MARCH 2021

OUR BRAIN ON POLLUTANTS

Supplemental Material

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Our Brain on Pollutants

by Miranda Le, Niyanta Joshi, Kevin Sun, & Lauren Beckett

Air pollution is a threat to our brain health. This news segment breaks down the biological and societal factors of this issue. Miranda, newscaster of HBS News, takes us through the case study of Smogsville: a fictional urban center whose residents are faced with an increased level of air pollution exposure and a greater incidence of age-related neurological disease. She calls in some experts to explain how this issue emerged. Niyanta is a neurologist in Smogsville who has observed first-hand an increase in the incidence of age-related neurological disease in her patients. She defines what age-related neurological diseases are, the pathways that air pollutants take into the body, and how pollutants change brain structure and function to lead to neurological disease. Miranda then steers the conversation over to public health officials, Kevin and Lauren, who delve into the societal influences of this issue. Kevin points to the geography of Smogsville, which has put marginalized communities closer to major roads thereby increasing their exposure to traffic-related air pollution. Lauren then explains that low-income and minority communities are not only victims of environmental injustice, but also are burdened with increased risk of age-related neurological disease. The HBS News team comes together at the end to discuss individual and institutional changes necessary to alleviate the air pollution and neurological disease burden in Smogsville.

The entirety of the segment will take place on the platform gather.town, where each person is represented by an avatar and can move around the digital world of Smogsville. While Smogsville is a fictional town, it has been crafted to highlight all of the biological and societal threats that actual US residents face.

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ANNOTATED BIBLIOGRAPHY

The following bibliography contains annotations for various references and research studies used while making the documentary. Moreover, it also includes additional articles that the viewers can read for supplemental information regarding the topics covered in our documentary.

INTRODUCTION

Supplemental Material: Annotated Bibliography

(1) Impact of Accumulating Environmental Pollutants on Public Health

South Coast AQMD, director. The Right to Breath. The Right to Breath South Coast AQMD, 2018, www.aqmd.gov/home/research/right-to-breathe-home.

The Right to Breath documentary focuses on the burden of air pollution on Southern California residents - highlighting the impact of our world's increasing environmental damage on health outcomes. The film also builds on the disproportionate concentration of these impacts on residents who live in low-income, minority communities close to the sources of pollution. As per our discussion on the imminent large scale shifts, this film balances worldly context with a community specific example of the reality of linkage between environmental risks and human health risks.

(2) Demographic Transition Implications for Age-Related Disease

Gregory Petsko Ted Talk: The Coming Neurological Epidemic Petsko, G. (2013, January 27). Retrieved January 13, 2021, from https://www.ted.com/talks/gregory_petsko_the_coming_neurological_epidemic/transcript?language=en

Petsko in his TED talk on aging and neurological diseases, highlights a global identity shift, as the world evolves in a growing number of older individuals with longer life spans. Petsko highlights an urgent need to question existing systems, like the healthcare system, that is based on standard, decade-old assumptions. Petsko provides deeper insights into the demographic shift to come and its consequences as they intersect with environmental, epidemiological, and other societal shifts.

BIOLOGY

Supplemental Material: Annotated Bibliography

(1) Effects of Oxidative Stress on Brain Structure

Cheignon, C., Tomas, M., Bonnefont-Rousselot, D., Faller, P., Hureau, C., & Collin, F. (2018). Oxidative stress and the amyloid beta peptide in Alzheimer's disease. Redox biology, 14, 450–464. https://doi.org/10.1016/j.redox.2017.10.014
Link: https://pubmed.ncbi.nlm.nih.gov/29080524/

In this review, researchers explore the existing link between oxidative stress and Alzheimer's disease in relation to the consequences of oxidative damage. They also explore the implications of metal ions in Alzheimer's disease.

(2) Introduction to how air pollution is associated with brain damage

Offord, C. (n.d.). Air pollution may damage people's brains. Retrieved March 05, 2021, from https://www.the-scientist.com/features/air-pollution-may-damage-peoples-brains-66473

In this research article, the correlation between air pollution and cognitive decline was closely explored, and with it the relationship between genetic predisposition to neurodegeneration and environmental risk. Of particular interest, was a study in which Calderon Gardicdeuna's found that mouse cell lines expressing a mutated version of the gene coding for amyloid precursor protein, a peptide implicated in Alzheimer's diseases, produced greater levels of biomarkers for oxidative stress with increasing exposure to nano-size particle matter. The interplay in this study between oxidative stress, exposure to PM, and Alzheimer's disease presents an interesting case study on air pollution to supplement the analysis of the impact of pesticides and subsequent oxidative stress.

(3) MRI brain scans visualizing PM2.5 exposure

Chen JC, Wang X, Wellenius GA, Serre ML, Driscoll I, Casanova R, McArdle JJ, Manson JE, Chui HC, Espeland MA. Ambient air pollution and neurotoxicity on brain structure: Evidence from women's health initiative memory study. Ann Neurol. 2015 Sep;78(3):466-76. doi: 10.1002/ana.24460. Epub 2015 Jul 28. PMID: 26075655; PMCID: PMC4546504.
Link: https://pubmed.ncbi.nlm.nih.gov/26075655/

This research study conducted MRI scans of older women to study the effects of PM2.5 exposure on brain structure and function. They observed that older women with greater PM2.5 exposures had significant decline in white matter.

BIOLOGY

Supplemental Material: Annotated Bibliography

(4) Brain and Gut Connection for Pollutants

Mutlu EA, Comba IY, Cho T, Engen PA, Yazıcı C, Soberanes S, Hamanaka RB, Niğdelioğlu R, Meliton AY, Ghio AJ, Budinger GRS, Mutlu GM. Inhalational exposure to particulate matter air pollution alters the composition of the gut microbiome. Environ Pollut. 2018 Sep;240:817-830. doi: 10.1016/j.envpol.2018.04.130. Epub 2018 May 18. PMID: 29783199; PMCID: PMC6400491.
Link: https://pubmed.ncbi.nlm.nih.gov/29783199/

This article delves into a topic not explored in our video: the relationship between pollution and the gut microbiome. The research findings indicated that exposure to PM alters the microbiota throughout the GI tract.

Sources for images used:

Bailly, D. (n.d.). The brain from top to bottom. Retrieved March 10, 2021, from https://thebrain.mcgill.ca/flash/d/d_08/d_08_cl/d_08_cl_alz/d_08_cl_alz.html

- Amyloid plaques and neurofibrillary tangles are buildups of protein that also occur as part of the normal aging process, but in people with Alzheimer's-type dementias, the amounts of these proteins that build up are far greater. This article has images useful to visualize what these abnormal buildups can look like in the brain.

Harvard Health. (n.d.). Recognizing Alzheimer's disease. Retrieved March 10, 2021, from https://www.helpguide.org/harvard/recognizing-and-diagnosing-alzheimers.htm

- These scans provided in this article show the loss of brain mass associated with Alzheimer's disease and other dementias. In Alzheimer's disease, the region of the brain known as the hippocampus may be disproportionately atrophied as shown in the image.

Queensland Brain Institute. (2019, August 13). What is a neuron? Retrieved March 10, 2021, from https://qbi.uq.edu.au/brain/brain-anatomy/what-neuron

- This article goes into a deeper understanding of what the anatomy and functions of neurons look like. Dendritic spines are small structures that receive inputs from the axons of other neurons. The visualizations break down each part of the neuron into easily understandable diagrams.

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SOCIETY

Supplemental Material: Annotated Bibliography

(1) A Look Back: PM2.5 in 2019

AirNow. (2019). A Look Back: PM2.5 in 2019. Retrieved from https://epa.maps.arcgis.com/apps/Cascade/index.html?appid=6656472ac1d7492b87a826a921e2d81d

This governmental-generated, map-based summarization was based on the annual report of air pollution measurement taken from different places around the United States, Specifically, it clearly shows the inequality of receiving different levels of air pollution in terms of geographical distribution, from both a national level perspective and a city/zip code level perspective. This study stood out of others because its graphical design, which made it easier to comprehend but The associated dataset can be found at https://www.epa.gov/air-trends

(2) "Trump EPA declines to tighten soot pollution standards"

Valdmanis, Richard. "Trump EPA Declines to Tighten Soot Pollution Standards." Reuters, Thomson Reuters, 14 Apr. 2020, www.reuters.com/article/us-usa-epa-soot/trump-epa-declines-to-tighten-soot-pollution-standards-idUSKCN21W1X8.

An interesting article examines the current (2020) contrast between the EPA regulations versus Trump administrations' certain backlashes. This study was mentioned in the section of describing what the government has done to resolve the long-existing inequality of air pollution among different regions and demographics. This is a closely related article from the EPA regulation assessment (in round table discussion section) as it also pointed out the lack of funding and change from the central government level, in a media's perspective.

(3) Inequalities in air pollution exposure are increasing in the United States

Jbailya, Abdulrahman. "Inequalities in Air Pollution Exposure Are Increasing in ..." American University, 2020, www.researchgate.net/publication/342966414_Inequalities_in_air_pollution_exposure_are_increasing_in_the_United_States.

This article has helpful maps for racial and income disparities and summarizes the inequalities by connecting air pollution, race, and economic disparity together. It clearly shows the effect of systemic racism that racial minorities are forced to live in areas with limited opportunities and high pollution, while also suffering from financial restraints and lack of political representation.

(4) Long-Term Exposure to Ambient Air Pollution and Cognitive Function Among Hispanic/Latino Adults in San Diego, California

Ilango, S. D., Gonzalez, K., Gallo, L., Allison, M. A., Cai, J., Isasi, C. R., . . . Benmarhnia, T. (2021). Long-Term Exposure to Ambient Air Pollution and Cognitive Function Among Hispanic/Latino Adults in San Diego, California. Journal of Alzheimers Disease, 79(4), 1489-1496. doi:10.3233/jad-200766

Differences of air pollution level (PM2.5) in terms of zip code Outcomes found different in terms of many cognitive categories, such as language, processing, etc. Most populations impacted are people of color (predominantly latino communities).

SOCIETY

Supplemental Material: Annotated Bibliography

(5) Disparities in PM2.5 air pollution in the United States

https://science.sciencemag.org/content/369/6503/575

An interesting article that compares and contrast different factors that lead to higher pollution levels in certain locations in the US. They show that differences in PM2.5 between more and less polluted areas declined substantially between 1981 and 2016. However, the most polluted census tracts in 1981 remained the most polluted in 2016. The least polluted census tracts in 1981 remained the least polluted in 2016. What is suggested is the current efforts of environmental protection, especially air protection is sufficient in turning around the trend of polluting, but not able to overcome the long-term disparity caused by the political-economy framework. Some pictures in the article was used.

(6) University of Toronto study on the incidence of dementia in urban cities:

Chen H, Kwong JC, Copes R, Tu K, Villeneuve PJ, van Donkelaar A, Hystad P, Martin RV, Murray BJ, Jessiman B, Wilton AS, Kopp A, Burnett RT. Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. Lancet. 2017 Feb 18;389(10070):718-726. doi: 10.1016/S0140-6736(16)32399-6. Epub 2017 Jan 5. PMID: 28063597.
Link: https://pubmed.ncbi.nlm.nih.gov/28063597/

Researchers from the University of Toronto, as mentioned in the news segment, studied the relationship between one's proximity to a major road and the incidence of dementia and other neurological diseases.

(7) Racial and ethnic disparities of Alzheimer's disease prevalence:

Lines, L. (2014). Racial and Ethnic Disparities Among Individuals with Alzheimer's Disease in the United States: A Literature Review. doi:10.3768/rtipress.2014.rr.0024.1412

https://aspe.hhs.gov/report/racial-and-ethnic-disparities-alzheimers-disease-literature-review
Here, various research studies were compiled to form a comprehensive overview of the different racial and ethnic disparities faced by individuals with Alzheimer's disease. Some topics explored in this paper that were not referenced in the documentary were clinical trials participation, use of long-term services and supports, use of medications, health care expenditures, and caregiving.

(8) Differences in rate of dementia by socioeconomic status:

Yaffe K, Falvey C, Harris T B, Newman A, Satterfield S, Koster A et al. Effect of socioeconomic disparities on incidence of dementia among biracial older adults: prospective study BMJ 2013; 347 :f7051 doi:10.1136/bmj.f7051

Similar to the previous paper, this publication analyzes how socioeconomic disparities are associated with an increased incidence of dementia, specifically among older biracial adults. The discussion expands upon the mechanisms by which socioeconomic status may influence cognition, like through chronic stress and allostatic load.

SOCIETY

Supplemental Material: Annotated Bibliography

(9) Occupational risk factors in Alzheimer's disease

Santibáñez, M., Bolumar, F., & García, A. M. (2007). Occupational risk factors in Alzheimer's disease: a review assessing the quality of published epidemiological studies. Occupational and environmental medicine, 64(11), 723–732. https://doi.org/10.1136/oem.2006.028209
Link: https://pubmed.ncbi.nlm.nih.gov/17525096/

This review explores a social factor not addressed in our documentary: occupation. The researchers here find an increased risk of Alzheimer's disease in relation to occupational exposure to pesticides.

(10) Public disengagement with neuroscience

O'Connor, Cliodnha, and Helene Joffe. "Social Representations of Brain Research: Exploring Public (Dis)Engagement With Contemporary Neuroscience." SAGE, vol. 36, no. 5, 2014, doi:10.1177/1075547014549481.
Link: https://journals.sagepub.com/doi/full/10.1177/1075547014549481

This research article looks at the social patterns for why neuroscience is not often discussed in the media. One of the main issues for one's disengagement with neuroscience was the common interpretation of science as another "world", or social milieu. The ability to engage with knowledge about the brain was associated with a person's "type", whether it be "scientific" and "academic" or not. The lack of awareness about pollutants causing neurological disease may therefore be attributed with general disengagement with neuroscience and science in general.

HBS PLAN

Supplemental Material: Annotated Bibliography

(1) Basis for the "HBS Plan":

W. Byron Rumford (1966) The Need for a New Approach to the Politics of Pollution, Journal of the Air Pollution Control Association, 16:7, 359-361, DOI: 10.1080/00022470.1966.10468487
Link: https://www.tandfonline.com/doi/pdf/10.1080/00022470.1966.10468487

The author of this article makes the argument that past approaches to environmental pollution have all been on a “crisis to crisis” basis and moving forward, the public needs to be involved in the decision-making process.

(2) Case Study: Relevance of an intersectional HBS plan

Neumann, Pamela. “Toxic Talk and Collective (In)Action in a Company Town: The Case of La Oroya, Peru.” OUP Academic, Oxford University Press, 19 July 2016, academic.oup.com/socpro/article-abstract/63/3/431/2468846.

This research article delves into the dynamics of contaminated communities through a sociological lens. The focus is on La Oroya, Peru (one of the top ten most polluted places on earth) a town plagued by dangerously high lead levels that contest - not the contamination - but the closure of the metallurgical complex. The article discusses the subjectivity of environmental risk and the significance of community, collective self-understandings, and moral boundary making in community responses to toxic conditions and perception of risk. The perception in this instance actually suppresses the emergence of a sustained collective action, which raises surprising parallels to the lack of urgency in preventing rise of environmental hazards worldwide. This study serves to supplement the biological impact of exposure to environmental toxins with an understanding of the sociological factors that also impact and in instances amplify that exposure. This study also unveils economic, communal, and political elements that contribute to disproportionate impact environmental hazards and subsequent disease on communities.

(3) Public Health Approach to Aging World:

Harvard Chan School. “A Public Health Approach to an Aging World.” News, 25 June 2018, www.hsph.harvard.edu/news/multimedia-article/public-health-aging/.

This podcast explores how public health researchers are grappling with issues surrounding aging and longevity—from rethinking work to preventing Alzheimer’s disease. The implications of an ageing population are discussed by two of Harvard’s leading Researchers on aging and epidemiology. The first discussing the repercussions involved with the caretaking of aging populations and the second discussing the neurodegenerative diseases that likely supplement many of those added years. This podcast provides a cultural perspective, such as how working and socialization will impact aging and development of these diseases, as well as social insights into the inequalities and most vulnerable populations in this shift based largely on both income, education, gender.

HBS PLAN

Supplemental Material: Annotated Bibliography

(4) Policy Assessment for the Review of the National Ambient Air Quality Standards for Particulate Matter:

https://www.epa.gov/sites/production/files/2020-01/documents/final_policy_assessment_for_the_review_of_the_pm_naaqs_01-2020.pdf

The policy assessment of 2020 is one of the newest advocacy measurements proposed by experts inside the EPA as well as research institution experts. The goal of this assessment is to provide a fully detailed account of the different pollutants prevalent in the US, characterized by different particle categories, and their effect on people's health and long lasting effects.
This review particularly stands out as a governmental revision proposal for its progressive view of recognizing the disparity of environmental hazard, specifically air pollution here that was brought to different demographic populations differently. This review also seeked for revision toward older paradigms and EPA clean air acts that strengthen the existing standards by EPA to further issue protection methods for pollutants prevention and regulation

QUESTIONS FOR DISCUSSION

Supplemental Material: Additional

1. Why is an increased level of cytokines in the body as a reaction to pollutants in the body bad?

2. How will our health systems change as our population experiences an increase in the prevalence of neurological diseases?

3. What are some environmental factors that would put those of lower socioeconomic status at a greater risk for pollution exposure?

4. What are some ways that we can reduce racial disparities in pollution exposure and neurological disease prevalence, both individually and on a system-wide level?

5. What are some other social factors not mentioned in this documentary that could affect one's exposure to air pollution or one's risk of neurological disease?

6. What other types of environmental pollutants might influence one's susceptibility to neurological disease?

7. In what ways can you contribute to care in your community?

INTERVIEW TRANSCRIPTS

Supplemental Material: Additional

Dr. Yu Yu, UCLA researcher studying the effect of traffic-related air pollution on cognitive decline among Mexican American communities in California

"What kind of research have you done regarding pollutants and neurological disease?"
YU: Currently with cognitive impairment or dementia, there are major concerns for the older adults because of its relationship with morbidity and mortality. They also threaten to become even more prominent with increasing life expectancy and an aging population. Contrary to our knowledge of established risk factors including age, family history, cardiovascular disease, etc., we also find that environmental exposures, including air pollution, are associated with cognitive impairment. So most of our research is focused on how pollution, mostly traffic-originated, accelerates cognitive decline.

"From your research, how are you able to isolate air pollution as a risk factor for cognitive decline?"
YU: In a study, we usually try to model the air pollution exposure for each specific participant. And then we use like a longitudinal study design to see whether the exposures have the heavy association with the development of a certain disease. So we rely on exposure models to generate the exposure estimates, and we also have lots of support from the studies themselves.

"What types of populations are more at risk of pollutant exposure or neurological disease?"
YU: Currently our research is focused on Mexican Americans because this is a fast-growing segment of the US population and they have a particularly high prevalence of obesity and diabetes. They are also the most highly environmentally-exposed population in California. But generally, all age groups are at risk, especially since risk factors for cognitive decline like obesity and diabetes can affect anyone.

"Why is your area of scientific discovery relevant to an ordinary person in this country?"
YU: Cognitive impairment is a major concern for the aging society. It is becoming more and more important because of these issues I mentioned earlier, increasing life expectancy and the aging of the population, as well as the growing segment of the US population with an especially high prevalence of risk factors. We as researchers are trying to map out a complete view of how air pollution will increase this risk for this specific population. And so with this research, we hope to prompt programs to reduce traffic exposure and also promote early identification and treatment for people with cognitive decline.
You can see how important this is in some statistics. According to the Alzheimer's Association, there were about 5.7 million people living with Alzheimer's disease and other dementias in the United States in 2018, and that number is expected to reach 14 million in 2060. In 2018, it costs almost $280 billion dollars to care for those with dementia, and it will rise to as high as $1.1 trillion in 2050. So if we can mitigate the risk for cognitive impairment, it will bring a huge benefit in terms of the economic burden, as well as the social burden such as caregiving and family and social support.

INTERVIEW TRANSCRIPTS (CONT.)

Dr. Yu Yu Interview (Cont.)

“Where do you anticipate that this field of research is heading?”
YU: In terms of outcomes, we hope we can have more longitudinal studies to investigate this research topic so that we can develop a better understanding. If we can have enough input, not only from older adults, but also from studying people starting in childhood, that will be very important for studying risk factors. It would also be beneficial to develop better modeling techniques to generate better exposure estimates, which would help us correctly estimate the effects of air pollution on cognitive impairment. And in investigating the association between air pollution and cognitive impairment, you cannot just look at the air pollution exposures; you also need to think about other social factors like neighborhoods, socioeconomic status, and occupational status. The map of exposure and disease would be more comprehensive if we can connect more information and understand more about how social factors influence the association.

Sarah Kaye, Director of Family Services at OPICA Adult Day Program and Counseling Center

“What is OPICA and what is your role?”
KAYE: OPICA is an adult day center and our mission is to provide cognitive, physical, and emotional stimulation for people who are struggling with memory loss. I was trained as a social worker at OPICA, and my formal title is Director of Family Services. I do all the intakes and assessments for our new members who are coming in. In the interim I introduce the family to OPICA and figure out what program is best for them there, and then continue to follow the family during during their

“How do you see memory loss affecting your members and the people around them?”
KAYE: For the diagnosed person, it affects their life dramatically—it changes their relationships and their ability to do things on their own, which in turn affects their emotional state as well. So we might see depression, low self esteem, and similar conditions. As the dementia evolved, it really affects one’s identity. What's interesting is the diagnosed person themselves have less awareness of how it's affecting them as dementia progresses. So in some ways, it almost becomes easier for that person. A lot of the ways that memory loss affects the family are the same, like loss of independence and depression, but what’s different is that it's a grieving process. It causes stress, which in turn, sometimes causes physical illness as well. Their health is oftentimes affected by their role as caregiver.

INTERVIEW TRANSCRIPTS (CONT.)

Sarah Kaye Interview (Continued)

“What programs does OPICA have for members with memory loss?”
KAYE: The main day program is a seven-hour day and people come to anywhere between one and five days a week. During that time, we offer what we call cognitive stimulation, which is a series of brain exercises and they're usually focused on a theme, like current events or a holiday that's coming around. We do chair exercises in the morning and then we do yoga or Tai Chi in the afternoon. OPICA also has a really strong art program, whether it's more of a therapeutic art or art as an activity. We have live music a few days a week. All of these activities are happening in this main room, but we also have these side rooms, and those are for breakout groups. Those groups are for people who are a little bit higher functioning and can do more one-on-one interaction.

“What are the main goals of this type of programming?”
KAYE: The main goal is to provide a safe and dignified place for people who are struggling with memory loss. A place where they can hopefully maintain their level of cognition, but also avoid residential care. This is what we call an “Aging in Place” model where we want people to be able to stay at home as long as possible. So that's one goal, and the other goal is to support the family caregiver through educational classes and support groups.

“Do you see any gaps that need to be addressed by greater society in terms of geriatric care?”
KAYE: Yes. First, it's very, very expensive to get old. We all want to do it, but it's very costly and our society doesn't really invest in older adults. You often end up having to pay out of pocket for day care and for private health in the home. The cost of residential care is exorbitant, the cost of skilled nursing exorbitant, and Medicare could probably be covering more of those things. Another gap could be addressed by community education. We don't know a lot about older adults, and it would be great if we could invest more in that.