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Elemental sodium is a silvery white metal, soft enough to be cut with a knife. The element is so highly reactive that even though it is the sixth most common element on Earth, it does not occur in nature in its pure form, but only in compounds. For it to be in its pure, elemental form, it has to be synthetically prepared and must be kept under specific conditions. One way to stabilise elemental sodium is to keep it in oil. In a glass jar filled with oil, the elemental sodium looks like small, graphite coloured stones.

When I was six years old and needed an empty jar for a game I was playing, one such jar filled with elemental sodium covered in paraffin oil stood at an accessible height in our kitchen cabinet. My uncle, who works as a chemist, had left it there. Not overly interested in the little grey stones but in need of the jar, I proceeded to pour them into the sink, which had water drops all over it, as sinks normally do. The little grey stones, about six in total, each about 2 × 2 centimetres, quickly started to hiss and spark; after seconds, little flames crawled around the stones and seemed to only worsen the hissing and the sparking and the blazing. Scared of the fire, I turned on the tap as vehemently as I could. Every child knows water extinguishes fire.

Elemental sodium is highly reactive with other elements, including cold water. When a tiny amount, approximately the size of a finger nail, of elemental sodium (Na) is dropped in a body of water (H_2O), the silvery metal will quickly form a hissing ball of orange fire whizzing around on the water surface, until it eventually reacts to liquid sodium hydroxide (NaOH) and gaseous hydrogen (H_2).

The silvery chunks in the wet sink were bigger than a fingernail; too big to just fizz around and dissolve. The heat generated through the reaction with water had accelerated the reaction further and created tiny cracks through which water permeated the solid metal, accelerating the reaction further. With a deafening bang, the orange flaring and still-hissing chunks of elemental sodium exploded in the sink. It was a relatively small explosion, but a very big one for a kitchen sink, a six-year-old, and a cat. The sink needed replacement, the cat jumped off to live in the garden for two days in protest, and I had mild tinnitus and a t-shirt with burn holes. Thankfully, I also had an adequate escape reflex which, when the flames got out of hand, spared me from any significant physical damage.

Sodium compounds can be found in nature as different salts, such as sodium chloride (NaCl) — table salt — or sodium nitrate ($NaNO_3$), also known as Chile saltpetre. Large deposits of Chile saltpetre were traditionally mined and used as fertiliser in the extremely dry environment of the Atacama Desert in northern Chile long before European settlers and colonists arrived. Over the course of the 19th century, Chile saltpetre was intensively mined, extracted from its lithic deposits traditionally called caliche and subsequently exported to Europe and North America by the ton. All forms of saltpetre are an excellent fertiliser due to the mineral's high nitrogen content. In other regions of the world, the salt can also be found and is referred to as nitre, potassium nitrate (KNO_3), or simply saltpetre to distinguish it from the unique chemical composition in the Chilean deposits. Both saltpetre compounds suffice as a base for fertiliser or explosives.[1]

The increasing population density in 19th century Europe demanded a shift in agriculture and food production. Compost, animal and human manure were no longer sufficient as fertilisers, as they couldn't keep up with the rising need for grains and bread. In a public speech in 1898, the British chemist William Crookes addressed a problem lingering over the European people relying on grains and bread as a main source of nutrition: that of a population whose growth would outstrip agricultural capabilities to provide food. Crookes expected a major food crisis sometime in the 1930s, and suspected that traditional methods of crop rotation and reusing soil and fertilising it with manure, Chile Saltpetre and guano were simply not sufficient to provide the soil with enough nitrogen to support plant growth.[2] Moreover, the supply of Chile saltpetre from overseas would eventually become depleted. With all traditional methods of soil remineralisation exhausted, eventually, after years of intensive farming, the soil would become weak and tired. Farmers would have to move on to the next patch of land with fresh, virgin soil. And consequently one of the resources that would become sparse, according to Crookes, was fresh land itself. The world was mapped: the wide fertile plains of America were already extensively farmed for grains and corn, Europe did not have enough cultivable surface, and the options to find new soil were limited.[3] Even the powerful guano from South America — dry seabird and bat manure which is rich in nitrogen, an element essential for plant growth — was available only in finite amounts. The commerce with guano, this dusty, toxic, white gold massively fueled the colonisation and exploitation of remote bird islands, generated relative wealth and stability for Peru, and created dependence on the import of the material for European states.

1) *Chile Saltpetre*, Vedantu, 2021, `https://www.vedantu.com/chemistry/chile-saltpetre`, last accessed July 23, 2021.
2) John Hyde, *America and the Wheat Problem*, in "The North American Review", Vol. 168, No. 507, 1899, pp. 191 – 205, JSTOR, `www.jstor.org/stable/25119143`, last accessed June 1, 2021.
3) Ibid.

Both saltpetre and guano are sources of fixed nitrogen and therefore excellent for the production of fertiliser. Nitrogen (N), however, is not a rare element: we are surrounded at all times by atmospheric nitrogen (N_2), which makes up 80% of the air we breathe. The problem is access to fixed nitrogen, meaning nitrogen in a compound with another element in a state in which it is accessible to plants and other living beings. Examples of such fixed nitrogen are forms of saltpetre, in compounds with sodium or potassium. Likewise, guano contains high quantities of fixed nitrogen in the form of ammonia and nitrate. The idea of turning a finite resource into an infinitely available, renewable resource was, at the beginning of the 20th century, a significant scientific challenge which fueled the fantasies of politicians and scientists alike. Limited availability can be a daunting problem which has not stopped generations of humans from exploiting and becoming dependent on limited resources such as fossil fuels. Bread, respectively wheat or other grains, is in itself an infinite, renewable resource. Assuming the weather conditions are favorable, grains can be grown each year anew and, consequently, bread can be (re)produced. However, there was an apparent limit to agricultural growth, as William Crookes pointed out, and simultaneously no end in sight to population growth. Only at the end of the 19th century, when it became apparent to Crookes that current levels of agriculture would not be sufficient to feed the future population of Earth, did bread momentarily seem to be a finite resource. At the time Crooke gave his speech, the Earth's population was estimated to be around 1.6 billion, and nobody could have predicted the exponential growth that would follow over the course of the next century. From Crookes' lifetime to today, the Earth's population has increased sevenfold.[4]

Synthetic ammonia — fixed nitrogen from the air — was a capitalist dream, a scientific milestone, a solution to an impending food crisis and the fuel for devastating wars: the ability to sythesise ammonia from the air meant unlimited access to highly sought after fertilisers and explosives. Within the scientific community, the problem of synthesizing ammonia was well-known for years and yet no one had found a sufficiently efficient method. However, after working on this very problem for decades, German chemist Fritz Haber finally developed a method using high pressure and temperature control to produce ammonia from air in his laboratory in 1909. The so-called Haber process won him a Nobel Prize in chemistry and marked the beginning of a large-scale chemical industry in Germany. Carl Bosch, a fellow chemist and engineer, went on to develop the Haber process to be used on a larger scale, and in 1913, the first industrial sized Haber-Bosch plant began operations.[5] The ability to produce fixed nitrogen meant not only independence from imported sources of nitre or saltpetre but also unlimited access to formerly finite resources such as fertilisers and explosives. With the start of the First World War, the synthetisation of ammonia gained even more importance when Germany's access to South American saltpetre came to a halt through a naval blockade intended to shut off the German supply of explosives. Shortly after, the chemical group, BASF, holding the patent to the Haber-Bosch process, received monetary support from the government to scale up the production of ammonia to a maximum. Subsequently, the city-sized factory near Oppau was built. After extensive bombardment from the air by the French, an even larger factory was built in the German city Leuna, further to the East — and, therefore, further away from France.[6]

Those city-sized factories, equipped with monstrous machines, resemble real-life manifestations of the Heart Machine in Fritz Lang's film *Metropolis*. Representing a border within the class system, the Heart Machine keeps the city going with its never-ending grinding labour, pumping life into the city's electric system, providing light and enabling the idle life of a privileged upper class who loiter in the city's pleasure gardens. This machine is fueled by human labour which is seemingly indefinitely available. When a number of the workers die or have to be carried away injured as a result of an accident, they are immediately replaced by the next load of workers filling in the empty spaces. Similarly, in Oppau and Leuna, human labour must have seemed like a renewable resource. At the time, half the workforce was made up of a constant flow of prisoners and forced labourers. The machines in the belly of the big factory were complicated, and processes were broken up into small tasks performed by the workers. From an outsider's perspective, it must have been nearly impossible to understand the synergy of the individual parts. After the First World War, delegations from the victorious France and Britain were given tours through the factory. But since workers were instructed by their superiors not to operate the machines in front of the French and British delegation in order to safeguard the industrial secret, the particulars of synthetic ammonia and fixed nitrogen stayed in German hands, at least for the time being.[7]

The Haber-Bosch process, fixing nitrogen from the air, was developed to secure bread for the generations to come. But long before their use as fertiliser was discovered, different nitrogen-rich compounds found in nature were known to have explosive properties and were used as such in China and India, which possessed big deposits of naturally-occurring saltpetre. Only with the discovery of Chilean saltpetre was the material also discovered to be an excellent fertiliser. Thus, the fixed nitrogen products leaving the factories of Oppau and Leuna were simultaneously life-giving and lethal. In April of 1921, approximately 4,500 tonnes of ammonium nitrate fertiliser exploded in a warehouse within the factory in Oppau. The ammonium nitrate stored there was mixed in equal parts with another salt, ammonium sulfate, to eliminate the explosive properties of the

4) *World Population by Year*, Worldometers, https://www.worldometers.info/world-population/world-population-by-year/, last accessed July 23, 2021.
5) Sivaraj Ramaseshan, *The Amoral Scientist — Notes on the Life of Fritz Haber*, in "Current Science", Vol. 77, No. 8, 1999, JSTOR, www.jstor.org/stable/24103592, last accessed June 1, 2021.
6) Thomas Hager, *The Alchemy of Air: A Jewish Genius, a Doomed Tycoon, and the Scientific Discovery that Fed the World but Fueled the Rise of Hitler*, Broadway Books, New York City, 2008.
7) Ibid.

nitrate fertiliser. Nevertheless, the ratio of the two salts must have varied throughout the warehouse, making parts of the salt mountain more explosive than others. The incident killed between 500 and 600 people, and was determined to have been an accident.[8] It was a humbling moment for the men who had supposedly triumphed over nature by synthesising a finite natural resource. The tragedy would repeat itself on 4th August 2020, when a warehouse full of the same material, ammonium nitrate, violently exploded in the port of Beirut, killing hundreds and destroying a large part of the surrounding city. Although a potentially benign fertiliser, this particular batch, which was stored under precarious conditions for six years in the port, was actually meant to be processed by an explosives manufacturing company for mining in Mozambique.[9]

The dark side of synthetic nitrogen compounds can be seen in its potential as an indefinite access point to explosives and gunpowder. Both World Wars were fueled by explosives manufactured at Oppau and Leuna as well as synthetic gasoline, a later discovery by the same company, BASF. Similar to the homemade explosives, synthetic gasoline was meant to free Germany from depending on the oil market in the Middle East and North America. As with saltpetre, natural oil reserves were also discovered, over time, to be a finite resource. Producing synthetic gasoline was meant to lift this limitation. Ironically, synthetic gasoline is made from coal, which was at the time plentiful in Germany but is no less a finite resource than oil or naturally-occurring saltpetre. Burning through the amounts of fossil fuel that have been extracted from the Earth since the beginning of their industrial use has already altered the Earth's atmospheric compositions and thrown natural climate cycles out of balance. The further development of this offset and its effects on the climate can be predicted in more or less dystopian future scenarios, but remains mostly obscure to contemporary humans, since the long-term consequences stretch into the deep future of 100,000 years.[10] Similarly, saturating the Earth with large amounts of synthetic fixed nitrogen is tantamount to an open-ended experiment on a global scale. Gaining access to more fixed nitrogen than would naturally be available means that more plant life, and therefore animal and human life, can be sustained. Runoff fertiliser from large-scale agricultural fields often ends up in bodies of water in which, as a consequence, populations of algae explode and crowd out other species.[11]

The story of fixed nitrogen is a tale of shortage and excess, of renewability and finitude. We are still faced with these issues today: one need only think about fossil fuels, climate change, and the many humanitarian crises caused by food shortages that have occurred in the past few decades alone. This shortage is often due not to a lack of sufficient food being produced, but rather to problems in distributing this food equally and fairly. Under ideal circumstances of equal distribution, and without synthetic fixed nitrogen, agriculture can support around four billion people on Earth. As of June 2021, there are about 7.7 billion humans on Earth.[12] Synthetic fixed nitrogen allows for bread to be a renewable resource, by extension turning humans themselves into a regenerative resource. In *Metropolis*, Oppau, Leuna, and the wars of the 20th century and today, human labour and life seem like they can be spent and replaced. This exemplifies the brutality of the correlation between bread, nourishment, explosives, and labour. Moreover, the ongoing acceleration and growth of the global economy demands an increasingly infinite source of energy, rather than a finite one such as fossil fuels. Even if we minimise the use of fossil fuel and therefore manage to slow down the accelerating climate catastrophe caused by burning this organic matter carbonised over millions of years, it will sooner or later run dry. Sustaining more human life on Earth with naturally available resources simply requires the synthetisation of raw material. In the future, this will not only include the fixed nitrogen that ensures sustainable availability of bread, but also renewable energies such as solar, wind and hydraulic power.

The story of fixed nitrogen is also a tale of politics and logistics, neglect and greed. Today, we are still faced with the challenge of distributing food fairly in the world while big shiploads full of ammonium nitrate destined as explosives and fertilisers alike cross the oceans daily. Those ships are mainly fueled by avarice and expendable human labour. MV Rhosus, the cargo ship carrying the ammonium nitrate that would eventually explode in the port of Beirut, was abandoned by its legal owners after being deemed unseaworthy by Lebanese authorities. Left with the costly and potentially dangerous task of dealing with the explosive cargo of the ship, the Lebanese government failed to deal with the matter responsibly. As a consequence, years of neglect followed, where the ammonium nitrate was left in the warehouse until it exploded in 2020. Mass protests against negligence and corruption within the government emerged quickly after. This, of course, was not the first time that physical protest erupted as a response to a negligent governing body not meeting the basic needs and wishes of the people. Simmering dissatisfaction with the monarchy in France supposedly only discharged into the French Revolution after a particularly bad harvest and the resulting shortage of bread. Fixed nitrogen is implicit in most large-scale political and social conflicts, directly or indirectly. Sometimes it is the solution in the form of fertilizer, sometimes it acts as a trigger for dissent, and sometimes it is simple fuel for conflict in the form of explosives.

8) *The Oppau Explosion*, in "Nature", Vol. 108, No. 2713, 1921, https://doi.org/10.1038/108278a0, last accessed July 23, 2021.
9) Giorgia Guglielmi, *Why Beirut's Ammonium Nitrate Blast Was so Devastating*, Nature News, August 10, 2020, https://doi.org/10.1038/d41586-020-02361-x, last accessed July 23, 2021.
10) Curt Stager, *Deep Future*, Thomas Dunne Books, New York City, 2011.
11) *The Impacts of Nitrogen Pollution*, Soil Association, https://www.soilassociation.org/causes-campaigns/fixing-nitrogen-the-challenge-for-climate-nature-and-health/the-impacts-of-nitrogen-pollution/, last accessed June 10, 2021.
12) *World Population With and Without Synthetic Fertilizers*, Our World in Data, https://ourworldindata.org/grapher/world-population-with-and-without-fertilizer?country=~OWID_WRL, last accessed June 10, 2021.