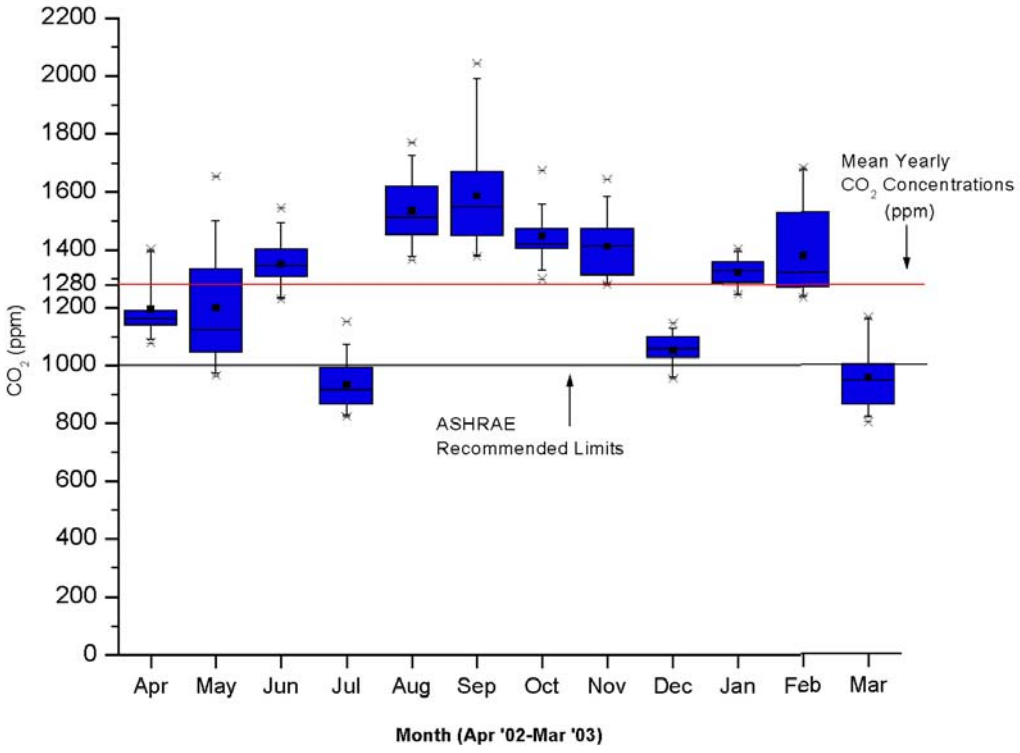


Figure 4 Monthly CO_2 concentrations (ppm) for all sample sites in the fertility clinic. The boxes represent the inner 25th and 75th percentile. The line through each box represents the median. The small solid black inner boxes represent the mean. The whiskers represent the 5th and 95th percentile. The x represents the 1st and 99th percentile and the line through the x represents the minimum and maximum. The red line represents the mean yearly CO_2 concentrations (ppm) for all months

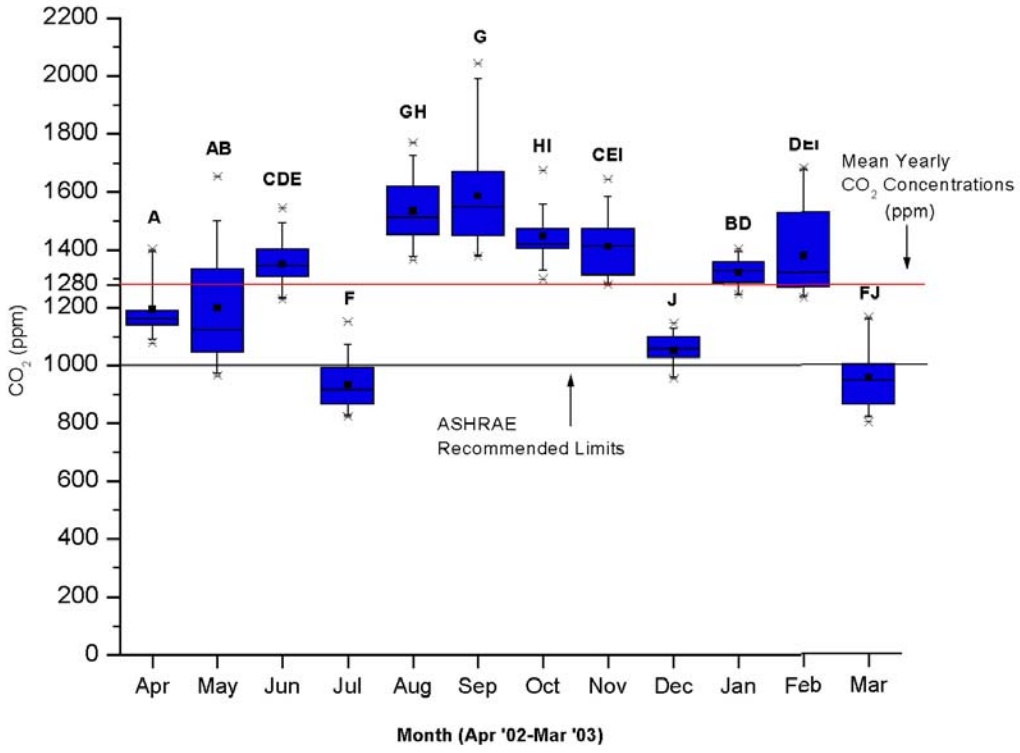


Figure 5 Comparison of monthly CO_2 concentrations. CO_2 concentrations in months with a corresponding letter are not significantly different ($p>0.05$). On the graph, the box represents the inner 25th and 75th percentile. The line through each box represents the median. The small solid black inner boxes represent the mean. The whiskers represent the 5th and 95th percentile. The x represents the 1st and 99th percentile, and the line through the x represents the minimum and maximum. The red line represents the mean yearly CO_2 concentrations (ppm) for all months

Variation in CO_2 Concentrations by Area

Because there are several heat pump systems located throughout the clinic, an analysis was performed on six areas within the clinic. Average yearly CO_2 concentrations varied significantly between the six areas ($p\leq0.006$) (Figure 6). A post hoc test of multiple comparisons using Tukey's procedure shows specifically where the significant differences occurred between areas (Figure 7). There are no significant differences in the nurses' station/laboratory area (Area 4) and patient examination rooms and lobby/waiting

room area (Area 5). Areas 1, 3, and 6 also had no significant differences and Area 1 and 2 had no significant differences.

Average monthly concentrations of carbon dioxide varied significantly between months and areas ($p<0.001$). A 3D surface plot was generated to detect the monthly differences between areas (Figure 8). Interaction plots comparing the 12 months and 6 areas show that there are interactions between month and area (Figures 9-10).

Identification of Potential Sources of CO_2

Sampling at the clinic was performed in the afternoon (~1:00 pm-3:00 pm) following peak occupancy. The CO_2 concentrations following peak occupancy were assumed to represent the highest concentrations of the day. To validate this assumption, an experiment was performed at the CARS clinic and in a classroom at ETSU to establish the change in CO_2 concentration during the day and how the increase related to occupancy.

The experiments were performed to evaluate if the increased CO_2 concentrations in occupied buildings were because of human activity. In the ETSU study, a classroom that was occupied with students coming and going throughout the day (with the door closed) was monitored to establish if occupants contributed to increased CO_2 concentrations. The study also provided data that suggest continued occupancy contributes to higher CO_2 concentrations. The CO_2 concentration was measured at 8:15 am and was measured periodically (~ every 4 hours). The beginning CO_2 concentration was 550 ppm and steadily increased to ~2400 ppm at ~4:00 pm (Figure 11).

To further substantiate the evidence that increased concentrations were because of human activity, CO_2 concentrations at the ETSU classroom was measured throughout the day when the building was unoccupied. The CO_2 concentrations in the unoccupied building were substantially lower with concentrations not exceeding 374 ppm (Figure 12) compared to outdoor ambient concentrations of ~350 ppm.

A second experiment was performed at the clinic. The sampling at the CARS clinic started at 8:45 am shortly after the clinic opened and continued until closing at ~4:00 pm. At 8:45 am, the CO_2 concentrations were measured at 727 ppm. As the day progressed and the total number of occupants increased at the CARS clinic, the CO_2 concentrations increased. At approximately 2:00 pm, the number of the patients seen at the clinic started to decrease and the CO_2 concentrations began to stabilize at ~1900 ppm and remained at ~1900 ppm until 4:00 pm.

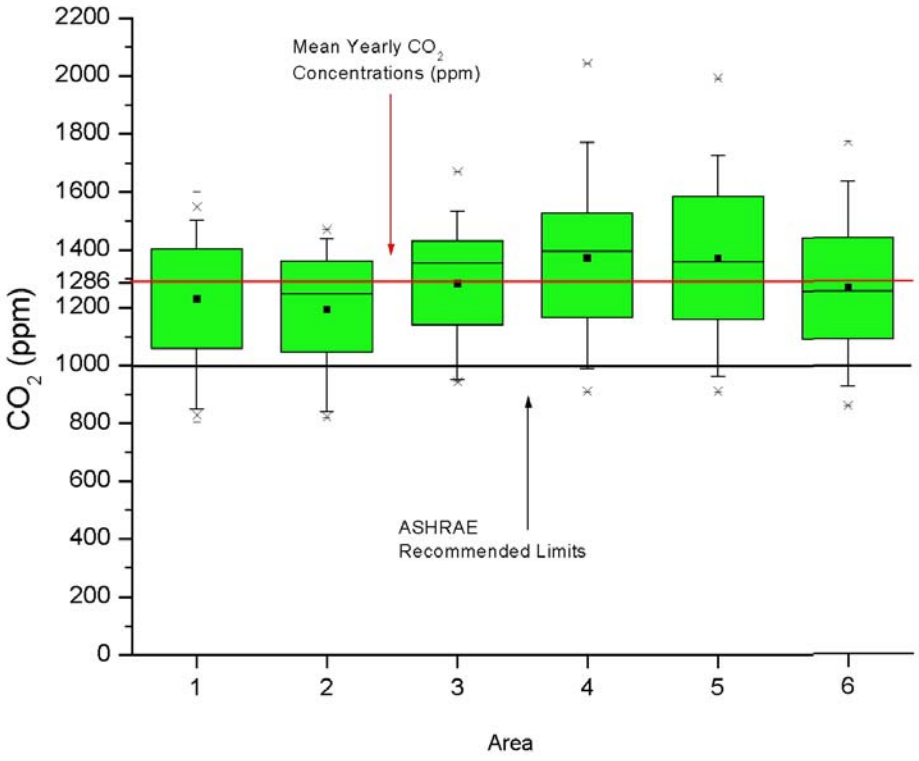


Figure 6 Mean yearly CO_2 concentrations (ppm) for all areas. Measurements were taken in 6 areas (total of 22 sample sites) once a month for 12 months. Areas 1 and 2 include doctors' offices and laboratories where embryos and sperm are stored. These areas are where the in vitro fertilization process is performed. Area 3 is the lunchroom/conference room and kitchen section. Area 4 includes nurses' stations and laboratories. Area 5 includes patient examination rooms and a lobby/waiting room. Area 6 includes patient examination rooms and doctors' offices. On the graph, each box represents the inner 25th and 75th percentile. The line through each box represents the median. The small solid black inner boxes represent the mean. The whiskers represent the 5th and 95th percentile. The x represents the 1st and 99th percentile, and the line above or through the x represents the minimum and maximum. The red line represents the mean yearly CO_2 concentrations (ppm) for all areas

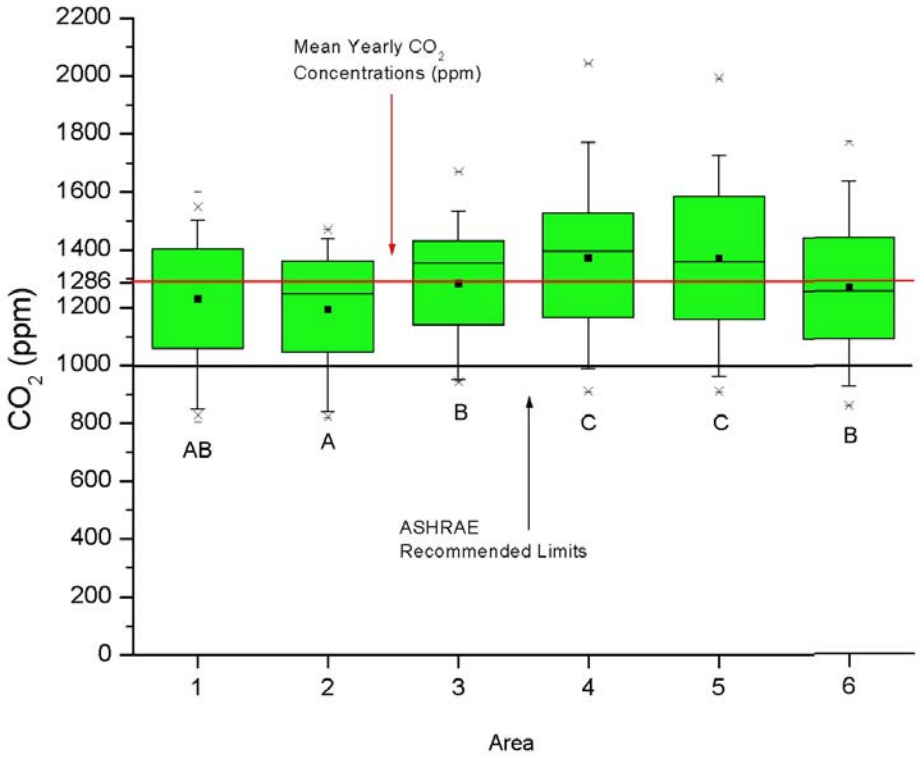


Figure 7 Comparison of CO_2 concentrations by Area. Means with a corresponding letter are not significantly different ($p>0.05$). Each box represents the inner 25th and 75th percentile. The line through each box represents the median. The small solid black inner boxes represent the mean. The whiskers represent the 5th and 95th percentile. The x represents the 1st and 99th percentile, and the line above or through the x represents the minimum and maximum. The red line represents the mean yearly CO_2 concentrations (ppm) for all areas

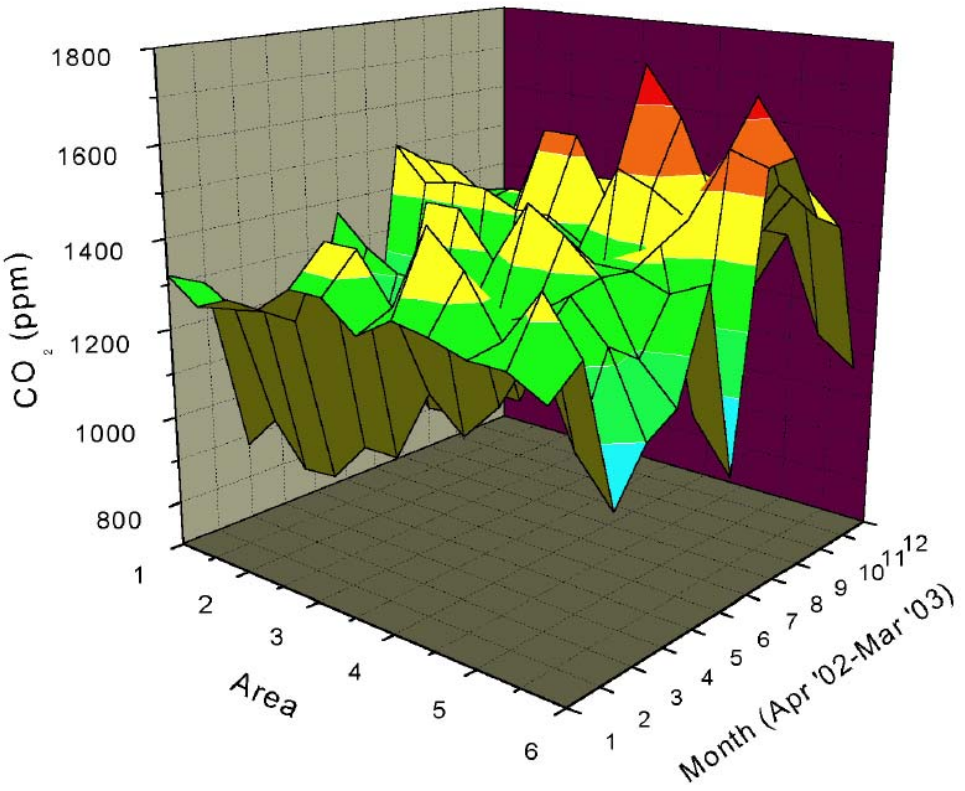


Figure 8 Comparison of CO_2 concentration by month and area. Areas 1 and 2 include doctors' offices and laboratories where embryos and sperm are stored. These areas are where the in vitro fertilization process is performed. Area 3 is the lunchroom/conference room and kitchen section. Area 4 includes nurses' stations and laboratories. Area 5 includes patient examination rooms and a lobby/waiting room. Area 6 includes patient examination rooms and doctors' offices

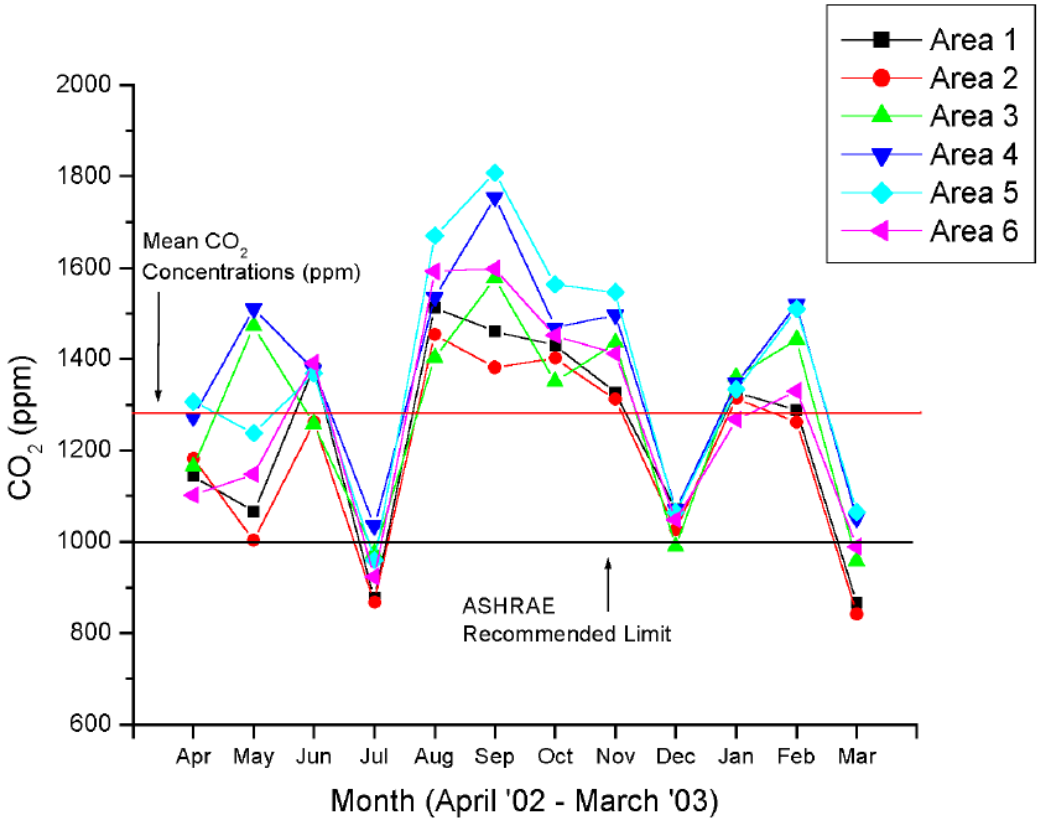


Figure 9 Interaction effect of month and area on mean CO_2 concentration (ppm). Areas 1 and 2 include doctors' offices and laboratories where embryos and sperm are stored. These areas are where the in vitro fertilization process is performed. Area 3 is the lunchroom/conference room and kitchen section. Area 4 includes nurses' stations and laboratories. Area 5 includes patient examination rooms and a lobby/waiting room. Area 6 includes patient examination rooms and doctors' offices

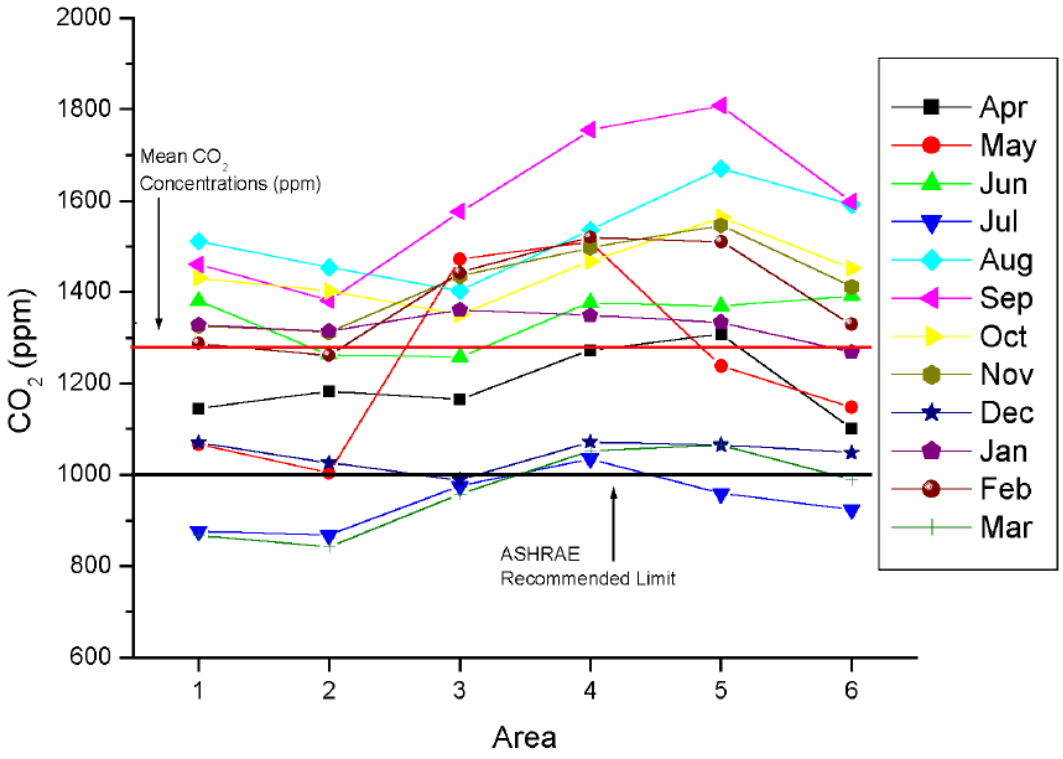


Figure 10 Interaction effect of area and month on mean CO_2 concentration (ppm). Areas 1 and 2 include doctors' offices and laboratories where embryos and sperm are stored. These areas are where the in vitro fertilization process is performed. Area 3 is the lunchroom/conference room and kitchen section. Area 4 includes nurses' stations and laboratories. Area 5 includes patient examination rooms and a lobby/waiting room. Area 6 includes patient examination rooms and doctors' offices

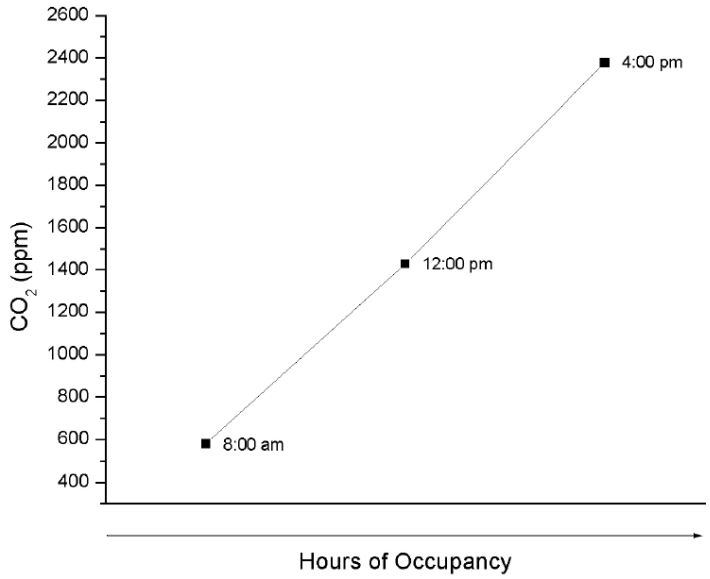


Figure 11 Influence of human activity on CO_2 concentrations. As time went by and the number of persons who occupied the room steadied or increased, the CO_2 concentrations increased. The room was constantly occupied with students for classes. When one group of students would leave, another group would replace them. The doors were closed each time a class started. This study was done at East Tennessee State University (Lamb Hall, Room 54)

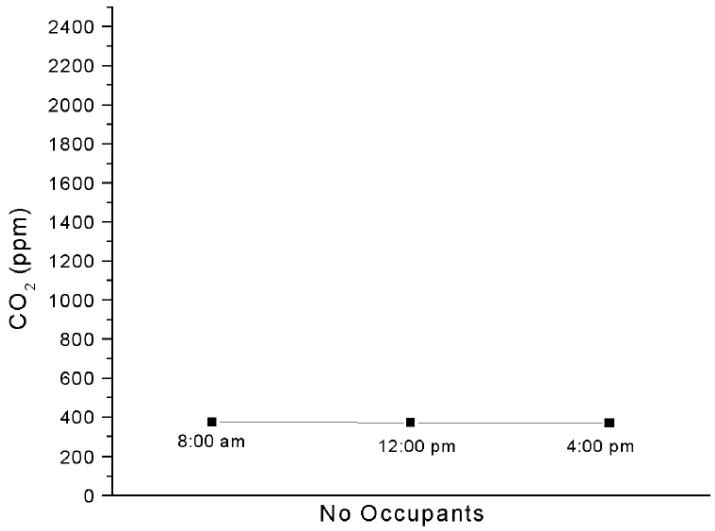


Figure 12 Change in CO_2 concentrations in an unoccupied building. With no occupants in the building and as time increased during an 8-hour period, the concentrations remained constant and only slightly higher than outside ambient concentrations (~350 ppm). The room was unoccupied, and the doors were closed for the duration of the study. This study was done at East Tennessee State University (Lamb Hall, Room 54)

Volatile Organic Compounds (VOCs)

A preliminary analysis for VOCs was performed using a portable PID meter (MiniRAE 2000) with a detection limit of 0.1 mg/m^3. All of the test compounds (formaldehyde, benzene, styrene and n-hexane) were at concentrations below the detection limit of the PID.

The target compounds (benzene, styrene, or n-hexane) were also below the detection limit of the VOC badges (OV-00). There were VOCs detected, and these include ethanol and isopropyl alcohol. The number of data points was too small to perform statistical analysis. The alcohol concentrations in the clinic were compared to concentrations of ethanol and isopropyl alcohol reported in the literature for IVF clinics (Table 6).

Formaldehyde and acetaldehyde concentrations were below the detection limit of the PID. Two areas of the clinic (waiting room and IVF laboratory) were analyzed for formaldehyde and acetaldehyde using badges (F-50). Formaldehyde concentrations were 0.03 ppm in the laboratory and 0.04 ppm in the waiting room. Acetaldehyde concentrations were 0.006 ppm in the IVF laboratory and 0.008 ppm in the waiting room. Outside concentration for formaldehyde was detected at 0.01 ppm and acetaldehyde was not detected (Table 7).

For the outside control, formaldehyde was the only VOC detected at 0.01 ppm. The control site for VOCs was located outside and near the air intake. The Advanced Chemical Sensor AIHA accredited laboratory performed other QA/QC measures for VOCs badges. A second badge, along with the samples, was processed at the same time for quality assurance. No compounds were detected on the control badges.

Table 6 Alcohol concentrations in the fertility clinic. Concentrations were measured using diffusive organic vapor badges that were subsequently analyzed by a commercial laboratory

Area	Location	Ethyl Alcohol[1] (ppm)	Isopropyl Alcohol[2] (ppm)
1	Doctors' offices and in vitro laboratories	0.26	0.63
2	Doctors 'offices and in vitro laboratories	0.24	0.82
3	Lunchroom/conference room and kitchen	0.08	0.39
4	Nurses' stations and patient laboratories	0.11	0.47
5	Patient exam rooms and lobby/waiting room	0.18	0.65
6	Patient exam rooms and doctors' offices	0.15	0.61
7	Outside	*	*
8	Average IVF Concentrations[3]	0.42	0.17

* None Detected
[1] OSHA PEL – 1000 ppm
[2] OSHA PEL – 400 ppm
[3] Gilligan, Antonia (1999)

Table 7 Formaldehyde and acetaldehyde concentrations in the fertility clinic. Concentrations were measured using diffusive organic vapor badges that were subsequently analyzed by a commercial laboratory

Location	Formaldehyde[4] (ppm)	Acetaldehyde[5] (ppm)
Waiting Room	0.04	0.006
IVF Laboratory	0.03	0.008
Outside	0.01	*

* None Detected
[4] OSHA PEL – 0.75 ppm
[5] OSHA PEL – 200 ppm

Quality Assurance/Quality Control

QA/QC for the Q-Trak real-time monitor for measuring CO_2, temperature, humidity, and CO included a factory calibration before sampling began. The results of the factory calibration for CO_2 and % humidity were within ±3%. In addition to the factory calibration, the instrument was calibrated with calibration gases (1000 ppm CO_2 and 35 ppm CO) obtained from TSI, Inc before each sampling event. The results of the calibration before each sampling event were within ±1% of the calibration gases (1000-1007 ppm for CO_2 and 35 ppm for CO). Quality control charts could not be generated because of a lack of duplicate samples. However, the

frequent calibration of the equipment reduces the need for duplicates. Based on EPA's "A Standardized EPA Protocol for Characterizing Indoor Air Quality in Large Office Buildings" frequent calibrations reduce the need for duplicate sampling for real-time sampling equipment (U.S. EPA 2000).

The DUSTTRAK™ was calibrated for proper flow rates before sampling. The flow rate was calibrated at 1.7 L/min and was checked before each sampling event to assure accuracy. The instrument's internal housing was cleaned and the internal filter was replaced before initial sampling. A thorough cleaning with isopropanol was performed on the interchangeable particulate adapters and nozzle before each sampling event. Isopropanol is the recommended cleaning solvent (TSI, Inc. 2000).

Duplicate samples were taken using the MiniRAE 2000 for detecting VOCs. No compounds were detected in the original samples or the duplicate samples. Results of the calibration prior to sampling assured an accuracy of 62%.

Duplicate samples were not taken for the diffusive monitoring badges for the VOCs. There were not enough samples taken for statistical power, and those badges were not analyzed statistically but rather compared to previous literature. The company from which the badges were obtained [Advance Chemical Sensors, Inc (ACS)] is an AIHA accredited laboratory. The ACS Laboratory analyzes blanks and performs matrix spikes with each group of badges. All ACS badges conform to OSHA requirements for accuracy and precision (accuracy at ±25 with 95% confidence limits).

Control sites were used for QA/QC of air quality parameters (CO_2, CO, temperature, humidity, particulates, and pressure). The results of the control data are included in Appendix B.

CHAPTER 5

DISCUSSION

Indoor Air Quality Parameters

Temperature, humidity, pressure, and particulates were measured monthly to establish baseline concentrations. Temperature measurements remained constant and were typical for a controlled environment. Recommended air temperature is between 22.8-25.6° C (73-78° F), depending on activity and clothing (U.S. EPA 2003b). There were some fluctuations throughout the facility because there were separate thermostats for the nine heat pump systems. There were no significant differences in temperature between areas of the facility on a given month. There were fluctuations between months as would be expected because of seasonal variations.

More than one heat pump was connected to a thermostat. Each thermostat was adjusted independently because of the special requirements of the embryo stored in a portion of the facility. Temperatures in the area of the incubators were adjusted slightly higher than the rest of the facility. This is done to prevent excessive temperature differences during embryo transfer. Fluctuations in temperature of the embryo can cause damage to the meiotic spindle by depolymerization and possibly causing chromosomal disruption and thus should be minimized (Elder and Dale 2000).

Temperatures in the incubators that store the embryo at the clinic are adjusted to 98.6° F (37°C). Temperatures inside the incubators must be constant and stabilized to prevent damage to developing embryo. The temperatures of the incubators at the clinic are within the range recommended by the European Society of Human Reproduction and Embryology (2000).

Relative humidity levels throughout the facility were within the recommended 30-60% relative humidity (U.S. EPA 2003b). OSHA has not established a standard but has recommended that humidity levels be 20-60% (OSHA 2003). Humidity in the clinic was directly proportional to outdoor levels and did not appear to affect the air quality. There were no visible signs of moisture associated with excessive humidity (i.e., no visible mold growth or condensation). There were no significant differences in humidity levels ($p>0.05$) in the six areas of the clinic during this investigation. There were significant differences between months ($p<0.05$) because of normal ambient fluctuations in humidity.

Air pressure in the clinic was negative, which suggests that more air is being pulled through the exhaust ventilation than is supplied through the intake (U.S. EPA 2003b). Thus, makeup air could be drawn into the clinic from sources other than the ventilation system. Negative pressure is the result of maintaining higher pressure outside to prevent contaminants from leaving the area. Positive pressure is the result of maintaining pressure higher inside. This prevents contaminants entering from outside of the system to enter room. Because it is important to prevent the migration of contaminants from entering the lab in which in vitro fertilization is conducted, positive pressure should be maintained. This is also true for areas in which the embryo transfer takes place. Contaminants that enter the laboratory because of negative pressure may have an adverse affect of embryo survival *in vitro*.

Average total and respirable particulate concentrations in the clinic were low (0.0039 mg/m^3 and 0.0005 mg/m^3, respectively) compared to average outside concentrations (0.034 mg/m^3 and 0.032 mg/m^3) and in inside control areas (0.014 mg/m^3 and 0.007 mg/m^3). Inside particulate concentrations were less than the National Ambient Air Quality Standard (NAAQS) of 50 $\mu g/m^3$ for PM_{10} and 15 $\mu g/m^3$ for $PM_{2.5}$ (U.S. EPA 2004). OSHA permissible exposure

limits (PEL) for particulates are 15 mg/m^3 for total particulates and 5 mg/m^3 for respirable particulates (OSHA 1997). The use of high efficiency particulate air (HEPA) filters dramatically reduced the particulate concentrations inside the clinic. According to information obtained from interviews of personnel working in the clinic, the HEPA filters are changed approximately every six months. The low concentrations of respirable and total particulates are indicative of an effective preventive maintenance program to reduce particulate and contaminants in the clinic.

Carbon Dioxide Concentrations

Elevated CO_2 concentrations (above 1000 pm) inside large office and school buildings are typically because of the number of occupants in the building and the low efficiency of the ventilation system (Scheff et al. 2000). As the number of occupants increases, there is a likelihood that the CO_2 concentration will increase. Inadequate ventilation is a likely cause of CO_2 concentrations exceeding 800 ppm (DiNardi 1998). The CO_2 concentrations at the CARS exceeded 800 ppm every sampling event suggesting that there is not sufficient ventilation for the size and occupancy of the CARS facility. The ASHRAE standard 62-1989 states that there must be a minimum of 15ft^3/min/ person of fresh outdoor air (DiNardi 1998). Measuring CO_2 concentrations is the most common method used to determine if there is an acceptable air exchange rate. CO_2 measurements are commonly used as a surrogate measure of ventilation.

The excessive concentrations of CO_2 (>1000 ppm) and the constant negative pressure in the clinic suggest that there are not enough fresh air intakes and/or fresh air entering the HVAC system. In other words, if the manual dampers on the fresh air intakes are closed or slightly open, there may be a chance that there are enough intakes, but not enough fresh air supplied. Likely sources of this makeup air could originate inside the building, causing an increase in carbon dioxide concentrations.

Carbon dioxide concentrations were compared between various areas of the clinic. There were some significant differences between areas of the clinic that had high occupancy and areas with low occupancy. However, because of the failure to obtain duplicate samples, the validity of the statistical analysis may come into question. The areas where the CO_2 concentrations significantly increased are the areas of high human occupancy. The areas that had low CO_2 concentrations are the *in vitro* laboratories and areas not commonly frequented by patients. Initially, it was suspected that the increased CO_2 concentrations were because of the CO_2 tanks located in Area 1 of the clinic. However, the area that houses the CO_2 tanks is an area of lower CO_2 concentrations. Therefore, occupancy appears to be the major contributor of high CO_2 concentrations rather than the CO_2 tanks.

The independent study for the CO_2 concentrations provides valuable information for the reliability of the CO_2 data and further validates that occupancy rather than the CO_2 tanks are responsible for the elevated concentrations. The assumption is that as occupancy increases or remains constant, with a flow of people in and out of a facility, there is an increase in CO_2 concentrations during the day. This was validated with the data that provides conditions with both no occupants in a facility and continued occupancy (in and out throughout the day).

Concentrations of CO_2 >1000 ppm, such as those found in the clinic, has been known to cause symptoms such as fatigue, headaches, increased pulse rate, hearing loss, hyperventilation, and dizziness (Robertson 2006). Because these exposures occur only in the work environment or during clinic visits and are not constant throughout the life of the occupant, the effects discontinue as the occupant returns to an outdoor ambient environment (Robertson 2006).

In an environment where patient equilibrium and health play a vital role in the success of embryo implantation, the excessive CO_2 concentration at the clinic could add unneeded stress to

the patient thus having an affect on the success of the implantation. Also, with increased CO_2 concentrations there is a risk of decreased job performance by doctors and employees at the clinic possibly having an affect on implantation success. Although implantation success rates were not analyzed for this study, possibilities exist based on past studies of job performance and decreased ventilation rates. A study done by Seppänen et al. (2006) compared job performance with decreased ventilation rates and found that job performance increased with increasing ventilation rates. Because CO_2 is a surrogate measure of ventilation, it is assumed that an increase in ventilation rates has a direct correlation with a decrease in CO_2 concentrations.

Although there are no serious implications of increased CO_2 concentrations below the OSHA standard of 5000 ppm, the elevated CO_2 concentrations in the clinic indicate that the ventilation system is not efficient. The potential exists for contaminants that may be detrimental to human health, to accumulate.

Volatile Organic Compounds (VOCs)

Three of the four VOCs that were measured (benzene, styrene, n-hexane) were below the 0.01ppm detection limit in the inside and outside samples. Because of the volume of traffic and location of the CARS clinic, compounds associated with vehicular traffic (benzene, n-hexane) were expected to be present in detectable concentrations. Formaldehyde was detected outside at 0.01 ppm, which is below the often-reported outdoor and indoor background concentrations of 0.03 ppm (U.S. Consumer Product Safety Commission 1997). The concentrations of formaldehyde detected at the CARS clinic were 0.04 ppm in the waiting room, 0.03 ppm in the *in vitro* laboratory and 0.01 ppm outside. The concentrations of formaldehyde found at the clinic are typical and do not appear to be above normally observed concentrations (U.S. Consumer

Product Safety Commission 1997). However, the concentration of formaldehyde inside the clinic is three to four times greater than outside and could possibly be reduced with proper ventilation. The presence of carpeting and the remodeling of the clinic in 1997 may contribute to the presence of formaldehyde in the clinic. The concentrations can likely be reduced with engineering controls (i.e., increasing the ventilation exchange rates).

Ethanol and isopropyl alcohol were not intentionally monitored, but were detected in the clinic. Both ethanol and isopropyl alcohol concentrations detected were significant enough to warrant discussion. Alcohols are typically used and can be detected in most clinical settings. Ethanol is typically used in the clinic to clean counter tops. Ethanol can be found mostly in the laboratory areas of the clinic. Isopropyl alcohol wipes are used to cleanse the skin before an injection and are typically found in the patient areas of the clinic. The concentrations of ethanol in the clinic were lower than average concentrations reported for other fertility clinics (Gilligan 1999). The concentrations of isopropyl alcohol were up to four times greater than average concentrations of other fertility clinics (Gilligan 1999). However, none of the concentrations exceeded OSHA standards. OSHA PEL standards for ethanol are 1900 mg/m^3. OSHA PEL standards for isopropyl alcohol are 980 mg/m^3. Although the concentrations did not exceed the OSHA standards and are well within safe concentrations for the average adult, the concentrations may have an effect on the embryo *in vitro*. Wynter et al. (1983) and Chen et al. (1999) suggest that ethanol may have various health effects including, but not limited to, malformations of the nervous system, growth retardation, damage to brain mitochondria, neural tube defects, and teratogenesis in embryo *in vitro*.

Although it is unclear where the isopropyl alcohol originated, it is possible that it may have migrated, as a result of negative pressure, from other parts of the building because the

building is made up primarily of medical facilities. The implications of the increased isopropyl alcohol to embryo *in vitro* are unknown. Data on the effects of isopropyl alcohol on developing embryo *in vitro* could not be found.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The CARS facility was monitored for several different air quality parameters including VOCs, CO_2, temperature, humidity, air pressure, and particulates. No significant elevated concentrations of VOCs were detected. Humidity, temperature, and particulates were within recommended OSHA, EPA, and ASHRAE ranges. The air pressure in the facility maintained a negative pressure, indicating air coming from sources other than the ventilation system. The only impact to the CARS facility was the elevated concentrations of CO_2. The concentrations of CO_2 in the clinic were over concentrations recommended by EPA and ASHRAE. Although there are no standards for CO_2 concentrations in public buildings, it is an indicator of insufficient ventilation. However, the ASHRAE standard does state that the ventilation system must be regulated such that there is a minimum of 15 ft^3/min/person of fresh air to keep CO_2 concentrations below 800 ppm. Based on the ASHRAE standard 62-1989, the CARS facility is not sufficiently ventilated as all CO_2 concentrations measured exceeded 800 ppm.

Because this study was performed without duplicate samples or positive and negative controls, the validity of the results cannot be assumed. Although the equipment was frequently calibrated, duplicate samples are necessary to detect outliers or false readings that may have an impact on the results of statistical analysis. The validity of this study is also in question because it was conducted when there was no evidence of a problem, thus the project essentially had no purpose other than to conduct readings of indoor air.

The study design was flawed and not executed properly. The first error in the study design was the lack of replicate samples. Environmental samples should be taken in replication to assess variability in the sampling process. Without replicate samples for this study, I could not assess the quality (accuracy and precision) of the data.

Although there were several control sites for this study. A control site that was similar to the clinic environment should have been used to assure accuracy of the data. Control sites are typically used to validate a sampling process. Using a facility in which similar activities occur as a control site would have strengthened the validity of the data.

Another error in the study design was the lack of samples taken from the incubators. To assess whether or not VOCs are present in concentrations that may affect embryo, the air quality supplied to and in the incubators should have been monitored. This could have been accomplished several different ways. Samples could have been taken from the air in the medical grade CO_2 tanks to determine what constituents were present. The filters used to scrub the CO_2 leading to the incubators could have been analyzed in conjunction with the analysis of the air quality in the CO_2 tanks. Those two results could have been used to assess the efficiency of the filtration system by comparing contaminants in the tanks versus what was actually filtered out. In addition, the air inside the incubators could have been analyzed. Because the study focused on the air quality that may affect embryos, it stands to reason that these sample areas should have been analyzed.

The lack of toxicity data does not enable conclusions to be drawn about the embryonic effect of contaminants reported in this study. Although there have been some studies on the effects of VOCs on developing embryo, most are conducted *in vivo*. There is a need to conduct experiments on embryo *in vitro.* Cohen et al. (1998) conducted a study in which they exposed

mouse embryo to the contaminant of concern (acrolein) as a result of a resurfacing project. A similar project should have been conducted for this study in order to assess the effects of ethanol, formaldehyde, acetaldehyde, and isopropyl alcohol on developing embryo *in vitro*.

Recommendations

It is recommended that the doctors at CARS consult with the owner of the building to determine if the ventilation system is appropriately designed and operated for the space serviced. This may be accomplished through a ventilation inspection along with a complete ventilation survey. All air intakes should be assessed to assure that all dampers are adjusted sufficiently to allow the 15 ft^3/min/person of fresh air as established by the ASHRAE standard.

Because of the inadequacies of this study and unreliable data, it is recommended that the CARS repeat this study using replicate samples, positive and negative controls with a specific study design and purpose.

It is also recommended that the CARS initiate a study of the air quality inside the incubators. This includes assessing the CO_2 used to supply the incubators. This should be done to assure that the embryos stored in the incubators are not exposed to concentrations of VOCs or other contaminants that are often found in medical grade CO_2. Such contaminants can be detrimental to the survival of embryo and should be identified.

It is recommended that the CARS perform an analysis of the adsorption of VOCs onto the charcoal filters used to filter ambient air and medical grade CO_2 provided to the incubators. An analysis of the filters may help to identify potential sources of contamination in the ambient air and in the medical grade CO_2.

A controlled experiment, involving mouse embryo exposed to various concentrations of contaminants found at the clinic, should be conducted. This will determine whether or not the contaminants found at the clinic can have an impact on developing embryo,

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APPENDICES

APPENDIX A

Statistical Analysis

Descriptive Statistics

Variable	N	N*	Mean	Median	TrMean	StDev
CO2-Clin	258	6	1280.5	1314.0	1277.7	238.9
Pressure	258	6	-0.04294	-0.05300	-0.04447	0.01633
Temp	258	6	73.824	73.800	73.799	1.246
Humidity	258	6	39.117	39.100	39.119	5.995
Totals	258	6	0.00377	0.00200	0.00281	0.00639
Resp	258	6	0.00051	0.00000	0.00038	0.00094

Variable	SE Mean	Minimum	Maximum	Q1	Q3
CO2-Clin	14.9	802.0	2043.0	1086.2	1436.0
Pressure	0.00102	-0.05900	0.00000	-0.05500	-0.03500
Temp	0.078	70.800	79.000	72.900	74.600
Humidity	0.373	28.900	50.400	34.175	44.425
Totals	0.00040	0.00000	0.06900	0.00100	0.00400
Resp	0.00006	0.00000	0.00900	0.00000	0.00100

Anderson-Darling Normality Test

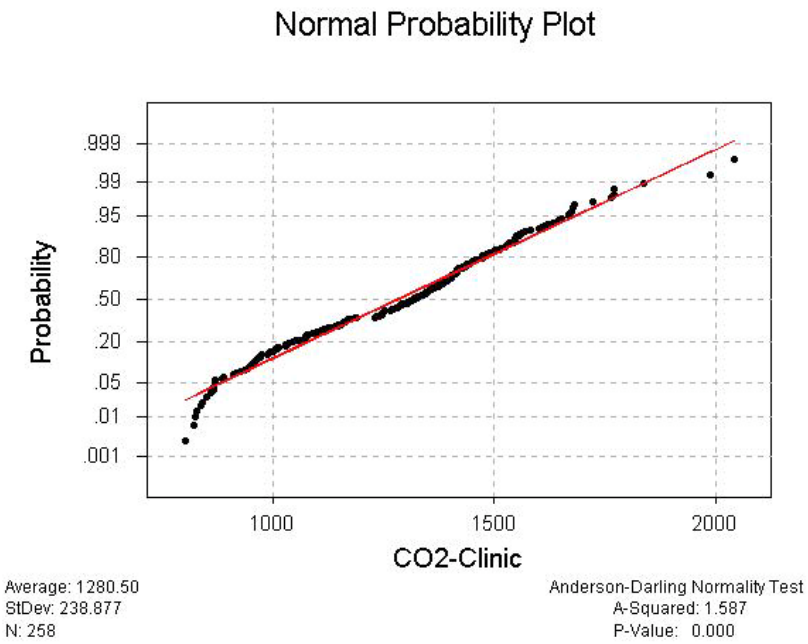

Figure 13 Results of Anderson-Darling Normality Test for CO_2 concentrations measured at 22 sites once a month for 12 months at the Center for Applied Reproductive Science. The CO_2 concentrations analyzed do not show a normal distribution as $p<0.05$

ANOVA

General Linear Model

```
Factor          Type Levels Values
Area           fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                           18 19 20 21 22
Month          fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for CO2-Clin, using Adjusted SS for Tests

Source          DF     Seq SS     Adj SS     Adj MS       F      P
Area             5    1133780    1061329     212266    4.95  0.006 x
Site ID(Area)   16     726483     685894      42868   11.72  0.000
Month           11   11130128    9855025     895911  244.84  0.000
Area*Month      55    1052601    1052601      19138    5.23  0.000
Error          170     622047     622047       3659
Total          257   14665038

x Not an exact F-test.

Unusual Observations for CO2-Clin
```

Obs	CO2-Clin	Fit	StDev Fit	Residual	St Resid
26	1166.00	1058.10	29.39	107.90	2.04R
37	1404.00	1558.78	37.72	-154.78	-3.27R
46	1494.00	1377.51	29.39	116.49	2.20R
57	1416.00	1307.58	34.92	108.42	2.20R
62	1389.00	1274.08	37.72	114.92	2.43R
103	1772.00	1607.00	33.94	165.00	3.30R
123	1525.00	1685.33	34.92	-160.33	-3.25R
125	2043.00	1826.00	33.94	217.00	4.33R
127	1991.00	1871.00	37.72	120.00	2.54R
167	1563.00	1427.58	34.92	135.42	2.74R
220	1246.00	1369.27	34.21	-123.27	-2.47R
237	1676.00	1573.00	37.72	103.00	2.18R
238	1304.00	1414.75	37.72	-110.75	-2.34R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS

Source	Expected Mean Square for Each Term
1 Area	(5) + 11.6314(2) + Q[1, 4]
2 Site ID(Area)	(5) + 11.6250(2)
3 Month	(5) + Q[3, 4]
4 Area*Month	(5) + Q[4]
5 Error	(5)

Error Terms for Tests, using Adjusted SS

Source	Error DF	Error MS	Synthesis of Error MS
1 Area	16.00	42890	1.0005(2) - 0.0005(5)
2 Site ID(Area)	170.00	3659	(5)
3 Month	170.00	3659	(5)
4 Area*Month	170.00	3659	(5)

Variance Components, using Adjusted SS

Source	Estimated Value
Site ID(Area)	3373
Error	3659

Least Squares Means for CO2-Clin

Area	Mean	StDev
1	1229.3	24.41
2	1192.6	34.52
3	1282.0	42.27
4	1364.6	31.51
5	1369.7	34.52
6	1272.5	31.25
Month		
1	1201.5	13.99
2	1236.0	13.99
3	1338.3	13.99
4	939.6	13.65
5	1527.8	13.65
6	1596.6	13.65

7		1440.9	13.99
8		1420.3	13.99
9		1041.0	13.99
10		1325.6	13.65
11		1392.0	13.65
12		962.0	13.65
Area*Month			
1	1	1145.2	24.70
1	2	1066.8	24.70
1	3	1380.3	24.70
1	4	877.3	24.70
1	5	1511.7	24.70
1	6	1461.2	24.70
1	7	1430.8	24.70
1	8	1327.3	24.70
1	9	1070.2	24.70
1	10	1327.5	24.70
1	11	1287.8	24.70
1	12	865.7	24.70
2	1	1183.3	34.92
2	2	1004.0	34.92
2	3	1262.7	34.92
2	4	868.3	34.92
2	5	1453.7	34.92
2	6	1381.7	34.92
2	7	1402.3	34.92
2	8	1312.3	34.92
2	9	1025.7	34.92
2	10	1314.0	34.92
2	11	1261.7	34.92
2	12	841.7	34.92
3	1	1164.5	42.77
3	2	1472.0	42.77
3	3	1257.5	42.77
3	4	974.5	42.77
3	5	1402.5	42.77
3	6	1576.0	42.77
3	7	1351.0	42.77
3	8	1435.5	42.77
3	9	989.0	42.77
3	10	1361.0	42.77
3	11	1443.0	42.77
3	12	958.0	42.77
4	1	1273.3	30.25
4	2	1487.8	35.41
4	3	1377.3	30.25
4	4	1034.5	30.25
4	5	1536.0	30.25
4	6	1755.0	30.25
4	7	1444.8	35.41
4	8	1497.3	30.25
4	9	1048.4	35.41
4	10	1349.3	30.25
4	11	1519.5	30.25
4	12	1052.0	30.25
5	1	1307.0	34.92
5	2	1237.7	34.92

```
5     3       1369.3     34.92
5     4        959.7     34.92
5     5       1670.7     34.92
5     6       1808.0     34.92
5     7       1564.0     34.92
5     8       1547.0     34.92
5     9       1065.0     34.92
5    10       1334.0     34.92
5    11       1510.0     34.92
5    12       1064.7     34.92
6     1       1135.8     35.33
6     2       1148.0     30.25
6     3       1382.9     35.36
6     4        923.5     30.25
6     5       1592.2     30.25
6     6       1598.0     30.25
6     7       1452.3     30.25
6     8       1402.2     35.36
6     9       1047.5     30.25
6    10       1267.7     30.25
6    11       1330.3     30.25
6    12        989.8     30.25

* NOTE * No multiple comparisons were calculated for the
         following terms which contain or interact with
         random factors.
Area
```

General Linear Model

```
Factor          Type Levels Values
Area           fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                           18 19 20 21 22
Month          fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for Pressure, using Adjusted SS for Tests

Source          DF     Seq SS     Adj SS     Adj MS       F      P
Area             5  0.0000253  0.0000148  0.0000030    2.91  0.047 x
Site ID(Area)   16  0.0000692  0.0000163  0.0000010      **
Month           11  0.0682729  0.0613652  0.0055787      **
Area*Month      55  0.0000588  0.0000588  0.0000011      **
Error          170  0.0000800  0.0000800  0.0000005
Total          257  0.0685061

x Not an exact F-test.

** Denominator of F-test is zero.
** Unable to do multiple comparisons.

Unusual Observations for Pressure
```

Obs	Pressure	Fit	StDev Fit	Residual	St Resid
1	-0.025000	-0.026917	0.000333	0.001917	3.20R
45	-0.038000	-0.035583	0.000333	-0.002417	-4.03R
50	-0.035000	-0.036417	0.000333	0.001417	2.36R
72	-0.036000	-0.037750	0.000333	0.001750	2.92R
138	-0.057000	-0.055417	0.000333	-0.001583	-2.64R
179	-0.054000	-0.052083	0.000333	-0.001917	-3.20R
204	-0.055000	-0.053750	0.000333	-0.001250	-2.09R
226	-0.058000	-0.056583	0.000333	-0.001417	-2.36R
227	-0.056000	-0.057694	0.000428	0.001694	3.16R
243	-0.002000	-0.000750	0.000333	-0.001250	-2.09R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS

Source	Expected Mean Square for Each Term
1 Area	(5) + 11.6314(2) + Q[1, 4]
2 Site ID(Area)	(5) + 11.6250(2)
3 Month	(5) + Q[3, 4]
4 Area*Month	(5) + Q[4]
5 Error	(5)

Error Terms for Tests, using Adjusted SS

Source	Error DF	Error MS	Synthesis of Error MS
1 Area	15.99	0.0000010	1.0005(2) - 0.0005(5)
2 Site ID(Area)	170.00	*	(5)
3 Month	170.00	*	(5)
4 Area*Month	170.00	*	(5)

Variance Components, using Adjusted SS

Source	Estimated Value
Site ID(Area)	0.00000
Error	0.00000

Least Squares Means for Pressure

Area	Mean	StDev
1	-0.04258	0.000119
2	-0.04306	0.000168
3	-0.04317	0.000206
4	-0.04309	0.000153
5	-0.04286	0.000168
6	-0.04319	0.000152
Month		
1	-0.02714	0.000000
2	-0.03365	0.000000
3	-0.03521	0.000000
4	-0.03658	0.000000
5	-0.05297	0.000000
6	-0.05562	0.000000
7	-0.05559	0.000000
8	-0.05368	0.000000
9	-0.05347	0.000000
10	-0.05368	0.000000

11		-0.05726	0.000000
12		-0.00103	0.000000
Area*Month			
1	1	-0.02700	0.000000
1	2	-0.03417	0.000000
1	3	-0.03567	0.000000
1	4	-0.03700	0.000000
1	5	-0.05300	0.000000
1	6	-0.05500	0.000000
1	7	-0.05467	0.000000
1	8	-0.05283	0.000000
1	9	-0.05200	0.000000
1	10	-0.05300	0.000000
1	11	-0.05583	0.000000
1	12	-0.00083	0.000000
2	1	-0.02633	0.000000
2	2	-0.03400	0.000000
2	3	-0.03533	0.000000
2	4	-0.03667	0.000000
2	5	-0.05233	0.000000
2	6	-0.05600	0.000000
2	7	-0.05567	0.000000
2	8	-0.05433	0.000000
2	9	-0.05300	0.000000
2	10	-0.05433	0.000000
2	11	-0.05800	0.000000
2	12	-0.00067	0.000000
3	1	-0.02700	0.000000
3	2	-0.03350	0.000000
3	3	-0.03500	0.000000
3	4	-0.03650	0.000000
3	5	-0.05350	0.000000
3	6	-0.05600	0.000000
3	7	-0.05600	0.000000
3	8	-0.05400	0.000000
3	9	-0.05400	0.000000
3	10	-0.05400	0.000000
3	11	-0.05700	0.000000
3	12	-0.00150	0.000000
4	1	-0.02775	0.000000
4	2	-0.03290	0.000000
4	3	-0.03500	0.000000
4	4	-0.03650	0.000000
4	5	-0.05325	0.000000
4	6	-0.05600	0.000000
4	7	-0.05556	0.000000
4	8	-0.05400	0.000000
4	9	-0.05390	0.000000
4	10	-0.05400	0.000000
4	11	-0.05675	0.000000
4	12	-0.00150	0.000000
5	1	-0.02700	0.000000
5	2	-0.03333	0.000000
5	3	-0.03533	0.000000
5	4	-0.03633	0.000000
5	5	-0.05300	0.000000
5	6	-0.05500	0.000000

```
5     7     -0.05567  0.000000
5     8     -0.05333  0.000000
5     9     -0.05367  0.000000
5    10     -0.05300  0.000000
5    11     -0.05800  0.000000
5    12     -0.00067  0.000000
6     1     -0.02777  0.000000
6     2     -0.03400  0.000000
6     3     -0.03491  0.000000
6     4     -0.03650  0.000000
6     5     -0.05275  0.000000
6     6     -0.05575  0.000000
6     7     -0.05600  0.000000
6     8     -0.05357  0.000000
6     9     -0.05425  0.000000
6    10     -0.05375  0.000000
6    11     -0.05800  0.000000
6    12     -0.00100  0.000000
```

General Linear Model

```
Factor          Type Levels Values
Area            fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                            18 19 20 21 22
Month           fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for Temp, using Adjusted SS for Tests

Source           DF     Seq SS     Adj SS     Adj MS       F      P
Area              5     2.6823     2.4314     0.4863    0.16  0.974 x
Site ID(Area)    16    48.7014    49.1478     3.0717    4.48  0.000
Month            11   120.3717    77.7876     7.0716   10.30  0.000
Area*Month       55   110.3334   110.3334     2.0061    2.92  0.000
Error           170   116.6822   116.6822     0.6864
Total           257   398.7710

x Not an exact F-test.

Unusual Observations for Temp

Obs      Temp       Fit   StDev Fit  Residual   St Resid
 12   72.7000   74.5380      0.4648   -1.8380     -2.68R
 15   76.0000   74.5380      0.4648    1.4620      2.13R
 19   76.2000   73.9313      0.5232    2.2687      3.53R
 21   72.5000   74.2635      0.5183   -1.7635     -2.73R
 50   74.7000   76.2694      0.4026   -1.5694     -2.17R
 51   75.8000   74.3500      0.5166    1.4500      2.24R
 67   79.0000   76.9444      0.4026    2.0556      2.84R
 72   74.5000   76.9028      0.4026   -2.4028     -3.32R
 89   77.3000   75.2278      0.4026    2.0722      2.86R
160   75.5000   73.1861      0.4026    2.3139      3.20R
163   75.1000   73.7250      0.5166    1.3750      2.12R
```

```
166   74.9000   72.8880      0.4648    2.0120      2.93R
179   74.6000   72.3944      0.4026    2.2056      3.05R
221   71.2000   73.1611      0.4026   -1.9611     -2.71R
226   74.7000   73.1194      0.4026    1.5806      2.18R
235   72.4000   73.8880      0.4648   -1.4880     -2.17R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS

Source            Expected Mean Square for Each Term
 1 Area           (5) + 11.6314(2) + Q[1, 4]
 2 Site ID(Area)  (5) + 11.6250(2)
 3 Month          (5) + Q[3, 4]
 4 Area*Month     (5) + Q[4]
 5 Error          (5)

Error Terms for Tests, using Adjusted SS

Source            Error DF  Error MS  Synthesis of Error MS
 1 Area              16.00    3.0730    1.0005(2) -   0.0005(5)
 2 Site ID(Area)    170.00    0.6864  (5)
 3 Month            170.00    0.6864  (5)
 4 Area*Month       170.00    0.6864  (5)

Variance Components, using Adjusted SS

Source         Estimated Value
Site ID(Area)           0.2052
Error                   0.6864

Least Squares Means for Temp

Area            Mean     StDev
1              73.86    0.2066
2              73.79    0.2922
3              74.02    0.3578
4              73.90    0.2667
5              73.77    0.2922
6              73.67    0.2645
Month
 1             73.99    0.1915
 2             74.34    0.1916
 3             74.41    0.1916
 4             74.59    0.1870
 5             73.75    0.1870
 6             74.77    0.1870
 7             72.82    0.1916
 8             73.35    0.1916
 9             73.87    0.1916
10             73.51    0.1870
11             73.44    0.1870
12             73.17    0.1870
Area*Month
1     1        73.88    0.3382
1     2        74.97    0.3382
1     3        75.68    0.3382
```

1	4	76.32	0.3382
1	5	74.60	0.3382
1	6	74.90	0.3382
1	7	72.35	0.3382
1	8	72.60	0.3382
1	9	72.72	0.3382
1	10	73.17	0.3382
1	11	72.53	0.3382
1	12	72.65	0.3382
2	1	73.00	0.4783
2	2	75.33	0.4783
2	3	74.63	0.4783
2	4	75.47	0.4783
2	5	73.47	0.4783
2	6	73.93	0.4783
2	7	73.33	0.4783
2	8	73.23	0.4783
2	9	72.87	0.4783
2	10	73.87	0.4783
2	11	73.53	0.4783
2	12	72.83	0.4783
3	1	73.50	0.5858
3	2	74.25	0.5858
3	3	73.90	0.5858
3	4	72.70	0.5858
3	5	73.40	0.5858
3	6	75.05	0.5858
3	7	72.80	0.5858
3	8	74.85	0.5858
3	9	75.10	0.5858
3	10	74.60	0.5858
3	11	74.45	0.5858
3	12	73.65	0.5858
4	1	74.55	0.4142
4	2	74.13	0.4849
4	3	74.25	0.4142
4	4	73.78	0.4142
4	5	73.55	0.4142
4	6	75.32	0.4142
4	7	72.83	0.4849
4	8	72.90	0.4142
4	9	74.80	0.4849
4	10	73.42	0.4142
4	11	73.90	0.4142
4	12	73.30	0.4142
5	1	74.90	0.4783
5	2	74.13	0.4783
5	3	74.43	0.4783
5	4	75.13	0.4783
5	5	74.00	0.4783
5	6	74.83	0.4783
5	7	72.77	0.4783
5	8	72.77	0.4783
5	9	73.73	0.4783
5	10	72.60	0.4783
5	11	72.90	0.4783
5	12	73.03	0.4783

```
6     1        74.13    0.4839
6     2        73.20    0.4142
6     3        73.57    0.4843
6     4        74.18    0.4142
6     5        73.50    0.4142
6     6        74.60    0.4142
6     7        72.82    0.4142
6     8        73.73    0.4843
6     9        74.00    0.4142
6    10        73.42    0.4142
6    11        73.35    0.4142
6    12        73.55    0.4142

* NOTE * No multiple comparisons were calculated for the
         following terms which contain or interact with
         random factors.
Area
```

General Linear Model

```
Factor          Type Levels Values
Area            fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                           18 19 20 21 22
Month           fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for Humidity, using Adjusted SS for Tests

Source           DF     Seq SS     Adj SS     Adj MS       F      P
Area              5      41.12      41.54       8.31    1.50  0.243 x
Site ID(Area)    16      82.87      88.31       5.52    2.40  0.003
Month            11    8461.41    7550.56     686.41  298.03  0.000
Area*Month       55     258.85     258.85       4.71    2.04  0.000
Error           170     391.54     391.54       2.30
Total           257    9235.79

x Not an exact F-test.

Unusual Observations for Humidity

Obs  Humidity       Fit   StDev Fit  Residual   St Resid
  6   38.9000   36.1764      0.7374    2.7236      2.05R
 27   44.8000   47.6514      0.7374   -2.8514     -2.15R
 38   41.0000   44.5833      0.9464   -3.5833     -3.02R
 46   47.1000   44.2681      0.7374    2.8319      2.14R
 50   37.4000   44.4931      0.7374   -7.0931     -5.35R
 62   46.6000   44.0583      0.9464    2.5417      2.14R
 68   39.3000   42.1681      0.7374   -2.8681     -2.16R
 72   47.1000   42.3931      0.7374    4.7069      3.55R
 82   39.3000   42.2167      0.9464   -2.9167     -2.46R
 89   41.8000   45.5431      0.7374   -3.7431     -2.82R
104   44.5000   42.0500      0.9464    2.4500      2.07R
124   46.2000   42.8352      0.8515    3.3648      2.68R
```

```
125   37.8000   41.4102      0.8515   -3.6102     -2.87R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS

Source            Expected Mean Square for Each Term
 1 Area           (5) + 11.6314(2) + Q[1, 4]
 2 Site ID(Area)  (5) + 11.6250(2)
 3 Month          (5) + Q[3, 4]
 4 Area*Month     (5) + Q[4]
 5 Error          (5)

Error Terms for Tests, using Adjusted SS

Source            Error DF  Error MS  Synthesis of Error MS
 1 Area              15.99      5.52    1.0005(2) -   0.0005(5)
 2 Site ID(Area)    170.00      2.30  (5)
 3 Month            170.00      2.30  (5)
 4 Area*Month       170.00      2.30  (5)

Variance Components, using Adjusted SS

Source         Estimated Value
Site ID(Area)           0.2767
Error                   2.3032

Least Squares Means for Humidity

Area            Mean     StDev
1              39.06    0.2769
2              39.69    0.3916
3              39.42    0.4796
4              38.62    0.3575
5              38.62    0.3916
6              39.54    0.3546
Month
 1             37.40    0.3509
 2             46.25    0.3510
 3             45.34    0.3509
 4             44.65    0.3425
 5             45.95    0.3425
 6             42.93    0.3425
 7             41.46    0.3510
 8             36.31    0.3509
 9             29.68    0.3510
10             34.48    0.3425
11             33.90    0.3425
12             31.53    0.3425
Area*Month
1     1        36.13    0.6196
1     2        47.05    0.6196
1     3        44.45    0.6196
1     4        42.35    0.6196
1     5        46.57    0.6196
1     6        43.30    0.6196
1     7        42.70    0.6196
```

1	8	36.58	0.6196
1	9	30.10	0.6196
1	10	33.95	0.6196
1	11	34.50	0.6196
1	12	31.00	0.6196
2	1	38.80	0.8762
2	2	48.03	0.8762
2	3	46.23	0.8762
2	4	46.27	0.8762
2	5	48.97	0.8762
2	6	43.17	0.8762
2	7	42.10	0.8762
2	8	35.10	0.8762
2	9	29.50	0.8762
2	10	34.40	0.8762
2	11	32.77	0.8762
2	12	30.93	0.8762
3	1	37.75	1.0731
3	2	44.40	1.0731
3	3	46.30	1.0731
3	4	45.40	1.0731
3	5	46.95	1.0731
3	6	43.35	1.0731
3	7	41.10	1.0731
3	8	36.85	1.0731
3	9	29.20	1.0731
3	10	35.10	1.0731
3	11	34.75	1.0731
3	12	31.85	1.0731
4	1	37.93	0.7588
4	2	44.41	0.8883
4	3	45.22	0.7588
4	4	44.20	0.7588
4	5	42.55	0.7588
4	6	42.35	0.7588
4	7	40.24	0.8883
4	8	36.72	0.7588
4	9	29.98	0.8883
4	10	34.50	0.7588
4	11	33.63	0.7588
4	12	31.75	0.7588
5	1	36.60	0.8762
5	2	45.90	0.8762
5	3	42.93	0.8762
5	4	43.53	0.8762
5	5	43.37	0.8762
5	6	41.77	0.8762
5	7	40.97	0.8762
5	8	36.90	0.8762
5	9	30.07	0.8762
5	10	34.93	0.8762
5	11	34.50	0.8762
5	12	31.93	0.8762
6	1	37.17	0.8863
6	2	47.72	0.7588
6	3	46.88	0.8872
6	4	46.18	0.7588

```
6     5        47.30    0.7588
6     6        43.65    0.7588
6     7        41.62    0.7588
6     8        35.72    0.8872
6     9        29.25    0.7588
6    10        34.00    0.7588
6    11        33.25    0.7588
6    12        31.72    0.7588

* NOTE * No multiple comparisons were calculated for the
         following terms which contain or interact with
         random factors.
Area
```

General Linear Model

```
Factor          Type Levels Values
Area            fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                           18 19 20 21 22
Month           fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for Totals, using Adjusted SS for Tests

Source          DF     Seq SS     Adj SS     Adj MS       F      P
Area             5  0.0002095  0.0002206  0.0000441    1.15  0.374 x
Site ID(Area)   16  0.0006161  0.0006121  0.0000383    1.00  0.464
Month           11  0.0010427  0.0012841  0.0001167    3.04  0.001
Area*Month      55  0.0021003  0.0021003  0.0000382    0.99  0.496
Error          170  0.0065315  0.0065315  0.0000384
Total          257  0.0105000

x Not an exact F-test.

Unusual Observations for Totals

Obs    Totals       Fit   StDev Fit  Residual   St Resid
 23  0.021000  0.008111    0.003012  0.012889      2.38R
 84  0.018000  0.007778    0.003865  0.010222      2.11R
139  0.003000  0.023778    0.003865 -0.020778     -4.29R
140  0.069000  0.027528    0.003865  0.041472      8.56R
141  0.002000  0.022694    0.003865 -0.020694     -4.27R
142  0.032000  0.019542    0.004562  0.012458      2.97R
143  0.004000  0.016458    0.004562 -0.012458     -2.97R
152  0.034000  0.011803    0.003476  0.022197      4.32R
170  0.032000  0.013111    0.003865  0.018889      3.90R
172  0.000000  0.011444    0.003865 -0.011444     -2.36R
176  0.021000  0.008741    0.003888  0.012259      2.54R
213  0.020000  0.008426    0.003478  0.011574      2.26R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS
```

Source	Expected Mean Square for Each Term
1 Area	(5) + 11.6314(2) + Q[1, 4]
2 Site ID(Area)	(5) + 11.6250(2)
3 Month	(5) + Q[3, 4]
4 Area*Month	(5) + Q[4]
5 Error	(5)

Error Terms for Tests, using Adjusted SS

Source	Error DF	Error MS	Synthesis of Error MS
1 Area	15.98	0.0000383	1.0005(2) - 0.0005(5)
2 Site ID(Area)	170.00	0.0000384	(5)
3 Month	170.00	0.0000384	(5)
4 Area*Month	170.00	0.0000384	(5)

Variance Components, using Adjusted SS

Source	Estimated Value
Site ID(Area)	-0.00000
Error	0.00004

Least Squares Means for Totals

Area		Mean	StDev
1		0.002806	0.000729
2		0.004306	0.001031
3		0.004375	0.001263
4		0.004991	0.000941
5		0.004639	0.001031
6		0.002780	0.000933
Month			
1		0.004173	0.001433
2		0.005299	0.001434
3		0.002853	0.001433
4		0.004597	0.001399
5		0.001847	0.001399
6		0.002653	0.001399
7		0.010952	0.001434
8		0.005020	0.001433
9		0.002049	0.001434
10		0.003403	0.001399
11		0.002528	0.001399
12		0.002417	0.001399
Area*Month			
1	1	0.005167	0.002531
1	2	0.006167	0.002531
1	3	0.002667	0.002531
1	4	0.002333	0.002531
1	5	0.001667	0.002531
1	6	0.000500	0.002531
1	7	0.004000	0.002531
1	8	0.001167	0.002531
1	9	0.002167	0.002531
1	10	0.004167	0.002531
1	11	0.002167	0.002531
1	12	0.001500	0.002531

2	1	0.006333	0.003579
2	2	0.002667	0.003579
2	3	0.001333	0.003579
2	4	0.004333	0.003579
2	5	0.000667	0.003579
2	6	0.000667	0.003579
2	7	0.024667	0.003579
2	8	0.004000	0.003579
2	9	0.000667	0.003579
2	10	0.000667	0.003579
2	11	0.002000	0.003579
2	12	0.003667	0.003579
3	1	0.006000	0.004383
3	2	0.009000	0.004383
3	3	0.002500	0.004383
3	4	0.007500	0.004383
3	5	0.002000	0.004383
3	6	0.001000	0.004383
3	7	0.018000	0.004383
3	8	0.001500	0.004383
3	9	0.001000	0.004383
3	10	0.001000	0.004383
3	11	0.002000	0.004383
3	12	0.001000	0.004383
4	1	0.002500	0.003099
4	2	0.010713	0.003628
4	3	0.006000	0.003099
4	4	0.004750	0.003099
4	5	0.002000	0.003099
4	6	0.006500	0.003099
4	7	0.004713	0.003628
4	8	0.004500	0.003099
4	9	0.002713	0.003628
4	10	0.009000	0.003099
4	11	0.002000	0.003099
4	12	0.004500	0.003099
5	1	0.003333	0.003579
5	2	0.001000	0.003579
5	3	0.004333	0.003579
5	4	0.007667	0.003579
5	5	0.003000	0.003579
5	6	0.003000	0.003579
5	7	0.004333	0.003579
5	8	0.011333	0.003579
5	9	0.005000	0.003579
5	10	0.004333	0.003579
5	11	0.006000	0.003579
5	12	0.002333	0.003579
6	1	0.001707	0.003620
6	2	0.002250	0.003099
6	3	0.000285	0.003624
6	4	0.001000	0.003099
6	5	0.001750	0.003099
6	6	0.004250	0.003099
6	7	0.010000	0.003099
6	8	0.007618	0.003624
6	9	0.000750	0.003099

```
6    10     0.001250  0.003099
6    11     0.001000  0.003099
6    12     0.001500  0.003099

* NOTE * No multiple comparisons were calculated for the
         following terms which contain or interact with
         random factors.
Area
```

General Linear Model

```
Factor          Type Levels Values
Area            fixed      6 1 2 3 4 5 6
Site ID(Area) random     22  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
17
                           18 19 20 21 22
Month           fixed     12  1  2  3  4  5  6  7  8  9 10 11 12

Analysis of Variance for Resp, using Adjusted SS for Tests

Source           DF     Seq SS     Adj SS     Adj MS       F       P
Area              5  0.0000054  0.0000067  0.0000013    1.07  0.412 x
Site ID(Area)    16  0.0000220  0.0000199  0.0000012      **
Month            11  0.0000207  0.0000240  0.0000022      **
Area*Month       55  0.0000699  0.0000699  0.0000013      **
Error           170  0.0001084  0.0001084  0.0000006
Total           257  0.0002265

x Not an exact F-test.

** Denominator of F-test is zero.
** Unable to do multiple comparisons.

Unusual Observations for Resp

Obs      Resp       Fit   StDev Fit  Residual   St Resid
 23  0.005000  0.001639    0.000388  0.003361      4.82R
 56  0.003000  0.001435    0.000448  0.001565      2.37R
 79  0.003000  0.001444    0.000461  0.001556      2.39R
107  0.002000  0.000663    0.000456  0.001337      2.04R
140  0.002000  0.000639    0.000498  0.001361      2.18R
142  0.004000  0.002500    0.000588  0.001500      2.77R
143  0.001000  0.002500    0.000588 -0.001500     -2.77R
163  0.004000  0.002556    0.000498  0.001444      2.31R
174  0.001000  0.003459    0.000499 -0.002459     -3.94R
175  0.002000  0.003709    0.000499 -0.001709     -2.74R
176  0.009000  0.004832    0.000501  0.004168      6.70R
194  0.003000  0.000917    0.000498  0.002083      3.34R

R denotes an observation with a large standardized residual.

Expected Mean Squares, using Adjusted SS

Source            Expected Mean Square for Each Term
 1 Area           (5) + 11.6314(2) + Q[1, 4]
```

```
 2 Site ID(Area)  (5) + 11.6250(2)
 3 Month          (5) + Q[3, 4]
 4 Area*Month     (5) + Q[4]
 5 Error          (5)

Error Terms for Tests, using Adjusted SS

Source            Error DF  Error MS  Synthesis of Error MS
 1 Area              15.99 0.0000012    1.0005(2) -   0.0005(5)
 2 Site ID(Area)    170.00         *  (5)
 3 Month            170.00         *  (5)
 4 Area*Month       170.00         *  (5)

Variance Components, using Adjusted SS

Source         Estimated Value
Site ID(Area)          0.00000
Error                  0.00000

Least Squares Means for Resp

Area            Mean     StDev
1           0.000361  0.000131
2           0.000361  0.000186
3           0.000750  0.000228
4           0.000565  0.000170
5           0.000500  0.000186
6           0.000762  0.000168
Month
 1          0.000381  0.000000
 2          0.000441  0.000000
 3          0.000787  0.000000
 4          0.000389  0.000000
 5          0.000458  0.000000
 6          0.000333  0.000000
 7          0.000941  0.000000
 8          0.001412  0.000000
 9          0.000358  0.000000
10          0.000556  0.000000
11          0.000208  0.000000
12          0.000333  0.000000
Area*Month
1     1     0.000000  0.000000
1     2     0.001167  0.000000
1     3     0.000167  0.000000
1     4     0.000500  0.000000
1     5     0.000167  0.000000
1     6    -0.000000  0.000000
1     7     0.000833  0.000000
1     8     0.000333  0.000000
1     9    -0.000000  0.000000
1    10     0.000833  0.000000
1    11     0.000167  0.000000
1    12     0.000167  0.000000
2     1     0.000000  0.000000
2     2     0.000333  0.000000
2     3     0.000333  0.000000
```

2	4	0.000000	0.000000
2	5	0.000000	0.000000
2	6	0.000000	0.000000
2	7	0.000667	0.000000
2	8	0.002333	0.000000
2	9	0.000333	0.000000
2	10	-0.000000	0.000000
2	11	-0.000000	0.000000
2	12	0.000333	0.000000
3	1	0.001000	0.000000
3	2	0.000500	0.000000
3	3	0.002000	0.000000
3	4	-0.000000	0.000000
3	5	0.000500	0.000000
3	6	0.000000	0.000000
3	7	0.002500	0.000000
3	8	0.001000	0.000000
3	9	0.000500	0.000000
3	10	0.000500	0.000000
3	11	0.000500	0.000000
3	12	-0.000000	0.000000
4	1	0.000000	0.000000
4	2	0.000398	0.000000
4	3	0.001250	0.000000
4	4	0.001250	0.000000
4	5	0.001000	0.000000
4	6	0.000750	0.000000
4	7	0.000065	0.000000
4	8	0.000500	0.000000
4	9	0.000065	0.000000
4	10	0.001000	0.000000
4	11	0.000250	0.000000
4	12	0.000250	0.000000
5	1	0.000667	0.000000
5	2	-0.000000	0.000000
5	3	0.000667	0.000000
5	4	0.000333	0.000000
5	5	0.000333	0.000000
5	6	0.001000	0.000000
5	7	0.000333	0.000000
5	8	0.000333	0.000000
5	9	0.001000	0.000000
5	10	-0.000000	0.000000
5	11	0.000333	0.000000
5	12	0.001000	0.000000
6	1	0.000620	0.000000
6	2	0.000250	0.000000
6	3	0.000304	0.000000
6	4	0.000250	0.000000
6	5	0.000750	0.000000
6	6	0.000250	0.000000
6	7	0.001250	0.000000
6	8	0.003971	0.000000
6	9	0.000250	0.000000
6	10	0.001000	0.000000
6	11	0.000000	0.000000
6	12	0.000250	0.000000

One-way Analysis of Variance

```
Analysis of Variance for CO2-Clin
Source     DF        SS        MS        F        P
Month      11  11172911   1015719    71.55    0.000
Error     246   3492128     14196
Total     257  14665038
```

```
                                  Individual 95% CIs For Mean
                                  Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
 1         21    1193.8      99.3            (-*-)
 2         21    1199.8     200.3            (-*-)
 3         21    1351.4      81.3                  (-*-)
 4         22     933.1      83.7  (-*-)
 5         22    1534.6     113.5                        (-*-)
 6         22    1586.4     191.7                          (-*-)
 7         21    1447.6      83.5                     (-*-)
 8         21    1411.3     104.0                    (-*-)
 9         21    1051.2      56.4       (-*-)
10         22    1322.7      50.4                  (-*-)
11         22    1378.5     145.2                    (-*-)
12         22     954.4     110.1   (-*-)
                                  -----+---------+---------+---------+-
Pooled StDev =    119.1             1000      1250      1500      1750
```

```
Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00124

Critical value = 4.62

Intervals for (column level mean) - (row level mean)

               1         2          3          4          5          6

       2    -126
             114

       3    -278      -272
             -37       -32

       4     142       148       299
             379       385       537

       5    -460      -454      -302      -719
            -222      -216       -64      -484

       6    -511      -505      -354      -771       -169
            -274      -268      -116      -536         66

       7    -374      -368      -216      -633        -32        20
            -134      -128        24      -396        206       258

       8    -338      -332      -180      -597          5        56
```

	-97	-91	60	-359	242	294
9	22	28	180	-237	365	416
	263	269	420	1	602	654
10	-248	-242	-90	-507	95	146
	-10	-4	147	-272	329	381
11	-303	-297	-146	-563	39	91
	-66	-60	92	-328	273	325
12	121	127	278	-139	463	515
	358	364	516	96	698	749

	7	8	9	10	11
8	-84				
	156				
9	276	240			
	516	480			
10	6	-30	-390		
	244	207	-153		
11	-50	-86	-446	-173	
	188	152	-209	62	
12	374	338	-22	251	307
	612	576	216	486	541

One-way Analysis of Variance

```
Analysis of Variance for CO2-Clin
Source     DF        SS        MS        F        P
Area        5   1133780    226756     4.22    0.001
Error     252  13531258     53695
Total     257  14665038
```

```
                                  Individual 95% CIs For Mean
                                  Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1          72    1229.3     217.4         (----*----)
2          36    1192.6     205.4   (------*-------)
3          24    1282.0     213.5          (--------*---------)
4          45    1371.7     245.3                    (------*------)
5          36    1369.7     268.5                   (-------*-------)
6          45    1269.2     237.6            (------*------)
                                  ---------+---------+---------+-------
Pooled StDev =    231.7                 1200      1300      1400
```

```
Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00474

Critical value = 4.03

Intervals for (column level mean) - (row level mean)

                1           2           3           4           5

       2         -98
                 171

       3        -208        -263
                 103          85

       4        -268        -327        -257
                 -17         -31          77

       5        -275        -333        -262        -146
                  -6         -21          86         150

       6        -165        -224        -154         -37         -47
                  86          71         180         242         248
```

APPENDIX B

Raw Data

Table 8 Air quality measurements obtained from the CARS, April 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.025	1115	24.4	33.7	0	0.010	0.000
2	-0.027	1078	23.4	34.3	0	0.013	0.000
3	-0.028	1155	22.8	35.8	0	0.002	0.000
4	-0.027	1160	22.9	36.3	0	0.001	0.000
5	-0.027	1176	23.2	37.8	0	0.002	0.000
6	-0.028	1187	22.9	38.9	0	0.003	0.000
7	-0.027	1141	23.2	37.0	0	0.013	0.000
8	-0.026	1162	22.5	39.9	0	0.000	0.000
9	-0.026	1247	22.7	39.5	0	0.006	0.000
10	-0.027	1190	22.8	38.0	0	0.007	0.002
11	-0.027	1139	23.3	37.5	0	0.005	0.000
12	-0.028	1394	22.6	37.7	0	0.002	0.000
13	-0.027	1159	23.5	37.5	0	0.003	0.000
14	-0.028	1171	24.0	37.2	0	0.005	0.000
15	-0.028	1369	24.4	39.3	0	0.000	0.000
16	-0.026	1345	22.7	34.8	0	0.004	0.002
17	-0.028	1402	24.2	38.3	1	0.004	0.000
18	-0.027	1174	24.6	36.7	0	0.002	0.000
19	-0.028	1101	24.6	35.9	1	0.001	0.000
20	-0.028	1116	22.8	38.5	0	0.002	0.000
21	-0.027	1089	22.5	38.0	0	0.001	0.001
22	*	*	*	*	*	*	*

*Missing Data

Table 9 Air quality control measurements obtained from the CARS, April 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.030	353	24.7	24.4	0	0.012	0.010
1^{st}	-0.027	536	23.9	30.6	0	0.009	0.003
2^{nd}	-0.027	547	24.3	31.5	0	0.006	0.002
3^{rd}	-0.026	828	24.8	32.8	0	0.033	0.001
4^{th}	-0.026	608	24.6	32.5	0	0.007	0.003

Table 10 Air quality measurements obtained from the CARS, May 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.034	1123	23.9	47.7	0	0.021	0.005
2	-0.034	1055	23.7	46.6	0	0.004	0.000
3	-0.034	1013	23.4	46.3	0	0.002	0.001
4	-0.035	1166	23.7	48.5	0	0.009	0.000
5	-0.034	1009	24.0	44.8	1	0.001	0.001
6	-0.034	1035	24.4	48.4	0	0.000	0.000
7	-0.034	965	23.4	47.5	1	0.001	0.000
8	-0.034	1075	24.3	48.0	1	0.003	0.000
9	-0.034	972	24.5	48.6	1	0.004	0.001
10	-0.033	1445	23.5	45.1	0	0.007	0.000
11	-0.034	1499	23.4	43.7	0	0.011	0.001
12	-0.033	1654	23.4	43.5	0	0.020	0.000
13	*	*	*	*	*	*	*
14	-0.033	1475	23.5	44.4	0	0.008	0.001
15	-0.033	1404	23.3	44.8	1	0.003	0.000
16	-0.034	1335	22.8	41.0	0	0.000	0.000
17	-0.033	1286	24.1	47.7	1	0.002	0.000
18	-0.033	1092	23.3	49.0	0	0.001	0.000
19	-0.034	1110	22.8	48.9	0	0.002	0.001
20	-0.034	1147	22.5	48.3	0	0.001	0.000
21	-0.034	1045	22.8	47.9	0	0.001	0.000
22	-0.034	1290	23.4	45.8	0	0.005	0.000

*Missing Data

Table 11 Air quality control measurements obtained from the CARS, May 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.033	333	23.9	48.8	0	0.054	0.048
1^{st}	-0.033	510	24.4	44.1	0	0.014	0.009
2^{nd}	-0.033	551	24.6	46.1	0	0.008	0.007
3^{rd}	-0.034	772	23.5	46.2	0	0.003	0.003
4^{th}	-0.034	580	24.4	48.6	0	0.025	0.009

Table 12 Air quality measurements obtained from the CARS, June 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.038	1343	24.6	43.6	0	0.006	0.001
2	-0.036	1494	24.4	47.1	0	0.002	0.000
3	-0.035	1339	24.3	47.4	0	0.004	0.000
4	-0.035	1401	24.3	44.4	0	0.002	0.000
5	-0.035	1329	24.4	46.8	0	0.001	0.000
6	-0.035	1376	23.7	37.4	0	0.001	0.000
7	-0.035	1247	24.3	46.9	0	0.003	0.000
8	-0.035	1230	23.2	46.7	0	0.000	0.000
9	-0.036	1311	23.6	45.1	0	0.001	0.001
10	-0.035	1283	23.4	46.0	0	0.002	0.002
11	-0.035	1232	23.2	46.6	1	0.003	0.002
12	-0.035	1416	23.4	45.5	0	0.010	0.003
13	-0.035	1416	23.4	45.9	0	0.011	0.001
14	-0.035	1264	23.5	45.8	0	0.002	0.001
15	-0.035	1413	23.6	43.7	1	0.001	0.000
16	-0.035	1374	23.3	39.8	0	0.003	0.001
17	-0.035	1345	23.6	42.4	0	0.002	0.001
18	-0.036	1389	23.8	46.6	0	0.008	0.000
19	*	*	*	*	*	*	*
20	-0.035	1307	23.1	46.4	0	0.000	0.000
21	-0.035	1325	22.9	47.1	0	0.001	0.000
22	-0.035	1545	23.3	46.4	0	0.001	0.001

*Missing Data

Table 13 Air quality control measurements obtained from the CARS, June 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.036	369	27.7	41.1	0	0.049	0.048
1^{st}	-0.034	702	25.9	39.6	0	0.016	0.010
2^{nd}	-0.034	547	26.0	40.8	0	0.014	0.009
3^{rd}	-0.034	856	25.3	42.8	0	0.006	0.004
4^{th}	-0.034	537	24.6	41.5	0	0.010	0.009

Table 14 Air quality measurements obtained from the CARS, July 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.038	866	26.1	39.8	0	0.002	0.002
2	-0.037	828	25.1	39.3	0	0.004	0.000
3	-0.037	866	24.2	40.5	0	0.003	0.000
4	-0.037	867	24.3	43.6	0	0.001	0.001
5	-0.037	850	24.4	43.8	0	0.004	0.000
6	-0.036	987	23.6	47.1	0	0.000	0.000
7	-0.037	823	24.4	44.4	0	0.009	0.000
8	-0.037	867	23.9	46.9	0	0.002	0.000
9	-0.036	915	24.1	47.5	0	0.002	0.000
10	-0.037	999	22.7	47.2	0	0.014	0.000
11	-0.036	950	22.5	43.6	0	0.001	0.000
12	-0.036	1152	22.8	45.3	0	0.007	0.001
13	-0.036	1003	23.2	44.7	0	0.003	0.003
14	-0.036	1003	23.2	44.7	0	0.003	0.003
15	-0.037	1073	23.5	41.4	0	0.006	0.000
16	-0.037	961	23.4	39.3	0	0.001	0.001
17	-0.036	1008	24.2	45.0	0	0.004	0.000
18	-0.036	910	24.2	46.3	0	0.018	0.000
19	-0.037	859	23.6	46.0	0	0.000	0.000
20	-0.037	887	23.3	44.9	0	0.001	0.000
21	-0.036	955	23.6	47.2	0	0.002	0.001
22	-0.036	993	23.3	46.6	0	0.001	0.000

Table 15 Air quality control measurements obtained from the CARS, July 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.039	333	30.2	46.7	0	0.035	0.034
1st	-0.037	513	29.0	33.5	0	0.005	0.006
2nd	-0.037	506	27.1	37.0	0	0.006	0.004
3rd	-0.037	707	26.7	38.7	0	0.005	0.001
4th	-0.037	493	26.3	40.4	0	0.005	0.004

Table 16 Air quality measurements obtained from the CARS, August 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.053	1601	25.2	41.8	0	0.005	0.000
2	-0.053	1503	23.1	47.4	0	0.001	0.001
3	-0.053	1513	23.1	47.6	0	0.001	0.000
4	-0.053	1489	23.7	46.3	0	0.001	0.000
5	-0.053	1460	23.6	47.4	0	0.000	0.000
6	-0.053	1504	23.4	48.9	0	0.002	0.000
7	-0.053	1453	23.1	46.9	0	0.000	0.000
8	-0.052	1470	22.8	49.6	0	0.002	0.000
9	-0.052	1438	23.2	50.4	0	0.000	0.000
10	-0.054	1429	23.2	47.2	0	0.001	0.000
11	-0.053	1376	22.8	46.7	0	0.003	0.001
12	-0.054	1621	23.1	44.0	0	0.001	0.001
13	-0.053	1386	22.9	43.5	0	0.004	0.001
14	-0.053	1365	23.0	43.0	0	0.002	0.001
15	-0.053	1772	23.3	39.7	0	0.001	0.001
16	-0.053	1680	22.8	44.5	0	0.006	0.001
17	-0.053	1725	23.5	41.3	0	0.001	0.000
18	-0.053	1607	23.7	44.3	0	0.002	0.000
19	-0.052	1646	23.1	49.6	0	0.004	0.002
20	-0.053	1543	23.1	46.6	0	0.001	0.000
21	-0.053	1546	22.8	48.5	0	0.001	0.000
22	-0.053	1634	23.3	44.5	0	0.001	0.001

Table 17 Air quality control measurements obtained from the CARS, August 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.052	360	29.9	38.9	0	0.056	0.053
1st	-0.054	600	27.2	35.9	0	0.012	0.006
2nd	-0.053	680	28.2	39.0	0	0.007	0.007
3rd	-0.052	975	25.4	35.6	0	0.002	0.001
4th	-0.052	595	25.8	43.8	0	0.009	0.008

Table 18 Air quality measurements obtained from the CARS, September 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.054	1549	24.3	43.1	0	0.000	0.000
2	-0.055	1474	23.9	43.4	0	0.001	0.000
3	-0.055	1458	23.7	42.9	0	0.000	0.000
4	-0.055	1450	23.4	42.3	0	0.002	0.000
5	-0.056	1388	23.6	44.3	0	0.000	0.000
6	-0.056	1448	24.1	43.8	0	0.000	0.000
7	-0.056	1378	23.3	44.5	0	0.001	0.000
8	-0.056	1379	23.1	41.9	0	0.000	0.000
9	-0.056	1388	23.5	43.1	0	0.001	0.000
10	-0.056	1670	23.7	43.5	0	0.001	0.000
11	-0.056	1482	24.1	43.2	0	0.001	0.000
12	-0.056	1838	23.4	41.7	0	0.005	0.001
13	-0.056	1525	24.3	43.7	0	0.009	0.001
14	-0.056	1614	24.3	46.2	0	0.001	0.001
15	-0.056	2043	24.2	37.8	0	0.011	0.000
16	-0.055	1764	22.8	40.9	0	0.003	0.001
17	-0.055	1991	24.2	40.6	0	0.002	0.001
18	-0.055	1669	24.4	43.8	0	0.004	0.001
19	-0.056	1549	23.4	45.5	0	0.003	0.000
20	-0.055	1556	22.9	45.1	0	0.012	0.000
21	-0.056	1514	23.8	42.6	1	0.000	0.000
22	-0.056	1773	24.6	41.4	1	0.002	0.001

Table 19 Air quality control measurements obtained from the CARS, September 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.056	386	27.7	39.1	0	0.043	0.040
1st	-0.055	678	24.6	41.6	0	0.007	0.005
2nd	-0.055	642	25.1	45.4	0	0.005	0.004
3rd	-0.054	1042	22.8	44.5	0	0.002	0.001
4th	-0.055	734	23.5	48.1	0	0.019	0.004

Table 20 Air quality measurements obtained from the CARS, October 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
1	-0.054	1448	22.4	41.9	0	0.003	0.001
2	-0.054	1417	21.9	42.1	0	0.003	0.001
3	-0.054	1436	22.2	43.2	0	0.003	0.002
4	-0.055	1399	22.1	43.0	0	0.005	0.000
5	-0.054	1473	22.7	44.1	0	0.004	0.001
6	-0.057	1412	23.2	41.9	0	0.006	0.000
7	-0.055	1403	22.7	42.8	0	0.003	0.000
8	-0.056	1398	23.0	41.7	0	0.069	0.002
9	-0.056	1406	23.2	41.8	0	0.002	0.000
10	-0.056	1403	23.0	41.1	0	0.032	0.004
11	-0.056	1299	22.3	41.1	0	0.004	0.001
12	-0.056	1546	22.7	39.8	0	0,008	0.000
13	*	*	*	*	*	*	*
14	-0.056	1330	22.5	39.6	0	0.003	0.000
15	-0.055	1528	22.8	40.8	0	0.002	0.000
16	-0.055	1557	22.0	38.8	0	0.004	0.000
17	-0.056	1676	23.1	41.5	0	0.003	0.001
18	-0.056	1459	22.8	42.6	0	0.006	0.000
19	-0.055	1420	22.3	42.0	0	0.002	0.000
20	-0.056	1439	22.3	42.6	0	0.034	0.002
21	-0.057	1415	23.1	40.8	0	0.002	0.001
22	-0.056	1535	23.0	41.1	0	0.002	0.002

*Missing Data

Table 21 Air quality control measurements obtained from the CARS, October 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.056	386	12.1	30.4	0	0.023	0.021
1st	-0.054	627	20.5	41.4	0	0.021	0.004
2nd	-0.052	606	22.0	38.2	0	0.005	0.003
3rd	-0.053	1049	21.9	41.1	0	0.001	0.000
4th	-0.052	595	21.6	36.5	0	0.009	0.002

Table 22 Air quality measurements obtained from the CARS, November 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates ≤10 µm (mg/m^3)	Respirable Particulates ≤2.5 µm (mg/m^3)
1	-0.052	1420	22.3	36.3	0	0.000	0.000
2	-0.052	1309	22.2	36.5	0	0.000	0.000
3	-0.053	1312	22.3	37.5	0	0.001	0.001
4	-0.053	1291	22.0	36.7	0	0.004	0.000
5	-0.053	1279	22.4	37.3	0	0.001	0.001
6	-0.054	1353	24.2	35.2	0	0.001	0.000
7	-0.053	1284	22.2	36.2	0	0.001	0.001
8	-0.055	1347	22.6	34.4	0	0.002	0.002
9	-0.055	1306	23.9	34.7	0	0.009	0.004
10	-0.054	1474	23.9	36.5	0	0.002	0.001
11	-0.054	1397	23.7	37.2	0	0.001	0.001
12	-0.054	1516	23.8	35.4	0	0.011	0.000
13	-0.054	1563	22.8	37.6	0	0.005	0.001
14	-0.054	1434	22.2	38.2	0	0.001	0.001
15	-0.054	1476	22.1	35.7	0	0.001	0.000
16	-0.053	1644	22.3	37.1	0	0.032	0.001
17	-0.053	1583	23.1	37.1	0	0.002	0.000
18	-0.054	1414	22.6	36.5	0	0.000	0.000
19	*	*	*	*	*	*	*
20	-0.053	1369	22.5	36.4	0	0.001	0.001
21	-0.054	1430	23.6	35.1	0	0.002	0.002
22	-0.054	1346	23.6	34.9	0	0.021	0.009

*Missing Data

Table 23 Air quality control measurements obtained from the CARS, November 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.054	378	5.4	36.9	0	0.019	0.018
1^{st}	-0.054	671	23.1	26.9	0	0.021	0.008
2^{nd}	-0.054	597	23.5	27.7	0	0.012	0.008
3^{rd}	-0.054	1004	23.4	34.2	0	0.016	0.001
4^{th}	-0.054	576	23.7	29.5	0	0.004	0.004

Table 24 Air quality measurements obtained from the CARS, December 2002

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates ≤10 µm (mg/m^3)	Respirable Particulates ≤2.5 µm (mg/m^3)
1	-0.051	1032	22.7	30.5	0	0.000	0.000
2	-0.051	1075	22.1	30.1	0	0.000	0.000
3	-0.054	1128	23.7	29.8	0	0.006	0.000
4	-0.051	1028	22.0	30.0	0	0.001	0.000
5	-0.052	1058	22.4	30.3	0	0.001	0.000
6	-0.053	1100	22.9	29.9	0	0.005	0.000
7	-0.053	959	22.7	29.6	0	0.001	0.000
8	-0.053	1073	22.6	29.7	0	0.000	0.000
9	-0.053	1045	22.8	29.2	0	0.001	0.001
10	-0.054	1003	23.9	29.2	0	0.001	0.000
11	-0.054	975	24.0	29.2	0	0.001	0.001
12	-0.054	1114	23.6	29.9	0	0.003	0.000
13	*	*	*	*	*	*	*
14	-0.054	955	23.9	29.2	0	0.000	0.000
15	-0.054	1146	23.8	30.3	0	0.004	0.000
16	-0.054	1099	22.6	30.2	0	0.002	0.000
17	-0.053	1069	23.6	30.6	0	0.000	0.000
18	-0.054	1027	23.4	29.4	0	0.008	0.003
19	-0.054	1069	23.1	30.0	0	0.000	0.000
20	-0.054	971	23.2	29.0	0	0.000	0.000
21	-0.054	1034	23.4	28.9	0	0.000	0.000
22	-0.055	1116	23.6	29.1	0	0.003	0.001

*Missing Data

Table 25 Air quality control measurements obtained from the CARS, December 2002

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.056	372	17.4	21.3	0	0.025	0.025
1st	-0.055	608	23.6	27.7	0	0.009	0.005
2nd	-0.055	510	23.7	24.2	0	0.009	0.001
3rd	-0.055	919	23.5	29.2	0	0.001	0.001
4th	-0.055	624	23.4	29.5	0	0.011	0.002

Table 26 Air quality measurements obtained from the CARS, January 2003

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates ≤10 µm (mg/m^3)	Respirable Particulates ≤2.5 µm (mg/m^3)
1	-0.053	1359	23.1	32.7	0	0.004	0.001
2	-0.053	1349	22.5	33.5	0	0.002	0.002
3	-0.052	1323	22.6	34.6	0	0.004	0.000
4	-0.053	1290	22.9	34.5	0	0.012	0.001
5	-0.052	1250	22.7	34.0	0	0.001	0.001
6	-0.055	1394	23.5	34.4	0	0.002	0.001
7	-0.054	1245	22.6	35.0	0	0.001	0.000
8	-0.055	1337	23.7	34.0	0	0.000	0.000
9	-0.054	1360	23.6	34.2	0	0.001	0.000
10	-0.054	1318	23.8	35.0	0	0.001	0.000
11	-0.054	1404	23.6	35.2	0	0.001	0.001
12	-0.055	1370	23.5	33.7	0	0.001	0.001
13	-0.054	1316	23.1	35.1	0	0.013	0.001
14	-0.054	1328	22.9	34.9	0	0.002	0.001
15	-0.053	1383	22.6	34.3	0	0.020	0.001
16	-0.053	1357	22.2	34.5	0	0.010	0.000
17	-0.053	1358	22.8	35.4	0	0.001	0.000
18	-0.053	1287	22.7	34.9	0	0.002	0.000
19	-0.053	1254	22.5	35.0	0	0.001	0.001
20	-0.054	1321	23.2	33.7	0	0.001	0.000
21	-0.054	1250	22.9	33.8	0	0.001	0.001
22	-0.054	1246	23.5	33.5	0	0.002	0.002

Table 27 Air quality control measurements obtained from the CARS, January 2003

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.055	363	15.1	24.6	1	0.034	0.032
1st	-0.055	706	24.3	29.0	0	0.022	0.007
2nd	-0.055	548	24.4	29.4	0	0.012	0.011
3rd	-0.053	908	22.2	33.6	0	0.027	0.001
4th	-0.055	577	23.6	34.6	0	0.004	0.003

Table 28 Air quality measurements obtained from the CARS, February 2003

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates ≤10 µm (mg/m^3)	Respirable Particulates ≤2.5 µm (mg/m^3)
1	-0.056	1271	21.8	34.6	0	0.001	0.000
2	-0.055	1267	21.6	35.3	0	0.003	0.000
3	-0.056	1320	22.5	35.7	0	0.001	0.000
4	-0.055	1269	22.7	34.8	0	0.005	0.001
5	-0.055	1247	22.9	34.2	0	0.001	0.000
6	-0.058	1353	23.7	32.4	0	0.002	0.000
7	-0.056	1234	22.7	33.2	0	0.006	0.000
8	-0.059	1273	22.7	32.0	0	0.000	0.000
9	-0.059	1278	23.8	33.1	0	0.000	0.000
10	-0.057	1533	23.8	34.7	0	0.002	0.000
11	-0.057	1353	23.4	34.8	0	0.002	0.001
12	-0.058	1683	23.7	33.9	0	0.002	0.001
13	-0.056	1410	23.6	33.6	0	0.002	0.000
14	-0.056	1415	23.4	33.3	0	0.002	0.000
15	-0.058	1683	23.7	33.9	0	0.002	0.001
16	-0.058	1550	22.4	34.1	0	0.007	0.000
17	-0.058	1676	22.8	34.6	0	0.006	0.001
18	-0.058	1304	22.9	34.8	0	0.005	0.000
19	-0.057	1251	22.2	34.0	0	0.001	0.000
20	-0.057	1239	22.3	34.2	0	0.000	0.000
21	-0.059	1303	23.7	32.1	0	0.001	0.000
22	-0.059	1528	23.7	32.7	0	0.002	0.000

Table 29 Air quality control measurements obtained from the CARS, February 2003

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.058	375	14.7	26.1	1	0.042	0.041
1st	-0.058	668	24.1	29.7	0	0.023	0.006
2nd	-0.057	555	24.4	30.5	0	0.017	0.012
3rd	-0.057	992	23.2	33.9	0	0.004	0.001
4th	-0.058	600	23.7	35.2	0	0.009	0.004

Table 30 Air quality measurements obtained from the CARS, March 2003

Sample Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (°C)	Relative Humidity (%)	CO (ppm)	Total Particulates ≤10 µm (mg/m^3)	Respirable Particulates ≤2.5 µm (mg/m^3)
1	-0.002	953	22.7	30.7	0	0.005	0.000
2	-0.001	869	22.3	30.9	0	0.001	0.000
3	-0.001	883	22.4	31.2	0	0.001	0.000
4	-0.000	837	22.4	31.2	0	0.001	0.001
5	-0.000	802	22.4	31.1	0	0.000	0.000
6	-0.001	850	23.3	30.9	0	0.001	0.000
7	-0.000	821	22.1	31.3	0	0.002	0.001
8	-0.001	864	22.8	30.8	0	0.008	0.000
9	-0.001	840	23.1	30.7	0	0.001	0.000
10	-0.002	972	23.3	31.8	0	0.001	0.000
11	-0.001	944	23.0	31.9	0	0.001	0.000
12	-0.002	1166	23.2	32.2	0	0.012	0.001
13	-0.001	989	22.8	32.0	0	0.002	0.000
14	-0.002	1003	22.8	32.1	0	0.002	0.000
15	-0.001	1050	22.9	30.7	0	0.002	0.000
16	-0.000	1158	22.0	32.6	0	0.005	0.001
17	-0.001	1074	23.1	31.2	0	0.001	0.001
18	-0.001	962	23.3	32.0	0	0.001	0.001
19	-0.001	942	23.0	32.5	0	0.000	0.000
20	0.000	937	22.5	32.9	0	0.002	0.000
21	-0.001	925	23.6	30.0	0	0.000	0.000
22	-0.002	1155	23.2	31.5	0	0.004	0.001

Table 31 Air quality control measurements obtained from the CARS, March 2003

Control Site ID	Pressure (in. H_2O)	CO_2 (ppm)	Temperature (^oC)	Relative Humidity (%)	CO (ppm)	Total Particulates 10 µm (mg/m^3)	Respirable Particulates 2.5 µm (mg/m^3)
Outside	-0.001	381	10.8	17.9	0	0.017	0.015
1^{st}	-0.001	596	22.4	24.5	0	0.010	0.004
2^{nd}	-0.001	495	22.3	22.6	0	0.007	0.007
3^{rd}	-0.001	890	23.2	31.3	0	0.005	0.002
4^{th}	-0.001	664	23.5	30.2	0	0.003	0.002

VITA

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