Understanding the Relationship Between Air Quality Seasonal Environments by Establishing a Differentiation of the Symptoms and Causes of Vocal Function Disorders When Compared to Pollution Data

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Approval Page

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Abstract

This study is an analysis of the relationship between air quality seasonal environments by establishing a differentiation of the causes of vocal function disorders when compared to pollution data. Sandra L. Gaskell, 2014: Applied Dissertation, Nova Southeastern University, Abraham S. Fischler School of Education. ERIC Descriptors: Air Pollution, Vocal Cord Dysfunction, Voice Symptoms, Oropharynx, Laryngeal Syndromes, Allergy, Asthma, Cough, Seasonal Environment, Workplace Pollution.

This applied dissertation was designed to examine the relationships between the severities of symptoms of laryngeal disturbances involving the oropharynx in a geographic environment in order to classify and compare them to the air quality scales. Research by the Air Resources Board of the total respiratory system between the sinuses and the lungs has been absent in vocal function research evaluating the impact of pollutants on the oropharynx and larynx. Voice disorders reported in the seven counties may show predictable rates based upon the seasonal pollution rates. This study is intended to raise awareness regarding the main vocal function diagnoses, symptomology data, environmental factors, and geospatial relationships inhibiting voice therapy progress near the San Joaquin Valley Air Pollution Control District monitor sites. A survey methodology will be employed, consisting of both qualitative and quantitative data collection and analysis. The survey will be e-mailed to a random sample of otolaryngologists, speech pathologists, and radiation-oncology physicians. Both quantitative and qualitative information will be analyzed through the use of appropriate statistical formulas to obtain results.

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Chapter 1: Introduction

Statement of the Problem

The worst air quality in the United States has placed a burden on those suffering from vocal function disorders in the Central Valley of California. Although the Air Resources Board health analysis includes the lungs and sinuses, research on the effects of pollution on the tissues and function of the oropharynx and larynx has been limited. This study is concerned with collecting the diagnoses and symptom clusters that have been identified from records of vocal dysfunction sufferers located within this environment through a survey of health professionals. This primary investigator believes that the inclusion of the oropharyngeal, pharyngeal, and laryngeal physiology into the existing rhinitis and bronchial research within the Air Resources Board health reporting should complete respiratory system representation. By comparing the vocal dysfunction diagnoses and symptoms from the seven counties of the San Joaquin Valley Air Pollution Control District (SJVAPCD) to the geographic monitor sites data, the result may be a set of recommendations for the population affected by seasonal sensitivities.

The Topic

The Central Valley of California is a broad basin between two mountain ranges that captures dust in the fall, fog in the winter, pollen in the spring, and chemicals in the summer heat. This environment has been identified as a catch basin for smog and air pollution. Speech-language pathologists practicing in the Central Valley are confronted with complications of allergy and irritation that may impair progress of recovery for their patients. It is proposed that the diagnoses of vocal function referrals located from within this environment be differentiated and classified so that they may be compared to the air quality scales in the geographic regions represented by medical professional respondents from the Central California's San Joaquin

Valley Air Pollution Control District (SJVAPCD). This classification will be accomplished by creating a survey that will be presented to regional ear, nose and throat (ENT) otolaryngology and radiation-oncology physicians, nurses, and speech-language pathologists. Survey results will be used to differentiate the vocal function diagnoses and georeference the spatial and temporal data.

Voice disorders reported in the seven counties of Central California's San Joaquin Valley Air Pollution Control District (SJVAPCD) may show predictable rates based upon population. As reported in the findings of a preliminary questionnaire titled "Voice Function in the Central Valley: ENT and Radiation-Oncology Physician Survey" (Gaskell, 2011), a range of voice disorders exists that may be linked to environmental factors or exacerbated by air quality. A differentiated approach was developed based upon the findings of this preliminary questionnaire by Gaskell that presented issues affecting regional voice therapy. This preliminary questionnaire was available on March 25, 2011 through an email link for random volunteers who were members and physicians of the American Academy of Otolaryngologists (AAO). The survey participants volunteered to screen the protocol (AAO, 2011).

The blind responses to the preliminary questionnaire from unidentified random respondents remained viable for a 48-hour period only before they were erased (Surveygizmo, 2011). There were a total of 105 respondents, with 35 listing themselves as being identified with the SJVAPCD counties. Some of the responses were false tests where all items were not scored. All responses from those who replied that they had patients in more than one region were discarded. This left a random sample of the individuals who named only one county of California as their place of practice. Important information about the design of the survey was interpreted from the sample questionnaire. The instrument has been revised and evaluated by the dissertation statistician for reliability after the sample was reviewed (Enders, 2011).

The Research Problem

In order to raise awareness regarding the lack of information within the primary health related documentation of the SJVAPCD, this study will review the research reported by Hall, Brajer, and Lurmann (2006) regarding the specialization of the oropharyngeal and laryngopharyngeal portion of the human anatomy. Review of the health report to the SJVAPCD indicated that the specialization of otolaryngologists addressed by the study included the nasopharynx, sinus indications, and the respiratory system, but no information regarding vocal function or laryngeal mucosa or oral transit of particulate matter was included. Vocal function rehabilitation after diagnosis requires pretreatment voice output levels to be provided to speech-language pathologists in the Central Valley of California. Questions asked regarding the amount of time spent on voice quality measures in the entry interviews by the physicians provides valuable information regarding perceived environmental causes of voice problems. It is necessary to determine what the main vocal function diagnoses consist of, what pretreatment, presurgery/radiotherapy output levels were, and symptomology data that were gathered, and the quantity of voice function of patients referred for outpatient, home health, or eTherapy treatment.

Otolaryngologists' intake findings are essential to diagnostics of speech-language professional voice treatment in this geographic region of California. This geographic analysis investigates the risks and propensities of voice treatment in the Central Valley of California in the SJVAPCD. The most commonly referred patient voice diagnoses have been hypothesized from preliminary questionnaire responses as voice therapy for head and neck cancer (HNC); voice as repetitive strain injury (RSIV) on workman's compensation; vocal cord nodules, polyps or cysts, vocal cord paralysis, vocal abuse; tissue degradation from reflux or GERD; Parkinson disease vocal tremors; therapy after thyroid surgery; and spasmodic dysphonia. Most referrals from a physician are of patients experiencing prolonged chronic hoarseness or laryngitis. Medical coding for the most common initial referral diagnoses are from the acute respiratory infections ICD-9 codes, the upper respiratory tract ICD-9 codes, such as Diagnosis Code 464.00 of Acute Laryngitis, or 784.49 for Hoarseness. Many times the specific code information is all that is listed on the physician's referral request (American Medical Association, 2011).

Intake procedures of otolaryngologists and speech pathologists include measures of vocal function through self-reporting of patient data. Various survey instruments are used daily such as the Voice-Related Quality of Life (V-ROQL) measure (Hogikyan & Sethuraman, 1999), the Consensus Auditory-Perceptual Evaluation of Voice (CAPEV) assessment (Kempster, Geratt, Abbott, Barkmeier-Kraemer & Hillman (2009), the GRBAS Voice Rating Scale (GRBAS) perceptual questionnaire (Hirano, 1981; Carding, Wilson, MacKenzie & Deary, 2009), the Paradoxical Vocal Fold Movement Questionnaire (PVFM) (Vertigan, Theodoros, Gibson & Winkworth, 2007), the Voice Handicap Index (VHI) checklist (Jacobson et al., 1997), the Voice Sensation Checklist (Towey, 2005), and other rating scales such as the M.D. Anderson Symptom-Inventory Patient Outcome Instrument (Cleeland, 2000). By using these voice quality surveys during intake, and through listening to the sound production during question responses, a brief clinical assessment places categorical symptom information into use. The information regarding the intake survey interview procedures is information necessary for the speech pathologist to prepare the correct set of evaluation procedures for supporting the clinical medical diagnosis and creating a therapy treatment plan. It is important to know which interview instruments are used by professionals.

In a preliminary questionnaire, voice therapy services were reviewed within the SJVAPCD geographic area of 90-100 miles surrounding Modesto using the Internet, various telephone directories, professional associations (American Speech-Language-Hearing Association, 2011), and physician referral listings. This was done in order to approximate the number of possible participants. The major voice and swallowing centers were located in Sacramento, Fresno, and the San Francisco Bay Area. Voice therapy practices require a close relationship between the speech pathologist and the referring physician—ear, nose and throat (ENT) specialists—for access to the instrumental evaluation and a relationship providing medical collaboration with the physician. Diagnosis and treatment is a team effort including more than one profession. A list of possible respondents was compiled for the region of the SJVAPCD.

The SJVAPCD tracks detailed air quality data geographically linked to the regions of the ENT practice locations (Figure 1). When collected, these data may hold validity in the temporal distribution of health relationships indicating a schedule of poor air quality that corresponds to the degree of severity of vocal function symptoms. This schedule could then be used for understanding the relationship between air quality, seasonal effects on the environment, a differentiation of the causes of vocal function disorders when compared to air quality data, and the relationship between severity of symptoms and laryngeal disturbances involving the oropharynx and laryngopharynx.

Geospatial relationships between the distances traveled for a vocal function diagnostic and treatment appointment, and the practitioner may also be a deterrent to chronic hoarseness or individuals experiencing laryngitis in the Central California SJVAPCD. Geographic and socioeconomic conditions and limitations to access for diagnosis and treatment have been considered in the literature review of Hall, Brajer, and Lurmann (2006) in the environmental health review. According to Towey (2009), insurance coverage paying for rural speech therapy via the Internet has gained approval. It has been widely accepted for rural, nonambulatory patients, and in areas where there is a shortage of speech pathologists according to Banotai (2011). This information could be related to the amount of therapy gains for patients who may be directly affected by distances and the particulates trapped in the air at certain elevations and times of the year such as the boundaries of the Central Valley where wood burning smoke, dust and smog accumulate.

Survey questions regarding the Central California SJVAPCD air quality geospatial data were created and asked in the preliminary questionnaire in order to define which types of pollutants caused symptoms and which times of the year voice symptoms were experienced. The ranking of significance for responses from the preliminary questionnaire were found to be in this order of influence: a) pesticides and spraying, 40% of the respondents rated these with a 75%–90% impact; b) dust and harvesting, 26% of the respondents rated these with 75%–90% impact; c) smog and fumes, 17% of the respondents rating these with 75%–90% impact; and d) allergies to pollen in the air, 17% of the respondents rated this with 75%–90% impact. These questions were posed so that the Likert Scale options were from 0%-25%, 25%-50%, etc., with one variable of influence presented at a time. A secondary objective of the study will attempt to relate the actual air quality data to the perceived impact by each type of foreign air agent, and the impact of the elements upon patient improvement.

Environmental factors affecting the increased need for voice therapy can be seen in the climate, topography, the types of laborers living and working in the Central Valley, and the habits that this environment promulgates (SJVAPCD, 2011; Baldassacre, 2006). The Central

Valley has been known for its high rates of respiratory stress due to the smog combined with high temperatures, the yearly Tule fog (moisture content) at low temperatures, and the reoccurrence of Valley Fever (*Coccidioidmycosis*) brought yearly by the dust storms carrying dust filled with organic materials and fungus spores. The weather creates a yearly incubator of illness that increases complications of associated illness causing voice disorders to increase in severity. The increase in number of people suffering from voice disorders during these times who present with complaints and are referred for therapy may be estimated.

Employment in the Central Valley focuses on agriculture, construction, education, and automotive service (SJVAPCD, 2011). Each of these professions has associated activities which increase the risk of acquiring some form of voice disorder. Within the interviews of past voice evaluations there were statements regarding examples of breathing diesel fumes reported by a transportation manager, of vocal abuse reported by a school teacher and a nurse, of being crushed by a steel girder reported by a construction welder, yelling reported by a coach, prolonged exposure to dirt and dust reported by a farm worker, and over use of tobacco and alcohol reported by patients with HNC (Gaskell, 2011).

Background and Justification

Therapy services for voice rehabilitation address the disorder categories that may be directly affected by elements in the environment. The patients suffering from these disorders experience increased symptom distress during various times of the year. At these times, they are required to avoid breathing the outside air. Outside air is the initial contact with airborne contaminants through the nasal and the oral cavities. The exposure to dust, particulates, allergens, or chemicals occurs during breathing and speaking and affects the tissues of the mucosal lining of the oral cavity, nasopharynx, and oropharynx. The education for the care of these tissues has been mostly dependent upon the dental community.

According to the preliminary questionnaire results, swallowing difficulties were reported by 55% of the respondents (Gaskell, 2011). Oral hygiene product use was reported as 2.9%. There were 20% of the respondents who provided oral hygiene products to 25%-50% of their patients. Xerostomia (dry mouth) complaints were reported by 42% of the respondents. There were 38% of the respondents reporting oral mucositis (hyposalivation or increase in saliva viscosity) complaints. There were 36% of the respondents complaining of trismus that impeded mastication. Information regarding the tissues of the orpharynx may be important to the understanding of air quality effects.

Populations of Voice Disorders. Medical insurance companies that approved provider lists in the Modesto area are Aetna, Blue Shield, Anthem Blue Cross of CA, Kaiser Permanente, CIGNA, Humana, United Healthcare, HealthNet, and Assurant. California's population was 37,059,235 (Census, 2010). According to eHealthInsurance (2010), the total California Health Maintenance Organization (HMO) enrollment was at 15,699,228. The annual employee premium was about $741. Claims made by teachers and other professionals for voice therapy were submitted to Workman's Compensation Insurance, preferred provider organizations (PPO), managed care organizations (MCO) and Health Maintenance Organizations (HMO). According to the National Institute on Deafness and other Communication Disorders (NIDCD) approximately 7.5 million people in the United States have trouble using their voices. The population of the U.S. is now at 308,745,538, according to the U.S. Census Bureau (2010). The number of people reporting voice problems was .2%. The California state population with voice disorders can be calculated by using the .2%. Out of the population of California (37,059,235), there are estimated to be 74,118 people per year suffering from a voice disorder. Out of the state population, 510,385 people were in the Modesto area. This means that 1,020 (or .2%) of the residents of this region per year may suffer from some type of voice disorder.

The percentage of randomly selected respondents to the preliminary questionnaire by county was Stanislaus County, 35.3%; Merced County, 14.7%; Fresno County, 14.7%; Madera County, 11.8%; San Joaquin County, 11.8%; Kings County, 8.8%; and Kern County, 2.9% (Gaskell, 2011). The distance driven to clinics for therapy was described as 10-30 miles for 32.4% of the patients. The survey had six questions that centered upon how thorough an interview questionnaire was administered before treatment by the otolaryngologist offices. The major response was that the office staff administers the interview questionnaire, but none of the offices listed a standard voice evaluation interview questionnaire used by speech pathology (scored above 15%) during the initial interview. The four major voice disorders listed by respondents were neurogenic disorders, nodules or cysts, reflux or GERD, and head–neck cancer. Of these disorders, the vocal abuse symptoms of nodules and cysts were 58% of the patients treated, followed by the reflux patients, and then the neurogenic disorder patients (Gaskell, 2011).

Of the respondents, there were 14% who thought that during the entire year there was air pollution or particulates that affected their voice. An additional 14% thought that there was a 3-month period every year when they were symptom free. The majority of the respondents thought that the fall harvest season held the most symptom reactivity. The patient population should then be predicted to have a larger number of complaints during the months of August through October.

Clusters of symptoms. Voice disordered patients undergo evaluations to measure six components of vocal function (Stemple, 2000). For example, patients recovering from radiation-oncology and surgery due to a cancer diagnosis have groups or "clusters" of symptoms. These symptoms can be grouped as components of an evaluation including functional daily living as well as the vocal function output of respiration, phonation, resonance, pitch, loudness, and rate of speech (Molassiotis, Wengstrom & Kearney, 2010). Other areas of symptoms can be viewed as the secondary or causal conditions based upon the type of disorder or lesion such as exposure to foreign substances, a lack of innervations causing weakness or flaccidity, or damaged tissues causing stiffness or edema and tightness. Symptoms related to vocal function disorders that can be identified with coughing, secretions, and wheezing (Noonan, Ward, Navidi, & Sheppard, 2012, pp. 3-4), nasal congestion and postnasal drip (Sacha & Quinn, 2011, pp. 81-82), nasal discharges and airway reflexes (Pauluhn & Mohr, 2006, p. 285), inflammation along the respiratory regions in adenoids, sinuses, pharyngeal wall, and otitis media (Kariya, Okono & Nishizaki, 2014), or acute chronic cough, dyspnea, chronic sputum production, episodic laryngospasm (Moscato et al., 2014) were reported in air pollution. Other symptoms of vocal dysfunction written about in athletic review, in medical and clinical research, in the tobacco industry literature, in educational literature, in occupational workplace studies, or other literature sources where these symptoms can be identified in order to illicit medical attention.

Deficiencies in the evidence

There is limited information available to researchers seeking an understanding of how the environmental conditions affect the number of cases of vocal function disorders in the California Central Valley. Patients living in the poor air quality districts of the SJVAPD may suffer more severe symptoms than patients in other regions. They may need to follow different therapy recommendations and exposure requirements because of the geographic air quality information available for their part of the Central Valley SJVAPCD.

The symptoms of allergy caused by environmental air quality and other pollutants need to be differentiated from the symptoms of vocal function disorders. Treatments for the allergies and other symptoms may have an effect upon the recovery of patients and may be the cause of a diagnosis of hoarseness or laryngitis. Since there has been limited research and information for the anatomical region of the oropharynx within the research of the Central Valley SJVAPCD health report, further research is needed.

Audience

It is the belief of the primary investigator that the information gathered from the health care professionals regarding the symptoms of vocal dysfunction as it relates to the location and temporal occurrence can form a baseline for medical recommendations. The findings may be used by therapists for developing patient directives for specific times of the year much like the School Flag Program instituted using the Environmental Protection Agency (EPA) color code. The levels of color coded air quality are accompanied by a list of directives for exposures. Physicians and speech pathologists may use the findings to interpret symptom clusters at certain times of the year based upon the levels of pollution as they relate to the visible disturbances of the patients. Further research by the health professionals within the Air Resources Board may introduce further observations for the regions of physiology of the respiratory system in order to provide more complete guidelines. Pollution information provided through the monitoring stations of the Air Resources Board that may be extrapolation can form the basis for forming strategies. The geographic representation of the physician responses when mapped against the monitoring site pollution data should reveal temporal patterns of symptom clusters. Other groups of individuals that may find this information valuable are athletes, military, recreation professionals, public education, regional planners, and biologists. Many of the physiological studies which were performed on experimental animals have implications for living organisms and the effects of the particulates on tissues whether the cells are flora or fauna. The information gathered may provide important data for developing strategies in many areas.

Definition of Terms

More complex associations for the definitions have been included in order to explain the processes of tissue functions as a background for describing the effects of air pollutants on already affected tissues. There is a classification manual providing guidance for the diagnosis of vocal function disorders that has been referenced for diagnostic criterion (Verdolini, Rosen, & Branski, 2006). Diagnostic classifications of voice disorders referenced in this study will be as they are defined by Verdolini et al. (2006) according to the American Speech-Language and Hearing Association Classification of voice disorders refined by the voice disorders division of the Association. Information will be gathered regarding these classifications: a) neurogenic voice disorders (e.g., Parkinson disease vocal tremors, after thyroid surgery, and spasmodic dysphonia); b) tissue degradation from LPR, reflux, or GERD, Chronic Cough; c) head-neck cancer (HNC); and d) repetitive strain injury of voice (RSIV) usually vocal cord nodules, polyps, or cysts.

Nomenclature for air quality descriptions have been retrieved from the San Joaquin Valley Air Pollution District website and documents available there (SJVAPCD, 2014). The following terms provide a definition of the terms used in this study so that the understanding in context is clearly defined:

- Air Basin. An area of the state designated by the ARB pursuant to Subdivision (a) of Section 39606 of the CH&SC that has similar meteorological and geographic conditions.

- Air Pollutants. Substances that are foreign to the atmosphere or that are present in the natural atmosphere in concentrations that may result in adverse effects on humans, animals, vegetation, and/or materials.

- Air Quality Alerts. An air quality flag program that includes a color code that indicates the forecast of air quality is funded by the Asthma Coalition. It is based upon an air quality index rating schedule:

0-50 (Green) Good—no health advisory recommendation,

51-100 (Yellow) Moderate—recommendation that unusually sensitive people should consider reducing prolonged physical activity or heavy exertion,

101-150 (Orange) Unhealthy for sensitive groups—people with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion,

151-200 (Red) Unhealthy—people with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion,

201-300 (Purple) Very Unhealthy–people with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion. Everyone else should also avoid prolonged or heavy exertion.

- Ambient Air. Air occurring at a particular time and place outside of structures. Often used interchangeably with the term outdoor air.

- Biogenic. Produced by living organisms, Biogenic emissions are of extreme interest because of the predominance of agriculture in the San Joaquin Valley; however, the District has no authority to regulate biogenic emissions. Preliminary studies indicate that biogenic emissions may be at least two times more than the total hydrocarbon emissions already quantified in the emissions inventory (in the AQAP).
- Carbon Monoxide (CO). Carbon monoxide is a colorless, odorless gas that is the result of the incomplete combustion of fossil fuels. More than 80% of the CO emitted in urban areas is contributed by motor vehicles. CO interferes with the blood's ability to carry oxygen to the body's tissues and results in numerous adverse health effects. CO is a criteria pollutant.
- Criteria Air Pollutant. An air pollutant for which acceptable levels of exposure can be determined and for which a federal or state ambient air quality standard has been set Examples include Ozone, Carbon Monoxide, Lead, Nitrogen Dioxide, Sulfur Dioxide, and PM10.
- Exceedance. An air pollutant that is monitored and found to be above the state and/or federal ambient air quality standard for that pollutant.
- Hydrocarbon (HC). Any of a large number of compounds containing various combinations of hydrogen and carbon atoms. They may be emitted into the air as a result of fossil fuel combustion and fuel volatilization, and are a major contributor to smog.
- Oral mucositis. Hyposalivation, an increase in saliva viscosity, causes complaints common to many voice disorders.

- Oxides of Nitrogen (NOx). A general term that refers to compounds of nitric oxide (NO), nitrogen dioxide (NO2), and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. NO2 is a criteria pollutant, and may cause numerous adverse health effects.
- Particulate Matter (PM10). A major air pollutant consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists. The size of the particles (10 microns or smaller, about 0.0004 inches or less) allows them to enter the air sacs deep in the lungs where they may be deposited and result in adverse health effects. PM10 also causes visibility reduction and is a criteria air pollutant.
- Particulates. See particulate matter.
- Photochemical Reaction. A term referring to chemical reactions brought about by the light energy of the sun. Photochemical reactions create harmful air pollutants such as ozone.
- Repetitive strain injury of voice (RSIV). Individuals with this complaint are usually workman's compensation insurance clients. The condition is usually a result of vocal abuse and can include physiological evidence of nodules, calluses or other injuries. This activity can result in any of the epithelial and lamina propria abnormalities of the vocal fold.
- San Joaquin Valley Air Basin (SJVAB). The air basin is a geographic region defined by the ARB that has similar meteorological and geographical conditions and consists of all of San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, and Tulare Counties, and the Valley portion of Kern County.

- San Joaquin Valley Air Pollution Control District. The region of California that lies between the Sierra Nevada Mountains and the Coastal Range which was created by the San Joaquin River watershed. Air quality for this district is monitored by outposts throughout the region. The entire Central Valley Air Pollution District contains 20 counties, but we are only reviewing seven counties.
- Smog. Smog is a combination of smoke, ozone, hydrocarbons, nitrogen oxides, and other chemically reactive compounds, which, under various conditions of weather and sunlight, may result in a murky brown haze that causes adverse health effects. A primary source of smog is automobiles.
- Tissue degradation from Reflux or GERD. Stomach contents and gastroesophageal fluids find their way back up to the level of the larynx causing acid burn of the delicate tissues which can damage the tissue's ability to retain the suppleness and moist qualities necessary for vocal production.
- Trismus. Fibrosis that can impede mastication. Typically, functioning soft tissues have a healthy layer of mucous surrounding them. The mucous keeps the vocal folds moist which is crucial to vocal health. The lubrication enables the soft tissues to glide past each other with minimal resistance (Mossman, Shatzman, & Chencharick, 1982).
- Vocal cord nodules. Nodules appear as localized masses bilaterally, yet not always symmetrically placed, and typically at the midpoint of the midpoint or at the anterior third or posterior two-thirds of the length of the vocal fold.
- Vocal cord paralysis. This can be a peripheral nervous system pathology such as an interruption of the innervation to the Superior Laryngeal Nerve, the Unilateral or

Bilateral Recurrent Laryngeal Nerve, or due to Myasthenia Gravis, or a form of Neuropathy.

- Vocal cysts. Vocal fold cysts are usually encapsulated structures sometimes attributed to glandular duct blockage, phonotrauma, or a congenital condition. They commonly appear as an hourglass closure pattern during stroboscopic evaluation.
- Vocal Function. Typically functioning groups of anatomical and neurological components involved in the production of sound.
- Vocal polyps. The presence of benign masses located within the lamina propria of the membranous vocal folds. Most are unilateral, yet some may be broadly attached to the vocal fold surface or hanging from the vocal fold swinging in and out with each movement.
- Voice Baseline Measures. The levels at which an individual produces sounds from the vocal tract.
- Voice Evaluation. For the purpose of this applied dissertation, the voice evaluation is the clinical findings between the instrumental measurement of voice quality, the patient's self-analysis of the impact of their perceived voice disorder, the evaluation of the six vocal components using the perception of the speech pathologist, the oralperipheral exam to observe neurological function, the history of the problem, and the medical history. These components should be combined with the ENT instrumental evaluation results in order to formulate a diagnosis and prognosis after a course of treatment (Stemple, 2000).
- Volatile Organic Compounds (VOC). Hydrocarbon compounds exist in the ambient air. VOCs contribute to the formation of smog and/or may be toxic themselves. VOC

emissions are a major precursor to the formation of ozone. VOCs often have an odor, and some examples include gasoline, alcohol, and the solvents used in paints.

- Xerostomia. Hyposalivation or "dry mouth" complaints are a side effect that affects 47.3% of radiotherapy patients (Cheng, 2009; Grandi, Silva, Streit, & Wagner, 2007). Extreme lack of saliva has been attributed to loss of appetite (Ogama et al., 2010). Verdolini et al. (2002) found that hydration influences vocal fold mechanics.

Purpose of the Study

In order to better understand the geospatial dispersion and differentiation of the perceived effects of environmental elements on various classifications of vocal function disorders, and etiologies, a preliminary questionnaire will be directed to physicians in the San Joaquin Valley Air Pollution Control District (SJVAPCD). The regions where these physicians practice are in San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, and Kern Counties. This survey was designed by a speech-language pathologist to assess the beliefs and perception of physicians and speech-language pathologists in the SJVAPCD. The purpose of this study is to present and analyze the results of a preliminary questionnaire developed by a Central Valley speech-language pathologist directed toward the lack of specialized information on vocal function, oropharynx and laryngopharynx involvement reported by the Air Resources Board and the SJVAPCD health report. It is hoped that the analysis of the returned data will provide information allowing the determination of: a. the main vocal function diagnoses in the SJVAPCD, b. a description of how the respondents perceive the impact of the environmental quality of the SJVAPCD on these vocal function diagnoses, c. comparison of the spatial and temporal distribution of the vocal function diagnoses data to the georeferenced air quality levels and sources, d. the baseline output levels of vocal function symptomology data gathered, and e.

what is the significance of the distribution of the vocal function of patients who are referred for outpatient, home health, or eTherapy treatment when the reported population is compared to the county information.

This study is intended to raise awareness regarding the main vocal function diagnoses, what baseline pretreatment, presurgery/radiation-oncology output levels, and symptomology data are gathered, what environmental factors cause voice problems or inhibit voice improvement, and the quantity of vocal function patients referred for outpatient, home health, or eTherapy treatment.

Chapter 2: Literature Review

A review of pertinent literature is important in order to examine the issues surrounding the quality of the information received by the speech pathologist when a vocal function client is referred for treatment. The literature regarding how and why elements of a geographic region of environmental quality impacts vocal function is important will be reviewed. Since the physiology of the oropharynx, pharynx, and larynx have had less exposure in the current research of the Air Resources Board and American Lung Association, a literature review required gaining information from other specialties and industries.

The research gathered came from agriculture research, epidemiology and immunology research, public works-firefighter and roads divisions research, workplace and occupational health research, hospital research, the World Health Organization research, the Environmental Protection Agency (EPA) research in the United States and in other countries, the copper and other mining industry research, the pharmaceutical industry research, sports medicine research, military research, the tobacco industry mitigation research, sleep apnea research, and the nuclear power industry research. Literature was accessed from sources such as the American Speech-language Hearing Association literature, and from environmental health literature, medical journal literature, neurology and otolaryngology journal literature, orthodontics journal literature, respiratory therapy journal literature, and geographic spatial imaging literature.

While performing the risk analysis for air quality monitoring for the Air Resources Board, Hall, Brajer and Luhrmann (2008) described their exposure assessment approach for estimating the adverse health effects of the environment. The key feature in the difficulty for air quality improvement was the topography. The area where an individual is located can determine air pollution exposure. Volatile organic compounds can be found in the form of residual fuel combustion, farming operations, dirt roads, managed burning and disposal, or construction (Hall et al., 2008, p. 1006). The measurement of these particulates is done through a system of devices placed around the valley to count the ambient concentrations, with the most intense effects found to be during days in the summer when there is low wind, high heat, and active farming and industry. These relative risk factors can be translated into an economic valuation where the financial impacts are measured primarily in health effects. This means that loss of time at work or school, illness, hospitalizations, or the pain and inconvenience of irritations may be caused through exposure (Hall et al., 2008, p. 1008).

The American Lung Association has studied the risk factors of air pollution and cited the most polluted cities in America as being in the counties of the San Joaquin Valley Air Pollution Control District. In the State of the Air Report for 2011, when this study began, the counties in the SJVAPCD and their rankings were Kern County, number 1; Fresno County, number 2; Kings County, number 11; Stanislaus County, number 14; Merced County, number 15; Madera, number 2 (listed with Fresno), and San Joaquin County, number 19 (American Lung Association, 2011). According to the State of the Air Report of 2013, during the California drought the quality of the air in some areas has deteriorated in such a way that the national worst air regions have repositioned to Kern County, number 1; Fresno County, number 2; Madera, number 2; Kings County, number 3; Stanislaus County, number 5; Merced County, number 9; and San Joaquin County, number 15 (American Lung Association, 2013). These ratings were based upon the number of days these regions were exposed to counts higher than any other region in the United States. A review of the booklet showed that the major considerations were upper respiratory risks associated with exposure and an explanation of the air quality index levels.

Topography: geographic spatial epidemiology. What are the environmental causes that make the air quality so poor in this particular geographic area and reduce improvement of vocal function therapies by physicians and speech pathologists? The region's farming and agricultural economy has required the use of spraying with pesticides and fertilizers. Harvesting and plowing accounts for much of the dust during harvesting. The topography traps smog and fumes produced by vehicles, machinery, and industry. The large areas of agricultural lands and grasslands produce native and cultivated plants that release pollen into the air that affects allergies. Writing for the American Speech-Language Hearing Association magazine, Kelcher and Baker-Brehm (2003) addressed basic voice difficulties in children living in urban, suburban, and rural regions who were exposed to pollution and airborne allergens distinctive to each type of a child's environmental exposure and affected their vocal health including the antihistamines which can dehydrate them requiring an increase in fluid intake (Kelcher & Baker-Brehm).

Health risks, patterns of disease distribution, and environmental factors have been discussed by Lai, So, and Chan (2009) while they describe the two geographic research traditions in spatial epidemiology. They discuss communicable, contagious, and infectious disease through various examples around the world where geographic information system technology has animated the spatiotemporal aspects of the spread of these outbreaks (Lai et al., 2009, p. 144). By using the comparison between spatial hazards, environmental pollution, or the movement of organisms across the earth, a visual display of the patterns of interactions are beneficial when evaluating the data. The data can be used for verification of predictions or for mapping the progress from a larger region in order to make policy decisions regarding disease patterns.

Patterns in the dispersion of disease can be analyzed through viewing the clustering of symptoms in a geographic region (Cromley & McLafferty, 2002, pp. 130-133). A study parameter needs to be developed in order to analyze the spatial clusters, the population at risk, the geographical scale of the event, and the criteria for judging the definition of a given cluster. In the case of our study, the comparison will be made between the air quality information compiled by the emissions collection sites in the geographic region defined by the SJVAPCD, to the reporting of the vocal function disorders by the physicians and therapists located in those collection zones.

Organic Pollutants. The declaration that the larynx is no longer considered "an immunologically nonessential organ" where irritants move through a mechanical valve to land on the "important" tissues came in a pilot study by Geneid, Ronkko, Airaksinen, Voutilainen, Toskala, Alku, and Vilkman, (2009) on exposure to organic dust. By looking at the symptoms of hoarseness, huskiness, and tense voice, speaking difficulties along with shortness of breath and a weak voice were used to detect how the larynx reacted to organic dust. The results of the continued rated dust exposures over 30 minutes were a significant increase of these symptoms: shortness of breath, gasp for air, loss of resonance, tense voice, effortful phonation, and hoarseness (Geneid et al., 2009). Research in other areas has addressed some ways that organic materials enter the atmosphere and settle in soils. In a study of dairy and cattle farms, Beck, Heutelbeck, and Dunkelberg (2007) examined how volatile organic compounds that originate in that industry can settle in houses and stables and how these are transmitted. Desai, Minai, Gordon, O'Neil, Weidemann, and Arroliga, (2001) reported in their research how *Coccidioidomycosis,* a dimorphic fungus that grows in soils, was spread in the region. Schneider, Hajjeh, Speigel, Jibson, Harp, Marshall, and Gunn, (1997) discussed a situation where a fungus growing in top soils was disturbed and distributed during an earthquake event resulting in an outbreak of San Joaquin Valley Fever.

More recent Valley Fever investigations took place during an ethnographic research project by Sarah Rios categorizing attitudes and exposures on the highest rated counties for Valley Fever infection: Merced, Madera, Fresno, Tulare, Kern, Monterey, Kings, and San Luis Obispo (Merced Sun Star, 2014). She describes those who were affected as field workers who are exposed to pesticides, dust, heat, and exhaustion who likely do not even know they have Valley Fever. The health risks of environmental organic exposures not only affect farmworkers, but public works, roads, and even archaeologists who take precautions against breathing the fungus (Schultz, 2013). Valley Fever is a very real risk to archaeologists according to Mark D. Elson (New York Times, 2013) since the dry soils and low rainfall allows the fungus to lay dormant for prolonged periods.

Aerial distribution of organic pesticides occurs at all times of the year for different crops, and overspray has been studied by Tulve, Egehy, Fortmann, Xue, Evans, Whitaker, and Croghan, (2011). Their study estimated the amount of dermal exposure and indirect ingestion of pollutants over time in order to establish a protocol for different approaches to estimating transfer coefficients where one of the measurements was breathing outdoor air.

Ethnic labor force beliefs shape exposure: Population descriptions for the area within the SJVAPCD have been made by using the 2010 census and from other state and federal dispersion data. This population contains constituents from various ethnic cultural groups which have been reported as having differing perceptions regarding air pollution. In 2011, Johnson published a study looking at the attitudes toward air pollution, management, and beliefs affecting the population's behaviors concerning air pollution. The portion of Johnson's study which looked at the perception of the risk of the poor air quality showed that when viewed in terms of ethnic perception, the population base working in ambient air had less concern for poor air quality than did the class of population working in the outdoor exposure regions (Johnson, 2011, p. 986). The ethnic populations the most interested in air quality were African American and Hispanic, with the Caucasians holding a less informed view of the impact of poor air.

The Johnson study included in the literature review covered the geographic regions of New York, New Jersey, Arizona, Washington State, Norway, and Canada. It also looked at the attitudes of various immigrant populations in the United States who were Iranians, Vietnamese, Mexicans, Hispanics, Asian Americans, Indian Americans, Chinese-Canadians, or Anglo-Canadians. Johnson conducted a literature review of various psychological, anthropological, and social perspectives for sorting these environmental perceptions into understandable frameworks. There was a comparison drawn between the acculturation process, the value structure, the risk perception and the views of these populations regarding air quality. Johnson concludes that people with different levels of acculturation and ethnicities are "…inclined to stay indoors when pollution is high or have a sense of personal obligation to reduce air pollution" with one exception. This one exception is seen in the acculturated Hispanics' lower concern or familiarity with the risks of air pollution which may have implications for the geographic region of the SJVAPCD (Johnson, 2011, p. 996-97). Farmworkers are proportionately more Hispanic meaning that they are less aware of the risks of pollution and yet they are more exposed.

Socioeconomic status and geospatial proximity in a California study of four main chemical components of pollution were studied where a disproportionate level of asthma-related illness was reported. According to the data from Meng, Wilhelm, Ritz, Balmes, Lombardi, Bueno and Pickett, (2011), Latino, African American, Asian/Pacific Islanders having asthma-like symptoms and being under the federal poverty level had higher annual exposures to nitrogen dioxide in large particulates. Using GIS from air quality data monitor site, residential locations were mapped to calculate the 12 month annual pollution rates. They concluded that disparities of exposure based upon race, ethnicity, and poverty level for Californians having asthma symptoms were exposed to increased pollution rates when compared to other localities (Meng, et al., 2011, p 76).

The effects of particulate pollution: Another study reviewed eight children in an agricultural community who lived next to a potato field. Weppner, Elgethun, Lu, Hebert, Yost, and Fenske, (2006) looked at organophosphorus insecticide and sampled this on the children's playground. They found that on the day of spraying, the concentrates were four times higher on the playground than on a day with no spraying.

Research on pesticide use in greenhouses, florist shops, and veterinary departments focused on the effects of sprays on employees. Bouvier, Blanchard, Momas, and Seta (2006) concluded that occupational exposure in the target businesses showed an average exposure to pesticides. Further study showed that hand washing reduced the exposure by half. This study did not look for any differences between airborne and other exposure measures. These pollutants were associated with precipitating irritation of the nasal respiratory epithelium and resulted in an increase in hospital stay rates. The study examined the rates of particulate matter and ozone and compared that to patient complaints and rate of hospital stay.

A five-year review of hospital records and environmental pollution air station data, showed a correlation between daily atmospheric pollutants and hospital epistaxis presentation. The elements from the environment which were measured were atmospheric ozone, carbon monoxide, sulphur dioxide, nitrogen dioxide, and particulate matter less than PM10. According to Bray, Monnery, and Toma (2004) the increase in the hospital epistaxis patients was strongly associated with increased airborne particulate matter and less strongly associated with increased concentrations of atmospheric ozone. When the patient census decreased, the air quality showed improved levels. When the air quality became poor, the hospital census for epistaxis increased. Comparing government-gathered air quality data for specific geographic regions with the number of medical cases suffering from respiratory maladies severe enough for patients to seek hospital care showed an association of levels of increased discomfort with poorer air quality (Bray et al., 2004, p. 657).

Jimemez, Chang-Fu, Claiborn, Gould, Simpson, Larson, and Liu, (2006) described the characteristics and the effects of agricultural burning in eastern Washington. While measuring particulate matter exposure, Wilson and Brauner (2006) compared ambient to nonambient components to estimate the total amount of personal exposure. They explained that nonambient exposure is caused by cooking, cleaning, second hand smoke, hobby, hair spray, and other personal products in spray cans The ambient exposure is from the outdoor environment and infiltrates into the indoors. If a subject's time outdoors had a known value, and exposures in the personal environment were known, then the outcome could hold a therapeutic value for reducing the risk of breathing harmful substances in the workplace or at home.

Various studies used the Environmental Protection Agency (EPA) measures of air quality in specific geographic regions to compare it to the intensity of the appearance of disease. In 2009, Bhattacharyya and Shapiro conducted a National Health Interview Survey child sample for the years between 1997-2006. There were 126,060 children with a mean age of 8.6 years in the 12-month prevalence study that looked at the rates of ear infections, allergies and seizures over the period of time that air quality data was reported for the area in which these patients lived.

The air quality data which was taken from the year-by-year measured totals contained three main constituents of particulate pollution: carbon (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2). These are some of the main pollutants measured by the air collection stations (Bhattacharyya and Shapiro, 2009, pp. 242-243). Brauer, Hoek, and Smit (2007, pp. 880-882) also compared traffic pollutants to the amount of otitis media and respiratory illnesses among 4146 Dutch children over a 2-year period. To understand the relationship between air quality, hay fever, and sinusitis, Bhattacharyya and Shapiro (2009) sampled 313,982 adult patients with a mean age of 45.2 years. Using the EPA air quality measurements for the years and geographic area, the elements of CO, NO2, and SO2 were compared to the rate of infirmity. The results of the sampling showed an association exists between poor air quality and an increased prevalence of respiratory conditions from an area surrounding the University of Minnesota. The studies cited suggest there is an association between ear, nose, and throat infections and exposure to traffic-related air pollution or air pollutant emissions.

In one of the most recent studies relating to air pollution, health risks and traffic, Zhang and Batterman (2013) compare two comprehensive models for spatial-temporal predictions for how nitrogen dioxide, traffic flow, proximity, and traffic volume at distances from residences show the exposure of populations at different intervals. Their conclusions, based on the Comprehensive Modal Emissions Model and the Motor Vehicle Emission Factor Model, are that risks vary between locations on roads out to a distance of 100 meters and that accounts for the diversity of population exposures (2013, p. 315). Spatial analysis of traffic associated poor air quality that would affect both indoor and outdoor locations. In a georeferenced residential postal code group of 835,607 individuals treated in 205 London medical practices, Carey, Atkinson, Kent, Staa, Cook and Anderson, (2013) correlated evidence linking long-term air pollution exposure with respiratory mortality.

The accuracy of measurements of air pollution created through heavily used mobility patterns was examined by Setton, Marshall, Brauer, Lundquist, Hystad, Keller, and Cloutier-Fisher, (2011) because of the tendency of people to move around over time and pass through changing pollution concentrates. This study in Southern California showed that using a residence-only accounting process created a negative bias in the air pollution effects measurements on individuals. This study took existing data from other agencies and compared them to new extrapolated data. It accounted for all environments where an individual might be exposed to breathing pollution, and offers an example of extrapolating interdisciplinary geographic metadata.

Health effects in Phoenix, Arizona relating to air particulates of secondary sulfate, traffic, and copper smelter derived particles were reviewed by Mar, Ito, Koenig, Larson, Eatough, Henry, and Kim, (2006) as they related to cardiovascular mortality rates for that study region. The researchers took related data for amounts of these substances and developed a method for determining the health risks to residents within certain distances of the source of the pollution. This study offers a method for using distances plus content of particulates to show how pollutants affect the variable of heart disease which may be used to determine vocal function exposures.

Workplace exposure to pollutants can affect the upper respiratory and lower respiratory systems. A symptom highly reported in research has been the airway reflex to cough. The cough has been described as a “forced expulsive maneuver, usually against a closed glottis” seen as a disruptive symptom or a sign of disease, and is classified as “chronic” if it persists for more than eight weeks (Moscato, Pala, Cullinan, Folletti, Van Wijk, Pignatti, Quirce, Sastre, Toskala, Vandenplas, Walusiak-Skorupa, and Malo, 2014, p. 293). Occupations align with the agents of trigger elements based upon the type of industry and the materials used to perform the workplace actions (Moscato et al., 2014, p. 294). Using a neuropathic approach to understanding a range of sensory symptoms in upper airway neural dysfunction, Chung, McGarvey, and Mazzone (2013) try to isolate triggers for "repeated throat clearing, chest tightness, hoarse voice-dysphonia, vocal-cord dysfunction, globus sensation, dysphagia, or irritable larynx" when temperature, a deep breath, laughing or phone talking occur. Through introducing a series of stimuli to evoke coughing, the study records action potentials to identify the afferent-nerve-dependent cough and establishing a case for using pharmaceuticals that target appropriate afferent encoding in response to irritant stimuli (Chung et al. p. 416).

The activation of mucosilatory production from the neurological response of sensory nerves was seen as a reaction to the pollutants carbon dioxide, ozone, and nitrous oxide (Lin & Zacharek, 2012). After repeated exposures to the antigen to which the body had an abnormal hypersensitivity, it released allergen-specific immunoglobulin E followed by a complex chemical chain involving Type 2 helper T-cells, and other inflammatory cascades that set off a chain reaction across mast cell degranulation releasing histamines, trytase, and leukotrienes for vasodialation and afferent nerve stimulation which increase the secretions (2012, p. 189). Depending on the contact tissue regions of deposition where particulates of chemical compounds begin the chain reactions on the receptors "localized to epithelium, infiltrating inflammatory cells, endothelium, and submucosal glandular cells" activated in allergic rhinitis (2012, p. 190).

During a histological analysis of the cellular damage on the larynx after inhalation exposure, questions were raised about whether the development of lesions was a toxicological response or an adaptive change (Osimitz, Droege, & Finch, 2007, p. 236). The study organized the cellular morphological occurrences into four categories of change (2007, p. 230):

1) An increase in cell division resulting in more cells present (hyperplasia),
2) A reversible adaptive proliferation of cells by replacing a cell by a differentiated adult cell (metaplasia),
3) A possible precursor to malignant neoplastic changes in an atypical cellular proliferation (Dyplasia),
4) Benign or malignant neoplasms able to invade surrounding tissues—a proliferation of cell growth without a cause (Neoplasia).

The changes in the cells caused researchers to question whether the dose or the chemical was causing the growth. They also observed regressions in the tissue changes following recovery periods.

Allergies and irritants both organic and inorganic. Diagnostic procedures for allergies in pediatric and adult populations were reviewed in the study by Bozek, Krajewska, and Jarzab (2011). Seasonal exposures to grass, rye, and mugwort pollens were measured to determine if the older and younger populations had a significant difference in their reactions. The results showed that the reactions were not significantly different between the age groups. Symptoms were listed and monitored for the study, but there were no listed symptoms from the oropharynx. Lin and Zarek (2012, p. 1920) also suggested that seasonally specific allergens become more active when combined with increases in humidity, other compounds in the wind, and temperature. Some examples of this activation may be the increase in dioxide levels with a rise in temperature that increases asthma symptoms, ragweed in urban environments seems to take effect early in a season when temperatures and carbon dioxide levels are high, or when temperatures spike along with the peak pollen periods.

Studies regarding allergy were some of the few that contained vague references to the oropharyngeal physiology as it related to the passing of irritants from the nasopharynx to the respiratory system. Krouse, Dworkin, Carron, and Stachler (2008) referred to this condition as inflammation caused by the passage of thick mucus from the sinuses to the larynx then on to the respiratory tract triggered by exposure to dust mites. They showed that there was an increase of vocal fold edema due to the allergic reaction accompanied by symptoms such as mucus, coughing, hoarseness, and vocal strain caused by the exposure to dust. Seasonal effects were reported by Bousquet, Boushey, Busse et al. (2004) after patients were exposed to pollens and molds (*Alternaria* and *Cladospoium*) in the environment. Symptoms produced by this exposure were shortness of breath, wheezing and coughing. The study reported a longitudinal view of the seasons and the effects of the airborne pollen and symptom severity. A study showing that there was a link between the upper and lower airways was performed by Ciprandi, Cirillo, Klersy, Marseglia, Caimmi, and Vizzaccaro, (2005). They found that allergic airway inflammation was shown to cause airflow limitations in both nasal and bronchial levels. This study took a total symptom score as compared to the nasal obstruction scores in order to show that nasal obstruction during and after pollen season persisted in several symptom parameters (Ciprandi et al., p.433).

Seasonal effects were not only reported in the allergy studies. A longitudinal, repeated-measures study of stationary air pollution sources was done in a city. The city held fourth place nationally in the amount of contaminating emissions in the air (Salamanca, Mexico) and those contaminants increased during the winter. At the same time in winter, there was an increase in people's symptoms of wheezing, asthma, rhinitis, and dyspnea that corresponded to the increased contaminants (Linares, Guizar, Amador, Garcia, Miranda, Perez, and Chapela, 2010, p. 8).

This review of the literature, found one study that showed a direct correlation between the airway intake of any of the named particulates and vocal function of the oropharynx. Randhawa, Nouraei, Mansuri, and Rubin (2010) used the survey responses of 30 males and 40 females in a review of the Voice Handicap Index survey after they were exposed to various contaminants. The exposures were defined as: 83% dust mites, 55% house dust mites, and 40% grass pollen. Of the patients, 23 did not react to any of these common allergens. The results of this study were that patients with more airborne allergies responded to the Voice Handicap Index with scores showing that they had incidents of undiagnosed vocal dysfunction (Randhawa et al., p. 172). Overall, there were more research articles about allergy than any of the other contaminants in the environment affecting the nasopharynx and the respiratory system. The Randhawa et al. study was rare in that it included the reference to the oropharynx.

Athletes compete in environments other than their own locations since they travel to compete in different climates and elevations during the year. Sacha and Quinn (2011) brought together upper airway research that studied athletes who contended with nasal dyspnea, rhinorrhea, nasal congestion, and post nasal drip. They reported on the filtering of air through the nasal cilia and how it related to humidity, moisture, warming, heat, and high activity with increased respiration. Some exercised-induced rhinitis occurred both indoor and outdoor. Of the athlete participants, 40% reported that the symptoms adversely affected their performance. Outdoor allergens, indoor fossil fuel air treatment systems, swimming pool chemicals, and heavy traffic pollution were some of the irritants and pollutants named as contributors to the upper respiratory ailments (Sacha and Quinn, 2011, pp. 82, 86). Allergen suppression in athletes was studied in an exercise-induced asthma-like condition brought on by airway drying when Cohn, Sataloff, and Branton (2001) were asked to diagnose a case of voice dysfunction. The researchers took a holistic approach to patient interviews of athletes and performers in order to define the symptoms of the disorder, and the symptoms of the side-effects of the immunotherapy. By using a review of the allergy symptoms, and any antecedents (e.g. perfume, wind, dust, climate, clothing, GERD medications, and any other information) they put together a strategy to prevent the side effects of the antihistamine from interfering with performance (Cohn et al., 2001, p. 560).

In a discussion of workplace exposure to irritants, Brooks and Bernstein (2011) defined particulates as triggers or aggravates to an allergic reaction. The three conditions that their study identified as antecedents to an allergic reaction were allergic sensitization to a substance, acute exposure to high concentrations of an irritant, and aggravation of preexisting asthma (2011, p. 748). They defined an irritant as an "extreme incipient inflammatory reaction of the tissues to an injury" and said the response to the irritant was of a pulmonary nature. One study used the example of inhaled wood smoke as the antecedent to a grave elicited airway reflex. The "airway reflex" was identified through the symptoms of cough, expiration reflex, apnea, and Brady apnea, but laryngeal irritants within wood smoke were not delineated for any of the constituents in this study by Lin and Kou (1997). Wheezing, sore throats, and throat infections were reported during an intervention targeting wood burning in a Montana community. Data were gathered through the use of a parent survey at a public school (Noonan, Ward, Navidi & Sheppard, 2012). That study looked at both ambient indoor levels and outdoor environmental pollution of the mountain community.

Military workplace environments contain chemical and biological pollution of the atmosphere and the soil and that has implications for the upper respiratory system according to Korzeniewski, Nitsch-Osuch, Chcialowski, and Korsak (2013). The contaminates include crustal dust, sand storms, oil well fires, burn pit emissions, industrial pollutants, and other major health hazards (2013, p. 119). In this literature review, the risks for upper respiratory tract syndromes were reviewed based upon the levels of exertion and irritant sources (2013, p. 122).

There are National Ambient Air Quality Standards (NAAQS) for chemical substances giving the pollutant, the averaging time of exposure, the level of exposure, and the form of distribution (Higgins & Reh, 2012, p. 212). For example, carbon monoxide with an 8-hour averaging time at 9 parts per million not to exceed more than one time a year, or nitrogen dioxide with a 1-hour average time at 100 parts per billion annual mean exposure. Cigarette smoke that induces sinonasal mucosal irritation causes chronic rhinitis and allergic rhinitis affecting the sinonasal epithelial cells. The main contributing chemical of cigarette smoke consists of nitrogen, carbon dioxide, methane, hydrogen cyanide and other chemicals.

Smoke exposure research by the tobacco industry isolated nicotine in the saliva of children where parent reporting stated there was a smoke-free environment (Seaman, 2014). Intake questionnaires were inadequate for determining exposures, with the saliva samples coming back with 80% accuracy when compared to 56% in blood samples when a component of nicotine “cotinine” was identified in the saliva samples. The reasons for admittance to the hospital was for asthma treatment for these children, so this study does not speak to air irritants found in the saliva as the cause, but it shows that smoke in the environment may be a contributing factor in asthma attacks.

Respiratory tract delineation. Whether the research studies were centered on the nasopharynx or the respiratory tract and trachea, the central feature for particulate passage measurements were that there was no mention of the oropharynx or the laryngopharynx. The upper and lower respiratory physiology was reviewed in relation to the diseases of the airways by Prezant, Levin, Kelly and Aldrich (2008). Studies using aerosolized particles or other dispersion techniques used measuring processes that harvest tissues in order to account for the amount, transport, and size of particulate matter. The study following the workers at the World Trade Center (WTC) after the disastrous 911 attack contained details that described hoarse voice, a symptom chart, an accounting of the upper and lower respiratory disease symptoms and a discussion of the temporal value of exposure times. The physiology of the affected areas of transported aerosolized exposures with high-concentrations of particulates, and various chemicals were divided anatomically as the upper respiratory reactive upper airways, the lower respiratory airways, the parenchymal or interstitial lungs, and the lungs and pleura. The physiological breakdown of the speech system follows the airflow through the nares to the lungs via the nasopharynx, the oropharynx, the laryngopharynx with the boundary of these three areas at the juncture where the uvula is lowered. Respiration occurs through the nares and through the oral cavity in most cases. The deposition of particulate matter measured during experiments where the particulates were introduced only through the nose would not account for the amount being deposited on tissues in the oropharynx and laryngopharynx.

There have been a number of studies utilizing mathematical, computer generated, physical three-dimensional, and simulated soft tissue models for recreating natural breathing in order to replicate aspiration and expiration of the respiratory system. These studies have been done in the drug industry for studying aerosol transports for oral indications. These models define both the mouth-throat-tracheal natural breathing patterns as well as the inspiratory gauged velocity of breaths. These studies look at the role of the tongue standing alone, or the roles and interactions of all parts of the system namely the nose (stand alone or in conjunction with), mouth, pharynx, and larynx aimed at understanding the properties of air flow. Before the drug companies could perfect their delivery systems for particulate aerosols, they had to be able to target the physiology of the receptor sites for drug delivery. Through a review of the air flow turbulence models, other scientists began to use this information to understand how particulates were deposited and absorbed into the human body.

During an investigation into the collapsibility of the tongue in patients suffering from apnea, a model of three-dimensional flow features was developed in order to view the role of the tongue. In the model by Rasani, Inthavong, and Tu (2011), they were able to establish the properties of the tongue and its role in the collapse of the human pharyngeal airway. Since the tissues of the tongue mainly consist of water (giving it weight and mass), the study was looking at the incompressibility of the tongue as it relates to the pharyngeal wall, the soft palate, and how the air flow to the vocal folds can be affected by tongue position (Rasani et al., 2011, p. 3). Measurements were described of the pharynx behind the glottis in order to define the standard openings of the oropharynx for determination of the quantity of air flow. Using variables, they were able to isolate tongue constriction height, and the limitation of flow rate of air during expiratory events where the position of the head and the flaccidity of the tongue interfered (2011, p. 5). Finally, in a discussion regarding snoring in the conclusion of the study nonapneic individuals were referenced that had been measured to gauge varied stiffness of the tongue along the pharyngeal airway (2011, p. 8). These measurements may be useful in the future due to the automatic response by the tongue during inspiration in an attempt to block off the airflow while breathing unclean air by bunching the tongue in the rear of the mouth, seemingly to capture impurities on the bulbus surface of the tongue. In studies reviewed, the models portrayed open airways while developing respiratory patterns. Research regarding the tongue in airway displacement may hold value when future investigations mature regarding inhalation of pollution.

Narrow or broad pharyngeal spaces carry significance in the transport of pollutants and irritants through the oropharyngeal space. Mouth breathing versus nasal breathing can also be a contributing factor to the amount of an irritant entering the trajectory regions for particulates. Orthodontic diagnoses use classification systems for the dimensions of the pharyngeal opening. There are critical relationships between the dentofacial and craniofacial structures as they relate to vocal function (Batool, Shaheed, Rizvi, & Abbas, 2010). Upper airway width has been identified as one of the causes of apnea. Using the McNamara Air-way Analysis measurement system (McNamara, 1984), comparisons were made between the cephalometrics of individuals with open bites, constricted palates, high mandibular plane angles showing that they had allergies, adenoid, tonsilar enlargement, and open mouth breathing postures.

Studies regarding aerosol particle transport were performed using real and computer models of the nose and mouth, of the "extrathoracic" oral (oropharynx) and nasal, of the mouth and throat, a combination of the mouth, pharynx, larynx, and trachea (without the nose), and of the upper tracheobronchial (from the larynx down). The trajectories of airborne particulate material align with the inspiratory flow emanating from specific regions anterior to the nasal and oral cavity openings. According to Se, Inthavong, and Tu (2010) the airway geometry at the nostril inlet, at the nasopharynx, and at the oropharynx clearly affect mucosiliatory action of the cilia wall regions trapping and removing the pollutants. Also, that in spite of the defenses built into wall structures, there is a particular air flow current stream where particulates become "entrained in the airflow and deposit deep into the respiratory system" (Se, p. 287). Se et al. transformed a realistic three-dimensional model into a computer generated adult-sized mannequin in order to build a virtual room to study the air flow model of turbulence of the movement of particles around the standing figure in the room (p. 289). They visualized the velocity vectors within the breathing regions of both the nares and the oral inhalation regions based upon large breath and short breath (p. 292). Around the human body there exists "a region (or area) of particles that are inhaled" which is a critical area or "plane" which can be compared to the trajectories of moving pollutants in any given environment (p. 299). The pathway toward the nose is different from the pathway toward the mouth. The measurements in this study give important information regarding locality of humanoid element in gravitational setting, turbulence readings, distance to the contaminant, and the properties (weight/size) of the pollutants when they are released upstream from the inhalation region.

Viewing the human throat as an effective filter, Ali, Reddy, and Mazumder (2008) developed a process for giving the particulates an electron charge in order to track the location and distance of the deposition. This was done in order to rank pharmaceutical delivery system efficiency. They also compared charged and uncharged nebulized deposition characteristics (2008, p. 404). The charge was reduced during transport, and the smaller the particle the further it traveled. Moussa (2007) developed a way to measure radioactive particles where the radioactive particles within the dust particle decay based upon where the atom is located within the dust particle. Transport in the anterior nose was filtered and stopped by the nasal hairs with the dust containing radioactivity deposited on the epithelium (Moussa, 2007, p. 310). He was able to determine how the electron absorbed fraction values affected by self-attenuation was reduced based upon dust particle size and electron energies.

In current research by Inthavong, Ge, Li, and Tu (2013) after the trajectories study, a more detailed model was developed to assess the accuracy of the 2010 study where the more detailed facial features and airway geometry had been perfected. In this case the pollutant particles were static and released from rest to "mimic a contaminant source that was disturbed by free-stream flow" into the nasal or oral route trajectory zones (Inthavong et al., 2013, p. 283). Previous data of velocity for mouth breathing were used in the simulations. The velocity vectors showed the trajectories of the particulates in the airways and were seen in visualizations surrounding the standing figure model (Inthavong et al., 2013, p. 289). The particulates in the near breathing region vector points are in the critical area. The addition of the ability to track each particle through the airway to its destination gave this study the ability to correlate the local deposition of each particle in order to make calculations. The importance of this study to the vocal function literature review is that the particles can now be tracked through the airway and it can be determined where the flow velocity and location in the air stream will carry the pollutant or allergen (Inthavong et al., 2013, p. 291).

The circumstances of exposure relating to the trajectories of inhalation for the oral route and the respiratory route are discussed by Deguigne, Lagarce, Boels, and Harry (2011) while they investigated an accidental discharge of metam sodium into sewers. Metam sodium is used as a fungicide or herbicide in agriculture but when placed into solution with water becomes a gaseous substance (Deguigne et al., 2011, p. 416). This study is important due to the exposures being real in comparison to other studies where the experimental method is to apply the exposure. They observed two farmers who accidentally ingested via the oral route, and 79 patients exposed during spraying or irrigating farmland and neighbors to the farmland. Symptom effects of the exposure were coughing, skin erythema, nose and throat irritation and other symptoms in common with air pollution studies (Deguigne et al., 2011, p. 418-420).

Public awareness of the effects of industrial air pollution on respiratory function was sparked near a sugar mill in Pakistan. Gull, Nawaz, Ali, Hussain, Nawaz, and Mushtaq, (2013) discovered through a survey administered to the residents. The residents close to the mill reported that the smoke from the industrial mill was black and fell onto their homes like snow (Gull et al., 2013, 2281). Although the residents live in deteriorating conditions in the industrial zone with a high percentage affected by poor respiratory health, the local industrial laws allow for industrial air pollution. The laws of a country and geospatial relationships play a role in human health with some geographic locations receiving no limitations on poor quality emissions standards.

Fine and coarse particulates are differentiated in a study by Longest and Holbrook (2012). The delivery models for a pharmaceutical aerosol required respiratory tract geometry replication. The dynamic structure of the tract was built mathematically to visualize a whole lung model versus a regional model of deposition. The most diverse region of differentiation in humanoid contribution is between the mouth and throat. For that study, Longest and Holbrook considered the respiratory tract as the oral cavity, pharynx, larynx, and at times the upper trachea (Longest & Holbrook, 2012, p. 302). They speculated that studies of particulate deposition in the nasal region in regard to drug delivery should be limited to the vestibule and valve regions (anterior one-third) of the nose. The whole-lung deposition models based upon tidal volume were used to estimate the amount of the deposited pharmaceuticals that penetrated through the branches of the respiratory system traveled.

An excellent summary of the past research in human mouth-throat deposition by Jayaraju, Brouns, Lacor, Belkassen, and Verbanck (2008) described how research from 2002 through 2008 advanced the use of laser doppler, particle image velocimetry, ultraviolet spectrophotometric assay in fluid particle, and dry powder deposit. The conclusion of their study was that "large eddy simulation" where turbulent duct flow could isolate the region in the stream of air, carried the particulates the furthest. They concluded that "velocity and kinetic energy profiles showed…quantitatively…that mouth-throat deposition…model" predicted deposition of smaller particle sizes (Jayaraju et al., 2008). Jayaraju et al.'s contribution was to delineate the upper respiratory tract (URT) as the "URT: mouth, pharynx, larynx, and trachea" as the division between the URT and the lower respiratory tract (LRT) (Jayaraju et al., 2008, p. 258). They also contributed the explanation for why the nasal pathways were eliminated from studies in many cases. In URT studies the nasal asymmetry interrupts the turbulence and complicates the analysis making the oral cavity the preferred inhalator pathway (Jayaraju et al., 2008, p. 258) leading to the physiology of the URT. This may suggest that a closed mouth posture in polluted air quality reduces particulate transport.

The shape of particulate matter compounds and the geometry of human variable mouths and throats may also affect the amount of deposition in the respiratory system. A drug study by Li and Edwards (1997) used the extrathoracic (mouth and throat) oropharyngeal cast of various geometries. They defined three primary sources of particle deposition as gravitational settling, stochastic diffusion, and oscillating turbulent [air] flow (Li & Edwards, 1997, p. 43). Their other contribution to research was the identification of the mouth and throat as being "wet" making a bouncing particle unable to be "re-entrained" into the airstream. This means that not only is the mucus membrane protecting tissues, it is also affecting the weight of the compound being transported, and identified the center stream of an airflow. These were identified by them as boundary conditions, and resolving to the fact that the primary site of particle capture was in the laryngeal region. They isolated the carrier particle sizes in dry powder and wet aerosol particles during capture and explained that the force of the attachment is exactly four times greater than the spherical shaped particle and a flat surface" which is important in drug delivery systems (Li & Edwards, 1997, p. 48).

Moving down from the mouth and throat, Xi and Longest (2008) described the physics of why and where particles are deposited on the tissues of the larynx. By including an artificial glottis, they created a more accurate representation of the deposition locations of particulates. Using knowledge gained from lung cancer position, where sidestream and mainstream cigarette smoke affected tissues, the laryngeal jet was described. The airform emanating at the glottal aperture "extends downstream through the trachea and is skewed to the right wall." The tide of air flow has a reversal and a "large recirculation zone develops near the left tracheal wall" contributing to deeper penetration and more deposition on the right tracheal wall and the right branches of the lungs (Xi & Longest, 2008, p. 1723).

While discussing transport and deposition of nano-particles, Zhang and Kleinstreuer (2004) also identified the laryngeal jet and stated that "the air flow in the larynx and directly below is transitional-to-turbulent which may complicate flow structures" and reference the fact that the oral cavity had been discounted in their study (Xi & Longest, 2004, p. 180). Xi and Longest (2008) were sponsored by the Philip Morris Company in a mitigation action. The implications for inhalation of pollutants was set on the replication cast as being 20 breaths per minute (Xi & Longest, 2008, p. 1724) with the study delineating only the size and shape of particulates and not the composition. Zhang et al. (2004) concluded in relation to air flow where cyclic patterns occurred, there was a minor effect on the nanoparticle deposition and transport. Where the inhalation flow rate was higher, the deposition rate was reduced (Zhang & Kleinstreuer, 2004, p. 197).

In a study of a bacterium and its effects on the respiratory system, Kariya, Okano, and Nishizaki (2014) took the bacterium through the entire system. Since the initial introduction of the bacterium was through the oral and nasal routes, and the primary symptom was inflammation and asthma-like symptoms, rhinitis is the first symptom in the nasal sinuses similar to pollution responses. The mucous membranes reacted with sinusitis and nasal congestion, facial pain, posterior drainage, and inducing a cough. Adenoiditis and adenoid hyperplasia contributed to the beginning of otitis media with symptoms of middle ear infections that led to a sore throat. When the throat became enflamed, it gave rise to oral cavity diseases if colonized bacteria in mucosal tissues became involved. Tonsillitis and tonsil hypertrophy can cause the palatine tonsils to inflame and when left untreated can enlarge into a pharyngeal disease with the main symptom of pharyngitis as a severe sore throat. The laryngeal diseases may be developed from the drainage from these ailments, but the laryngeal region is more affected by reflux or acidity from the esophagus (Kariya et al., 2014, p. 1471-1476).

Cellular level tissues. Tissues of the respiratory tract affected by deposition of airborne pollutants are the oral cavity, nasopharynx, larynx, pharynx, and the laryngopharynx. Whole body hydration and superficial measures of tissue susceptibility to accept foreign materials would be tissues where dehydration was reflected in the vocal fold mucosa, increasing its viscosity and reducing mucosa mobility (Franca & Simpson, 2009). Typically functioning soft tissues have a healthy layer of mucous surrounding them. Keeping the vocal folds moist and lubricated is crucial to vocal health. This enables the soft tissues to glide past each other with minimal resistance (Mossman, Shatzman, & Chencharick, 1982). Since chemicals found in airborne pollutants affect tissues on a cellular level, the formation of fine scar-like structures (fibrosis) causes tissues to harden (trismis). Fibrosis increases the rigidity of the tissues due to reduced mobility and lowers the flow of fluids through these tissues and affects the function and nature of the tissues (Bae, Joen, & Chung, 2008; Dijkstra, Sterken, Paten, Spijkervet, & Roodenburg, 2007). The first lines of cells that come into contact with the irritant typically suffer a higher degree of damage, with the response of the airway mucosa to be to remodel the cell walls with an increase of submucosal mast cells after an irritant exposure (Brooks & Bernstein, 2011, p.754).

According to a study by Rees, Jones, Pinkerton et al. (2008) asthma prevalence was seen as a contributing factor in throat symptoms. They concluded that pollution in the environment may contribute to pharyngeal inflammation where chemical exposure through the epithelium plays a part in activating leucocytes. The study looked at the mucosal immune response to environmental pollution. A laryngeal mucosal pinch biopsy along with a questionnaire was used to collect the data. Air quality data gathered through the environmental agency for the regions where every patient lived was used to confirm exposure levels. Qualitative data collected from the questionnaires indicated that high levels of particulates from the environment were associated with self-reported sore throats with a trend towards increased asthma, with the levels of pollution data confirmed in areas where individuals had pinch samples containing leucocyte expression. Prezant, Levin, Kelly, and Aldrich, (2008, p. 92) included a symptoms chart that included cough and sore throat as symptoms of the oropharynx, pharynx and laryngopharynx. Another study involving asthma patients exposed to black carbon and sulfates from diesel exhaust showed that changes in the methylation of genes in the asthma pathway were similar to those from traffic roads with heavy truck and bus flow (Sofer, Baccarelli, Cantone, Coull, Maity, Xihong & Schwartz, 2013, p. 151). Zanobetti, Luttman-Gibson, Horton, Cohen, Coull, Hoffman, Scwartz, Mittleman, Li, Stone, de Souza, Lamparello, Koutrakis and Gold, (2014) was able to identify the effects of exposure to black carbon, organic carbon, carbon dioxide, and sulfate particulate matter influencing mortality when temperature and humidity increased the measurement of the diameter (constriction) of the brachial artery after exposure (Zanobetti et al., 2014, p. 246).

Genetic structures exposed to particulate pollutants have been exposed to biochemical processes where a methyl group is added to the cytosine or adenine nucleotides changing the DNA tissues within cells. Health effects in literature include endothelial dysfunction, arterial vasoconstriction, blood coagulation, and less serious effects of stress and inflammation. Baccarelli, Wright, Bollati, Tarantini, Litonjua, Suh, Zanobetti, Sparrow, Vokonas and Schwartz, (2009) found that in a population of 718 elderly adults, the association of black carbon particulate matter and sulfur from incomplete combustion contributed to negative health effects (Baccarelli et al., 2009, p. 575-577). A study investigating how industrial environmental pollution damages DNA by mutation and methylation in gametes measured over 3 to 10 weeks, revealed an increase in sperm mutation frequency in mice exposed to ambient air. The details of the DNA reactions and strand breaks were hypothesized to have occurred from oxidative stress (Yauk, Polyzos, Rowan-Carroll, Somers, Godschalk, Van Shooten, Berndt, Pogribny, Williams, Douglas and Kolvalchuk, 2008). It was also reported hypermethylation of the sperm DNA of mice that breathed ambient air not filtered by the experimental method involved followed removal from the environmental exposure. Their findings implicated tissue changes after prolonged exposures, and pointed toward the probabilities that the mutations continued to occur in the cells long after exposure. Kleinman (2010) tissue studies also showed that cellular level changes persisted for up to a week after the exposure to the contaminates ended (Kleinman, 2010, p.10).

In a fine particulate matter exposure assessment overview performed in 2010 at the University of Northern British Columbia, the properties of particulate matter, and classifications of exposure and dosage were described as they were associated with health effects. Millar, Abel, Allen, Barn, Noullett, Spagnol, and Jackson, (2010) have compiled a listing of evidence-based methods for understanding those pollutant exposures. Since the most common measurement of particulate matter is based upon mass, the two most common measures are mass-based metrics expressed in aerodynamic diameter. Three decades of research had been reviewed where toxicological studies showed that exposure induced physiological responses in sensitive populations (Millar et al., 2010, p. 283). The review explained that the resulting findings caused concern in regard to finer particulate matter than had previously been reported. Also in the literature review, a symptom list had no reference to laryngeal concerns with the exception of coughing. Fine particulates had especially low solubility causing them to reach deeper into the respiratory tract.

Dosing exposure. Exposures were also reviewed to include internal and external exposures to pollutant concentrations. Exposure was reviewed as an element in determining the accuracy of data. When exposure occurs on all levels in all locations where a population inhabits or passes through, then the integrated exposures over a period of time increases the reliability of the data. So looking at the macro and micro environments that an individual passes through will be important in determining the dosing of the airborne pollutants. Using the literature review results, the definition of how to measure dosage were developed. Bradman, Gaspar, Castorina, Tong-Lin, McKone and Maddalena, (2012) led research on exposures in an educational setting funded by the California Air Resources Board. The definition of a dose established by the Environmental Protection Agency (EPA) states that a reference dose is an estimate of the daily acute or chronic exposure that is likely to be without risk of adverse effects (Bradman et al., p. 109).

According to Bennett, McKone, Evans, Nazaroff, Margni, Jolliet, and Smith Bennett (2002, p. 287), the intake fraction for exposures can be expanded to include different portions of the exposures as a dose, an internal dose, a biologically effective dose, and an intake fraction. The "dose" is the amount of pollution that crosses internal and external boundaries of the human body. The "internal dose" is the amount of a pollutant that crosses boundaries of the human body and is capable of interacting with target sites or tissues. The "delivered biologically effective dose" is the amount of the pollutant that reaches and interacts with a target site or tissue. The "intake fraction" is the portion of the pollutant that is taken into the human body relative to the total mass of the pollutant that is emitted into the environment.

While calculating dosage, there are major differences from routes of administration, not only in the transport of the material, but the irritancy of the larynx and nasal cavity. Owen (2013) discussed both delivery systems for inhaled pharmaceuticals. He stated that the preliminary work to produce the formulations to be delivered depends upon the dosing apparatus (Owen, 2013, p. 111). When developing the formulas, he used data from systemic responses of the whole respiratory system to the constituents of any mixture, and particle size. Dosing through inhalation is not exact, and the exact dose delivered is not known and is dependent upon "exposure, concentration, particle size, exposure time, breathing patterns," and "regional deposition in the respiratory tract." External variables and time provide a formula for using respiratory minute volume, airstream concentration of the drug, duration of daily exposure, body weight, and inhaled fraction (Owen, 2013, p. 112). The World Health Organization definition of dosage as it relates to "an estimate of the daily acute or chronic exposure that is likely to be without risk of adverse effects," might lead to a similar formula to identify a method for delineating risk.

Mucosilatory transport (MCT) of irritants. Tissues of the target sites have lubricated and moistened mucosa to maintain the viscosity of the secretions of the epithelium. The degree to which the viscosity is healthy and fluid affects the filtration system which performs the function of protecting the airway is not definitely known. Schwab and Zenkel (1998) reviewed the theories regarding the deposition of particulates upon inhalation. Different studies were reviewed that looked at the filtration capabilities in nasal inhalation and looked at nasal mucosa, cilia propulsion, and size of particulate matter. The transporting of particles which had been inhaled in order to eliminate them was labeled mucocilatory transport by Schwab and Zenkel (1998). In an article on environmental pollution and markers in the trachea, the same process was referred to as the mucocilatory escalator (Foltinova, Schrott-Fisher, Zilinek, Foltin, & Freysinger, 2002). The smaller the particles, the easier they move through the nose to the nasopharynx and down into the lower respiratory tract. Most of the nasal cavity is lined with ciliated mucosa. Depending on the type of chemicals in the pollutant, the toxic effects upon the cilia transporting the elements varies. The chemicals named by Foltinova et al. (2002, p. 714) were listed as being cadmium, nickel, chromium, and copper. The chemicals named by the Schwab and Zenkel (1998, p. 121) as calcium oxide, silicone dioxide, aluminum oxide, magnesium oxide, sulfur trioxide, and sodium oxide.

The process of mucocilatory transport or escalator is important to understand because of the elimination process which passes through the oropharynx and laryngopharynx regions.

The “synchronized motion of the cilia of the pseudostratified columnar epithelium” is covered by a layer of mucus. The cilia are not innervated, but affected by natural motion explained in the theory of Brownian motion, and transport is affected by factors such as the inertia of the particles, velocity of exhalation, the mass and solubility of the particles, and overall quality of motion and mucus layer (Foltinova et al., 2002, p. 714). Therefore the clearing of particulates from the nasopharynx through the oropharynx and laryngopharynx depends upon the velocity of the mucocilatory escalator (transport). This process has been defined as the elimination of particles which had been inhaled and filtered through the nose, and then swallowed and ultimately excreted through the feces. Various studies measured the elements in the inhaled substances and through the eliminated by-product. Respiration plays an intricate part in the effects of air pollutants upon the tissues of the oropharynx and laryngopharynx.

The materials passing through the laryngopharynx and potentially being deposited onto the vocal fold mucosa has been studied on the nasapharynx, the trachea, and studied on the microscopic level of the mucosa layer of the cilia and the epithelial lining. *To date there has not been research on pollutants on the laryngeal vestibule or on the lamina.* According to Schwab and Zenkel (1998), the depositional mechanisms of particulate pollutants are sedimentation, diffusion, and centrifugation (collision). The diameter of the pollutant particle determines penetration into the respiratory tract. The density of the pollutant determines the duration of time that the pollutant remains in the system, and the velocity of the movement and spread of the particles (Schwab & Zenkel, 1998, p. 122). Distribution of the particulates occurs through the velocity of airflow against the resistance of the particulate dimension, and lodging these particles into the crevices between cilia. The cilia acting as filters are the surfaces of attachment showing irritation with reactivity to aerosol contaminates.

The tracheobronchial and alveolar phases of mucocilatory transport position the particulates for expiration (coughing) during mucocilatory clearance by using mucus and motion according to Foltinova, Schrott-Fisher, Zilinek, Foltin, and Freysinger (2002) . But due to the corrosive properties of the pollutants, destruction and paralysis occurred evidenced by stagnated masses of cilia found in the scanning electron microscope (SEM) images where there had been an absence of intraciliary pressure with hypersecretion (Foltinova et al., 2002, p. 716). These images were the result of a series of experiments where Viennese grey rabbits were exposed to in situ real conditions of dust fall and then histologically excised for the preservation of their tracheas (Foltinova, et al., 2002, p. 719). These conditions and research resulted in the finding that the epithelial lining of the respiratory system was adversely affected by pollutants, which leads to a sidebar that aerosols transported through the nasopharynx and laryngopharynx may be distributing pollutant particulates in the oropharynx.

In a 2012 research study, particulate matter was measured of the mucocilatory transit (MCT) system of a living organism, it utilized the trachea of a mouse airway. With the presentation of a powder delivery system into the airway, the previous studies which used a fluid delivery system were compared in order to develop a novel approach to measurement of particulates. Donnelley, Morgan, Siu, and Parsons (2012) studied the behavior of the particles upon delivery into the mouse airway over a five minute period of time. The particles were deposited close to the dorsal tracheal wall (Donnelley et al., 2012, p. 551). Other studies described MCT as a process, but in this study it is used as an indicator of respiratory health. With the ability to measure the transit rate and behaviors of the movement of the foreign elements, potential therapies were suggested by this study. The importance of this study to the current research into the oropharynx is the ability to measure the "in vivo" transit of the pollutants. Phase Contrast X-ray Imaging (PCXI) is a noninvasive method to track the movement of particulates. The technology to target distal regions of the lungs may prove to be useful in possibly capturing images in the oropharynx and laryngopharynx of the soft tissues of the vocal function process. By successfully observing the pollutant markers on the trachea, how much similar deposition might be observed throughout the system? Functional limitations of this experiment may be useful in future exploration of the effects of particulate matter on the vocal function of soft tissues and examine the effects on the epithelial tissues of the laryngopharynx.

Temporal distribution: Geographic Information Systems. Studies using a visualization of the statistical data are examples of how information might be displayed in order to explain complex environmental problems. Jerrett and Finkelstein (2006) explored frameworks for visualizing medical data. In order to incorporate the landscape of chronic health effects from air pollution they needed to organize the spatial processes. Their framework consists of the geography of susceptibility, then the geography of the exposure, and finally the points where the two intersect that is called the geography of risk (Jerrett & Finkelstein, 2006, p. 1237). These visualizations are based upon data from collection points set out across a landscape. The monitor site locations need to be positioned in order to collect accurate representations of the problem, and according to Dionisio, Rooney, Arku, Friedman, Hughes, Vallarino, Agyei-Mensah, Spengler and Ezzati,(2010) they have to be both mobile and stationary sites on paved roads, dirt paths, and examined based upon the "spatiotemporal patterns of air pollution and the effects of sources in these neighborhoods" (Dionisio et al., 2010, p. 608). Dionisio et al. studied a region of varying socioeconomic industrial communities in Ghana, with mostly poverty level neighborhoods, where within a seven kilometer area there were up to 18 mobile and stationary monitor sites.

In contrast to the Ghana study, a Europe-wide ecological analysis was written after gathering air pollution and population healthcare grids, Richardson et al. (2013) showed a weighted average mapping of concentrations of the effects throughout Europe using a colored scale. The Dionisio study showed that Ghana had higher pollution levels in lower socioeconomic regions that affected health, whereas, in Europe the "richer Western European regions tended to experience higher pollution levels" because of their industries that enabled their wealth (Richardson, Pearce, Tunstall, Mitchell and Shortt, 2013, p. 9). The monitor sites were fixed European Air Quality Monitoring Network sites of the European Environmental Agency (EEA) public database. Through visualizing the mapped regional differences, the illustration made the information instantly meaningful. By putting population health information sharing on interactive time-sequenced maps, the information for health effects could be viewed to see the seasonal changes. Beltz (2010) created a "health in motion" display showing all of the dimensions of health for the Institute for Health Metrics incorporating health, pollution, economic, and financial data time-sequenced, multi-layered map incorporating two-dimensional and satellite image views.

The air sampling network for the San Joaquin Valley Air Pollution Control District consists of four monitoring stations in San Joaquin County, two in Stanislaus County, two in Merced County, three in Madera County, eight in Fresno County, three in Kings County, five in Tulare County, and nine in Kern County totaling 36 collection sites within this study area of the California Central Valley (ARB, 2013). These were established according to the Air Monitoring Network Plan with the air basin boundaries defined based upon topography.

Purpose Statement

The endpoints of the health report for the SJVAPCD named regional poor health effects stated by their main authority as being the regional premature mortality of populations residing in the SJVAPCD, especially in Fresno and Kern Counties. Respiratory entry of airborne particulates and pollutants affect the nasopharynx as the nasal system filters the air. Particles that pass through the filters to the pharynx are at risk. When the individual is a mouth breather, there is no filter, and the particles travel through the entry gate of the oropharynx. The symptoms of nasal congestion, sore throat, and coughing are all obvious signs of airborne pathogens entering the human body. Throughout the literature review of the health risks inherent in the geography of the Central Valley, published articles show the areas of the highest danger are along the Highway 99 corridor. The highest concentrations of particulate matter temporal exposures are in Fresno and Bakersfield. Rhinitis and bronchitis cases were reported with a statistical relationship to the air quality, whereas laryngeal effects were not reported (Hall, Brajer, & Lurmann, 2006, pp. 2-59).

The purpose of this study is for understanding the relationship between air quality, seasonal effects on the environment, for providing a differentiation of the causes of vocal function disorders when compared to air quality data, and for correlating the relationship between severity of symptoms and laryngeal disturbances involving the oropharynx and laryngopharynx in the seven counties of the SJVAPCD.

Research Questions

The research questions that were addressed in this study emerged from an examination of the problem and a review of current literature on the topic of geographic environmental factors interfering with rehabilitation, and physician perception of patient diagnosis and requirements for referral to a speech-language pathologist. Four guiding questions were formulated.

1. What are the diagnostic classifications of oropharyngeal and vocal function disorders in the Central Valley California San Joaquin Valley Air Pollution Control District?

2. What are the perceived opinions regarding the impact of the environmental air quality in the Central California San Joaquin Valley Air Pollution Control District upon oropharyngeal and vocal function?

3. Is there a significant relationship between the spatial and temporal distribution between the georeferenced occurrence of oropharyngeal and vocal function disorder classifications and air quality levels and contaminates impacting a geographic population area?

4. What baseline levels and environmental symptomology questionnaire-survey were administered by the ENT, nurses, staff, SLP during intake to differentiate severity and possible causes of oropharyngeal or vocal function disorders?

Chapter 3: Methodology

Participants

The target population in this study will include the licensed medical professionals, otolaryngology physicians, and radiation-oncology physicians who work in the seven counties in the San Joaquin Valley Air Pollution Control District (SJVAPD). The regions where these physicians practice are in San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, and Kern Counties. The target population will also include speech-language pathologists who service clients with voice disorders. During 2013, the Little Blue Book (Sharecare, 2013) contributed a grant of the use of the directories of the physicians and medical professionals in the region. The contact information for the target population for the preliminary questionnaire was obtained from the American Speech-Language-Hearing Association's (ASHA) mailing list of members from the voice division, the American Academy of Otolaryngologists (AAO), and from known ENT physicians. The demographics from the preliminary exposure of speech-language pathologists located through the ASHA members search database showed 101 speech-language pathologists within a 45-mile radius of Modesto. Eight of the 101 speech-language pathologists work in private practice. Of the 93 remaining pathologists, 15% work in skilled facilities and hospital settings, and approximately 75% of the speech pathologists work in administration and education.

A larger search for the seven counties of the SJVAPD for ASHA members who are part of the Voice Division will include these professionals listed above within the seven counties: Stanislaus County, Merced County, Fresno County, Madera County, San Joaquin County, Kings County, and Kern County. One of the grant opportunities for this study was provided by The

Little Blue Book company that has provided the professional listing directories of all medical professionals in these counties considered for this study (Sharecare, 2013), where four books contain the contact information for physicians, specialty, and therapy professionals.

Inclusion of the otolaryngology professionals with the speech pathologist professionals is regarded as teamwork building to produce a positive environment for patient care (Bloominathan & Desai, 2012). This synergy between speech pathologists and otolaryngologists is a collaboration network where the surgeon/physician provides the medical diagnoses through the instrumental examination, and the speech pathologist provides the functional diagnoses and makes management decisions for interventions. Given the visual product of the instrumental evaluation, the speech pathologist provides the patient with further explanation, offering strategies and therapies for the vocal physiology. It is important to include both professions in information gathering during this research study.

Participant eligibility. A stratified sampling will be used to select a sample of the Otolaryngologists, medical professionals, and Radiation-Oncology physicians based upon their location within the San Joaquin Valley Air Pollution Control District. This method will be selected because medical professionals and physicians refer vocal function patients to speech-language pathologists based upon certain diagnostic features. ENT and Radiation-Oncology physicians were located within the seven SJVAPD counties using Google Maps while preparing the preliminary pilot questionnaire in 2011. The stratified random sample for the proposed study will be from the Little Blue Book (Sharecare, 2013).

The appropriate numbers of ENTs and radiation-oncology physicians in the seven counties will be selected in order to run statistical evaluations of the data (Creswell & Kohler, 2008, p.154). The population will be divided into groups based upon their geographic location by: (a) the seven counties, and (b) by profession. A simple random sample will then be used to select participants from each group in relation to their size in the population. A survey will be used to examine the diagnostic features of those being assessed, and the assessment practices of the participants.

Instrument

Voice disorders reported in the seven counties of Central California's San Joaquin Valley Air Pollution Control District (SJVAPCD) may show predictable rates based upon population (San Joaquin Valley Air Pollution District, 2011). As reported by the findings in a preliminary questionnaire (Gaskell, 2011), a range of voice disorders existed that may be linked to environmental factors or exacerbated by air quality. A differentiated approach has been developed based upon the findings of the preliminary questionnaire by Gaskell (2011) titled *Voice Function in the Central Valley: ENT and Radiation-Oncology Physician Survey* which presented issues affecting regional voice therapy. This preliminary questionnaire on March 25, 2011 was only available for 48 hours, and accessible through an email link sent to random members of the American Association of Otolaryngologists (AAO) and physicians volunteering to screen the protocol.

Early development leading to the preliminary questionnaire design began on February 4, 2011 by reviewing doctor surveys. In the medical field there are surveys designed for medical intake questionnaires, for health information, and for doctor's opinions. Review of the intake and health survey questionnaires did not yield the kind of approach for asking physician questions about their practices. Most of them were patient directed. Surveys which were looking for the physician's opinions of a product or service were accessed, but were not asking about their practice, but about the product or service of the vendor. In order to develop questions that could answer the unique set of research questions for this study, an original approach based upon the physician's location, environment, and their beliefs about patient care needed to be designed.

Sample results from preliminary questionnaire. Some information on how the questions were answered, how some of the questions were redundant, and how the preliminary questionnaire could be rewritten to reduce the number of questions to be more concise was derived from the preliminary questionnaire results. Survey questions regarding the Central California SJVAPCD geospatial data were asked in order to define which types of pollutants and what times of year the voice symptoms were experienced. The ranking of significance for responses from the preliminary questionnaire were found to be in this order of influence: a) pesticides and spraying with 40% of the respondents rating this with 75%–90% impact; b) dust and harvesting with 26% of the respondents rating this with 75%–90% impact; c) smog and fumes with 17% of the respondents rating this with a 75%–90% impact; and d) allergies to pollen in the air with 17% of the respondents rating this with 75%–90% impact. These questions were posed so that the options were on a Likert Scale from 0%–25%, 25%–50%, and so on, with one variable of influence presented at a time. The study will attempt to relate the actual air quality data to the perceived impact of each type of foreign air agent, and inquire as to the reasons that the impacts of the elements affect patient improvement. The preliminary questionnaire included a variety of questions which could be answered by yes and no, by Likert Scale opinion rating, and a combination of continuous or categorical scoring based upon respondent opinion of significance. This medium for data collection can be distributed electronically through a survey entity, through an email, or by hard copy. The form of questionnaire shall be determined by the individual preference of the participant. Recruitment of the participants by the primary investigator will begin through email, then follow-up will occur through telephonic communication and general mail service.

There is the possibility of a page on a website for access to the survey. This can be accomplished through attaching the questionnaire by linking it to a custom-designed website and email link to the primary investigator. On the website, there may be a copy of the information brochure which has been developed to promote the study. There may be the possibility to place an interactive survey form onto the website through a generic survey company. This would facilitate fast completion of the survey. There could also be a Facebook page designed for acquiring the survey results. There are many electronic means for gathering the survey data once the initial contacts have been made. Because of the broad range of distribution possibilities, a basic schedule of contact will be listed in the design section describing a phased approach.

Design. A quantitative non-experiment, cross-sectional, correlational research design will be utilized to examine the current attitudes, practices, and actual patient population data as these compare to the current 2013 findings from the regional pollution control district record air quality data. The cross-sectional design can be used to identify the practices and beliefs of the survey respondents through using the correlational design because the focus of data collection is on a specific period in time (Creswell & Kohler, 2008, p. 389). The surveys will be delivered through an electronic transmission linked to a survey collecting company website or a personal website designed for this project. The phased recruitment shall be set up on a temporal basis: Phase 1, Respondents will be contacted through an initial email, with instructions to reply with a confirmation email; Phase 2, the survey link email with the introduction, explanation, and survey instruction information will be sent. The survey may also be downloaded, filled out by hand, and returned using a hard copy communication. Phase 3 allows for participants who did not respond to be sent another email invitation after two weeks; Phase 4, at the four week period, a last request will be sent.

Geographic Information System and Air Resources Board. The science of the use of cartography for mapping the occurrence or spread of disease or "disease ecologies" has been improved through the use of geographic information system (GIS) technology and visual display (Koch, 2005, p. 215). The significance of the temporal distribution of vocal function disorders patients would be visualized along with the air quality GIS data maps (Lai, So, & Chan, 2009, p. 95). As the survey results are compiled, the differentiation of the vocal function disorders may be mapped as well as their comparison to the air quality information for specific regions within the SJVAPCD. This mapping will assist physicians and medical practitioners to visualize the exposures because of the geographic air quality information when compared to their responses and the responses of the medical professionals surrounding them (Cromely & McLafferty, 2002, p. 153).

In order for the spatial epidemiological study to be visualized, three types of data should be gathered. The spatial data necessary is the geographic locations of the patient records from the reporting physician, the locations of the air quality collection facilities, and the results of the air quality geographic references. This would be in the form of digital cartographic data topographic in nature to include contours and features of the environment. Sociodemographic, economic, and ethnicity census data may be additionally integrated into the spatial data set. The representation of the spatial distribution of the responses to the survey provided may be approached from the plot point pattern method. This would allow the analysis to proceed for determining whether these disease occurrences and their spatial distribution exhibit any patterns of some sort of cluster or common theme from their random distribution over the specified geographic region for the study.

In the case of mapping the responses provided to the survey, the exact positions of the disease incidences may not be at a specific street address level and may not be known at the census tract level. Using a count model may allow the point-based data to be combined into an areal unit of distribution. This may be accomplished through the use of a point-in-polygon function available in the ARC View GIS software. Also, the interpolation may use sample points derived from the response charting in order to predict values of variables from unsampled areas. This could be accomplished through using a kernel density realization method based upon data sets nearby which could be replicated from the combination of all spatial planes. This could also be analyzed using a spatial sampling approach where interpolation of the surfaces of the varying degree of smoothness of the data is displayed. Spatial interpolation of the air pollution index (API) has been performed by government agencies and this data is available.

Through presenting a visualization of the results of the survey titled Voice Function in the Central Valley Physician Survey when compared to the API for the time of the responses, the severity of symptoms at the time of the air quality data set collection may reveal some association between increased symptomology and increases in the reduced air quality. Mapping the results of the disease patterns and air quality patterns may lead to a better understanding of the causative relationships between human health and the environment (Lai et al., 2009, pp. 95, 107). The end goal of visualization of the factual collection of data would be to assist in the identification of causes of disease by correlating the disease patterns to the geographic variation of environmental factors.

Procedures

Data analysis. The results of the surveys will be analyzed using descriptive statistics showing the means, the percentages, and the standard deviations for the posed questions. Descriptive statistics will be used to determine the diagnostic classifications of oropharyngeal and vocal function disorders, the perceived opinions regarding the impact of the environmental air quality, and the baseline levels and environmental symptomology questionnaire-survey were administered by the ENT, nurses, staff, SLP during intake to differentiate severity and possible causes of oropharyngeal or vocal function disorders in the Central Valley California San Joaquin Valley Air Pollution Control District. The means and standard deviations will be used to describe the study variables considered in this study. Moreover, in order to determine whether there is a significant relationship between the spatial and temporal distribution between the georeferenced occurrence of oropharyngeal and vocal function disorder classifications and air quality levels and contaminates impacting a geographic population area, a Pearson's correlation analysis will be conducted. The significance level considered for the correlation analysis will be set at 5%. The null hypothesis states that there is no significant relationship between the spatial and temporal distribution between the georeferenced occurrence of oropharyngeal and vocal function disorder classifications and air quality levels and contaminates impacting a geographic population area. Evidence to reject the null hypothesis will be based on the *p*-value of less than .05.

Subject confidentiality. Participant confidentiality guarantee will be explained through the consent form which will give a briefing of the facts of the survey and state that any identities will not be revealed to any third party without the explicit signature of permission. The consent form is delivered in the group of emailed documents when the survey is delivered. If the electronic survey is taken, access to the actual survey will require signing the first page consent before the window for the survey will open. The risk to the participants is minimal due to the optional nature of the survey participation and the anonymity of the work product. Visualizations on the mapping by products will be through the use of a buffering tool in order to generalize the geographic region of the respondents and the generalized manner in which the medical data is reported using the Likert scale responses with a mileage buffer extension.

Limitations. The San Joaquin Valley Air Pollution Control District (SJVAPCD) data which came out in the spring of 2013 is the most current air quality information available. The time that this survey will take in order to complete the analysis may be viewed as a comparison between different temporal planes. When the research began on this topic, the report from 2010 air quality ratings was accessed. The difference between the responses to the data survey and the year of the last air quality data may be of some concern. The limitations are then stated to be that the time difference between the perceived responses of the medical practitioners and the most recent air quality findings for the respondent's particular region may be close but not completely accurate.

In order to obtain an accurate measurement between the reports from medical practitioners to the current air quality, the sample date for the survey submission may be compared to the air quality data for the most current readings matching the practitioner's survey date. Also, within the survey there are questions specific to which seasons affect specific disorders the most. Prior knowledge regarding the seasonal air quality follows the system established by the SJVAPCD to rate individual days and geographic regions according to their health rating levels for safe outdoor activity. Since the data for the air quality for the entire year is available to the public through the Internet, the general public can reduce or increase their activity levels accordingly.

A control in place for determination of the volume of patients reported by the respondent includes questions specifically rating the seasonal patient counts on the Likert scale. The survey also includes questions revolving around which seasons each type of diagnosis is expected to be referred to their offices, and which diagnoses are more susceptible to poor air quality. The extrapolation of these questions can form a control for the possibility that seasonal increases in the amount of air pollution and how they affect specific diagnoses do not affect the correlation between the variables of the study.

After a review of the literature, there were few references to the vocal function disorders within the American Lung Association or the SJVAPCD references. The focus of this study was to present and analyze the results of a preliminary questionnaire developed by a Central Valley speech-language pathologist directed toward the lack of specialized information on vocal function, oropharynx and laryngopharynx involvement reported by the Air Resources Board and the SJVAPCD health report. Therefore, the analysis for this study was focused on describing study variables in this study rather than providing comparisons between sample populations. Moreover, this study does not provide a review of the perceptions of the medical professionals from other poor air quality regions around the country.

Anticipated Outcomes

The instrument for presenting the interrogatory questions to participants in order that they may voice their opinion will be centered upon these four research questions with the following anticipated outcomes:

1. There may be a diagnostic classification of oropharyngeal and vocal function disorders in the Central Valley California San Joaquin Valley Air Pollution Control District.

2. The perceived opinions regarding the impact of the environmental air quality in the Central California San Joaquin Valley Air Pollution Control District upon oropharyngeal and vocal function should be correlated by the caseload findings georeferenced to be layered over the air quality data.
3. There may be a significant relationship between the spatial and temporal distribution between the georeferenced occurrence of oropharyngeal and vocal function disorder classifications identified and the air quality levels of contaminates impacting a geographic population area.
4. Baseline levels of patient reporting of environmental symptomology supplied through questionnaire-survey interview administration by the ENT, nurses, staff, and speech-language pathologists during intake. The personnel administering the interviews, and the quantity of the interview protocols may defend the distribution of the perceived causes of oropharyngeal or vocal function disorders.

Based upon the literature review which guided the development of the questions on the instrument, and the pollution information provided through the monitoring stations of the Air Resources Board, the results of the data extrapolation will form the basis for forming strategies. The geographic representation of the physician responses when mapped against the monitoring site pollution data should reveal temporal patterns of symptom clusters.

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FIGURES

Figure 1. The Counties of the San Joaquin Valley Air Pollution Control District. San Joaquin Valley Air Pollution District, (2011). Retrieved by the author from http://www.valleyair.org/

California in the San Joaquin Valley Air Pollution Control District- shown are the seven counties.

Figure 2. The State of the Air 2013 National survey: Counties of the San Joaquin Valley Air Pollution Control District rankings during the 2013 report. Retreived by the author from the website

http://www.stateoftheair.org/2013/city-rankings/most-polluted-cities.html

BY OZONE	BY YEAR ROUND PARTICLE POLLUTION	BY SHORT-TERM PARTICLE POLLUTION
#1: Los Angeles-Long Beach-Riverside, CA	#1: Bakersfield-Delano, CA	#1: Bakersfield-Delano, CA
#2: Visalia-Porterville, CA	#1: Merced, CA	#2: Fresno-Madera, CA
#3: Bakersfield-Delano, CA	#3: Fresno-Madera, CA	#3: Hanford-Corcoran, CA
#4: Fresno-Madera, CA	#4: Los Angeles-Long Beach-Riverside, CA	#4: Los Angeles-Long Beach-Riverside, CA
#5: Hanford-Corcoran, CA	#4: Hanford-Corcoran, CA	#5: Modesto, CA
#6: Sacramento--Arden-Arcade--Yuba City, CA-NV	#6: Modesto, CA	#6: Salt Lake City-Ogden-Clearfield, UT
#7: Houston-Baytown-Huntsville, TX	#7: Visalia-Porterville, CA	#7: Pittsburgh-New Castle, PA
#8: Dallas-Fort Worth, TX	#8: Pittsburgh-New Castle, PA	#8: Merced, CA
#9: Washington-Baltimore-Northern Virginia, DC-MD-VA-WV	#9: El Centro, CA	#9: Fairbanks, AK
#10: El Centro, CA	#10: Cincinnati-Middletown-Wilmington, OH-KY-IN	#10: Logan, UT-ID
#11: Merced, CA	#11: Philadelphia-Camden-Vineland, PA-NJ-DE-MD	#11: Provo-Orem, UT
#11: San Diego-Carlsbad-San Marcos, CA	#12: Louisville-Jefferson County-Elizabethtown-Scottsburg, KY-IN	#12: Stockton, CA
#13: Modesto, CA	#12: St. Louis-St. Charles-Farmington, MO-IL	#13: Las Cruces, NM
#14: Birmingham-Hoover-Cullman, AL	#14: Allentown-Bethlehem-Easton, PA-NJ	#14: Visalia-Porterville, CA
#14: Cincinnati-Middletown-Wilmington, OH-KY-IN	#14: Canton-Massillon, OH	#14: Eugene-Springfield, OR
#16: Las Vegas-Paradise-Pahrump, NV	#14: Fairbanks, AK	#16: Chicago-Naperville-Michigan City, IL-IN-WI
#17: Louisville-Jefferson County-Elizabethtown-Scottsburg, KY-IN	#14: Macon-Warner Robins-Fort Valley, GA	#17: Seattle-Tacoma-Olympia, WA
#17: New York-Newark-Bridgeport, NY-NJ-CT-PA	#18: Atlanta-Sandy Springs-Gainesville, GA-AL	#17: Green Bay, WI
#19: Charlotte-Gastonia-Salisbury, NC-SC	#18: Phoenix-Mesa-Glendale, AZ	#19: Indianapolis-Anderson-Columbus, IN
#20: Oklahoma City-Shawnee, OK	#20: Cleveland-Akron-Elyria, OH	#19: Harrisburg-Carlisle-Lebanon, PA
#20: Philadelphia-Camden-Vineland, PA-NJ-DE-MD	#20: Indianapolis-Anderson-Columbus, IN	#21: Phoenix-Mesa-Glendale, AZ
#20: Beaumont-Port Arthur, TX	#22: Steubenville-Weirton, OH-WV	#22: Allentown-Bethlehem-Easton, PA-NJ
#23: Phoenix-Mesa-Glendale, AZ	#22: Wheeling, WV-OH	#23: San Diego-Carlsbad-San Marcos, CA
#24: Pittsburgh-New Castle, PA	#24: Dayton-Springfield-Greenville, OH	#24: Portland-Vancouver-Hillsboro, OR-WA
#25: St. Louis-St. Charles-Farmington, MO-IL	#24: Birmingham-Hoover-Cullman, AL	#25: South Bend-Elkhart-Mishawaka, IN-MI

Figure 3. The State of the Air 2013 National survey:

People at Risk in 25 U.S. Cities Most Polluted by Short-term Particle Pollution (24-hour $PM_{2.5}$)

2013 Rank[1]	Metropolitan Statistical Areas	Total Population[2]	Under 18[3]	65 and Over[3]	Pediatric Asthma[4,6]	Adult Asthma[5,6]	COPD[7]	CV Disease[8]	Diabetes[9]	Poverty[10]
1	Bakersfield-Delano, CA	851,710	254,658	77,793	18,232	50,187	25,296	167,656	44,022	200,571
2	Fresno-Madera, CA	1,095,829	321,487	114,718	23,016	65,120	33,800	224,505	59,435	272,942
3	Hanford-Corcoran, CA	153,765	42,382	12,366	3,034	9,354	4,504	29,646	7,656	27,949
4	Los Angeles-Long Beach-Riverside, CA	18,081,569	4,542,151	2,021,451	325,187	1,139,030	597,808	3,983,369	1,059,886	3,038,607
5	Modesto, CA	518,522	146,498	56,563	10,488	31,303	16,547	110,394	29,447	119,325
6	Salt Lake City-Ogden-Clearfield, UT	1,776,528	540,098	159,329	36,476	108,788	50,041	317,657	84,494	222,300
7	Pittsburgh-New Castle, PA	2,450,281	487,427	424,058	48,891	175,676	134,681	705,328	194,442	304,860
8	Merced, CA	259,898	80,991	25,034	5,798	15,039	7,658	50,722	13,340	68,371
9	Fairbanks, AK	99,192	25,056	6,759	2,143	6,027	3,659	22,166	5,466	9,045
10	Logan, UT-ID	127,549	39,974	10,727	2,780	7,751	3,467	21,185	5,592	19,977
11	Provo-Orem, UT	540,834	188,312	36,206	12,718	31,034	13,052	78,928	20,237	75,340
12	Stockton, CA	696,214	201,446	73,891	14,422	41,628	21,911	146,134	38,937	124,573
13	Las Cruces, NM	213,598	56,503	26,936	5,681	15,816	9,408	47,038	15,117	61,023
14	Eugene-Springfield, OR	353,416	68,420	54,567	6,475	29,763	16,874	91,147	26,384	73,046
14	Visalia-Porterville, CA	449,253	145,232	43,101	10,398	25,559	13,075	86,663	22,830	113,766
16	Chicago-Naperville-Michigan City, IL-IN-WI	9,729,825	2,409,527	1,137,848	178,564	606,154	450,627	2,427,061	695,509	1,406,443
17	Green Bay, WI	309,469	75,014	39,345	5,720	21,574	12,487	72,064	19,336	32,227
17	Seattle-Tacoma-Olympia, WA	4,269,349	956,101	505,469	67,682	322,196	133,881	1,058,057	289,663	506,278
19	Harrisburg-Carlisle-Lebanon, PA	687,222	150,880	104,875	15,134	48,425	35,784	186,263	50,760	70,738
19	Indianapolis-Anderson-Columbus, IN	2,103,574	538,477	245,760	50,965	150,174	127,524	543,297	156,272	304,431
21	Phoenix-Mesa-Glendale, AZ	4,263,236	1,107,303	540,544	93,175	302,805	166,853	963,671	297,791	727,056
22	Allentown-Bethlehem-Easton, PA-NJ	824,916	184,267	127,180	18,156	57,703	41,844	223,884	60,999	93,243
23	San Diego-Carlsbad-San Marcos, CA	3,140,069	726,602	362,928	52,020	203,011	106,254	707,051	187,806	462,997
24	Portland-Vancouver-Hillsboro, OR-WA	2,262,605	528,336	264,695	47,250	179,204	91,968	529,364	150,599	330,960
25	South Bend-Elkhart-Mishawaka, IN-MI	564,679	145,837	75,670	13,868	40,240	34,946	150,972	43,341	98,292

Notes:

1. Cities are ranked using the highest weighted average for any county within that Combined or Metropolitan Statistical Area.
2. **Total Population** represents the at-risk populations for all counties within the respective Combined or Metropolitan Statistical Area.
3. Those **under 18** and **65 and over** are vulnerable to $PM_{2.5}$ and are, therefore, included. They should not be used as population denominators for disease estimates.
4. Pediatric asthma estimates are for those under 18 years of age and represent the **estimated** number of people who had asthma in 2011 based on state rates (BRFSS) applied to population estimates (U.S. Census).
5. **Adult asthma** estimates are for those 18 years and older and represent the **estimated** number of people who had asthma in 2011 based on state rates (BRFSS) applied to population estimates (U.S. Census).
6. Adding across rows does not produce valid estimates, e.g., summing pediatric and adult asthma.
7. **COPD** estimates are for adults 18 and over who have been diagnosed within their lifetime, based on state rates (BRFSS) applied to population estimates (U.S. Census).
8. **CV disease** is cardiovascular disease and estimates are for adults 18 and over who have been diagnosed within their lifetime, based on state rates (BRFSS) applied to population estimates (U.S. Census).
9. **Diabetes** estimates are for adults 18 and over who have been diagnosed within their lifetime, based on state rates (BRFSS) applied to population estimates (U.S. Census).
10. **Poverty** estimates come from the U.S. Census Bureau and are for all ages.

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Figure 4. The State of the Air 2013 National survey: Monitoring Sites Locations