Introduction

This bibliography is the second draft of a work in progress. Successive drafts will be posted to the project website at http://www.accord3.com/pg68.cfm. It includes some citations that are definitional in nature and others that are topic-specific reference studies. It is being developed for two uses.

First, and ultimately, it will serve as a resource for the people of Hawaii and for the agencies of County government that are periodically faced with health questions associated with geothermal energy production. As described in the Project Description, this is one of the products of the assessment. Readers are reminded that the focus is strictly on health and is not intended to be comprehensive nor inclusive of other questions associated with policy, permitting or technologies. Second, it is a reference of resources that will be used by the Study Group during its deliberations.

Successive drafts will be posted and replace this one. The project team welcomes the suggestions of additional possible citations from both the Study Group as well as interested others. Suggestions can be sent to: geothermalhealth@gmail.com or padleraccord@gmail.com.
I. GEOTHERMAL PLANTS ABROAD

II. GEOTHERMAL PLANT IN HAWAII


   • Short Description: A health risk assessment of Puna Geothermal Venture was conducted to measure chronic exposure of hydrogen sulfide emissions. The study concluded that the air around the monitoring stations in residential areas near the site do not pose a public health hazard.


   • Short Description: Since the development of geothermal wells in 1976, residents leaving near the plant raised concerns of the health effects from hydrogen sulfide being released into the atmosphere. A health survey was carried of people living in close proximity as well as residents living away from the plant to see any correlating prevalence in the rate of the number of acute and chronic health conditions in these study areas. The results of the study revealed =inconclusive results because of the difficulty of distinguishing whether the point source originated from the geothermal wells or Kilauea’s volcanic activity.


   • Short Description: The U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry conducted a test on levels of hydrogen sulfide in residential areas near the Puna Geothermal Venture plant. The study found that concentrations of hydrogen sulfides are similar to those of natural occurrences. Furthermore, maximum concentrations of hydrogen sulfides emitted from the plant were well below the federal agency’s minimum risk levels, and thus indicating levels of exposure of causing health problems is no more than that of the exposure from Hawaii Island’s natural processes.

- **Short Description:** In 1974 permission to build a geothermal plant began. In 1976, the drilling for geothermal energy was completed. Various studies and tests were undertaken before and after the geothermal plant was completed to examine for environmental impacts within one-mile radius. The baseline study show no threat to the surrounding area, however, certain elements (such as heavy metals) should continue to be monitored incrementally over time.


- **Short Description:** Using a worst case scenario, Dr. Brooks assessed the maximum predicted hydrogen sulfide concentrations of 12,78 ppb and its exposure to residents living approximately 6,000 feet and 20,000 feet from Puna Geothermal Venture. The study suggests little evidence of serious adverse health effects would be expected in adults and children. Moreover, the maximum predicted levels of hydrogen sulfide discharge are less than emergency levels used by Federal and State regulatory agencies.

### III. EMISSIONS FROM PUNA GEOTHERMAL VENTURE

1) Gases

#### A. Hydrogen Sulfide (H2S) Information


- **Short Description:** A health risk assessment was performed to evaluate the health consequences from short-term exposure to H2S resulting from an accident or unplanned release from Puna Geothermal Venture’s (PGV’s) operation in Puna, Hawaii. Using
worst case analysis, the maximum levels predicted to impact the community are less than emergency evacuation levels used by several Federal and State regulatory agencies.


• **Short Description:** EPA finds that the potential for human and environmental exposures from routine emissions of H2S from oil and gas wells exists, but insufficient evidence exists to suggest that they expose present any significant threats. On the other hand, an accident release of H2S from an oil or gas well could have severe consequences because of its toxicity and its potential to travel significant distances downwind under certain circumstances.


• **Short Description:** Although some symptoms increased with exposure, the magnitude of these changes was relatively minor. Increased anxiety was significantly related to ratings of irritation due to odor. Whether the effect on verbal learning represents a threshold effect of H2S or an effect due to fatigue across exposure requires further investigation. These acute effects in a healthy sample cannot be directly generalized to communities where individuals have other health conditions and concomitant exposures.


• **Short Description:** Hydrogen sulfide is a colorless gas with a sewer or rotten egg smell that is primarily found in destinations with high geothermal activity. At low concentrations, H2S can irritate
eyes and act as a depressant. At higher concentrations, H2S can cause upper respiratory irritation and pulmonary edema. Hydrogen sulfide is known to have resulted in tourist fatalities in various parts of Japan and the geothermal field in Rotorua, New Zealand. Moreover, it is calculated that exposure to 500 ppm of H2S for 30 minutes can result in headache, dizziness, an unsteady gait, and diarrhea. It can also be followed by the development of bronchitis and bronchopneumonia. Acute exposures to >700 ppm of H2S can result in unconsciousness within a matter of minutes and eventual death from H2S poisoning.


- **Short Description:** Forty-nine adults living in Lovington, Tatum, and Artesia, the sour gas/oil sector of Southeastern New Mexico were tested for neurobehavioral impairment. In the report, it was found that multiple hydrogen sulfide exposures impaired neurobehavioral functions.


- **Short Description:** Two hundred and two unexposed subjects were compared with nineteen hydrogen sulfide exposed patients. Hydrogen sulfide impairments associated with H2S were similar in 19 workers (44% had been unconscious) and in 16 bystanders who had not been unconscious.


- **Short Description:** In this study, the authors compared symptoms of adverse health effects, reported by residents of two communities exposed mainly to chronic, low-levels of industrial sources of hydrogen sulfide, to health effects reported by residents in three reference communities in which there were no known industrial sources of hydrogen sulfide. The results of this study emphasize the need for further studies on the adverse health effects related to long-term, chronic exposure to hydrogen sulfide.

- **Short Description:** The fact sheet defines, describes the properties, health effect of H2S, and protection against exposure. Low concentrations irritate the eyes, nose, throat and respiratory system (e.g., burning/tearing of eyes, cough, shortness of breath). Asthmatics may experience breathing difficulties. Moderate concentrations can cause more severe eye and respiratory irritation (including coughing, difficulty breathing, accumulation of fluid in the lungs), headache, dizziness, nausea, vomiting, staggering and excitability. A level of H2S gas at or above 100 ppm is Immediately Dangerous to Life and Health


- **Short Description:** H2S exposures at concentrations below the current occupational limits cause physiological changes in pulmonary function, thus suggesting that asthmatics are at risk. Studies of fetal and neonatal brain tissue have shown an abnormal development, and the long-term consequences of these neuronal changes have not yet been assessed.


- **Short Description:** A few studies explored the relationship between H2S and the endocrine system, growth and reproduction, including effects on carbohydrate metabolism, smooth muscle function and core temperature control. Since subjects were also exposed to other substances it is difficult to ascribe the effects of symptoms to H2S parse

• **Short Description:** Each profile includes the following: (A) The examination, summary, and interpretation of available toxicologic information and epidemiologic evaluations on a hazardous substance to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects; (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure that present a significant risk to human health of acute, subacute, and chronic health effects; and (C) Where appropriate, identification of toxicologic testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.


• **Short Description:** The study highlights the human health effects caused by hydrogen sulfide. The severity of the effects depends on the concentration of the gas and level of exposure. Its odor at concentrations as low as 0.5ppb can be detected by smell. At above 150ppb, hydrogen sulfide becomes odorless and can cause olfactory fatigue. At such level, it can also pose serious health risks and even become life-threatening.


• **Short Description:** “In May 2000, the Agency for Toxic Substances and Disease Registry of the US government conducted a health investigation in response to community concerns regarding ambient and indoor hydrogen sulfide (H2S), odor, and health symptoms in Dakota City, Nebraska. The objective was to determine whether adult residents in an area with repeated exposure to H2S showed poorer performance on neurobehavioral tests than unexposed residents. Study participants were required to meet age (X16 years of age) and length of residency (2 years) eligibility requirements. A battery of computer-assisted standardized neurobehavioral tests was administered in English or Spanish. A questionnaire was used to collect information about
participants, demographic and health status. Three hundred forty-five people agreed to participate. After the exclusion of 10 persons, analyses were conducted on 335 participants; 171 residents in the target area and 164 residents in the comparison area. The two groups were comparable in demographic characteristics and various health conditions. Overall, neurobehavioral test results for the target and comparison groups were similar. Residence in the H2S-exposed area was associated with marginally poorer performance on a test of memory, namely, match to sample score, and a test of grip strength. However, these differences were not significant. Deficits in overall neurobehavioral performance were not associated with exposure to H2S in this study."

“Sensory and Cognitive Effects of Acute Exposure to Hydrogen Sulfide.” Fiedler, Nancy; Kipen, Howard; Ohman-Strickland; Zhang, Junfeng; Laumbach, Robert; Kelly-McNeil, Kathey; Olejeme, Kelechi; Lioy, Paul. 2008. Department of Environmental and Occupational Medicine, and School of Public Health, University of Medicine and Dentistry of New Jersey–Robert Wood Johnson Medical School, Piscataway, New Jersey, USA; School of Medicine, Morehouse University, Atlanta, Georgia, USA. 1(2).

- **Short Description:** Effects of low-level exposure to hydrogen sulfides have been reported to adversely affect cognitive function and sensory performance in humans. This study shows that symptoms increase with exposure, but with minor concerns to adverse cognitive effects. The greater concern deals more with anxiety and irritation due to odor. This is with exception of individuals that have other health conditions and contaminant exposures, of whom experience higher levels of sensitivity to hydrogen sulfide exposure.

**H2S Studies in Other Places**

**Rotorua**


- **Short Description:** In this study, the authors classified areas within Rotorua as high-, medium, or low-H2S exposure areas. Results showed exposure-response trends, particularly for nervous system diseases, but also for respiratory and cardiovascular
diseases. The results of the study suggest that there are chronic health effects from H2S exposure, and that further investigation is warranted.

B. Sulfur Dioxide (SO2) Information


• Short Description: According to the Agency for Toxic substances and Disease Registry the effects of exposure to sulfur dioxide depend on the dose, the durations, how the person is exposed, personal traits and habits, and whether other chemical are present.


• Short Description: Sulfur dioxide is irritating to the eyes, throat, and respiratory tract and induces coughing, burning of the eyes, and difficulty breathing. While these reactions are considered relatively short-term effects, tourists with pre-existing asthmatic conditions can be sensitive to SO2 at low concentrations and suffer more severe consequences. In fact SO2 is known to have played a significant role in the death of several tourists at Aso, Japan, and in Hawaii Volcanoes National Park. In these situations, half of the fatalities involved asthmatic tourists. The World Health Organization (WHO) air quality guidelines have set a maximum exposure limit for SO2 at 175 ppb for 10 minutes and 44 ppb over a single day. In contrast, the United States Geologic Survey (USGS) Volcanic Hazards Program notes that a concentration of 6–12 ppm of SO2 can result in the immediate irritation of the nose and throat, 20 ppm can cause immediate eye irritation, and 10,000 ppm will irritate moist skin within minutes.

• **Short Description:** This study determines whether subjects with mild asthma or seasonal rhinitis have greater bronchomotor responses to sulfur dioxide (SO2) than normal subjects. The authors studied 7 asthmatic, 7 atopic, and 7 normal subjects, 23 to 37 year of age. They measured the change in specific airways resistance (SRaw) provoked by 10 min of breathing 1, 3, and 5 ppm of SO2 delivered by mouthpiece on separate days at least 48 h apart. The results indicated that subjects with mild asthma develop bronchoconstriction after exposure to concentrations of SO2 well below currently accepted standards for occupational exposure, and that SO2-induced bronchoconstriction is mediated by parasympathetic pathways.


• **Short Description:** Sulfur dioxide (SO2) is one of a group of highly reactive gasses known as “oxides of sulfur.” The largest sources of SO2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%). In 2010, EPA revised the primary SO2 NAAQS by establishing a new 1-hour standard at a level of 75 parts per billion (ppb).


• **Short Description:** The Environmental Protection Agency links short links short-term exposures to SO2, ranging from 5 minutes to 24 hours, with an array of adverse respiratory effects including bronchoconstriction and increased asthma symptoms. Asthmatics at elevated ventilation rates are particularly vulnerable to SO2. Emissions that lead to high concentrations of SO2 generally also lead to the formation of other carbon oxide (Sox). SOx when combined with other compounds in the atmosphere can form small particles. These particles penetrate into the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death.

• **Short Description:** The United States Geological Survey sulfur dioxide as substance that affects upper respiratory tract and bronchi. The World Health Organization recommends a concentration of no greater than 0.5 ppm over 24 hours for maximum exposure. Exposure to 6-12 ppm can cause immediate irritation to the nose and throat; 20 ppm can cause eye irritation; while 10,000 ppm will irritate moist skin within minutes.

C. **Fluorine Information**


• **Short Description:** Fluorine is a naturally-occurring, pale yellow-green gas with a sharp odor. It is very irritating to the skin, eyes, and respiratory tract. The Occupational Safety and Health Administration (OSHA) has set limits of 0.2 milligrams per cubic meter (0.2 mg/m$^3$) for fluorine, 2.0 mg/m$^3$ for hydrogen fluoride, and 2.5 mg/m$^3$ for fluoride in workroom air to protect workers during an 8-hour shift over a 40-hour work week.

D. **Boron and Associated Gas Elements**


• **Short Description:** Boron trifluoride is highly reactive in the presence of moister present in the air. It is visible if at a high enough concentration, The gas strongly irritates the skin and respiratory system, therefore inhalation or contact should be avoided.


• **Short Description:** Specific data relating to the toxic effects of born trifluoride on humans are not available. The odor threshold of
boron trifluoride has not been determined, although there are reports of rather pleasant, acidic odor was detected by personnel handling animals exposed to it at a concentration of 3.0 ppm. Others have said that boron trifluoride had a pungent, suffocating odor, but these reports do not contain data on the environmental concentrations. Cotton soded with born trifluoride in water was placed on the skin for a day or so, which resulted in acid burn.


• **Short Description:** The purpose of this report to provide the public with an overall perspective on the toxicology of boron. The report contains descriptions and evaluations of the health effects of boron relative to public health.

E. Radon


• **Short Description:** According to the EPA, decaying radium produces radioactive gas known as Radon. Radon occurs naturally, and has been linked to lung cancer.

“Residential Radon Exposure, Histologic Types, and Lung Cancer Risk. A Case-Control Study in Galicia, Spain.” Barros-Dios, Miguel Juan; Ruano-Ravina, Alberto; Perez-Rios, Monica; Castro-Bernardez, Margarita; Abaoi-Arca, Jose; and Tojo-Castro, Marta. 2012. *American Association for Cancer Research*. http://cebp.aacrjournals.org.eres.library.manoa.hawaii.edu/content/21/6/951.full

• **Short Description:** Second to smoking, Radon is the second largest cause of lung cancer and first to non-smokers. When exposed to concentrations higher than 50 Bq/m³ individuals increase their risks to lung cancer by two folds compared to those that are not. Susceptibility to tobacco smokers, are at an even higher risk of lung cancer.


• **Short Description:** It has been estimated that radon causes about
20,000 deaths each year in the U.S. It is an odorless chemical, that is also tasteless, and invisible to the naked eye. Radon is considered a carcinogen and causes lung cancer to humans.

2) Metals

F. Zinc

“Criteria for a Recommended Standard: Occupational Exposure to Zinc Oxide.” Centers for Disease Control and Prevention. 

- **Short Description:** Zinc oxide can be harmful when the fumes are inhaled. The fume is particularly hazardous because of its small particle size that can enter the human body, and cause damage. Zinc oxide is a white or yellowish-white, amorphous, odorless powder.

www.ncbi.nlm.nih.gov/pubmed/15891778

- **Short Description:** Zinc is essential for human health, but for the environmentalists, free zinc is considered a toxic pollutant. Excess free zinc is known to be toxic to the body tissue.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1567081/

- **Short Description:** The health effects of zinc are critically summarized in this report including effects on:
  1. Zinc deficiency and toxicology
  2. Immunological and reproductive function
  3. Genotoxicity and carcino-genicity.

In doing so, the report identifies factors of risks and benefits that zinc has to human health via immune, reproductive, and neurological function, as well as the cardiovascular system. Finally, the report also looks at the biological effects of zinc at the molecular level.

G. Nickel
http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000FDBJ.txt

- **Short Description:** This report evaluates information on the adverse health effects associated with nickel. EPA states that regular exposure to nickel leads to the development of tumors of the nasal cavities and lungs. However, the toxicity database on nickel is limited, which suggests further studies.


- **Short Description:** This study is a compilation of toxicological information on nickel beginning with a public health statement, relevance to public health, health effects, chemical and physical information, and regulations and advisories. With regards to human health effects, the most common harmful health effect of nickel in humans is rash formation due to allergic reaction. Approximately 10-20% of the population is sensitive to nickel. Other more severe cases include chronic bronchitis, reduced lung function, and cancer of the lung and nasal sinus. Lung and nasal sinus cancers occurred in workers who were exposed more than 10mg nickel/m^3 as nickel compounds that were hard to dissolve such as nickel subsulfide.

“Occupational Safetey and Health Guideline for Nickel (Soluble Compounds).” Occupational Safety and Health Administration. 2012.
www.osha.gov/SLTC/.../recognition.html

- **Short Description:** The Occupational Safety and Health Administration (OSHA) reports of soluble nickel compounds can have adverse affects to the cardiovascular system, kidneys, and central nervous system in humans. They may also be carcinogenic to humans, while some of its compounds are linked to causing cancer to the nasal cavity and lung. According to OSHA permissible exposure limit is 1 milligram per cubic meter (mg/m(3)) of air as an 8-hour time-weighted average (TWA) concentration.

The National Institute for Occupational Safety and Health (NIOSH) recommends exposure limit of 0.015 mg/m(3) of up to 10-hours workday and 40-hours workweek. The American Conference of
Governmental Industrial Hygienists (ACGIH) recommends the limit value of 0.1 mg/m(3) as a TWA for a normal 8-hour workday and a 40-hour workweek. Additionally, nickel is identified as human carcinogens.

**H. Copper**


- **Short Description:** On the one hand, copper is an essential nutrient for humans, on the other hand, it causes gastrointestinal distress including: nausea, vomiting, and/or abdominal pain in humans. Copper can also irritate the respiratory tract and has been known to cause coughing, sneezing, runny nose, pulmonary frosts, and build up of mucus. The metal has been linked to causing damage to the kidney as well as the immune system.


- **Short Description:** This report summarizes and evaluates information relevant to the health effects associated with copper. Oral ingestion can result symptoms of dizziness, headache, diarrhea, vomiting, and abdominal pain. When inhaled, copper can cause damage to lung and liver functions. Women should avoid drinking copper contaminated water as it has been reported to develop gastroenteritis.


- **Short Description:** The study supports the findings of copper toxicity as a causal factor of Alzheimer’s disease and mild cognitive impairment. The author recommends that people should check copper levels in their drinking water and use an alternate source if it is 0.1 ppm or higher.

**I. Chromium**
“Hexavalent Chromium.” Occupational Safety and Health Administration. 2012.  

• Short Description: Workers who are exposed to hexavalent chromium compounds in the air may develop lung cancer. The compounds irritate or damage the nose, throat, and lungs, as well as, the eyes and skin. Hexavalent chromium has been known to cause permanent eye damage and result ulcers to the mucous membranes of the nasal passages. Prolonged skin contact can result in dermatitis and skin ulcers to some workers, while other may develop an allergic reaction to chromium.

http://www.cdc.gov/niosh/topics/hexchrom/

• Short Description: The report indicates Hexavalent Chromium compounds to be potential occupational carcinogens. Hexavalent Chromium compounds is associated with lung, nasal, and sinus cancer. It irritates the nasal and eardrum. Dermal exposure to Hexavalent Chromium compounds can cause skin irritation, ulceration, sensitization, and allergic contact dermatitis.


• Short Description: The health effects of chromium depend on the typology of exposure. For instance, inhaling chromium compounds effects the respiratory system whereas gastrointestinal deficiencies are caused by oral and dermal exposures.

J. Manganese


• Short Description: Manganese is a natural substance found in rocks. Manganese is silver-colored in pure form. It can also be produced artificially to make pesticides, such as maneb or mancozeb, and used as fuel additives in gasoline. Manganese is
essential for good health and can be found in several food items, including grains and cereals, and drinks such as tea.

“Ambient Concentrations of Manganese Compounds in EPA Region 5”. Environmental Protection Agency. 2010.
http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewInd&lv=list.listByAlpha&r=231334&subtop=341

• Short Description: Manganese is a naturally occurring metal. Exposure to low levels of manganese is considered to have nutritional benefits to both humans and animals. However, exposures over-exposure is harmful and have been associated with neurological problems, such as slowed eye-hand coordination. The most recent National Air Toxics Assessment results identify manganese compounds as the largest contributor to neurological non-cancer health risk in the U.S.

http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=102&tid=23

• Short Description: Manganese is an essential nutrient, and eating a small amount of it each day is important to stay healthy. Existing scientific information cannot determine whether excess manganese can cause cancer, however, loss of sex drive and sperm damage has been observed in men exposed to high levels of manganese. The most common health problems to involve the nervous system include movements that become slow and clumsy.

K. Cadmium

“Cadmium Fact Sheet”. Environmental Protection Agency. 2012.

• Short Description: In its purest form, cadmium is a soft silverwhite metal that naturally forms on the earth’s surface. Cadmium commonly enters the body through oral ingestion and breathing. The greatest concern is associated with long-term exposure to low doses of cadmium. Over times, cadmium can cause kidney damage. Although the damage is not life-threatening, it can lead to the formation of kidney stones and affect the skeleton. Lung damage has also been observed.

“Occupational Exposure to Cadmium: Section 5 – V. Health Effects.”
Occupational Safety and Health Administration. 1993. 

- **Short Description:** Cadmium is primarily linked to lung cancer and kidney damage. This is typically a result of acute exposure through the respiratory system from breathing in the fumes and dust compounds. Symptoms of cadmium include fever and chest pain. In extreme cases, pulmonary edema may develop and death may occur after several days of exposure.


- **Short Description:** Breathing in high levels of cadmium damages the lungs and may cause death. Long-term exposure to low-levels of cadmium compounds build up in the kidney, which causes damage. The U.S. Department of Health and Human Services (DHHS), The International Agency for Research on Cancer (IARC), and the U.S. Environmental Agency identifies as cadmium as carcinogenic to humans.

I. Selenium


- **Short Description:** Selenium is an essential for human health at low levels. However, EPA has found it to potentially cause health effects from acute exposures: hair and fingernail changes; damage to the peripheral nervous system; fatigue and irritability. No Health Advisories have been established for short-term exposures, although it has the potential to cause the following health effects from long-term exposures: hair and fingernail loss; damage to kidney and liver tissue, and the nervous and circulatory systems. Finally, there is no evidence that selenium has the potential to cause cancer from lifetime exposures in drinking water.

• **Short Description:** Selenium compounds tested in mice and rats by the oral route produced an increase in the incidence of liver tumors. Thus far, the available data provide no suggestion that selenium is carcinogenic to humans, and the evidence for a negative correlation between regional cancer death rates and selenium is not convincing.

“**Toxicological Profile for Selenium.”**

• **Short Descriptions:** Depending upon the level of intake, selenium can have nutritional or toxic effects. For the most part people living in the U.S. do not suffer from selenium deficiency. However, excessive intake of selenium can cause adverse health effects if doses are taken more than 5 times greater than the Recommended Dietary Allowance (RDA).

**M. Lead**


• **Short Description:** Lead is a naturally occurring metal. It can be toxic to both humans and animal. Children are particularly vulnerable as their growing bodies absorb more lead, and their brains and nervous systems are affected greatly compared to adults. Miscarriage or premature birth can also result from exposure to lead. Adults can suffer cardiovascular functions, experience kidney failures, problems with reproduction in both women and men, and damage to the nervous system.


• **Short Description:** Both acute and chronic exposure to lead adversely affects the body. The level of exposure and frequency dictates the severity of medical symptoms. Acute lead exposure may cause loss of appetite, nausea, vomiting, stomach pains, constipation, insomniac, fatigue, mood fluctuations, headache, joint or muscle aches, anemia, and reduced sex drive. Chronic exposure is linked to damage to the blood-forming, nervous, urinary, and reproductive systems.
http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=96&tid=22

- **Short Description:** Lead is harmful to the human body, especially, the nervous system, the hematological and cardiovascular systems, and the kidney. However, lead is not limited to the biological systems mentioned above as it can increase blood pressure and cause anemia. Severe damage to the brain and kidneys can occur with high exposure lead levels for both women and men. Moreover, pregnant women risk miscarriage when exposed to high levels of lead. In men, high levels of lead poisoning lead to organ failure and reduction in sperm count levels.

N. Arsenic

http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/arsenic/sab_index.cfm

- **Short Description:** Arsenic occurs organic and inorganically. This review is only of inorganic arsenic. Oral exposure to inorganic arsenic is known to cause cancer of the skin, lung, and bladder in humans. Industrial activities have increased the concentration of arsenic in the environment, often resulting in toxic concentrations of arsenic in soil, air, and water. In addition, certain geographic areas have high levels of arsenic in their underground rock formation, which can be leached and cause high arsenic concentrations in drinking water.


- **Short Description:** This report focuses on inorganic arsenic. The toxicological profile of inorganic arsenic is such that it is poisonous to the body. Oral doses above 60,000 ppb can result in death. Ingestion of lower levels ranging between 300 to 30,000 ppb can cause the following symptoms: abdominal pain, nausea, vomiting, and diarrhea. Other effects include fatigue, abnormal heart rhythm, and blood-vessel damage. Arsenic is also known to cause skin cancer, and when breathed-in, can cause sore throat and irritate the lungs.

- Short Description: This report focuses on organic arsenic. When ingested organic arsenic can burn lips, cause throat constriction, trigger abdominal pain, dysphagia, nausea, vomiting, diarrhea, convulsions, coma, and even death. Air exposure of the compound can irritate the respiratory tract, skin, and eyes. In severe cases, chronic exposure to organic arsenic can cause cancer, dermatitis, anemia, or leukocytopenia.

O. Mercury


- Short Description: Humans are sensitive to the adverse affects of mercury. Mercury is associated to permanent brain damage and damage to kidneys. Breathing in mercury compounds damages the lining of the mouth and cause harm to the lungs. Inorganic mercury when ingested affects the stomach and intestines, which can cause nausea, diarrhea, or ulcers.


- Short Description: Mercury effects the neurological development. Fetus, babies, and growing children are highly sensitive to the problems associated with the chemical. Cognitive impairment, memory loss, attention, language, as well as fine motor and visual skills are vulnerable to adverse impacts from mercury.

higher levels of mercury that include the following symptoms: weakness, fatigue, anorexia, weight loss, and disturbance of gastrointestinal function. In real severe cases, the body may tremble and spasms may occur. Changes in human behavior have been linked to mercury such as insomnia, depression, and feeling of apathy. Direct exposure can cause severe rash irritation and damage to the skin.

3). Odor


- **Short Description:** “Physical symptoms may be reported in workplace and community settings in which odorous airborne chemicals are present. Depending upon exposure concentration, duration and relative irritant and odorant potencies, a variety of pathophysiological mechanisms may be invoked in explaining odor-associated health symptoms. Some of these imputed mechanisms fall under the traditional scope of toxicology and other involve attitudinal and/or behavioral responses to odors”.


- **Short Description:** Smeets and Dalton examines the link between the adverse reactions of human sensory attributed to airborne chemicals and people’s generated perception that stems from it. The awareness of the presence of the chemical affect people’s perceptions and interpretations of their chemical environment. In particular, unpleasant chemical odor can cause anxiety and stress that lead to adverse health effects.

4). Vibration

A) Acute vibration on Health

Important Disclosure: “Just as there is an acute form of vibration injury form turbines called Wind Turbine Syndrome, there is an acute form of injury from geothermal energy production, which might be called Geothermal Plant Syndrome. The result of chronic exposure in each case would be Vibro-Acoustic Disease (VAD). It is also clear from this report (and others) that people who have already suffered from chronic exposure to Infrasound and Low Frequency Noise (ILFN) are more sensitive to noise pollution. This is an important factor in understanding how different people respond to geothermal noise. This article makes a very important addition to understanding the health impacts of geothermal despite its focus on wind turbines”.

Recent field observations

- Ongoing data collection from multiple Wind Developments across SE Australia
- Includes information from following sources:
  - interviews with affected residents
  - medical records
  - treating physicians
  - personal health journals
  - acoustic monitoring inside homes

Summary of key findings

- Over 60 people interviewed so far
- Includes local residents, workers and visitors
- Symptoms characteristic of exposure to wind turbines (never previously experienced) noted up to 10km away
  - Night time waking in panicked state
  - Body vibrations
- Symptoms ALWAYS worsen with increasing exposure over time
- Consistent with previous findings of Medical practitioners such as
- Dr Amanda Harry (UK Rural Family Physician)
  - Dr David Iser (Australian Rural Family Physician)
  - Dr Nina Pierpont (US Paediatrician)
  - Dr Robert McMurtry in the Society for Wind Vigilance community health survey
- Many symptoms were known to, and reported by Acousticians such as Dr Leventhall, prior to 2004, in situations of known infrasound & low frequency noise (ILFN) exposure (Report for DEFRA by Dr G Leventhall, Dr P Pelmear & Dr S Benton May 2003, “A review of Published Research on Low Frequency noise and its Effects”)
- Symptoms start to resolve when
  - Turbines are off (especially if more than 24 hours)
  - People move away from turbines

BUT
- People “sensitized” with prolonged exposure then notice symptoms with other sources of ILFN
  - Pumps
  - Heating & Cooling compressors/ventilation systems

**Health problems identified**

- Preexisting medical conditions which worsen with wind turbine exposure
  - Hypertension (high blood pressure)
  - Angina
  - Diabetes
  - Tinnitus
  - Migraines

- Severe Chronic Sleep Deprivation (multiple causes which include)
  - Audible turbine noise
  - Waking in a panicked state, wide awake, sometimes on multiple occasions every night
    - Increased nocturnal urination
    - Children's sleep problems
    - Bed vibrating

- Severe Frequent Headaches
  - Head “in a vice”
  - Children with no previous history of headaches
  - Migraines triggered, especially from shadow flicker
  - Visual Blurring
    - Only occurring with turbine operation
    - Visual checks by health practitioners normal
  - Tinnitus (ringing or buzzing, one or both ears)
  - Ear pressure sensations (painful at times, especially if previous eardrum surgery)
  - Hyperacusis (extreme sensitivity to ‘normal’ sounds)
  - Balance disturbance (especially in elderly)
  - Motion sickness/vertigo like symptoms
  - Nausea (severe)
  - Irritability, extreme anger and other mood disturbances (also being reported in workers)
  - Memory & Cognitive deficits (worsening over time)
  - Depression, at times life threatening
  - Anxiety
  - Body vibrations
  - Tachycardias & arrhythmias (fast & irregular heartbeats)

**Additional clinical observations**

- Reports emerging of two specific clinical illnesses known to be caused by surges of adrenaline occurring with exposure to wind turbines (and other sources of ILFN)
  - Tako Tsubo heart attacks
  - Acute Hypertensive Crises

- Limited animal studies confirm infrasound exposure can result in adrenaline surges (NIEHS Toxicology of Infrasound report 2001)
ILFN induced Sympathetic nervous system stimulation, via Vestibular stimulation or direct stimulation of the brain, is experienced ACUTEly by the person affected as:

- Tachycardia (fast heart beat)
- Elevated blood pressure including acute hypertensive episodes
- Tako Tsubo heart attack episodes
- Nighttime waking in a panicked state
- Acutely anxious feelings
- Unmasking of previous PTSD symptoms (but either well controlled or in abeyance at time of initial exposure to wind turbines)
- Observations of new onset hypertension (high blood pressure) with turbine operation
  - Infrasound (experimental studies have shown this effect, via direct or indirect (vestibular) stimulation of sympathetic nervous system ‘fight-flight’)
  - Stress
  - Sleep Deprivation

Predictors of onset & severity
Predictors of Rapid Onset of Severe Symptoms of Wind turbine Syndrome (WTS) appear to be

- Living downwind of a line of turbines (cumulative impact)
- Presence of ground borne (seismic) vibrations
  - Beds vibrating
  - Glass of water vibrating

Other reports of residential overnight exposure to ILFN

- Overnight exposure to ILFN seems particularly damaging to health
- Others who have developed similar health problems including Tako Tsubo Heart attacks, sleep deprivation and high blood pressure which start to partially resolve when exposure ceases
  - Residents in suburban Melbourne next to industrial chillers at Melbourne University
  - Residents 5km away from open cut coal mining activities active at night (diesel machinery)

Links to vibro acoustic disease

- Substantial body of work by Professor Mariana Alves Pereira & Dr Nuno Castelo Branco over 30 years in Portugal
- Serious health concerns (VAD) with chronic exposure to ILFN (variety of sources)
- Based on their recent work, levels of measured ILFN inside homes near wind developments will result in VAD in residents

Tissue vibro acoustic disease served in VAD
Thickened collagen, resulting in
- Decreased lumen of blood vessels (arteries)
- Thickening of exterior lining of the heart (pericardium)

Malignant tumours in the sole autopsy case
- (patients with WTS have been noted to have elevated cortisol which will certainly decrease the body's own immunity and ability of the immune system to eradicate abnormal cells over time)

Professor Alves Pereira also described collagen pathology found in horses on the farm in Portugal, using a case control design
- I.e., collagen changes are "cross species", adding further weight to the evidence of a biological causal effect of ILFN on tissue with chronic exposure

The relationship between WTS & VAD

- I think Dr Pierpont is right, in stating as she did in Ontario that maybe we should call WTS "ILFN syndrome"
- Acousticians for years have been calling these symptoms "annoyance" without Medical Clinicians realising that there are serious health problems emerging with acute and chronic exposure (with a few notable exceptions such as Dr Harry, Dr Iser, Dr Pierpont & Dr Castelo Branco)

My conclusions
- There are multiple pathophysiological mechanisms causing the pathology we are seeing
- There is a difference between the effects and therefore the symptoms of acute exposure (WTS) and chronic exposure (VAD)
- There may be a synergistic effect eg angina
  - Acute effect – adrenaline surge leading to vasoconstriction
  - Chronic effect – collagen thickening producing structurally narrowed diameter of blood vessel
  - Both pathologies acting together will result in decreased blood flow to the heart muscle

Acoustics field data from inside Noel Dean's bedroom, Waubra
Mechanisms for harm to health

- KNOWN – audible noise
HIGHLY LIKELY – Infrasound & low frequency noise
- Airborne pulsations
- Resonance within dwellings
- Seismic (ground borne) vibrations
POSSIBLE – Electromagnetic radiation effects
OTHER?

What we know already

- Chronic severe sleep deprivation and high blood pressure are very damaging to health (extensive peer reviewed research)
- Both are being identified as new health problems in residents adjacent to wind developments after commencement of turbine operation
- Both are measurable

These need to be investigated and quantified

Research questions

1. What is a ‘safe’ setback distance?
2. What are the mechanisms of causation?

IV. HAWAII ISLAND WEATHER
V. HAWAII ISLAND DEMOGRAPHICS
VI. HAWAII ISLAND HEALTH