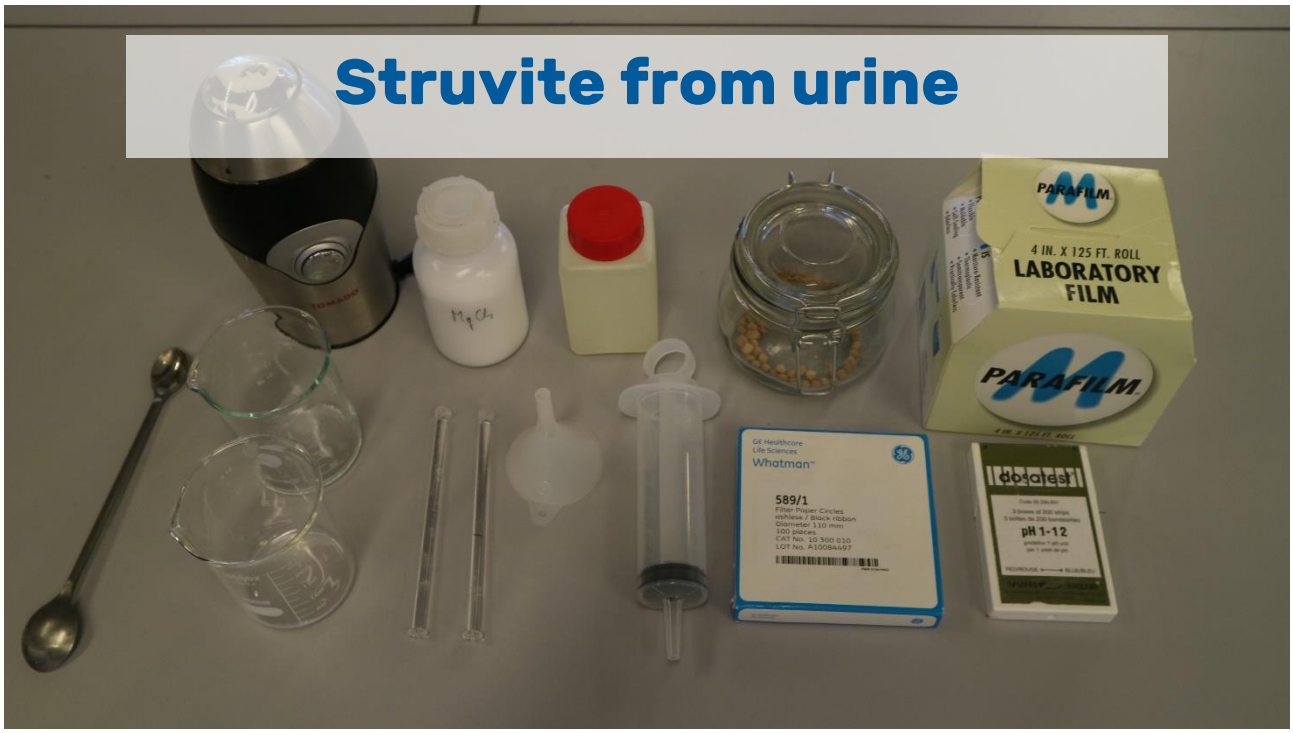
Teachers' Card



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General Introduction

- Lab activity targeted at high school students (14 to 19 years) who need to do a science project.

The toolkit should enable students to understand that wastewater contains valuable and useful compounds and that we can do so much more with urine than just discharging it through our toilets.

Besides, we hope to challenge students and create enthusiasm for science, technology and the environment.

In this toolkit we focus on topics, used during Chemistry:

- Synthesis
- Chemical Calculations
- Quantitative analysis

Urine contains valuable nutrients like ammonium and phosphate which we flush away as waste trough the toilet. During the purification of waste water, 70% of the energy is used for the removal of nitrogen/ammonium and phosphate. Ammonium is broken down to nitrogen during wastewater treatment and discharged into the environment. Phosphate is bound by bacteria in wastewater treatment plants and converted into sludge. This sludge will be burned as waste, while phosphorous is mined constantly to produce fertilizer and recovering phosphorus from mines is finite.

Wetsus investigates possibilities to recover nutrients from wastewater in order to establish a circular economy. From nutrients in urine we can make a fertilizer; struvite. Struvite is a mineral composed from ammonium, phosphate and magnesium and can be easily made from urine.

In this toolkit the students will make their own struvite from urine (module 2) and determine the concentration (module 3). In an extra module (module 4) they can create an experimental design to test their struvite or different recipes/sources for struvite. In order for the students to be able to understand the context of those modules, fist a theoretical module (module 1) is added with information about the current limitations of wastewater treatment and the importance of resource recovery in the future.

Key words: *Nutrient recovery, Urine, Colorimetry, Fertilizer, Circular economy, Chemistry, Experimental design.*

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Learning Outcomes

The toolkit should enable students to understand that waste products contain valuable and useful compounds and that we can do so much more with urine than just discharging it through our toilets. Besides, we hope to challenge students and create enthusiasm for science, technology and a sustainable environment for the future.

By the end of the lessons the students will be able to:

- Have basic knowledge of the nitrogen and phosphate cycle as a result of human activity.
- Understand the importance of a more sustainable way of recovering these resources.
- Have basic knowledge of the chemical principles of making struvite and colorimetric phosphate determination.
- Set up an experimental design to test their struvite and interpret the results.

Key Competence European Framework

Literacy competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S3. Ability to interpret the world and relate to others.
Mathematical competence and competence in science, technology and engineering
S2. Understanding of mathematical term and concept and know how to apply it.
S4. Readiness to address new problems from new areas.
S6. Ability to extract qualitative information from quantitative data
S7. Ability to formulate problems mathematically and in symbolic form so as to facilitate their analysis and solution.
S8. Ability to design experimental and observational studies and analyse data resulting from them.
S9. Ability to formulate complex problems of optimisation and decision making and to interpret the solutions in the original contexts of the problems
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning.
S2. Identifying available opportunities.
Citizen competence
S3. Ability to work effectively and collaborate with other team members
Cultural awareness and expression competence
S1. Ability to turn idea into action

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United Nations' Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice.

	 Enable access to basic services		 Equal access to global expertise
	 Safe medical devices	✓	 Sustainable urbanization
	 Access to education	✓	 Responsible consumption and production
	 Less hardship, more opportunities		 Strengthen resilience, reduce disaster impact
	 Safe and affordable water		 Reduce marine pollution
✓	 Energy – the golden thread	✓	 Sustainable use of terrestrial ecosystems
	 Safety of workers and economic growth		 Promote peaceful and inclusive societies
✓	 Resilient infrastructure and sustainable industrialization	✓	 Better access to technology and innovation

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Contents – Theoretical principles

Struvite ($(NH_4)\,Mg\,PO_4 . 6H_2O$) is a mineral composed from ammonium, phosphate and magnesium, and excellent for use as a fertilizer. Struvite can be made from urine in a simple manner. The advantages of making a fertilizer directly from urine are:

- Save energy, while phosphate and nitrogen don't need to be removed from urine
- Keep phosphorus in the cycle
- To keep a valuable product (fertilizer)

In this module, students can produce struvite from morning urine. An alternative for morning urine is a synthetic form of urine (see Module 2 – Struvite Synthesis).

At first the enzyme urease is added to the urine. Urease causes the conversion of urea into ammonia.

$$(NH_2)_2CO\ (aq) + H_2O\ (l) \rightarrow CO_2\ (g) + 2NH_3\ (g)$$

The ammonia reacts with water to form ammonium:

$$NH_3(g) + H_2O(l) \rightarrow NH_4^+\ (aq) + OH^-\ (aq)$$

An increase of pH is the result.

Subsequently, magnesium chloride is added, and in this step struvite occurs:

$$NH_4^+\ (aq) + Mg^{2+}\ (aq) + PO_4^{3-}\ (aq) + 6\ H_2O\ (l) \rightarrow NH_4MgPO_4 . 6\ H_2O\ (s)$$

From this resulting struvite the phosphate concentration can then be determined with colorimetry. In addition, it is possible to test whether the created struvite has a positive effect on the growth of plants.

Lab Procedure/Activity

In this toolkit the students will make their own struvite from urine (module 2) and determine the concentration (module 3). In an extra module (module 4) they can create an experimental design to test their struvite or different recipes/sources for struvite. In order for the students to be able to understand the context of those modules, fist a theoretical module (module 1) is added with information about the current limitations of wastewater treatment and the importance of resource recovery in the future.

Module 1 – Theoretical background

Module 2 - Struvite Synthesis.

Module 3 - Colorimetric phosphate determination.

Module 4 - Use of Struvite in an experimental design.

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Learning Pathway

Step 1- Introduction in the subject (30min – 180min).

Step 2 – Struvite Synthesis (60min).

Step 3 – Colorimetric phosphate determination (60min).

Step 4 – Experimental design (60 min), performance (up to 21 days) and evaluation of results (120min).

Evaluation

As an evaluation the students design an experimental setup to test the struvite. Besides this, the experiment can be performed and a teacher can ask for a written report or an oral presentation about the experiment or the results.

Description of Student's Cards

Module 1 – Theoretical Background

Information about the nitrogen and phosphate cycles, the importance of resource recovery from wastewater and the role of Wetsus in sustainable water technological innovations.

Module 2 - Struvite Synthesis.

Synthesis of Struvite from synthetic or morning urine. Chemical questions and calculations

Module 3 - Colorimetric phosphate determination.

Colorimetric phosphate determination on their own made struvite.

Module 4 – Use of Struvite in an experimental design.

Set up an experimental design to test their own made struvite and perform this experiments. Interpret data and learn to discuss about the results.

Sources

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