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DATA POINT

July 2024

Linking Medical Product Manufacturing Locations with Natural Hazard Risk: Implications for the Medical Product Supply Chain

KEY POINTS

- There is limited publicly available information about how medical product manufacturers weigh factors such as natural disaster and climate change risk in site selection decisions.
- This analysis compares publicly available drug and device manufacturing facility location data with FEMA's National Risk Index data describing relative risk of natural hazards occurring in a location.
- Drug and device manufacturers are disproportionately located in areas of high risk of natural hazards such as tornados, earthquakes, hurricanes, and other extreme weather events.
- Considering current and future risk due to climate change will be important for identifying potential supply chain vulnerabilities.
- Similar methods could be applied to examine other elements of the supply chain or product types.

BACKGROUND

The supply chain disruptions caused by the COVID-19 pandemic and recent shortages of critical medical products have underscored the importance of understanding and addressing vulnerabilities in the medical product supply chain. As of April 12, 2024, there were 164 shortages of drugs and biological products in the U.S. – the most in more than a decade.[1] Similarly, device shortages have increased within recent years, although the exact number of devices currently in shortage is unknown.[2] Shortages can be caused by a wide variety of factors, one being disruptions to manufacturing facilities.[3] Over the last several years, there have been multiple prominent examples of natural disasters impacting medical product manufacturing facilities, such as the tornado that shut down operations at a North Carolina Pfizer facility in 2023,[4] the severe flooding in Michigan that exacerbated the already ongoing infant formula shortage in 2022,[5] or the widespread

[1] FDA. FDA Drug Shortages: Current and Resolved Drug Shortages and Discontinuations Reported to FDA. Available at: https://www.accessdata.fda.gov/scripts/drugshortages/default.cfm, data downloaded April 13, 2024.
[2] T. Beleche, M. Kuecken, A. Sassi, K. Toran, E. Galloway, T. Henry, "Characteristics of Medical Device Shortages in the US, 2006-20," Health Affairs, vol. 41, no. 12, pp. 1790-1794, 2022.
[3] FDA (2020). Report | Drug Shortages: Root Causes and Potential Solutions. Available at: https://www.fda.gov/drugs/drug-shortages/report-drug-shortages-root-causes-and-potential-solutions, last accessed April 25, 2024.
[4] Pfizer (2023). Pfizer's Rocky Mount facility restarts production amid first phase of post-tornado recovery efforts. Available at: https://www.pfizer.com/news/announcements/pfizers-rocky-mount-facility-restarts-production-amid-first-phase-post-tornado, last accessed April 22, 2024.
[5] Abbott (2022). Abbott is restarting Similac production at Sturgis. Available at: https://www.abbott.com/corpnewsroom/nutrition-health-and-wellness/abbott-update-on-powder-formula-recall.html, last accessed April 22, 2024.

manufacturing shutdowns in Puerto Rico due to Hurricane Maria in 2017.[6] In addition to significant economic and social impacts, natural disasters can significantly disrupt operations and lead to downstream impacts on production or distribution of products. Many types of natural hazards are expected to increase in frequency or severity due to climate change, including hurricanes, severe storms, and other extreme weather events, and these impacts are not expected to be distributed equally across the U.S.[7]

Although natural hazards can significantly disrupt manufacturing operations, risks of natural disasters are generally not cited in factors driving medical product manufacturer location decisions. The peer-reviewed and grey literature cite general factors with significant impact on operational efficiency and cost-effectiveness,[8] such as tax and regulatory advantages,[9,10] infrastructure and transportation access,[11] and the presence of a skilled workforce.[12,13] However, overall, there is little publicly available information about the types of factors manufacturers consider in site selection decisions beyond those that can be logically inferred, e.g., tax incentives, cost of production, access to skilled workforce, labor and environmental regulations, etc. Furthermore, the ways in which manufacturers weigh or prioritize each of these factors, or what additional factors may be considered, is not publicly available information. Risks associated with natural disasters or climate change are not widely discussed in the literature as driving site selection decisions, although there is some evidence of an emerging role for these factors.[14,15]

This ASPE data point links manufacturer location data with the Federal Emergency Management Agency (FEMA) National Risk Index (NRI), which describes relative risk of experiencing a variety of natural hazards in order to highlight the ways in which natural disasters may pose supply chain vulnerabilities within the U.S. This analysis is exploratory and represents a potential approach to linking natural disaster and climate change risk with supply chain vulnerabilities.

METHODS

ASPE contracted with NORC at the University of Chicago (previously the National Opinion Research Center) to perform geospatial merges of drug and device manufacturing facility data with natural hazard risk data. NORC retrieved the drug manufacturer location list from the U.S. Food and Drug Administration (FDA) Electronic

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[6] USA Today (2017). Hurricane Maria halts crucial drug manufacturing in Puerto Rico, may spur shortages. Available at: https://www.usatoday.com/story/money/2017/09/22/hurricane-maria-pharmaceutical-industry-puerto-rico/692752001/, last accessed July 23, 2024.

[7] USGCRP (2018). Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

[8] SelectUSA (2023). The SelectUSA Investor Guide. Available at: https://trade.gov/sites/default/files/2023-05/2023SelectUSAInvestorGuide.pdf, last accessed May 9, 2024.

[9] Bartik T. (1985). Business location decisions in the United States: Estimates of the effects of unionization, taxes and other characteristics of states. Journal of Business & Economic Statistics, 3, 14-22.

[10] Buss T. (2001). The effect of tax incentives on economic growth and firm location decisions: An overview of the literature. Economic Development Quarterly, 15, 90-105.

[11] Barkley D., McNamara K. (1994). Manufacturers' location decisions: Do surveys provide helpful insights? International Regional Science Review, 17, 23-47.

[12] Kimelberg SM, Nicoll LA (2012). Business location decisions in the medical device industry: Evidence from Massachusetts. *Economic Development Quarterly:* 26(1):34–49. doi: 10.1177/0891242411430327

[13] Shivdasani Y, Kaygisiz NB, Berndt ER, Conti RM. The geography of prescription pharmaceuticals supplied to the USA: levels, trends, and implications. J Law Biosci. 2021 Jan 29;8(1):lsaa085. doi: 10.1093/jlb/lsaa085.

[14] Emerson, D. (2022). Area Development. Front Line: Extreme Weather Events Factor into Location and Sustainability Decisions. Available at: https://www.areadevelopment.com/sustainable-development/q1-2022/extreme-weather-events-location-sustainability-decisions.shtml, last accessed April 25, 2024.

[15] EPA (2024). Climate Risks and Opportunities Defined. Available at: https://www.epa.gov/climateleadership/climate-risks-and-opportunities-defined, last accessed May 9, 2024.

Drug Registration and Listing System (eDRLS).[16] Domestic and foreign establishments that manufacture, repack, or re-label drug products in the United States are required to register with the FDA and to list all of their commercially marketed drug products. Registration must be done within five days of beginning operations and they must renew registration annually between October 1 and December 31 of each year. Registrants must provide the name and full address of each establishment, all trade names used by the establishment, the kind of ownership or operation (e.g., individually owned, partnership, or corporation), the name of the owner or operator, and the type of operation being performed at each establishment.[17] Facilities with operations listed as "medicated animal feed manufacture" and "SIP foreign seller" were removed from the dataset. Supply chain disruptions from climate change can impact operations beyond manufacturing; for purposes of our analysis we include facilities listed as "Manufacture", "API Manufacture"; "Label"; "Relabel", "Analysis", "Pack", "Repack", "Sterilize", "Transfill", and refer to them collectively as "manufacturers". The eDRLS dataset included active registrations as of July 6, 2023. The final dataset included 5,288 manufacturing facilities representing 3,893 unique census tracts. Similar to the drug listing requirements, establishments that are involved in the production and distribution of medical devices intended for commercial distribution in the U.S., including those that are imported for export only, are required to register annually with the FDA. The information that is submitted includes the establishment or trade name, the name of the owner or operator, the establishment address, and the type of establishment (e.g., manufacturer, foreign exporter, etc.). NORC retrieved the medical device manufacturer location list from the FDA Establishment Registration and Medical Device Listing[18] and filtered for U.S. manufacturers. This dataset represented registered medical device establishments with active registrations as of July 16, 2023. The final device manufacturer dataset included 14,117 device manufacturing facilities representing 8,048 unique census tracts. The NORC team utilized the Spectrum Spatial geocoding service from Precisely[19] to perform geocoding of manufacturer addresses. Duplicate addresses were removed and addresses that could not be geocoded due to spelling or other errors were manually corrected as needed.

The NORC team obtained the March 2023 update of the National Risk Index (NRI) from FEMA.[20] Beginning in 2016, FEMA started work on the NRI and released the versions in October 2020 and August 2021 before releasing the most recent version in March 2023. The NRI utilizes multiple databases and the periods of records vary across hazard types and risk components with the most recent source dataset including data up to 2022. The NORC team linked the NRI database with the device and drug manufacturer lists described above at the census tract level. Because the NRI only provides risk ratings and scores for U.S. states, manufacturing facilities located in U.S. territories were excluded from this linked database and subsequent analysis. ASPE used this linked database to conduct the analysis presented in this brief. Here, we use two primary variable types from the NRI. These included risk scores (numerical, 1-100) and risk ratings (categorical, "Very Low" to "Very High"). Scores represent the national percentile ranking of the community's component value compared to all other communities at the same level (county or census tract). Ratings are provided in one of five qualitative categories describing the community's component value in comparison to all other communities at the same level. Rating categories are relative and do not have defined numerical cutoffs. Ratings are provided

[16] FDA (2023). Electronic Drug Registration and Listing System (eDRLS). Available at: https://www.fda.gov/drugs/guidance-compliance-regulatory-information/electronic-drug-registration-and-listing-system-edrls, data downloaded on July 6, 2023.

[17] FDA (2009). Providing Regulatory Submissions in Electronic Format—Drug Establishment Registration and Drug Listing. Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/providing-regulatory-submissions-electronic-format-drug-establishment-registration-and-drug-listing, last accessed July 23, 2024.

[18] FDA (2023). Establishment Registration and Medical Device Listing Files for Download. Available at: https://www.fda.gov/medical-devices/device-registration-and-listing/establishment-registration-and-medical-device-listing-files-download, data downloaded on July 16, 2023.

[19] Precisely. Spectrum Spatial. https://www.precisely.com/product/precisely-spectrum-spatial/spectrum-spatial

[20] FEMA (2023). National Risk Index: Data Resources. Available at: https://hazards.fema.gov/nri/data-resources, data downloaded on July 6, 2023.

in one of five qualitative categories that range from "very low" to "very high" based on an unsupervised machine learning algorithm that evaluates communities relative to each other. For more detail on the unsupervised machine learning approach used to generate these categories, see the NRI Technical Documentation.[21]

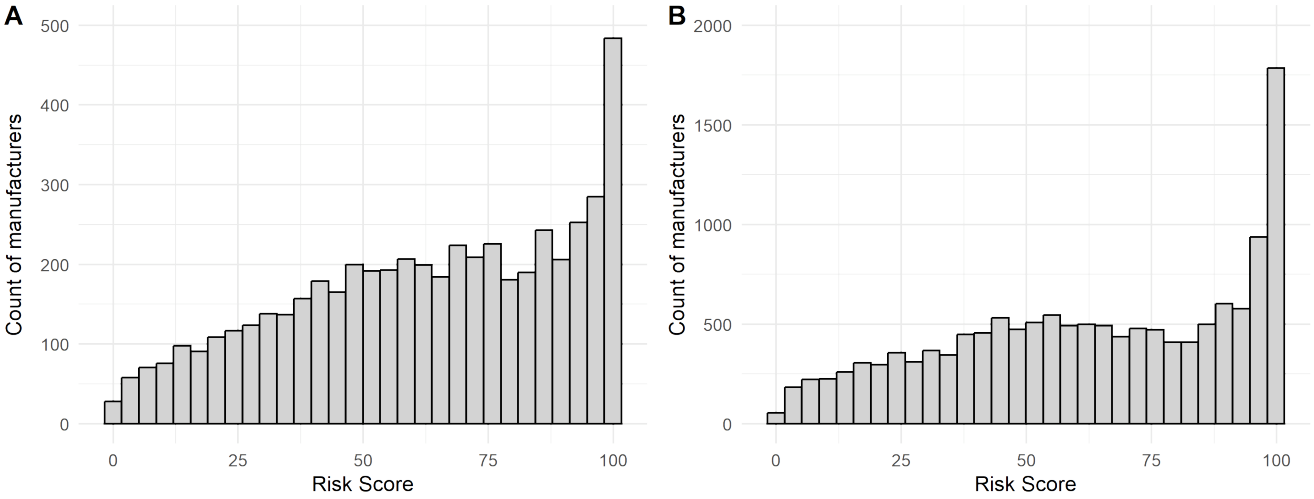
In this data point, we use composite risk index scores from the NRI to describe overall risk. The composite risk index score is calculated to measure a community's risk to all 18 hazard types: avalanche, coastal flooding, cold wave, drought, earthquake, hail, heat wave, hurricane, ice storm, landslide, lightning, riverine flooding, strong wind, tornado, tsunami, volcanic activity, wildfire, and winter weather. We also use risk index scores for specific hazard types. The risk index score for specific hazard types is calculated as a function of expected loss of building value, population, and/or agriculture value each year due to natural hazards and a community risk factor that accounts for social vulnerability and community resilience. In developing the NRI, FEMA included natural hazards that were included in at least half of the FEMA-approved state plans or those that were deemed to be of regional significance, i.e., had the capacity to cause widespread, catastrophic damage. Among the 18 hazards, avalanches, coastal flooding, hurricanes, tsunamis, and volcanoes were geographically limited and did not meet the threshold to be included in at least half of FEMA-approved state plans but these regional hazards were included in the NRI because they contribute significantly to risk. Additional details about these calculations are available in the NRI Technical Documentation.[22]

RESULTS

Both drug and device manufacturers are skewed toward locations with greater risk of natural hazards (Figure 1). More than a quarter of drug and device manufacturers are in areas categorized as very high or relatively high risk using the NRI's Composite Risk score (Table 1). When examining specific hazard types, 58% of drug manufacturers and 47% of device manufacturers are in areas at very high or relatively high risk in two or more hazard types. As expected, due to the range of potential hazard types across the U.S., there is no single hazard threatening a majority of facilities – rather, facilities are at risk from a variety of hazards including earthquakes, tornados, hurricanes, and storms.

[21] FEMA (2023). National Risk Index: Technical Documentation. Available at: https://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf, last accessed April 22, 2024.
[22] *Ibid.*

Figure 1: Histogram of NRI Composite Risk Scores among Drug (A) and Device (B) Manufacturers



Notes: The NRI Composite Risk Score ranges from 0 (lowest risk) to 100 (highest risk). Scores are determined by the given value's percentile ranking in the national distribution. For more detail, please see the NRI Technical Documentation.[23]

Table 1: Descriptive Analysis of NRI Composite and Hazard-Specific Risk Scores and Risk Levels of Drug and Device Manufacturing Locations

	Drug manufacturers	Device manufacturers
% of facilities in "very high" risk locations	10.7	14.7
% of facilities in "very high" or "relatively high" risk locations	26.6	30.4
Mean facility location risk score	62.3	62.6
Median facility location risk score	65.1	64.5
% of facilities located in areas with "very high" risk of 2+ hazard types	58.5	47.1
% of facilities located in areas at very high/relatively high risk for specific events:		
Avalanche	0.2	0.9
Coastal Flooding	1.2	1.2
Cold wave	10.9	6.5
Drought	1.1	1.0
Earthquake	15.3	23.2
Hail	14.5	11.9
Heat wave	21.6	16.2
Hurricane	13.1	12.9
Ice storm	11.9	8.2
Landslide	8.9	5.5
Lightning	27.7	20.9
Riverine flooding	13.9	9.3

[23] *Ibid.*

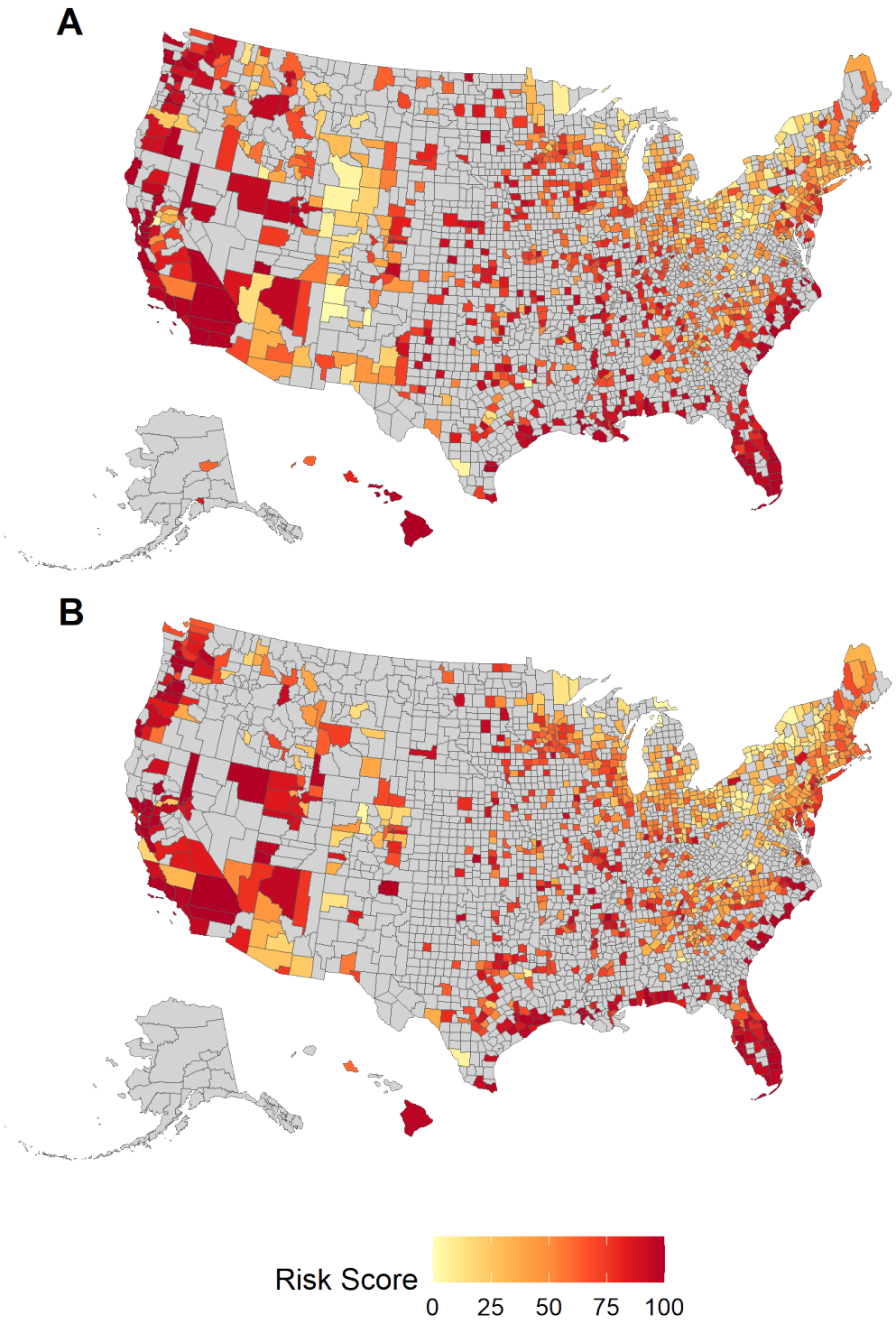
Strong wind	25.7	16.4
Tornado	32.5	24.7
Tsunami	0.3	0.1
Volcano	0.8	1.1
Wildfire	4.1	4.7
Winter weather	18.9	10.0

Notes: The NRI Composite Risk Score ranges from 0 (lowest risk) to 100 (highest risk). Scores are determined by the given value's percentile ranking in the national distribution. For every score, there is also a qualitative rating category that describes the nature of a community's component value in comparison to all other communities at the same level. The categories are "Very Low", "Relatively Low", "Relatively Moderate", "Relatively High", and "Very High". Rating categories are relative and there are no specific numeric values that determine the rating. For more detail, please see the NRI Technical Documentation.[24]

Figure 2 shows counties with at least one manufacturer of drugs (Figure 2A) or devices (2B), colored by their NRI risk score. This shows that although facilities are distributed throughout the U.S., many facilities are located in areas of high natural hazard risk, particularly on the west coast, throughout the midwest, and in the south.

[24] *Ibid.*

Figure 2: NRI Composite Risk Scores in Counties Containing Drug (A) or Device (B) Manufacturers



Notes: For purposes of visualization, the NRI county-level composite risk score was used. More than one manufacturer may be present in each visualized county. Gray counties denote those without any manufacturing facilities in the dataset. The NRI Composite Risk Score ranges from 0 (lowest risk) to 100 (highest risk). Scores are determined by the given value's percentile ranking in the national distribution. For more detail, please see the NRI Technical Documentation.[25]

[25] *Ibid.*

DISCUSSION AND CONCLUSIONS

This analysis demonstrates that medical product manufacturing facilities in the U.S. are located disproportionately in areas at high risk of natural hazards such as earthquakes, tornados, hurricanes, and storms. Specifically, a substantial percentage of drug and device manufacturing facilities are located in areas susceptible to earthquakes (15% and 23%, respectively), tornados (33% and 25%), winter weather (19% and 10%), flooding (14% and 9%), strong winds (26% and 16%), heat waves (22% and 16%), and hurricanes (13% and 13%). Each of these hazards can have a significant impact on manufacturing because of the potential for physical damage to facilities, power outages, or workforce impacts, and the downstream impacts to the supply chain can be significant.

While climate-related factors generally do not publicly appear to drive medical product manufacturer site-selection decisions, they may have operational impacts downstream to distributors, workers, and patients as well as to suppliers of raw materials. In the past, severe weather, such as hurricanes and tornadoes, flooding, wildfires, and drought/extreme heat have had impacts ranging from delayed product distribution to full suspension of operations, infrastructure damage, and major supply chain delay. The following are examples of how these hazards can result in plant closures or delays that affect the supply of medical products:

- In 2017, Hurricane Maria wiped out Puerto Rico's electrical grid which not only affected manufacturing but also health care. Dialysis treatment centers had to cut treatments short, and manufacturing facilities were running on generators at limited capacity. At that time, there were at least 30 critical drugs and 50 medical devices manufactured either solely or primarily in Puerto Rico.[26]
- In the summer of 2018, a company's facility outside of the U.S. saw repeated days of elevated temperatures which resulted in a reduction in production as the facility could not maintain the ambient temperature required under manufacturing rules.[27]
- In July 2023, a tornado caused extensive damage to a drug manufacturing site in North Carolina which threatened critical supplies for hospitals across the country.[28] The company resumed partial production in September 2023 and announced that although full production was anticipated by the end of 2023, the impact of the tornado on the site was expected to affect the supply of medicines from the Rocky Mount facility until at least mid-2024.[29] As of July 8, 2024, FDA listed the affected products as still in shortage and with an anticipated availability of November 2024.[30]

There is increasing understanding of the physical risks associated with climate change related events and the need to prepare for these emergencies. FDA previously conducted a similar analysis to the one described in this issue brief to evaluate the natural hazard risk to sites that manufacture essential medicines.[31] Using the NRI, they report that 34% of essential medicine manufacturing sites were at "relatively high" or "very high"

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[26] Aton, A. and E&E News (2017). Hurricane Maria Takes a Toll on Global Medical Supplies. Available at: https://www.scientificamerican.com/article/hurricane-maria-takes-a-toll-on-global-medical-supplies/, last accessed July 23, 2024.

[27] Furlong, A (2024). How a Hurricane Might Rip Through Your Medicine Cabinet. Available at: https://www.bloomberg.com/news/newsletters/2024-03-01/does-climate-change-cause-drug-shortages, last accessed July 23, 2024.

[28] Jewett, C (2023). Tornado Tears Through Pfizer's N.C. Site, Threatening Crucial Drug Supplies. Available at: https://www.nytimes.com/2023/07/20/health/tornado-pfizer-drug-shortage.html, last accessed July 23, 2024.

[29] Pfizer (2023). Pfizer's Rocky Mount Facility Restarts Production Amid First Phase of Post-Tornado Recovery Efforts. Available at: https://www.pfizer.com/news/announcements/pfizers-rocky-mount-facility-restarts-production-amid-first-phase-post-tornado, last accessed July 23, 2024.

[30] FDA (2024). Current and Resolved Drug Shortages and Discontinuations Reported to FDA. Available at: https://www.accessdata.fda.gov/scripts/drugshortages/dsp_ActiveIngredientDetails.cfm?AI=Atropine%20Sulfate%20Injection&st=c, last accessed July 23, 2024.

[31] FDA (2022). Executive Order 13944 List of Essential Medicines, Medical Countermeasures, and Critical Inputs. Available at: https://www.fda.gov/about-fda/reports/executive-order-13944-list-essential-medicines-medical-countermeasures-and-critical-inputs, last accessed July 23, 2024.

risk.[32] The FDA analysis demonstrates that a slightly higher percentage of essential medicine manufacturing facilities are in locations at risk of natural hazards in comparison with all drug (26.6%) or device (30.4%) manufacturing facilities, as described in this issue brief. FDA has provided numerous recommendations for manufacturers to consider natural hazards in risk management. For example, FDA released draft guidance in 2022 that suggested manufacturers consider geographic risk factors, including potential for natural disasters, in risk management planning.[33] In April 2024, FDA released recommendations for medical device manufacturers, distributors, and healthcare providers to engage in preparation activities to minimize potential disruptions to supply chains, business operations, and facilities, from natural disasters and other emergency situations.[34] Health care providers were encouraged to identify multiple delivery locations and distributors and to be prepared to implement conservation measures. Medical device manufacturers were encouraged to identify manufacturing sites susceptible to disruptions caused by severe weather and forecast demand for products produced in those locations to ensure sufficient production capacity in the event of a disaster, to develop plans for the continuity of business operations, and to identify critical suppliers that could be impacted by severe weather. Similarly, recommendations for distributors included identification of regions susceptible to disruptions caused by severe weather and developing plans for communication with customers about the availability of products and viable alternatives or substitutes. Additionally, the Centers for Medicare & Medicaid Services (CMS) announced the intent to issue a proposed rule that would require hospitals to update their existing emergency preparedness protocols for Medicare- and Medicaid-participating providers and suppliers to plan adequately for both natural and man-made disasters, including climate-related disasters, on the Office of Management and Budget Fall 2023 Unified Agenda.[35] According to the OMB Spring 2024 Unified Agenda, this proposed rule is expected to publish in summer 2024.[36]

This analysis does not take into account the ways in which these risks might evolve over time due to climate change. Some hazard types are expected to increase in frequency or severity due to climate change, and the geographic areas at greatest risk may shift over time. Therefore, for hazard types that are expected to be impacted by climate change, additional research may be warranted to examine the future risk of manufacturing facility locations, and increased emphasis on these factors may be warranted during site-selection to protect valuable manufacturing facilities and necessary global supply chains. Given the limited available information on manufacturer site selection decision-making, future work might also explore the ways in which natural disaster and climate change risks currently factor into site selection decisions. These decisions, and the rationale behind them, can have a variety of indirect impacts on the industry and society at-large. For example, if industry begins to prioritize climate change risk in future location decisions – both domestically and globally – this could lead to a geographic consolidation of industry in areas of comparatively low risk. This may result in an inequitable distribution of manufacturing facilities and associated jobs and introduce new vulnerabilities to the supply chain. Thus, natural hazard and climate change risks should be considered alongside other factors when seeking to understand supply chain vulnerabilities due to manufacturing locations.

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[32] FDA (2023). Fiscal Year 2023 Report on the State of Pharmaceutical Quality. Available at: https://www.fda.gov/about-fda/center-drug-evaluation-and-research-cder/report-state-pharmaceutical-quality, last accessed July 23, 2024.

[33] FDA (2022). Risk Management Plans to Mitigate the Potential for Drug Shortages: Guidance for Industry. Draft Guidance, Docket Number FDA-2022-D-0277. Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/risk-management-plans-mitigate-potential-drug-shortages, last accessed July 23, 2024.

[34] FDA (2024). Emergency Preparedness and Medical Devices: Supply Chain Recommendations for Health Care Providers, Device Manufacturers, and Distributors. Available at: https://www.fda.gov/medical-devices/emergency-situations-medical-devices/emergency-preparedness-and-medical-devices-supply-chain-recommendations-health-care-providers-device, last accessed July 23, 2024.

[35] OIRA (2023). Healthcare System Resiliency and Modernization (CMS-3426). Available at: https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202310&RIN=0938-AU91, last accessed July 24, 2024.

[36] OIRA (2024). Healthcare System Resiliency and Modernization (CMS-3426). Available at: https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202404&RIN=0938-AU91, last accessed July 24, 2024.

Manufacturing facility locations represent only one component of the medical product supply chain that faces potential disruption due to natural disasters. In order to provide a more holistic view of supply chain vulnerabilities, future work might explore other elements of the supply chain such as distribution channels or raw material manufacturing. This study was also only able to look at manufacturing facilities that are known to produce drugs and devices; however, the available data do not identify the actual products being manufactured at the facilities. Further research could examine mapping specific products, including ingredients, components, raw materials, ancillary parts, and substitutes, to facilities to better understand and identify the types of products that could be affected. This study was also limited in scope to manufacturers of drugs and devices and did not include other types of medical products such as critical foods or animal drugs that are also subject to shortage. Our analysis included facilities involved in labeling, packing and other non-manufacturing operations of drugs. Future work could further investigate the relationship between specific operations (manufacturing, labeling, packing, sterilization, etc.) and climate risks. Finally, the data used in this data point were limited in geographic scope. Additional research could expand the scope to include natural disaster risk and manufacturing facilities in U.S. territories as well as outside of the U.S. to more robustly examine implications for the entirety of the U.S. medical product supply chain. This data point outlines a potential approach that could be applied using additional data sources for other supply chain components, product types, or natural hazard risk to further examine the relationship between natural disaster risks, climate change, and supply chain vulnerabilities.

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