**ACTIVITY: Exploring small doses**

**Activity idea**

In this activity, students explore parts per million. They dilute food colouring to help them understand how small one part per million actually is.

By the end of this activity, students should be able to:

* make a liquid measure of one part per million
* recall the meaning of the term part per million
* explain the relationship between ppm and ppb
* explain that small concentrations can be in substances without being visible
* explain the importance of being accurate when making measurements in science

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Student handout: [Diluting doses](#diluting)

**Introduction/background**

Scientists are able to measure very small quantities accurately. Read the section on parts per million in [Measuring toxicity](https://www.sciencelearn.org.nz/resources/366-measuring-toxicity). Some toxins are stated in milligrams per litre (mg/L), micrograms per gram (µ/gm) or parts per million (ppm).

This activity will help give students an understanding of how small one part per million actually is. The activity may also help students appreciate even smaller measurements such as parts per billion – one part per million is equal to 1000 parts per billion.

***Visualising parts per million and parts per billion***

Here are some ways to help students visualise the scales involved with ppm and ppb.

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| **One part per million – 1 ppm** | **One part per billion – 1 ppm** |
| 4 drops of ink in a 208-litre barrel of water | 1 drop of ink in the largest tanker truck used to carry petrol |
| 2 minutes in 2 years | 1 second in nearly 32 years |
| 1 second in 11.5 days | 1 pinch of salt in 10 tonnes of potato chips  |
| 2.5 cm in nearly 26 kilometres | 1 sheet of toilet paper in a roll that stretches from New York to London |

The article [All in the dose](https://www.sciencelearn.org.nz/resources/365-all-in-the-dose) describes how it is the dose that makes the poison – the quantity of poison taken is critical to the effects of the poison on the consumer.

In this activity, students can visualise how there can be varying amounts of toxin within a substance. A strong toxin can be diluted to the point of becoming safe. Some toxins may even become medicinal at low levels. Some toxins, however, are so toxic that they are dangerous even in parts per million or parts per billion (ppb). Tetrodotoxin is an example. It has an LD50 (lethal dose) of 0.01 ppm or 10 ppb (10 micrograms per kilogram) in mice.

In this activity, the original food colour is 1:1 concentration (100% food colouring). By using 1 drop of colour to 9 drops of water, the new solution is becomes 1:10. Each new solution is 10 times more diluted than that in the chamber before it. Chamber 3 has a 1:100 solution, chamber 4 is a 1:1000 solution, chamber 5 is a 1:10 000, chamber 6 is a 1:100 000 and chamber 7 is a 1:1 000 000 (part per million).

Students could do this activity in groups of 3–4.

**What you need (per group)**

* Copies of the student handout [Diluting doses](#diluting)
* 3 plastic cups
* 2 eye-droppers
* 1 white plastic ice-block tray
* Toothpicks or paper clips
* Food colouring
* Water
* White paper
* Copies of [All in the dose](https://www.sciencelearn.org.nz/resources/365-all-in-the-dose)
* Copies of [Measuring toxicity](https://www.sciencelearn.org.nz/resources/366-measuring-toxicity)

**What to do**

1. Hand out copies of the student handout [Diluting doses](#diluting) and discuss. Assist students to get into small groups, gather the required materials and follow the instructions.
2. Discuss the findings:
* What happened to the colour concentration as you moved through the chambers?
* Can you see food colouring in each chamber?
* Is the food colouring present in each chamber?
* If you can’t see it, does it mean none of the original substance is present? (There will still be something of the original substance left. If the food colouring was a toxin, it may now be harmless because the dose is so small. However, some toxins are so toxic that, even in these small concentrations, they may still be lethal. Tetrodotoxin is lethal (at least in mice) at 10 parts per billion – that’s like 10 grains of sugar in a billion grains of sugar!)
* Were there differences in the results between the groups?
* What might have led to the differences? (Differences in measurement.)
* Discuss how inaccurate measurements may affect the toxicity of a substance when dealing with doses such as parts per million or parts per billion of toxic substances. Medicines are sometimes made from weak doses of toxins. One of the most deadly chemical substances for humans is the toxin botulinum. The LD50 (lethal dose) for botulinum is estimated at about 0.001 µg/kg (parts per billion) in humans – oral or injection. It is used in cosmetics (Botox®) – see [Poisons and toxins](https://www.sciencelearn.org.nz/resources/364-poisons-and-toxins). Imagine if the measurements were slightly out!
1. Read and discuss the articles [All in the dose](https://www.sciencelearn.org.nz/resources/365-all-in-the-dose) and [Measuring toxicity](https://www.sciencelearn.org.nz/resources/366-measuring-toxicity).

**Optional follow-up activities**

[Detecting toxins](https://www.sciencelearn.org.nz/resources/379-detecting-toxins)**Diluting doses**

1. Half fill 2 of the 3 cups with water. Label one cup ‘clean water’. It will be your supply of clean water. Label the other cup ‘rinsing’. This is for rinsing eye-dropper 1. The third cup labelled ‘wastewater’ will hold wastewater from eye dropper 1.
2. Practise holding the eye-dropper vertically to produce drops of a uniform size.
3. Label the white plastic ice-cube tray 1–12 to be sure you are counting the segments (chambers) in order. You will use 7 of these chambers.
4. Using eye-dropper 1, place 10 drops of undiluted food colouring in chamber 1. Dispense any remaining food colouring from the eye-dropper into the wastewater cup. Draw water from the rinsing cup and dispense into the wastewater cup to rinse (you may need to do this 2–3 times). Dry the eye-dropper
5. Use eye-dropper 1 again to transfer 1 drop of the food colouring from chamber 1 to chamber 2. Return any remaining food colouring in the eye-dropper to chamber 1. Rinse the eye-dropper in the rinsing cup as before and dry.
6. Use eye-dropper 2 to add 9 drops of clean water to chamber 2. Use this eye-dropper for adding clean water to the chambers to keep contamination to a minimum. Keep it in the clean water cup. Stir the contents of chamber 2 with a toothpick or paper clip.
7. Transfer 1 drop from chamber 2 to chamber 3 using eye-dropper 1. Rinse and dry the eye-dropper. Add 9 drops of water using eye-dropper 2 to chamber 3. Stir.
8. Continue the procedure of transferring 1 drop of the solution and diluting it with 9 drops of water until 7 chambers have filled.
9. Observe the changes to the solutions in each chamber. To help visualise the colour changes, place 1 drop from each chamber onto white paper.