The Myth of Historical Bio-Based Plastics:
Early Bio-Based Plastics Were Neither Clean Nor Green and Hold Lessons for Today

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Edited by Brent Grocholski

*_Science_ Perspectives are peer-reviewed; they have a maximum length of 1500 words and allow for no more than 15 references. However, far more resources and experts were consulted in the preparation of this manuscript, which I've listed here.

I'd like to thank Martin Wagner, Anja Krieger, Matthew Combs, Toulouse-Antonin Roy, Cecil Howell, Bathsheba Demuth, Jessica J. Lee, Susan Morris, Joris Mercelis and the anonymous peer-reviewers for helpful advice, feedback and for general correspondence. Additional thanks to the archivists at multiple institutions, including the University of Washington, the Hagley Library and Museum, the Science History Institute, West Virginia State Archives, and the South Charleston Interpretive Center.

Additional archival work on the development of early petrochemicals and petrochemical plastics can be found in another essay, Upriver, published in the Summer 2021 issue of Orion Magazine. Primary (archival) and secondary sources are listed here:

https://static1.squarespace.com/static/5703f76762cd94e407457a23/t/60afd1055192ed77a7966ff3/1622135045421/Upriver+Orion+Summer+2021+Resources.pdf

Image: Rebecca Altman, 2018, Somerville, MA (along Mass Ave to Davis Sq. bike path)

Primary and Secondary Sources Consulted by Topic

On terminology, definition of bioplastics, distinction between biobased, biodegradable and bioplastics:

Scott Lambert and Martin Wagner. 2017. Environmental performance of bio-based and biodegradable plastics: the road ahead. *Chem Soc Rev*, 46, 6855-6871.

For a journalistic overview, see Anja Krieger. 2019. Are Bioplastics a Better Environmental Choice? *Ensia*. Available at: https://ensia.com/features/bioplastics-bio-based-biodegradable-environment/

General sources on 19th and early 20th century plastics, including early generation bio-based plastics:

Jeffrey Meikle. 1997. *American Plastic: A Cultural History.* New Brunswick, NJ: Rutgers University Press.

Ken Geiser. 2001. *Material Matter*. Cambridge, MA: MIT Press.

M. Kaufman. 1963. *The First Century of Plastics: Celluloid and Its Impacts*. The Plastics & Rubber Institute, London, UK.

Strom, E. T.; Rasmussen, S. C., eds. 2011. *100+ Years of Plastics. Leo Baekeland and Beyond.* ACS Symposium Series, American Chemical Society: Washington, D.C.

Peter J. T. Morris. 1986. *Polymer Pioneers: A Popular History of the Science and Technology of Large Molecules.* Center for History of Chemistry: Philadelphia. PA.

Peter H. Spitz. 1987. *Petrochemicals: The Rise of an Industry.* John Wiley and Sons: New York.

Seth Rasmussen. 2018. Revisiting the Early History of Synthetic Polymers: Critiques and New Insights. *Ambix* 65(4), 356-372.

Kathryn Steen (2014) *The American Synthetic Organic Chemicals Industry, War and Politics, 1910-1930.* (University of North Carolina Press).

Center for International Environmental Law. 2017. Fueling Plastics. (4-Part Series). Available at: https://www.ciel.org/reports/fuelingplastics/.

On Hard Rubber:

John Tully. 2011. *The Devil's Milk: A Social History of Rubber.* New York: Monthly Review Press.

A. Hochschild, *King Leopold's Ghost: A Story of Greed, Terror and Heroism in Colonial Africa* (Houghton Mifflin, New York, 1998).

Jeffrey Meikle. 1997. *American Plastic: A Cultural History.* New Brunswick, NJ: Rutgers University Press.

Paul Blanc. 2016. *Fake Silk: The Lethal History of Viscose Rayon.* New Haven: Yale University Press.

On Gutta-Percha, see:

The Forest Research Institute of Malaysia. 2018. Gutta Percha, The Untold Story. Published April 10, 2018. Available at: https://www.frim.gov.my/gutta-percha-the-untold-story/ (Last accessed 11 March 2021).

Helen Godfrey. 2018. *Submarine Telegraphy and the Hunt for Gutta Percha: Challenge and Opportunity in Global Trade.* (Boston: Brill).

Bruce Hunt (2021) *Imperial Science: Cable Telegraphy and Electrical Physics in the Victorian British Empire.* Cambridge University Press. Also: Hunt (1998) Insulation for an Empire: Gutta-Percha and the Development of Electrical Measurement in Victorian Britain. In Frank A.J.L. James, ed. *Semaphores to Short Waves* (Royal Society of Arts: London).

John Tully. 2011. *The Devil's Milk: A Social History of Rubber.* New York: Monthly Review Press. And: Tully (2009) A Victorian Ecological Disaster: Imperialism, the Telegraph and Gutta-Percha. *Journal of World History* 20(4): 559-579.

Joon Ian Wong. (2016) The story of the humble latex, which laid the foundation for the global web. *Quartz*. Available at: https://qz.com/785119/the-forgotten-tropical-tree-sap-that-set-off-a-victorian-tech-boom-and-gave-us-global-telecommunications/

Re: Celluloid, in general, including factory hazards:

Robert Friedel. 1983. *Pioneer Plastic: The Making and Selling of Celluloid.* Madison, WI: University of Wisconsin Press and

Jeffrey Meikle. 1997. *American Plastic: A Cultural History*. New Brunswick, NJ: Rutgers University Press.

M. Kaufman (1963) *The First Century of Plastics: Celluloid and Its Sequel.* Published by the Plastics and Rubber Institute (London).

"Catastrophe: Celluloid Factory." *Time*, 6/19/1933.

"The Newark Celluloid Fire." 1880. *New York Times*. 1/7/1880, p. 8

"Carry Large Lines on New Celluloid Plant: Previous Experience Does not Deter Companies from Accepting Risk. The Standard. September 16, 1904. p. 235.

"The Dangers of Celluloid." 1897. Le Petit Journal. 16 May 1987.

William Haynes. 1953. *Cellulose The Chemical The Grows*. Doubleday & Co., New York.

Masselon, Roberts and Cillard. Herbert F. Hodgson, trans. 1912. *Celluloid: Its Manufacture, Applications and Substitutes.* Charles Griffin & Co., London.

Edward C. Worden. 1911. The Nitrocellulose Industry, Vol 1 & 2. Constable & Co., Ltd: London.

On the limited extent to which Celluloid replaced (v. imitated) natural materials (such as ivory, tortoise shell):

Jeffrey Meikle. 1997. *American Plastic: A Cultural History*. New Brunswick, NJ: Rutgers University Press.

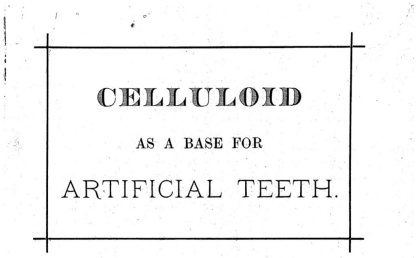
But most importantly, see Robert Friedel. 1983. *Pioneer Plastic: The Making and Selling of Celluloid.* Madison, WI: University of Wisconsin Press. T

Note: there are multiple parts to his argument worth spending time with, and another aspect brought to light more recently by scholars focused on the camphor trade (see below).

1. Celluloid could imitate natural materials like ivory or horn or tortoise shell, which was a selling point, used for marketing, though it was also a selling point that these materials could conserve said resources, an idea promoted by the companies and which has been perpetuated into today.

See both Friedel and Meikle on this. But also as an example,consider this corporate pamphlet as an example of how the celluloid industry talked about its products vis-a-vis natural resources.

Celluloid Manufacturing Company. 1878. Celluloid as a base for artificial teeth. Pamphlet. Published by the Celluloid Manufacturing Company, New York. Housed at the University of Michigan. Dental Historic Collection. See text on page 4. Available here: https://quod.lib.umich.edu/d/dentalj/2071181.0013.001/84?node=2071181.0013.001:6&view=pdf&size=100


CELLULOID
AS A BASE FOR
ARTIFICIAL TEETH.

graphs like a varnish. Emery and corundum wheels of great strength are also made of it. For a large number of articles usually made of ivory or hard rubber it is superior to either, its strength by actual tests being three times that of rubber. Thus, as petroleum came to the relief of the whale, has celluloid given the elephant, the tortoise, and the coral insect a respite in their native haunts; and it will no longer be necessary to ransack the earth in pursuit of substances which are constantly growing scarcer. In fact, like the fabled Proteus, celluloid appears in a thousand forms, and in all it is alike beautiful, strong, and durable.

As now manufactured, the material is all of the same quality, differing only in regard to colors or pigments, which, as before stated, can be added to produce any desired shade.

The extent that celluloid and other early plastics spared ivory or similar resources, is worth more careful investigation, and moreover, problematizing. Friedel digs into this, and so I highly recommend his work. I rely on his book as a secondary source, though I have not yet consulted his (and other) primary sources myself. The sociologist Richard York similarly dismantles a parallel historical myth about how oil didn't rescue the whale either. See: Richard York. 2017. Why Petroleum Did Not Save the Whales. *Socius*. (3): 1-13.

2. There may have been a perception of a natural resource shortages at the time, and in the case of ivory, that perception, notes Friedel, was enough to spur Celluloid R&D, already in the works, especially in the UK, under the name Parkesine, for example. (See: M. Kaufman. 1963. *The First Century of Plastics: Celluloid and Its Impacts*. The Plastics & Rubber Institute, London, UK.) And there is an idea circulating in popular media/the popular imagination that the desire to replace seemingly increasingly scarce and costly ivory in the billiard industry launched society toward plastics. But Friedel speaks directly to this idea, and suggests there is more to be understood than the way popular histories tend to reduce the issue. The exacting specifications required of raw ivory were hard to meet. The ivory needed to be uniform to create a balanced ball, and most ivory wasn't that way, making the industry hard to grow and scale, absent such uniformity. This, Friedel says, is better interpreted as a billard ball problem more so than an ivory supply problem. Despite celluloid, the ivory trade continued to flourish, meaning decimate the elephant population. He tracks market data to show how ivory use increased over the lifespan of celluloid and well into the 20th century.

3. Celluloid was in the end only a modest commercial product (again, see data in Friedel) UNTIL it found its signature use in film photography and cineamatory, which is where celluloid made the biggest impact. In this use, its expanding production didn't compete with or even replace the kinds of natural resources we often read about in association with celluloid.

4. Lastly, what's often underappreciated is the extent to which celluloid upped the demand on camphor, another natural resource, a forest product. As discussed in the perspective and in many of the citations that follow, celluloid (because of camphor) was of great detriment to the health and well-being of the environment and those communities who lived with and among the camphor forests particularly of Taiwan.

On camphor and celluloid:

"Old camphor kingdom comes alive." July 2, 2010. *Taiwan Today.* Available at: https://taiwantoday.tw/news.php?unit=18,23,45,18&post=24403

For images, video, other curated materials via the National Taiwan Museum, especially re: the Taiwan Provincial Camphor Refinery, e.g.,. https://www.ntm.gov.tw/en/content_174.html

Ch'en, Kuo-Tung [Chen Guodong]. 1998/2009. "Nonreclamation Deforestation in Taiwan, c. 1600-1976." In Mark Elvin and Liu Ts'ui-jung, eds. *Sediments of Time: Environment and Society in Chinese History*. Cambridge: Cambridge University Press: 693-727.

And Liu Ts'ui-jung [Cuirong Lio]. 1998/2009. "Han Migration and the Settlement of Taiwan." In Mark Elvin and Liu Ts'ui-jung, eds. *Sediments of Time: Environment and Society in Chinese History*. Cambridge: Cambridge University Press: 165-99.

Matthew Combs. 2018. *Camphor, a Plastic History: China, Taiwan and Celluloid, 1869-1937.* Dissertation. University of California, Irvine.

Antonio Tavare. 2004. *Crystals from the Savage Forest: Imperialism and Capitalism in the Taiwan Camphor Industry, 1800-1945.* Princeton.

Toulouse-Antonin Roy. 2019. 'The Camphor Question Is in Reality the Savage Question': Indigenous Pacification and the Transition to Capitalism in the Taiwan Borderlands (1895-1915). In *Critical Historical Studies*. Vol 126-158, p. 126-7. Also, A.H. Roy. 2020. War in the Camphor Zone: Indigenous Resistance to Colonial Capitalism in Upland Taiwan, 1895-1915. Japan Forum 0(0): 1-22.

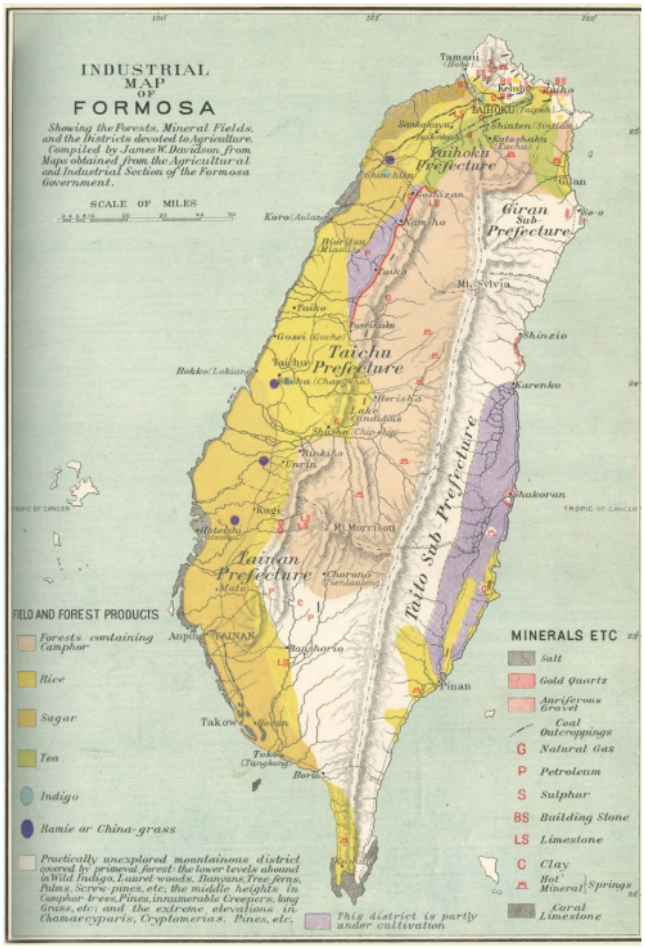
Pei-Hsi Lin. 2016. Firearms, Technology and Culture: Resistance of Taiwanese Indigenes to Chinese, European and Japanese Encroachment in a Global Context circa 1860-1914. Dissertation. Nottingham Trent University, UK.

Jeffrey Meikle. 1997. American Plastics: A Cultural History. New Jersey: Rutgers University Press.

Edward C. Worden. 1911. The Nitrocellulose Industry, Vol 1 & 2. Constable & Co., Ltd: London.

Ian Inkster. 2018. Indigenous Resistance and the Technological Imperative: From Chemistry in Birmingham to Camphor Wars in Formosa (Taiwan): 1860s-1914. *Palgrave Studies in Economic History*, in: David Pretel & Lino Camprubí (ed.), *Technology and Globalisation*, chapter 3, pages 41-74, Palgrave Macmillan.

Ronald C. Po. 2020. The Camphor War of 1868: Anglo-Chinese Relations and Imperial Realignments within East Asia. *The English Historical Review*, Volume 135, Issue 577, December 2020, Pages 1461–1487, https://doi.org/10.1093/ehr/ceaa313



Camphor forests shaded in pinky-brown. Source: James Wheeler Davidson, The Island of Formosa, Past and Present: History, People, Resources, and Commercial Prospects. Tea, Camphor, Sugar, Gold, Coal, Sulphur, Economical Plants, and Other Productions (London: Macmillan, 1903), 370. In Pei-Hsi Lin, 2016 dissertation, p. 80.

On the viscose rayon, cellophane industry, and on carbon disulfide in the viscose process:

Paul Blanc. 2016. *Fake Silk: The Lethal History of Viscose Rayon.* New Haven: Yale University Press.

D.C. Coleman. 1969. *Courtaulds: An Economic and Social History, volume II. Rayon*. Oxford University Press: Oxford, UK.

United Nations Environmental Programme, the International Labour Organization and the World Health Organization. 2002. *Concise International Chemical Assessment Document 46: Carbon Disulfide*. World Health Organization, Geneva. Available at: https://www.who.int/ipcs/publications/cicad/cicad46_rev_1.pdf

Shen, L., Worrell, E., & Patel, M. K. (2010). Environmental impact assessment of man-made cellulose fibres. Resources, *Conservation and Recycling*, 55(2), 260–274. doi:10.1016/j.resconrec.2010.10.001

Just About All About Cellophane. 1932. *Fortune*. February 1932: 74-75, 102.

Also, I won't list them here, but there are a number of resources on the viscose cellophane process DuPont used, for example, via The Hagley Museum and Library, particular in a number of early issues of DuPont Magazine.: https://www.hagley.org/

Tongass National Forest, SE Alaska, and viscose rayon pulp mills

Tongass Timber Act, 1947: United States, joint resolution, 80th Cong., 1st sess., H.J. Res. 205, and S.J. Res. 118.House Committee on Agriculture, Authorizing the Secretary of Agriculture to Sell Timber within the Tongass National Forest, 80th Cong., 1st sess., 1947; Senate Committee on Public Lands, Authorizing the Secretary to Agriculture to Sell Timber within the Tongass National Forest, 80th Congress, 1st session, 1947. Also see: 5 House Committee on Agriculture, Hearings on H.J. Res. 205.

Also, per Haycox (1990) see resources gathered within James Curry Papers via the Smithsonian; Curry served as attorney for the Tlingit, Haida and other Alaska Native villages, organized as the Alaska Native Brotherhood.

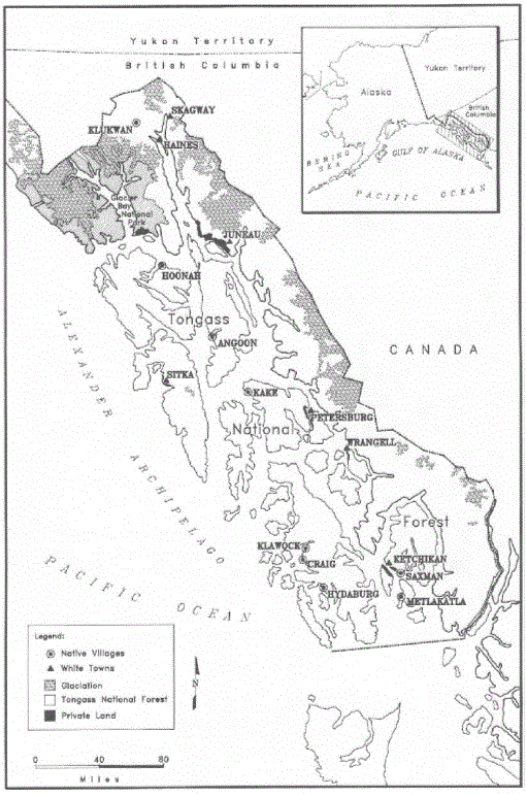


Image source: Hayxoc, 1990 (Western Historical Quarterly)

Hal Bernton. 1998. “Pulp Gold: Alaska's Bitter Harvest: To Cut or Not to Cut The Great Tongass Forest, There are No Easy Answers.” *The Seattle Times*. 28 April 1996.

K. Durban. 2005. *Tongass: Pulp Politics and the Fight for the Alaska Rain Forest* (University of Oregon Press, Corvallis, OR, 2nd ed).

K. Durban 1996. “End of an Era: Southeast Alaska Braces for Life after the Pulp Mills.” *Cascadia Times*. December 1996.

"Alaska's First Big Industrial Boom Under way in Rush for 'Green Gold." *Ponca City (OK) News*. December 8, 1953. p. 2

James Mackovjak. 2010. *Tongass Timber: A History of Logging and Timber Utilization in Southeast Alaska.* Durham, NC: Forest History Society. P. 57.

Ketchikan Co. Buys Timber in Alaska. *New York Times*. July 28, 1951. P. 24-25

Tongass National Forest" hearing before the Committee on Resources, House of Representatives, One Hundred Fourth Congress, second session, on H.R. 2413, a bill to transfer the Tongass National Forest to the state of Alaska, February 15, 1996--Wrangell, AK, February 16, 1996--Ketchikan, AK, United States Congress, House Committee on Resources. Available via: https://archive.org/details/tongassnationalf00unit

Puget Sound Pulp and Timber Co., 1953. "The Ketchikan Project." Annual Report. (Archives Foster Business Library, U of Washington).

"Territory to get pulp mill: contract signed for huge sale of timber in tongass forests. *Fairbanks Daily News-Miner*. 7/27/1951.

"Forester Hails Alaska Pulp Future. July 14, 1954. *Fairbanks Daily News-Miner*. p. 7

"Alaska's First Major Year Around Industrial Operation." July 14, 1954. *Fairbanks Daily News-Miner*. p. 7

Stephen W. Haycox. 1990. Economic Development and Indian Land Rights in Modern Alaska: The 1947 Tongass Timber Act. *Western Historical Quarterly.* Vol 21(1), 20-46.

US Forest Service. 1949. Technical Note Number 217: The Manufacture of Rayon. June 1949. Forest Product Laboratory, Madison, WI. Available at: https://www.fpl.fs.fed.us/documnts/fpltn/fpltn-217-1949.pdf Last accessed April 9, 2021.

Stephen Haycox. 2002. Frigid Embrace: Politics, Economics and Environment In Alaska. University of Oregon Press. Corvallis, OR. Chapter:3. "At Any Cost: Pioneer Alaska and Economic Development."

Baumgarte, Bridget Lee, "Alaska Natives And The Power Of Perseverance: The Fight For Sovereignty And Land Claims In Southeast Alaska, 1912-1947" (2015). UNLV Dissertation. http://dx.doi.org/10.34917/7777294

The Sword and the Shield The Defense of Alaska Aboriginal Claims by the Alaska Native Brotherhood By Peter M. Metcalfe. 2010. Tlingit Readers. Available at: https://kfsk-org.s3.amazonaws.com/wp-content/uploads/2018/06/The-Sword-and-Shield-by-Peter-M.-Metcalfe.pdf

Cecil Howell. 2021. Forest Cartography. Orion Magazine. Spring 2021 issue. (Print only.) Portion visible here: https://cecilhowell.com/An-Atlas-Ardift

On carbon disulfide continued use in modern viscose/rayon production, even if sourced for FSC-certified trees, see Paul Blanc. 2016. *Fake Silk: The Lethal History of Viscose Rayon.* New Haven: Yale University Press.

Changing Markets Foundation. 2017. *Dirty fashion: How pollution in the textiles supply chain is making viscose toxic* (2017). Available at: http://changingmarkets.org/wp-content/uploads/2017/06/ENGLISH_DIRTY_FASHION_EX_SUMMARY_FINAL_SPREAD_PAGE_WEB.pdf

On Bakelite and the emergence of petrochemical-based plastics:

For more on the multiple routes to formaldehyde through wood chemistry or via carbon monoxide, see U.S. Tariff Commission. 1938. *Synthetic Resins and Their Raw Materials*, *Report No. 31*, Second Series. p. 8.

Joris Mercelis. 2020. *Beyond Bakelite: Leo Baekeland and the Business of Science and Invention.* MIT Press: Cambridge, MA.

Jeffrey Meikle (1997) *American Plastic: A Cultural History* (Rutgers University Press).

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Wiebe E. Bijker. 1997. *Of Bicycles, Bakelites and Bulbs: Toward a Theory of Sociotechnical Change*. MIT Press.

M. Kaufman. 1963. *The First Century of Plastics: Celluloid and Its Sequel.* Published by the Plastics and Rubber Institute (London).

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American Chemical Society. 1993. The Bakelizer, commemorative pamphlet published by the National Historic Chemical Landmarks Program.

William Haynes. (1945-1954) *American Chemical Industry*, Volumes 1-6 (Van Nostrand).

Edwin E Slosson. 1917. Creative Chemistry. *The Independent* December 22, 1917, p. 557-565.

On chemurgy, or farm-ag-based plastics, see:

Mark R. Finlay. 2004. "Old Efforts at New Uses: A Brief History of Chemurgy and the American Search for Biobased Materials." *Journal of Industrial Ecology.* (7): 3-4: 33-46. Also.

Finlay. 2013. “Chemurgy and the Land Grant Colleges: Bridging Agriculture, Industry and Chemistry in the 1930s and Beyond.” *Bull. Hist. Chem*., Vol 38 (2).

Quentin R. Skrabec (2013) *The Green Vision of Henry Ford and George Washington Carver: Two Collaborators in the Cause of Clean Industry.* (McFarland and Company, Jefferson, NC).

William J. Hale. 1934. *The Farm Chemurgic*. Boston: Stratford Company. Available via HathiTrust: https://hdl.handle.net/2027/mdp.39015063567278

E.F. Lougee (former Editor of *Modern Plastics)*. 1943. *Plastics from Far and Forest.* New York: Plastics Institute.

“Automobiles and Soy Beans: An Interview by Arthur Van Vlissingen, Jr. with Henry Ford.” 1933. *Rotarian Magazine.* September 1933. Available via the University of Chicago library. https://www.lib.uchicago.edu/ead/pdf/crms226-0012-010a.pdf

"Ford Builds a Plastic AutoBody." *Modern Plastics*. September, 1941.

“Soybean Plastic”. 1938. *Science* 1/14/1938 87(2246): Supplement, p. 8, 10.

A.C. Beckel, G.H. Brother and L.L. McKinney. 1938. Protein Plastics from Soybean Products. *Ind Eng Chem* 30 (4): 436-440.

“Operating Floor of Wood Distillation Division, Ford Iron Mountain Plant, Iron Mountain, MI, 1935. Available at: https://www.thehenryford.org/collections-and-research/digital-collections/artifact/366508/ Last accessed March 12, 2021.

On the environmental complexity of modern plastics, including bioplastics, bio-based plastics and the insufficiency of an ahistorical technological fix (merely swapping bio-based carbon for fossil carbon) to plastics’ environmental, social, health problems:

Max Liboiron. 2021. *Pollution is Colonialism*. Duke University Press.

Narancic, Tanja; Cerrone, Federico; Beagan, Niall; O’Connor, Kevin E. 2020. Recent Advances in Bioplastics: Application and Biodegradation. *Polymers* 12, no. 4: 920. https://doi.org/10.3390/polym12040920

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Chem Soc Rev, 46, 6855-6871.

Stephanie B. Borrelle, Chelsea M. Rochman, Max Liboiron, Alexander L. Bond, Amy Lusher, Hillary Bradshaw, Jennifer F. Provencher. 2017. An international policy to stem plastic pollution. *Proceedings of the National Academy of Sciences* Sep 2017, 114 (38) 9994-9997; DOI: 10.1073/pnas.1714450114

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