An Analysis of Community Response to Poor Winter Air Quality Episodes in Salt Lake City, Utah from 2000 to 2015

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This investigation focuses on poor air quality episodes in Salt Lake City, Utah, as a result of winter temperature inversions in the Salt Lake Valley. The research question, "What strategies does the analysis of community response to poor winter air quality episodes from 2000-2015 in Salt Lake City, Utah offer for the reduction of emissions?" is concerned primarily with the relationship between Salt Lake residents and air quality research, education, and policy. The unique geography of the Salt Lake Valley makes it prone to cold-air pools during the winter that trap emissions in the valley for several days at a time. This leads to the buildup of particulate matter and significant health impacts on Salt Lake residents. Additionally, it led to the designation of Salt Lake as a nonattainment zone for air quality by the United States Environmental Protection Agency. Because of this, the Utah state government must prove that the state is actively improving the air. Several sources were synthesized and analyzed in order to determine which strategies have been effective in the past and what future actions could be taken to improve air quality in Utah. These include surveys conducted by the organization Envision Utah regarding the relationship between quality of life and air quality, personal interviews with University of Utah air quality researchers Kevin Perry and John Lin and air quality educator Deborah Burney-Sigman, a series of air quality research papers and news articles, and specific environmental policies. This analysis illustrates the need for more effective government policies that incorporate air quality education into schools, fund research programs, expand public transit and community involvement, and require more efficient combustion technologies.

Introduction

The geography of the Salt Lake valley contributes to residents experiencing unhealthy spikes in particulate matter with a diameter less than 2.5 μm (PM 2.5) during the winter. Salt Lake sits in the Salt Lake Valley at an elevation of 1288 meters and is confined by the Wasatch Mountains to the east, Oquirrh Mountains to the west, and the Traverse Mountains to the south. In the winter, this enclosed topography makes Salt Lake prone to temperature inversions as dense, cold air from the mountains drains into the valley and becomes trapped beneath a layer of lighter, warmer air (Whiteman, Hoch, Horel, & Charland, 2014). Snow cover and fog worsen this problem by reflecting sunlight instead of absorbing it, preventing the surface air from warming and mixing with the air above (Salt Lake City, n.d). During inversions, emissions remain trapped in the valley and react to form PM 2.5, which builds up until the inversion is disrupted by precipitation or strong winds.

The poor air quality episodes that occur in conjunction with these meteorological conditions have significant impacts on human health. PM 2.5 is associated with asthma, pulmonary disease, cardiovascular disease, various mental health issues, and low birth weight (Utah Physicians for a Healthy Environment, 2016). With the introduction of stricter environmental policy and new technology, air quality in Salt Lake has improved significantly since 1980 (SLC AIR, 2014). However, the city still fails to meet EPA standards for PM 2.5 and has high incidence of the diseases related to these pollutants. The American Lung Association ranks Salt Lake City 6th in the nation for worst 24-hour particulate air pollution and estimates that 560,974 people, or 19% of the population, are at-risk for severe respiratory diseases (American Lung Association, 2016). Residents have shown their dissatisfaction with the air through surveys, op-eds, and rallies, and this movement has inspired the development of many community education organizations dedicated to the improvement of the air. Additionally, the reduction of emissions - an issue generally pushed by the liberal population - is supported by both Republicans and Democrats in the Utah legislature because of the health crisis that the winter pollution poses. In spite of this, Utah remains 17th in the nation for greenhouse gas emissions per capita (US Energy Information Association, 2017). In addition, it has the highest growth rate of any state at 2.03%, which means that total emissions will continue to increase over time unless changes are made (Chen, 2016). Because air quality is such a prominent issue in Salt Lake, analyzing the efficacy of public policy and community involvement in response to the impacts of pollution allows for the development of future strategies for the reduction of emissions. These strategies are important not only for human health but also for the sake of the environment – the emissions that lead to the formation of PM 2.5 contain gases that contribute to climate change. Thus, this paper will explore the question, "What strategies does the analysis of community response to poor winter air quality episodes from 2000-

2015 in Salt Lake City, Utah offer for the reduction of emissions?" Specific legislation and community movements in response to the implications of air pollution will be compared to emission rates and public surveys in order to determine their effectiveness. This analysis will then be used to propose future strategies to reduce emissions and thus, protect human health and the environment.

Analysis of Community Response to Air Quality

Regulation of PM 2.5

Primary PM 2.5 is released directly into the atmosphere through combustion from power plants, vehicles, and wood burning (Utah Department of Air Quality, 2015). However, most of Salt Lake's PM 2.5 does not come from primary sources but rather forms through complex chemical reactions with compounds like nitrogen oxides (NOx), ammonia (NH3), and volatile organic compounds (VOCS) (Whiteman, 2015). These compounds are emitted from industrial and vehicular combustion as well as from solvents and gasoline vapors (Whiteman, 2015).

PM 2.5 was not regulated by the EPA until 1997 (United States Environmental Protection Agency, 2016). The specification occurred as studies began to show that particulate matter smaller than 2.5 micrometers was causing significant health issues (Whiteman, 2015). The small diameter and chemical composition of PM 2.5 can oxidize and inflame lung tissue, which both contribute to asthma and lung cancers (Xing, Xu, Shi, Lian, 2016). Furthermore, after the particles enter the lungs, they are transported to the heart through the bloodstream, which can lead to cardiovascular disease (Xing et al., 2016). In 2006, after more research came out about the impacts of specific concentrations of PM 2.5, the EPA lowered the standard for healthy air from 65 μg/m3 to 35 μg/m3 (UDAQ, 2015).

As part of the Clean Air Act of 1990, the EPA requires cities with a population greater than 350,000 to monitor and report air quality to citizens based on this designated standard (Tribby, Miller, Song, Smith, 2013). The Utah Department of Air Quality (UDAQ) has a six category standard to inform Utah residents of the current air quality conditions and their subsequent health implications.

AIR QUALITY INDEX (AQI)	PM 2.5	OZONE
GOOD	0 - 12.0 µg/m^3	0 - 0.059 ppm
MODERATE	12.1 - 35.4 µg/m^3	0.06 - 0.075 ppm
UNHEALTHY FOR SENSITIVE GROUPS	35.5 - 55.4 µg/m^3	0.076 - 0.095 ppm
UNHEALTHY	55.5 - 150.4 µg/m^3	0.096 - 0.115 ppm
VERY UNHEALTHY	150.5 - 250.4 µg/m^3	0.116 - 0.374 ppm
HAZARDOUS	ABOVE 250.5 µg/m^3	ABOVE 0.375 ppm
	BASED ON A 24HR AVERAGE	BASED ON AN 8HR AVERAGE

Chart 1: Utah Air Quality Index for PM 2.5 and Ozone (Wasatch Allergy and Asthma, 2017)

In addition to this, there are a series of hard and soft power policies that are instated on poor air quality days. A hard power policy uses force or money to persuade people while a soft power policy relies on suggestion (Tribby et al., 2013). For instance, wood and coal burning are prohibited during inversion episodes, which is an example of a hard policy because it is enforced with the threat of a $300 fine. On the other hand, advising that people should drive less on poor air quality days is an example of a soft policy. Soft policies tend to be favored by Utah politicians like Governor Gary Herbert because they are uncontroversial and easy to implement (Herbert, 2017). A study in 2013 analyzing traffic patterns in Salt Lake County from 2001 to 2011 was done to determine if people drove less on poor air quality days (Tribby et al., 2013). They found that traffic actually tends to increase during yellow and red air quality alerts, especially on canyon roads (Tribby et al., 2013). This suggests that, in order to prevent exposure to the pollution, people spend more time in vehicles, thus increasing emissions in the valley and perpetuating poor air quality. Studies like this raise questions about the efficacy of soft policies like Utah's air quality alert suggestions, especially when contextualized with human behavior. It is well known that people are creatures of habit, and breaking these habits requires a significant amount of intervention and incentive (Spence & Pidgeon, 2009). Additionally, people often fall into the trap of the "collective action problem" where they make decisions - in this case, driving on a red air day - that may impact the well-being of a greater good because they do not believe that their actions, as an individual person, will be significant enough to truly cause harm (Glifford, 2011). This becomes dangerous when everyone shares the same mindset, and the actions of one become the actions of all. Although the suggestion to drive less made by air quality alerts in Utah offers the incentive of better air quality and health, it seems that, based on the traffic pattern study, the desire to escape the bad air overrides this incentive. This behavior is then justified by the thought-process laid out in the collective action problem, illustrating that soft policies can have unintended consequences because they rely on voluntary behavioral changes, which are difficult to achieve. Thus, future soft policies need to be developed with careful regard to possible negative implications as well as with the intent of bolstering public support for hard policies.

The enforcement of the regulation of PM 2.5 by the EPA offers support for the use of hard policies as a central method to create positive change in Salt Lake's air quality. Winter temperature inversions have led to the failure of Salt Lake City to meet the 24-hour particulate standard set by the EPA which states that "the average of 98th percentile values collected for each of the three years is less than or equal to 35 µg/m3," (UDAQ, 2015). Thus, Utah has been designated as a nonattainment state and the state government is required to demonstrate that they are actively trying to improve the air through a State Implementation Plan (Tribby et al., 2013). Failure to produce a SIP and demonstrate that it is being implemented can result in mandatory economic sanctions on the nonattainment zone in question (Tribby et al., 2013). This offers an explanation for bipartisan support of the clean air initiative,

as Utah politicians face the threat of losing federal highway funding and grants to support pollution control. While some of the policies proposed during the legislative session each year would significantly reduce emissions fail to pass, there are many that succeed. As part of Utah's 2014 SIP, several retained hard policies and their associated emission reductions were laid out. Some of the most significant examples include the regulation of solid fuel burning through no-burn days and the regulation of specific architectural coatings and adhesives by requiring manufacturers to monitor and report the use of these materials (UDAQ, 2014). These policies have reduced the emissions of VOCs by an estimated 6,400 and 8,038 lbs/day, the grand total emission reductions being 38,964 lbs/day (UDAQ, 2014). There is a focus on VOCs because the federal regulations on vehicles and coal burning have already significantly reduced the amount of SO2 and NOx being released into the atmosphere, playing an integral role in the improvement of Utah's air quality since 1980 (D. Burney-Sigman, personal communication, January 29, 2017). The success of these policies show that regulation is perhaps the most effective method to reduce emissions. This success is likely a result of the fact that regulation does not require a change in behavior from the majority of people, but rather targets specific groups. Additionally, it is lawfully enforced through the use of fines, so these groups are incentivized to make changes.

Community Education

Although there has been great legal success in emission reform, conflict continues to exist between air quality activists and legislators regarding the amount of money and attention that should be put towards improving the air. Last year, for instance, the Utah Department of Air Quality only received half of the funding that it requested for air quality monitoring devices, which makes it difficult for them to carry out research and properly monitor air quality in the valley (Fahys, 2017). Similarly, the policy reform outlined in the 2014 SIP, though significant, still fails to improve the air enough to meet EPA standards. One of the most effective ways to inspire a greater focus on air quality within the community and the legislature comes from community education. A survey conducted in 2015 by Envision Utah with a sample size of 52,845 found that residents believe that Utah is performing worse on air quality than on any other issue, ranking it as the third most important issue for Utah's future (Envision Utah, 2015). Envision Utah conducted similar surveys in 1997 and in 2007, but air quality was not as large of a concern in either year (O'Donoghue, 2015). In fact, in the 2007 survey, only 3% ranked air quality as the most significant negative impact on the quality of life in Utah (Envision Utah, 2007). This large change in public opinion illustrates the important impact that public education has had on awareness. Several air quality education groups such as Utah Physicians for a Healthy Environment (UPHE), Breathe Utah, and the Utah Clean Air Partnership (UCAIR) have formed since 2005. In conjunction with the creation of these groups, awareness regarding the air quality issue has increased.

However, there are still many misperceptions about pollution sources and prevention. For instance, in the 2015 Envision Utah survey, people estimated that 44% of emissions came from vehicles, 17% from area sources like homes and businesses, and 39% from industry (Envision Utah, 2015). The actual values for source emissions are 57%, 32%, and 11% respectively (Envision Utah, 2015). These values have several implications. First, the discrepancies between the perceived values and actual values illustrate that people do not recognize the extent to which they, as drivers and homeowners, are responsible for air pollution. Second, the smaller contribution of industrial emissions is a result of regulation, reinforcing the point that hard legislation is effective. This leads to the final point: further emission reduction will be challenging because the majority of it comes from the combined emissions of the general population rather than from a specific group, which removes some of the Utah government's power to impose regulations (Maffly, 2014). Similarly, although more people are aware, that does not necessarily insinuate changes in behavior for similar reasons as those described in the analysis of soft policy. Nevertheless, raising public awareness is a good way to inspire policy change because the more people that care about an issue, the more inclined their representatives will be to focus on it. Thus, future soft policies should focus on funding public education as a method to increase support for hard policies. With raised public awareness also comes more community funding for research and clean air campaigns. In addition, as people come to truly understand the impacts that air quality has on their quality of life, behavior changes are entirely possible. Some individuals who now lead Salt Lake City's fight for clean air are evidence of this.

For the purpose of this investigation, one of the founders of Breathe Utah, Deborah Burney-Sigman, was interviewed. After living in Salt Lake for 10 years, Burney-Sigman became tired of the way that pollution impacted both her mental and physical health and decided to take action by creating an organization dedicated to educating the community about these impacts and solutions (Burney-Sigman, personal communication, January 29, 2017). Though her story and dedication to the issue are exceptional, the basis of what inspired her to take action is germane. People tend to respond to things that directly impact them. This explains why global climate change is so difficult to combat, because much of the world cannot see its effect on their daily lives. The poor air quality in Salt Lake has a silver lining in that its impacts during the winter months are noticeable. Particulate matter has been tied to Utah's high suicide rate and has caused respiratory issues in a significant portion of Utah's population, illustrating the direct impact that it has on Utah citizens (Bakian et al., 2015). It is important that the health implications continue to be stressed and studied because these impacts are the basis for the clean air movement and appeal to Utah's outdoor oriented community, with 94% of those surveyed by Envision Utah agreeing that clean air is important because it supports their health and well-being (Envision Utah, 2015). However, some people are less affected than others and may not see the health impacts directly affecting them. Additionally, in a

majority politically-conservative state, there is often a tendency to prioritize the economy over the environment. For instance, Republican Governor Gary Herbert's platform on air quality is primarily based on expanding public education and promoting voluntary emission reductions rather than making significant moves towards regulatory policy change (Herbert, 2017). His values are representative of the state as a whole, with 53% of the population stating that economic growth should be prioritized over protecting the environment and 12% unsure in the 2007 Envision Utah Values survey (Envision Utah, 2007).

In order to take advantage of the conservative approach to air quality legislation, the implementation of air quality education as a permanent fixture of the primary and secondary education curriculums could be proposed. Burney-Sigman notes the importance of focusing on children as the primary receptors of air quality education with the rationale that they will pass on their knowledge to their parents. This is backed up by research that showed that adults with children who received education on the conservation of wetlands "exhibited greater knowledge of wetlands and improved reported household water management behaviour," (Damerral, Howe, & Milner-Gulland, 2013). Burney-Sigman's group has created a comprehensive air quality curriculum so the resources necessary to expand education are readily available. This would ensure that all Utah students are exposed to information regarding air quality and can use this information to make future decisions while educating their parents in the process. Additionally, Burney-Sigman notes that educating children "appeals to common values that Utahns share."

Although this is a viable suggestion to help improve the air, it is imperative that the government direct more focus towards funding research and creating new hard policies because it is in these areas that measurable and significant change is possible. In order to convince politicians and Utah citizens that air quality needs to be approached in a more proactive manner, research and education about the economic impacts of poor air quality should be conducted. There have been many statements made that air quality negatively impacts Utah's economy by increasing health care costs (Utah Clean Air Partnership, n.d.). However, there is little existing research about the relationship between air quality and Utah's economy. If Utah politicians and citizens were presented with concrete evidence that taking a strong stance on emission reductions would boost the economy they might be more proactive about instating hard policies and funding research, given the focus of the community on prioritizing economic growth (Envision Utah, 2007). This could be done by tracking health care costs for businesses through the number of respiratory related hospital and doctor's visits and prescriptions purchased. In addition, the impacts of both poor air quality and climate change on winter tourism and ski resorts in Salt Lake could be investigated as winter recreation is a large part of the region's economy. Finally, many residential emissions can be reduced simply by upgrading certain appliances like water heaters. A study done by Utah Foundations in 2016 estimates that updates to the building code would save home-owners $3,750 over the course of 30 years. Conducting more studies similar to this one would provide evidence that converting to more efficient and environmentally friendly building design is cheaper in the long run.

Air Quality Research

Air quality research is perhaps the most effective and important component of the movement to improve the air because it offers the public facts about the way that air quality impacts their lives and also allows for the development of solutions to the issue. Funding for research can be supported by a mix of effective and collaborative soft and hard policies that work to raise public awareness in support of research funding. For the purposes of this investigation, Professor of Atmospheric Sciences at the University of Utah, John C. Lin was interviewed. His research focuses on atmospheric modelling using Lagrangian mathematics. This technique allows him to analyze the distribution and diffusion of pollution throughout Utah in order to understand the meteorological and chemical mechanisms that contribute to poor air quality episodes (J Lin, personal communication, February 4, 2017). This type of modeling has allowed his team to begin to pinpoint sources that are large contributors to air pollution in the Salt Lake Valley (Mendoza et al., n.d.). With the implementation of more air quality monitors, this type of modeling will offer new strategies for emissions reduction by allowing the government and community to find solutions for specific problem areas. One of the most significant problem areas that air quality research like this found are water heaters. The Utah Foundation suggests that "Were ultra-low NOx water heaters the standard between 2012 and 2014 there would have been 10 fewer instances of PM 2.5 exceeding federal guidelines, a 20% reduction." Requiring future installations of water heaters to be ultra-low NOx has failed to pass in the Utah legislature twice because of the extra $60-$150 cost to homeowners for these more efficient appliances (Penrod, 2015). With greater support from the community, bills like these will pass. In order to achieve this support, air quality educators like Burney-Sigman are focusing on educating individuals about the environmental and economic benefits of updating their water heater.

Yearly research reports by the DAQ consistently show that mobile sources like cars and construction machinery are the largest contributors to emissions that lead to the formation of secondary PM 2.5 (DAQ, 2015). In 2015, for instance, 45.9% of NOx emissions came from vehicles (DAQ, 2015). Although it is impossible to stop people from driving, the high volume of emissions from vehicles offer incentives for the expansion of public transit. The metropolitan area surrounding Salt Lake City suffers from urban sprawl, and though the city itself is bike friendly and has access to various train lines, there is a lack of transit in the western half of the valley. There has been success in recent years in terms of an increase in public transit use, especially with the addition of the FrontRunner, which runs 88 miles from north to south (Dalrymple, 2014). In 2013, for instance, there was a 3% increase in train and bus ridership, and in 2014 the University of Utah conducted a study that estimated that the TRAX system

reduced carbon emissions by upwards of 9.5 million pounds per year, illustrating that public transit is a worthy investment to reduce emissions (Dalrymple, 2014). However, Burney-Sigman notes that the expansion of public transit is a "complicated policy issue" and that community involvement is an important driving force in its expansion. Similarly, businesses and other organizations can offer employees incentives to take advantage of public transit by offering free passes and creating challenges to reduce emissions. For instance, Adobe hosts a "Clear the Air Challenge" during the winter and offers small prizes for employees who track transit use and reduce their overall emissions (Boyer, 2017). These types of competitions have proven to be effective, as the University of Utah community reduced car trips by 15,000 during the Salt Lake Travelwise challenge, modelling the importance and efficacy of incentives, education, and cooperation between all levels of the community (Clark-Proffitt, 2016).

Although research that has been done in recent years has significantly increased the amount of attention towards air quality in Utah and has offered scientific solutions, there is still a substantial amount that needs to be understood in order to fully address the issue. For instance, there is a lack of research on the economic and mental health impacts of air pollution in Salt Lake City, though many activists mention these impacts in their arguments. Additionally, the source of pollutants needs continued attention as there are still many unknowns in terms of the products of various flames and solvents.

Conclusion

Although air quality in Salt Lake City is a complex issue and has improved significantly since 1980, the analysis of community response since 2000 shows that there are a number of actions that can be taken to further improve it. Firstly, it is clear that public education has played an integral role in increasing community engagement towards air quality, and thus should continue to expand. The most effective and measurable method of expansion would be the implementation of air quality education into primary and secondary education curriculums. Secondly, in order to maintain public interest and increase scientific knowledge, air quality research needs to expand and receive full funding. Specifically, it would be beneficial to conduct research regarding the economic and mental health impacts of poor air quality, the main sources of pollutants, and new cost-effective and efficient technologies that reduce emissions. Not only will education and research give people the knowledge to better protect their health and the environment around them, but the analysis of community response illustrates that increased awareness will also make politicians more inclined to support air quality initiatives in order to align with the values of those they represent. On that note, if Utah politicians want to meet EPA standards, they need to focus on the implementation of effective soft and hard policies that raise public support for legislation that requires more efficient engines, appliances, and other technologies in new vehicles, homes, businesses, and industry. Additionally, the expansion of public transit would offer citizens incentives to drive less. In order to achieve these changes, it is clear that stronger communication needs to be established between scientific researchers, public educators, the general population, and the state government. If this happens, the quality of life in Salt Lake will increase significantly, benefiting residents, tourists, and the environment.

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