Chapter 1

Fertilizer

FIXME First, Allison has learned she does not need a colon after FM

Here are some thoughts on expanding the introduction to the Fertilizer Chapter. This might be a good moment to discuss the multidisciplinary nature of Kontinua. In a regular science class I'm guessing you wouldn't get electricity and Fertilizer in the same textbook. Why is there a chapter on Fertilizer here? Are you introducing us to the major ways science has given us more power and allowed population to grow? Can we discuss your thoughts on why problem solvers need a basic understanding of Fertilizer and I'll write up a new introduction to this chapter based on the discussion?

What do you think about adding a conclusion that talks about the connection between fertilizer (nitrogen), dynamite and the origin of the Nobel peace prize? I know you don't want too much history and philosophy but this seems like a great moment to add a little narrative spice.

Can we work POTATOES into this chapter!?!

Chapter text starts here:

One of the biggest problems humans face is: how can we get enough food to feed everyone? In 1950, there were 2.5 billion people on the planet, and about 65% were malnourished. In 2019, there were 7.7 billion people on the planet, and only 15% are malnourished. How did crop yields increase so much? There were several factors: better crop varieties, reliable irrigation, increased mechanization, and affordable fertilizers.

When a plant grows, it takes molecules out of the soil and uses them to build proteins. It primarily needs the elements nitrogen (N), phosphorus (P), and potassium (K).

When you buy a bag of fertilizer at the store, it typically has three numbers on the front. For example, you might buy a bag of "24-22-4". This means that 24% of the mass of the bag is nitrogen, 22% is phosphorus, and 4% is potassium.

Potassium comes as potassium carbonate (K_2CO_3), potassium chloride (KCl), potassium sulfate (K_2SO_4), and potassium nitrate (KNO_3). Any blend of these chemicals is known as "potash". Potash is dug up out of mines.

Phosphorus is also mined, but is refined into phosphoric acid (H_3PO_4) before it is put into fertilizer.

Nitrogen is an especially interesting case for 2 reasons:

- Worldwide farmers apply more nitrogen to their soil than potassium or phosphorous combined.
- 78% of the air we breathe is nitrogen in the form of N_2, but neither plants nor animals can utilize nitrogen in that form.

1.1 The Nitrogen Cycle

Converting the N_2 in the air into a form that a plant can use is known as *nitrogen fixation*. For billions of years, there were only two ways that nitrogen fixation occurred on earth:

- The energy from lightning causes N_2 and H_2O to reconfigure as ammonia (NH_3) and nitrate (NO_3). This accounts for about 10% of all naturally occurring nitrogen fixation.
- Cyanobacteria are responsible for the rest. They convert N_2 into ammonia.

Let's say that you are eating soybeans. There is a cyanobacteria called *rhizobia* that has a symbiotic relationship with soybean plants. Rhizobia fixes nitrogen for the soybean plant. The soybean plant performs photosynthesis and gives sugars to the rhizobia.

The proteins in the soybeans contain nitrogen from the rhizobia. When you eat them, you use some of the nitrogen to build new proteins. You probably don't use all the nitrogen, so your cells release ammonia into your blood.

Ammonia likes to react with things, so your liver combines the ammonia with carbon dioxide to make urea ($CO(NH_2)_2$). Your kidneys take the urea out of your blood and mix it with a bunch of water and salts in your bladder. When you urinate, the urea leaves your body.

If you urinate on the ground, the nearby plants can take the nitrogen out of the urea.

When you die, the nitrogen in your proteins will return to the soil as ammonia and nitrate.

For centuries, farms got their nitrogen from urine, feces, and rotting organic material. There were two challenges with this:

- Human pathogens had to be kept away from human food.
- There was simply not enough to support 7.7 billion people.

So we had to figure out how to do nitrogen fixation at an industrial level.

1.2 The Haber-Bosch Process

During World War I, two German scientists, Fritz Haber and Carl Bosch figured out how to make ammonia from N_2 and H_2 using high temperatures and pressures. This is how nearly all nitrogen fertilizer is created today.

Where do we get the H_2? From methane (CH_4) in natural gas. Today, 3-5% of the world's natural gas production is consumed in the Haber-Bosch process.

The ammonia is converted into ammonium nitrate (NH_4NO_3) or urea before it is shipped to farms.

1.3 Other nutrients

Healthy plants require several other elements that are sometimes applied as fertilizer: calcium, magnesium, and sulfur.

Finally, tiny amounts of copper, iron, manganese, molybdenum, zinc, and boron are sometimes needed.

Appendix A

Answers to Exercises

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