



Article

An Exploratory Investigation of Government Air Monitoring Data after Hurricane Harvey

Kwanita Adair¹, Shelly Miller²  and Margot Gage Witvliet^{1,*}

¹ Department of Sociology, Social Work and Criminal Justice, Lamar University, Beaumont, TX 77705, USA; kadair1@lamar.edu

² Department of Mechanical Engineering, University of Colorado Boulder, Boulder, CO 80309, USA; shelly.miller@colorado.edu

* Correspondence: mgage1@lamar.edu

Abstract: Southeast Texas is home to some of the largest refineries in the United States. During Hurricane Harvey, emergency shutdowns took place. In this exploratory investigation, we examine how government air monitors performed in measuring air quality in Beaumont, Texas during and in the months following Hurricane Harvey. Texas Commission on Environmental Quality (TCEQ) data from two active air monitors in Beaumont, Texas were analyzed during the year 2017–2018. Concentrations of sulfur dioxide (SO₂), nitric oxide (NO), oxides of nitrogen (NO_x), ozone, benzene, and hydrogen sulfide (H₂S) were investigated. The number of hours and days no data were reported by air monitors were also investigated. Yearly maximum values (MAX, all in parts per billion (ppb)) in 2017 for SO₂, NO, and NO_x (53.7, 113.4, 134, respectively) and their respective standard deviations (SD: 1.3, 3.4, and 14) were higher as compared to 2018 (MAX, all in ppb and (SD) = 40.9, (1.4); 103.9, (3.3); 123.8, (14), respectively). The data capture rate for these chemicals were between 88 and 97% in both years. During the months following Hurricane Harvey (August–December 2017) there was an increase in most maximum values. The yearly averages for H₂S were 0.68 ppb (SD 1.02) in 2017 and 0.53 ppb (SD 1.07) in 2018. Missing days were observed for both the H₂S and NO_x air monitors, with the highest number observed in 2017 (213 missing days) for the air monitor measuring H₂S. We identified that residents of Beaumont, Texas are exposed daily to low-level concentrations of air pollutants. H₂S is released each day at a level high enough to be smelled. Data capture rates for air monitors are not always above 90%. Improved air quality data and disaster preparations are needed in Beaumont, Texas.

Keywords: air pollution; air quality; environment and health; climate change; environmental justice



Citation: Adair, K.; Miller, S.; Gage Witvliet, M. An Exploratory Investigation of Government Air Monitoring Data after Hurricane Harvey. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5559. <https://doi.org/10.3390/ijerph19095559>

Academic Editors: José Ángel Fernández and Paul B. Tchounwou

Received: 24 February 2022

Accepted: 11 April 2022

Published: 3 May 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Air pollution is a worldwide public health concern [1]. Air pollution increases the chances of respiratory illnesses [2–4]. Children and the elderly are the most vulnerable groups for illness attributed to air pollution [5]. A link between the increase in air pollutants and deaths related to the heart and lungs is evident [6]. The World Health Organization estimates that 7 million people die from air pollution each year [7].

Prior studies conclude that those living near air-polluting petroleum refineries experience poorer health [8–10]. These people living near refineries also have a moderately higher risk of dying from lung cancer [11]. Living near environmental hazards is associated with pregnancy complications, childhood cancer, cardiovascular illness, and diabetes [12]. Irritation of the eyes, headaches, and dizziness are also reported health complaints when living in proximity to a refinery [13]. Natural disasters such as flooding, and hurricanes can make living in proximity to industry even worse [14]. Air pollutants released after a flood can damage the respiratory system. Chemicals from spills can contaminate water sources and soil, and this has the potential to negatively impact population health for years after a disaster [14].

In August 2017, Texas experienced Hurricane Harvey. According to the National Hurricane Center, Hurricane Harvey caused billions of U.S. dollars of damage, second to Hurricane Katrina [15,16]. Millions of pounds of air pollution were released during Hurricane Harvey [17]. Many Texas cities were impacted by Hurricane Harvey, but the city of Beaumont, Texas is unique in that the entire city is surrounded by industry, and when the flooding from Hurricane Harvey occurred, Beaumont, Texas—unlike the larger city of Houston—became a tiny island surrounded by polluting refineries. There was no way into or out of the city for days, except by boat or air.

A small city like Beaumont, Texas is easy to overlook on the map, but industry generates big business in this predominately African American city. The smell of air pollution is so common, residents refer to the pungent odor of rotten eggs as the “smell of money” [18]. Beaumont is the murder capital of Texas, with more crime per capita than Houston (the fourth largest city in the USA). The population of Beaumont, Texas is 118,296, with 48% being African American, 45% white, and 14% Latinx [19]. The average age of residents is 34 years [19]. Women make up 51% of the population, and the overall poverty rate is 19% [19]. Data from the Texas government show higher incidences of all cancers, including leukemia and respiratory cancer, in Beaumont compared to the rest of Texas [20]. Citizens of Beaumont not only die at a higher rate from cancer, but their chance of developing cancer is also higher than that of those in the rest of Texas. Age-adjusted incidence rates per 100,000 in Beaumont are 64.7 for respiratory cancer, 13.2 for leukemia, and 406.4 for all types of cancer. For comparison statewide, the incidence rates are 52.1, 12.9, and 391.8, respectively. Beaumont residents also have slightly higher levels of asthma than those in the rest of Texas [20].

Possible public health effects from Hurricane Harvey have yet to be investigated for the population of Beaumont, Texas. What we know is that between the cities of Beaumont, Corpus Christi, and Houston, Texas, it is estimated that about “40 petrochemical companies released more than 5.5 million pounds of chemicals as a result of the hurricane” [21]. In this exploratory investigation, we examine data from Texas Commission on Environmental Quality (TCEQ) air monitors pre- and post-Hurricane Harvey to investigate how the monitors performed in Beaumont, Texas during Hurricane Harvey.

In Beaumont, Texas, we used TCEQ data to identify two active air monitors. Figure 1 shows the ExxonMobil Beaumont Chemical Plant, Natgasoline, LLC located in Beaumont, Texas USA Goodyear Plant, and its adjacent proximity to Charlton Pollard Elementary School and Lamar University (>3 miles) in Beaumont, Texas USA [22]. Not shown is the ExxonMobil Polyethylene Plant located 3.5 miles from Westbrook High school in Beaumont, Texas USA. In the entire city of Beaumont, we identified that there are only two active air monitors: (1) Beaumont Downtown and (2) Beaumont Mary. The Beaumont Downtown air monitor is located at 1086 Vermont Avenue, 3.2 miles away from one of the refineries, but is closest to the Port of Beaumont ship traffic [22]. The Port of Beaumont is the fifth largest port in the nation. Beaumont Mary is located at 598 Craig Street, 1.7 miles away from the refiner and nearest to the Charlton Pollard elementary school that is across the street from the refinery [22]. This exploratory investigation is novel because Beaumont, Texas is a city with one of the largest industries in the United States, yet with only two air monitors. The public is not aware of how the air monitors are performing, especially during a disaster.

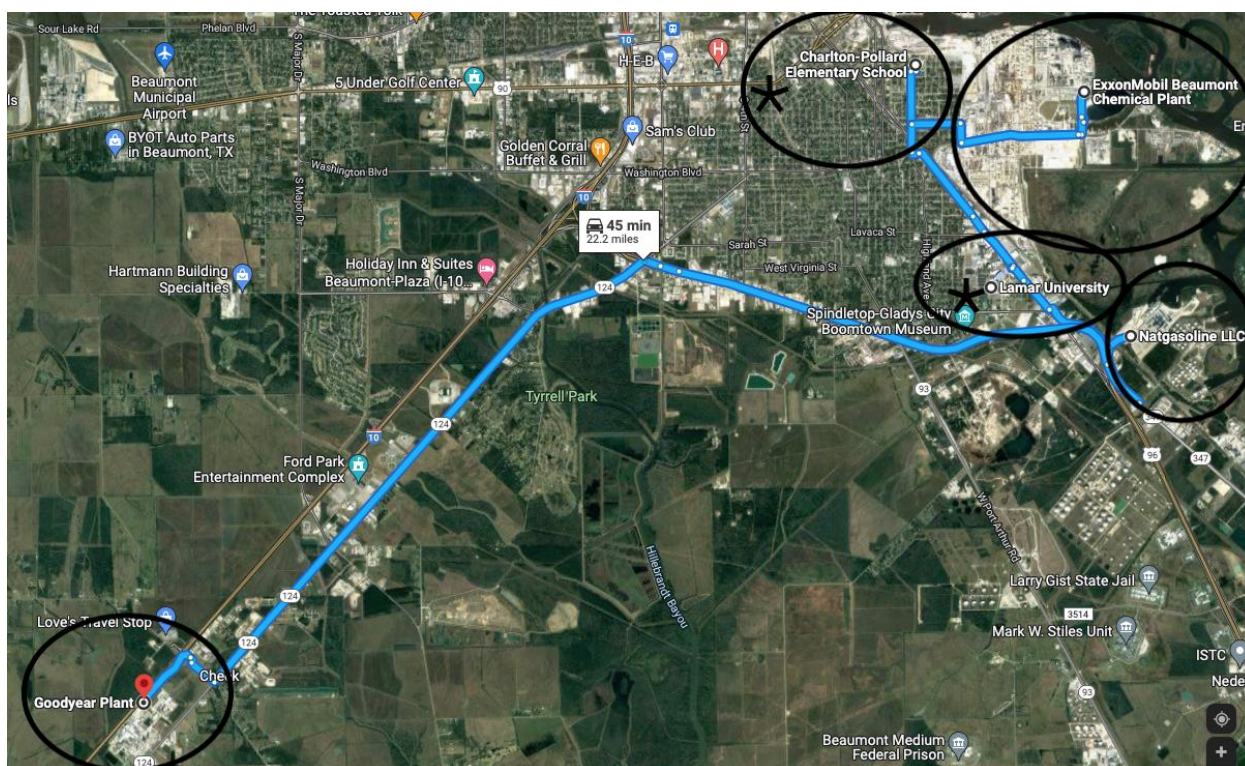


Figure 1. Map of Beaumont, Texas showing industries and location of two air monitors. The two stars on the map denote Beaumont Downtown (located within the Lamar University circle) and Beaumont Mary (located within the Charlton Pollard Elementary circle).

2. Methods

To investigate how air monitors in the city performed during Hurricane Harvey, the data produced by the Texas Commission on Environmental Quality (TCEQ) air monitors were examined. TCEQ is an environmental agency that helps maintain public health and natural resources in Texas to uphold economic development [23]. TCEQ offers information on air, land, water, permit licenses, and reporting programs and facilities [23]. TCEQ data are freely available to the public online. We investigated the TCEQ air quality data that were available to the public for the years 2017–2018 [23].

The air pollutant data extracted from the TCEQ database for the Beaumont Downtown air monitoring site included: sulfur dioxide (SO₂), nitric oxide (NO), nitrogen dioxide (NO₂), oxides of nitrogen (NO_x), ozone (O₃), and benzene. The Beaumont Mary air monitoring site only measures hydrogen sulfide (H₂S). In our investigation, air pollutant figures from the TCEQ database for both air monitors by year and month were reviewed. Next, we investigated the Beaumont, Mary air monitor by hour. Following this, we documented the number of days the air monitors were shut off. The aim of this approach was to obtain a snapshot overview of the air quality values during and after Hurricane Harvey.

3. Results

In Table 1, the yearly values (2017–2018) of chemicals, measured in parts per billion (ppb), are shown for the Beaumont Downtown. Data capture (CAP) is the percentage of valid data collected and MAX is the maximum value of the specified chemical reported by the air monitor. Yearly maximum values for SO₂, NO, and NO_x were higher during the 2017 Hurricane Harvey period (MAX, all in ppb = 53.7, standard deviation (SD) 1.3; 113.4, SD 3.4; 134.0, SD 14, CAP (in %) 95.8, 94.1, 95.6, respectively) as compared to 2018 (MAX, all in ppb = 40.9, SD 1.4; 103.9, SD 3.3; 123.8, SD 14; CAP (in %) 98.4, 97.9, 97.4, respectively). Yearly maximum values for NO₂, O₃, and benzene were higher in 2018. The calculated

average values appear relatively similar from 2017 to 2018. In 2017, we identified 68 days of missing data for all chemicals and 22 days missing data for benzene.

Table 1. Yearly values 2017–2018 chemicals measured at air monitor Beaumont Downtown.

	MAX	SH	MIN	AVG	SD	CAP (%)	Missing Hours	Missing Days
Sulfur Dioxide								
2017	53.7	52.9	−0.3	0.5	1.3	95.8	179	8
2018	40.9	38.7	−0.4	0.5	1.4	98.4	138	0
Nitric Oxide								
2017	113.4	101.5	−0.7	1.2	3.4	94.1	249	11
2018	103.9	91.6	−0.5	1.2	3.3	97.9	187	0
Nitrogen Dioxide								
2017	38.3	36.7	0.3	5.8	5.0	94.1	245	11
2018	43.7	39.9	0	5.8	4.8	97.9	187	0
Oxides of Nitrogen								
2017	134.0	127.8	0.2	6.9	14	95.6	271	8
2018	123.8	118.9	0	6.8	14	97.4	176	0
Ozone								
2017	88	84	−2	24	14	95.6	192	8
2018	96	94	−4	23	14	97.4	153	3
Benzene								
2017	7.29	5.28	0	0.22	0.3	88.9	1103	22
2018	27.6	3.40	0	0.15	0.4	93.3	1137	4

Note: MAX = Maximum Value, SH = Second Highest Value, MIN = Minimum Value, AVG=Average Value, SD = Standard Deviation and CAP % = Data Capture Rate.

In Figure 2, monthly values of chemicals extracted from Beaumont Downtown for August–December 2017–2018 are shown. Sulfur dioxide shows a monthly increase in the maximum value from August 2017 to November 2017. In 2017, the maximum values for nitric oxide fluctuate from August to December. Nitrogen dioxide appears to show the highest maximum values in 2017, with the exception of August and November 2017. Oxides of nitrogen have the highest maximum values in December for both 2017 and 2018 (MAX, all in ppb = 134.0, SD 14; 123.8, SD 14; CAP (in %) = 97.4, 88.4, respectively).

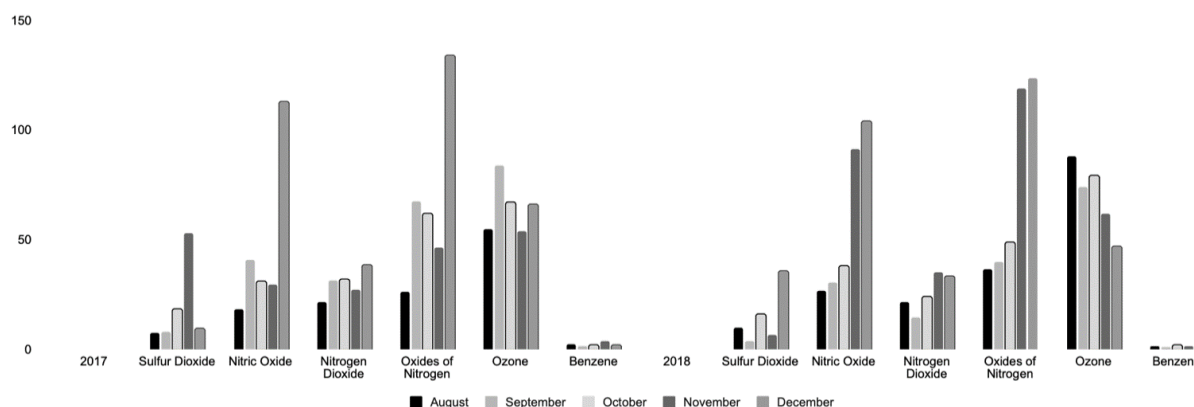


Figure 2. Beaumont Downtown Air Monitor Monthly Maximum Values in PPB For Air Pollutants, 2017–2018. Note: Figure 2 shows air monitoring data in parts per billion (PPB) for all pollutants from August to December in 2017 and 2018.

In November, maximum values for sulfur dioxide and benzene were higher in 2017 as compared to 2018. Maximum values for ozone appear to increase from 2017 to 2018. The highest number of missing days for all pollutants (i.e., sulfur dioxide, nitric oxide, nitrogen dioxide, oxides of nitrogen, ozone, and benzene) were in August 2017 (7 days missing). The Data Capture (CAP) rate in August 2017 was 74–75%, which means a likely

underestimation of values for the Hurricane Harvey period of 2017. Benzene appears to have the highest number of missing hours (87 h total) in August 2017.

In Table 2 the yearly values for H₂S measured at Beaumont Mary for 2017–2018 are shown. A higher amount of H₂S appears to have been released into the air in the year following the Hurricane Harvey period. However, given the number of missing days in 2017 as compared to 2018, the yearly value for H₂S in 2017 appears to be an underestimation. TCEQ Beaumont Mary air monitor showed 213 missing days in 2017, and in 2018 this figured dropped to 24 missing days. The yearly average (AVG) for H₂S concentration is 0.68 ppb, SD 1.02; 0.53 ppb, SD 1.07; CAP (in %) = 39.1, 92.5, respectively).

Table 2. Hydrogen sulfide monthly and yearly values measured at air monitor Beaumont Mary August–December 2017–2018.

	MAX	SH	MIN	AVG	SD	CAP (%)	Missing Hours	Missing Days
2017	17.18	11.44	−0.33	0.68	1.02	39.1	195	213
2018	24.30	20.46	−0.40	0.53	1.07	92.5	583	3

Note: AVG value in the table is above EPA values of 0.14 ppb. (i.e., H₂S EPA limit for children and elderly). Missing hours = denoted by TCEQ as calibration check. Missing days = a steady 24 h period of missing data. MAX = Maximum, SH= Second highest value, MIN = Minimum value, AVG = Average Value, SD = Standard Deviation, CAP = Data Capture. Values measured in parts per billion (ppb).

In Figure 3 the monthly values for H₂S are shown. The highest monthly maximum values for H₂S from August–October 2017 are (MAX, all in ppb = 9.49, SD 1.06; 8.38, SD 0.95, 9.20, SD 1.09; CAP (in %) = 73, 90, 95.7, respectively) with an increase in concentration observed during the August–October 2018 period (MAX, all in ppb = 11.85, SD 0.93; 17.58, SD 1.36; 14.21, SD 1.10; CAP (in %) = 94.6, 95.4, 95, respectively).

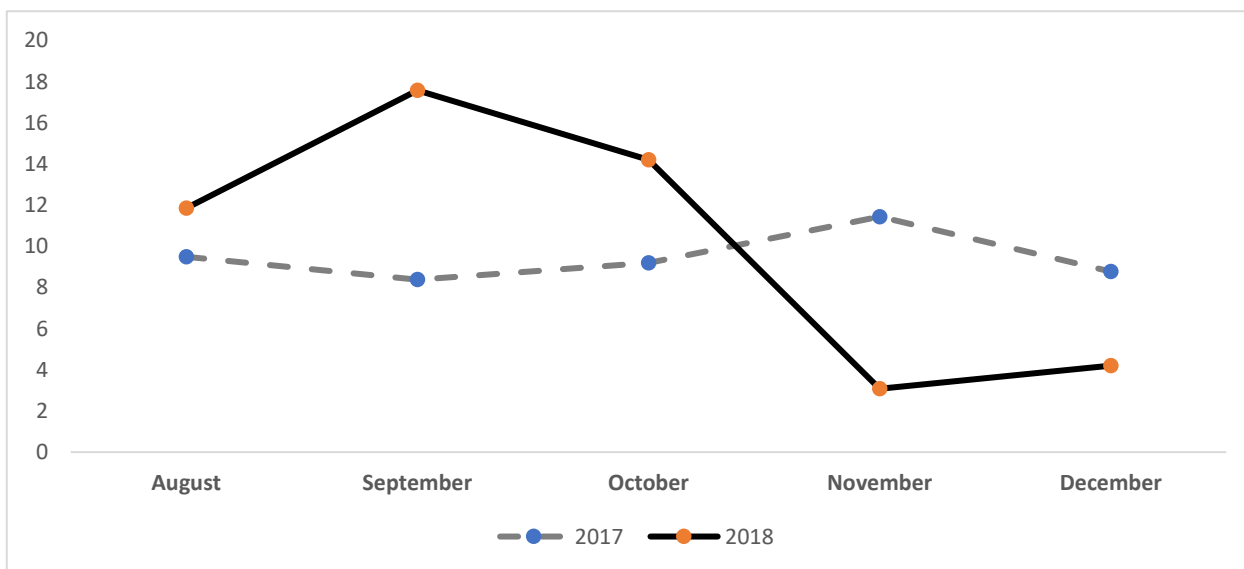


Figure 3. Beaumont Mary Air Monitor Monthly MAX Values, Hydrogen Sulfide 2017-2018. Note: Figure 3 shows air monitoring data in parts per billion (PPB) for H₂S from August to December in 2017 and 2018.

In Figure 4, hourly values for H₂S measured at Beaumont Mary for August and September 2017–2018 are shown. The highest hourly maximum value for H₂S was in 2018 in August (MAX = 11.85 ppb; CAP = 73%) and increased in September to 17.58 ppb; CAP = 90%. The 24 h H₂S average concentration was 0.14 ppb per day. In August and September 2018, measurements of H₂S reached over 10 ppb on three different days. The maximum values for H₂S in August and September exceeded 0.5 ppb in both 2017 and

2018. The minimum observed values exceeded 0.5 ppb at least once in August 2017 and in September 2018.

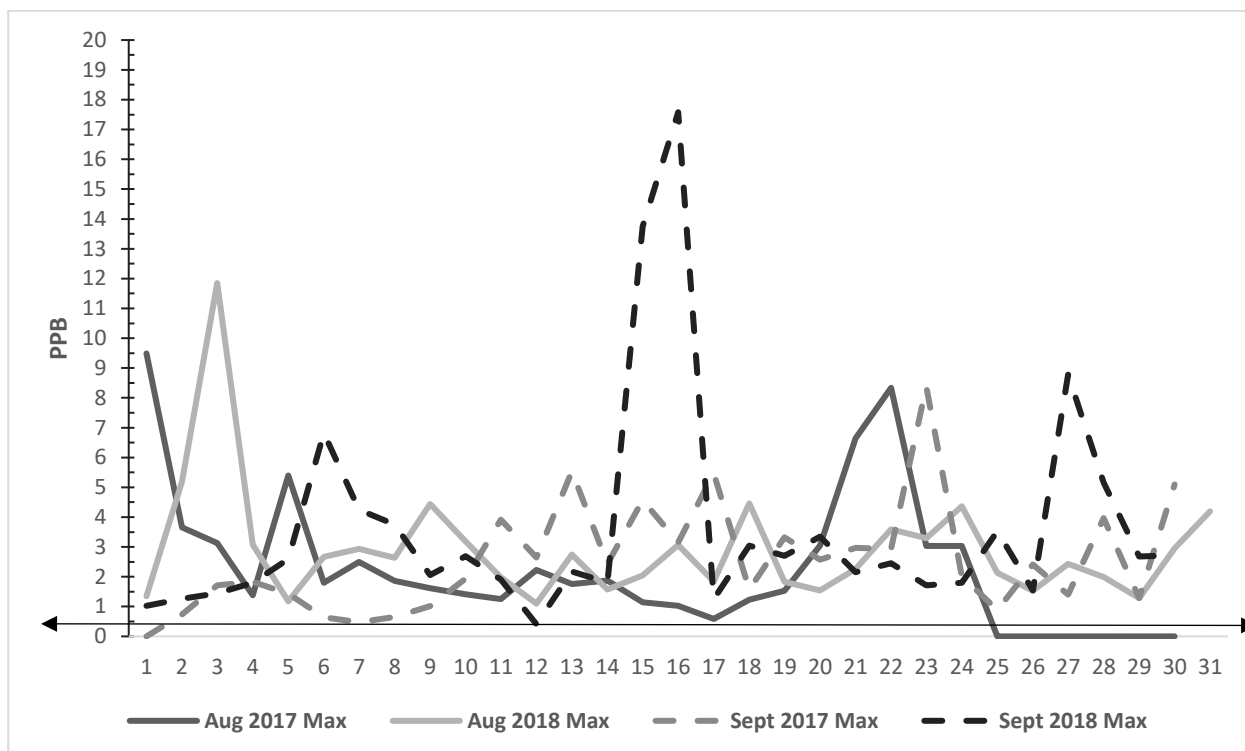


Figure 4. Beaumont Mary Air Monitor Hydrogen Sulfide MAX Values 30-Day Period, August 2017–2018 with Smell Line Arrow. Note: Figure 4 shows air monitoring data in parts per billion (PPB) for H₂S for the month of August in 2017 and 2018. Missing data shown at end of the month of August in 2017. Smell line arrow signifies the level at which H₂S can be smelled in the air.

A total of 206 missing days are evident before Hurricane Harvey occurred. The yearly average data capture for the Beaumont Downtown monitor did not meet industry standards in 2017, at 39.1%. In 2018, the yearly data capture rate improved and was slightly above industry standard at 92.5%. For the Beaumont Mary monitor, data capture was below industry standard at 29.1% in 2017 and improved slightly above industry standard to 92.5% in 2018. Missing data during the Hurricane Harvey period show days missing from 25 August to 1 September 2017.

4. Conclusions

The aim of this exploratory investigation was not to provide a comprehensive overview of air quality in Beaumont, Texas. We examined how the air monitors in the city were performing during Hurricane Harvey. We identified that air quality in Beaumont, Texas appears to remain consistent from the Hurricane Harvey period (2017) and thereafter (2018). However, because of missing data during the Hurricane Harvey period and the reality of seasonal trends in pollution that are not accounted for in this investigation, it is possible that the air pollution levels for 2017 are an underestimation. A strength of this exploratory investigation is that data validated by TCEQ are used. The TCEQ air monitors use either federal reference or equivalent methods, and the data meet EPA quality assurance criteria and are used for regulatory purposes [23]. We are unaware of any data available from industrial continuous emissions monitors, typically installed in emissions stacks to document pollutant emission rates; these data are usually the preview of the industrial facility. As such, we utilized the best data available to the public.

We did not expect to identify that the data capture rate would be under 90% before the Hurricane Harvey period. The TCEQ explanation for missing data capture rate lists

various reasons that data are rejected, including lost data and automatic calibration [23]. The low data capture rate before Hurricane Harvey suggests a need for more air monitors to be placed around the city, so that if one monitor is not performing optimally, there are multiple backup air monitors. The reason for missing data during the Hurricane Harvey period is that the TCEQ turned air monitors off to prevent them from being harmed during the storm [24]. During this time, government officials allowed industries to exceed permit mandates and temporarily release a higher amount of chemicals [24]. Industries were also allowed to self-report emissions to TCEQ. In situations of a disaster or in cities such as Beaumont, Texas with heavy industry, the use of unmanned aerial vehicles might be a useful solution [25].

Another issue that we identified is that neither Beaumont Downtown nor Beaumont Mary air monitors collect data for particulate matter (PM). PM was monitored 2010–2015 at Beaumont Mary and only in 2008 for Beaumont Downtown. PM₁₀ or PM_{2.5} is distinguished by the size of the particles. PM is a mixture of liquid and non-liquid particles in the air [26]. PM is commonly created from pollutants emitted from power plants, industries, and cars [26]. Fine particles are dangerous because they can enter the lungs and bloodstream [26]. People with heart and lung disease die earlier when exposed to PM [26]. A meta-analysis found a link between increased PM and increased risks of lung cancer [27]. Exposure to PM_{2.5} over a short period is linked to increased chronic obstructive pulmonary disease hospitalizations and death [27].

The Beaumont Mary air monitor is located closest to the refinery, but measures only one chemical. This leaves little information to be gleaned on the status of air quality for those living closest to the refinery. The city of Beaumont, Texas should consider installing not only more air monitors around the city, but also air monitors that measure a multitude of air pollutants in closer proximity to the areas and neighborhoods where people live and where industry is located.

We investigated the maximum and average values of chemical concentrations. Exposure depends on both concentration and time spent breathing the contaminated air. Beaumont, Texas has not only long-term low-level concentrations of air pollutants, but also has an increased level of concentrations and potential exposure in the months following a disaster. We observed that residents of Beaumont, Texas can smell H₂S in the air almost daily. This is noteworthy given that H₂S can be problematic for people with respiratory issues, and exposure to low levels of H₂S can trigger neurological problems [28]. Further investigation is needed to identify the extent to which H₂S might be impacting the health of residents. What is known is that, in 2009, TCEQ removed Beaumont, Texas from the Air Pollutant Watch List for H₂S [29]. Our observations of the air monitoring data measuring H₂S suggest that an official review of the Beaumont Mary air monitor is warranted.

Considering the high concentration of industry in Beaumont, Texas, it is critical that the air-monitoring plan includes an objective discussion with relevant stakeholders on how to reduce the length of time air monitors are shut down, and an expansion of the collection of more robust air pollutant data. The city of Beaumont, Texas needs industry for economic reasons. Nevertheless, it is imperative that public health and economics work together. A city with this much industry, that also faces an increased regular risk of natural disasters, needs a more nuanced plan to protect public health from industry that pollutes.

Author Contributions: Conceptualization, M.G.W.; methodology, M.G.W.; formal analysis, K.A. and M.G.W.; investigation, K.A. and M.G.W.; writing—original draft preparation, K.A. and M.G.W.; writing—review and editing, M.G.W. and S.M.; visualization, M.G.W. and S.M.; supervision, M.G.W. and S.M.; funding acquisition, K.A. and M.G.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by McNair Fellowship awarded to K.A.

Institutional Review Board Statement: Not applicable for studies not involving humans or animals.

Informed Consent Statement: Not applicable for studies not involving humans.

Data Availability Statement: TCEQ data available freely to the public online at <https://www.tceq.texas.gov/> (accessed on 22 February 2022).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization (WHO). Ambient (Outdoor) Air Quality and Health. 2018. Available online: [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health) (accessed on 10 June 2020).
2. Kurt, O.K.; Zhang, J.; Pinkerton, E.K. Pulmonary Health Effects of Air Pollution. *Curr. Opin. Pulm.* **2016**, *22*, 138. [CrossRef] [PubMed]
3. Kelly, J.F. Influence of Air Pollution on Respiratory Disease. *EMJ Respir* **2014**, *2*, 96–103.
4. Faustini, A.; Safoggia, M.; Colais, P.; Berti, G.; Bistani, L.; Cadium, E.; Cernigliaro, A.; Mallone, S.; Scarnato, C.; Forastiere, F. Air pollution and multiple acute respiratory outcomes. *Eur. Respir. J.* **2013**, *42*, 304–313. [CrossRef] [PubMed]
5. American Lung Association: Children and Air Pollution. 2019. Available online: <https://www.lung.org> (accessed on 10 June 2019).
6. Brook, R.D.; Franklin, B.; Cascio, W.; Hong, Y.; Howard, G.; Lipsett, M.; Luepker, R.; Mittleman, M.; Samet, J.; Smith, S.C., Jr.; et al. Air Pollution and Cardiovascular Disease. *CIR* **2004**, *109*, 2655–2671. [CrossRef] [PubMed]
7. WHO. How Air Pollution Is Destroying Our Health. 2019. Available online: <https://www.who.int/air-pollution/news-and-events/how-air-pollution-is-destroying-our-health> (accessed on 13 June 2019).
8. Mudu, P.; Terracini, B.; Martuzzi, M. (Eds.) Human Health in Areas with Industrial Contamination. Copenhagen “WHO Regional Office for Europe 2014. Available online: [https://apps.who.int/iris/bitstream/handle/10665/144490/Human%20Health%20in%20Areas%20with%20Industrial%20Contamination%20\(Eng\).pdf?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/144490/Human%20Health%20in%20Areas%20with%20Industrial%20Contamination%20(Eng).pdf?sequence=1) (accessed on 13 June 2019).
9. Cristian, G.; Marti, M.; Manolis, K. Health effects of non-occupational exposure to oil extraction. *Environ. Health* **2016**, *15*, 1–4. [CrossRef]
10. White, N.; teWaterNaude, J.; van der Walt, A.; Ravenscroft, G.; Roberts, W.; Ehrlich, R. Meteorologically estimated exposure but not distance predicts asthma symptoms in schoolchildren in the environs of a petrochemical refinery: A cross-sectional study. *Environ. Health* **2009**, *8*, 45. [CrossRef] [PubMed]
11. Cheng-Kaun, L.; Heu-Yang, H.; David, C.C.; Francesco, F.; Ro-Ting, L. Lung cancer mortality of residents living near petrochemical industrial complexes: A meta-analysis. *Environ. Health* **2017**, *16*, 101. [CrossRef]
12. Jean, B.D.; Juliana, M.A.; Chakrabort, J. Residential Proximity to Environmental Hazards and Adverse Health Outcomes. *Am. J. Public Health* **2011**, *101*, S37–S52. [CrossRef]
13. Pornpimol, K.; Panawadee, S.; Witaya, Y.; Suttinun, C.; Dusit, S. Health Effects of People Living Close to a Petrochemical. *J. Med. Assoc. Thai.* **2013**, *96* (Suppl. 5), 64–72.
14. WHO: Chemical Releases Associated with Floods. 2018. Available online: <https://apps.who.int/iris/bitstream/handle/10665/272392/WHO-CED-PHE-EPE-18.02-eng.pdf> (accessed on 27 June 2019).
15. National Hurricane Center. Costliest U.S Tropical Cyclones Tables Updated. 2018. Available online: <https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf> (accessed on 6 May 2019).
16. Kimberly, A. Hurricane Harvey Facts, Damage and Costs. The Balance. 2019. Available online: <https://www.thebalance.com/hurricane-harvey-facts-damage-costs-4150087> (accessed on 3 May 2019).
17. Mosier, J. Texas Plants Spewed 8 Million Pounds of Air Pollutants as Hurricane Harvey Hit. 2018. Available online: <https://phys.org/news/2018-08-texas-spewed-million-pounds-air.html> (accessed on 3 May 2019).
18. Mealer, B. Y'all Smell That? That's the Smell of Money. Available online: <https://www.texasmonthly.com/news-politics/yall-smell-that-thats-the-smell-of-money/> (accessed on 2 February 2022).
19. U.S Census Bureau. Quick Facts Beaumont Texas. 2010. Available online: <https://www.census.gov/quickfacts/fact/table/beamontcitytexas/PST120218> (accessed on 24 June 2019).
20. Christus Dubuis Hospital of Beaumont Port Arthur: Community Health Needs Assessment. 2019. Available online: <https://www.christushealth.org/-/media/files/homepage/giving-back/chna/2017--2019-chna-dubuis-beaumontport-arthur-rev.ashx?la=en> (accessed on 1 July 2020).
21. Sadasivam, N. Experts: Much of Harvey-Related Air Pollution Was Preventable. Available online: <https://www.texasobserver.org/early-shut-downs-upgrades-could-have-avoided-millions-of-pounds-of-pollutants-released-during-harvey/> (accessed on 6 February 2022).
22. Google Maps, 2022. Available online: <https://www.google.com/maps/dir/1086+Vermont+Avenue,+Beaumont,+TX/Charlton-Pollard+Elementary+School,+825+Jackson+St,+Beaumont,+TX+77701/598+Craig+Street,+Beaumont,+TX/Lamar+University,+4400+S+M+L+King+Jr+Pkwy,+Beaumont,+TX+77705/Port+of+Beaumont,+Main+Street,+Beaumont,+TX/@30.0576325,-94.097531,14z/data=!3m1!4b1!4m3!4m3!1m5!1m1!1s0x863eca77b90acd41:0x647edd42d05bea!2m2!1d-94.0710576!2d30.0364384!1m5!1m1!1s0x863eca95962a86fd:0x705d60f50de6ef63!2m2!1d-94.0872752!2d30.0712602!1m5!1m1!1s0x863ecaea10a8085d:0xd34bdf0bc2c0635a!2m2!1d-94.095008!2d30.071266!1m5!1m1!1s0x863eca78b5046bcb:0xa10be6fcc4ffd91!2m2!1d-94.0747071!2d30.0392256!1m5!1m1!1s0x863ecac07f74306f:0xb140c5a09ee160d7!2m2!1d-94.092493!2d30.0792731!3e0> (accessed on 22 February 2022).
23. Texas Commission on Environmental Quality (TCEQ). 2019. Available online: <https://www.tceq.texas.gov/agency/about-the-tceq> (accessed on 19 June 2019).

24. Environmental and Energy Study Institute: After the Storm: Texas Begins to Assess Environmental Impacts of Hurricane Harvey. 2017. Available online: <https://www.eesi.org/articles/view/after-the-storm-houston-begins-to-assess-environmental-impacts-of-hurricane> (accessed on 26 June 2019).
25. Angelevska, B.; Atanasovski, M.; Andreevski, I.; Arapinoski, B. Real-time urban air pollution monitoring using unmanned aerial vehicles. *Int. Sci. J.* **2020**, *8*, 29–32.
26. EPA: Particulate Matter Basics. 2018. Available online: <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM> (accessed on 4 June 2019).
27. Li, M.H.; Fan, L.C.; Mao, B.; Yang, J.W.; Choi, A.M.; Cao, W.J.; Xu, J.F. Short-term Exposure to Ambient Fine Particulate Matter Increases Hospitalizations and Mortality in COPD: A Systematic Review and Meta-analysis. *Chest* **2016**, *149*, 447–458. [[CrossRef](#)] [[PubMed](#)]
28. EPA (ATSDR) Hydrogen Sulfide Fact Sheet. Available online: http://www.epa.gov/sites/default/files/2017-12/documents/appendix_e-atsdr_h2s_factsheet.pdf (accessed on 26 March 2022).
29. Skelton Eleanor. TCEQ Says Sulfur Dioxide Levels No Longer Elevated in Beaumont. *The Examiner*. 2016. Available online: <http://theexaminer.com/stories/news/tceq-says-sulfur-dioxide-levels-no-longer-elevated-beaumont> (accessed on 3 July 2019).