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CIRCULAR CHEMISTRY IN THE DIGITAL ERA

CIRCULAR CHEMISTRY
IN THE
DIGITAL ERA

CURRICULUM
FOR
SECONDARY SCHOOLS

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PREFACE

*This document presents a teaching curriculum for secondary schools focused on the themes of circular, green, and sustainable chemistry, titled "**Circular Chemistry in the Digital Era**".*
*The curriculum aims to offer chemistry teachers, but potentially also other scientific discipline educators**, knowledge regarding the latest developments in chemistry in the context of sustainability and circularity**, framing these developments within the strategies and regulations of the European Union that guide the future of this industrial sector.*
*Additionally, the curriculum provides teachers with tools and teaching materials to innovate the teaching of chemistry and topics related to sustainable development through participatory methodologies, primarily based on hands-on experiences facilitated by **digital technologies** and online learning environments.*

*The curriculum is organized into **6 educational modules** that address key themes in green and circular chemistry, such as waste recycling and transformation processes, chemistry's contribution to reducing air and soil pollution, the growing commitment to eliminating toxic chemicals from natural and anthropic environments, and more.*

*Each module includes an in-depth section - the "**background knowledge**"- on specific theoretical concepts, placing the subject matter of the module within the broader scope of European strategies and directives. Following this introductory section are **educational activities** that can be carried out with students in the classroom, laboratories, or in non-formal learning settings. The activities include **instructions** for teachers and a **set of slides**.*

*It is important to note that the curriculum is complemented by a set of educational **videos and a digital game**, both of which are focused on the themes of circular chemistry and are easily accessible through the project website: https://ccdeproject.eu/.*

Best wishes from the Project Team.

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INTRODUCTION

A STRENGTHENED CHEMICAL SCIENCE–POLICY INTERFACE

1-WHY DO WE NEED A GLOBAL SCIENCE–POLICY BODY ON CHEMICALS AND WASTE?

A global science-policy body on chemicals and waste is functional and indispensable for the management of chemicals and wastes associated with human activities, such policies are aimed at reducing harm to human health and the environment. Currently, many countries and regional political unions have regulatory and policy frameworks that are complemented and expanded by joint international action, particularly with regard to pollutants that are transported over long distances through air and water.

2-WHAT IS CIRCULAR ECONOMY?

Figure 1. Chemical Recycling for a Circular Economy

The circular economy is an economic and business model that seeks to maximize efficiency in the use of natural resources and minimize waste and pollution. Unlike the traditional linear model, in which resources are extracted, used to produce goods and then discarded, the circular economy aims to keep materials in use for as long as possible through reuse, recycling and regeneration.

In this model, products and materials are designed to be reused, repaired and recycled. In addition, collaboration between companies, sectors and regions is encouraged to share resources and minimize waste. This reduces pressure on natural resources, reduces the environmental footprint and creates a more sustainable and resilient model.

The circular economy addresses both the economic and the social and environmental aspects of sustainable development. It aims to create a more efficient and fairer system that provides long-term benefits for both businesses and society as a whole.

The circular economy is based on three fundamental principles:

1. **Circular design**: it consists of designing products, processes and services to be more durable, repairable and recyclable. It also seeks to reduce the use of non-renewable materials and toxic substances, and increase the use of recycled and renewable materials.
2. **Circular life cycle**: this refers to maximizing the duration of use of products and materials through reuse, repair, renewal and recycling. It also seeks to minimize the amount of waste and the emission of pollutants into the environment.
3. **Circular cooperation and collaboration**: the aim is to foster collaboration between companies, sectors and regions to share resources and

knowledge. It also promotes the creation of new business models, such as leasing services or products as a service, which reduce the consumption of resources and generate new economic opportunities.

The circular economy implies a significant change in the way we produce and consume, and requires the collaboration and cooperation of all actors in the value chain, including consumers, manufacturers, retailers, governments and regulators.

Among the benefits of the circular economy are:

- Reduced pressure on natural resources: the circular economy seeks to minimize the use of raw materials and reduce dependence on non-renewable resources, which in turn reduces pressure on the environment.
- Reducing the amount of waste: through reuse, recycling and regeneration, we seek to reduce the amount of waste we generate that ends up in landfills or in the environment.
- Generation of new economic opportunities: the circular economy creates new business opportunities, such as the design and production of more durable products, repair and maintenance, waste management and the production of recycled materials.
- Improved business efficiency and competitiveness: the circular economy fosters resource efficiency and innovation in processes and products, which can improve competitiveness and reduce costs for businesses.
- Improved quality of life: by reducing pollution and waste, the circular economy can improve people's quality of life and the health of the environment.

In short, the circular economy is a sustainable and viable alternative to the traditional linear model, which seeks to maximize the value of resources and minimize environmental and social impacts.

3-Are there any examples of circular economy?

Incredible strides have been made in the last decade in the process of developing innovative activities to implement the circular economy; here are some examples:

- The production of textiles from orange processing waste
- The construction of a biogas plant from its own agro-food production residues
- The recycling of end-of-life tires through the use of microwaves
- Re-use where the raw materials come from the return of used furniture or clothes
- Recycling plastic to make new materials

These are just a few examples of products made by virtuous companies that have applied the principles of the circular economy.

4-What is Europe doing to develop a Circular Economy?

For years now, the European Union has been applying itself in the implementation of the circular and sustainable economy.
Starting in December 2015, the European Commission adopted the first Circular Economy Action Plan with 54 actions which have largely been implemented, furthermore in December 2019 the European Commission adopted the European Green Deal with the goal of adding climate neutrality by 2050.

In March 2020, the European Commission adopted the New Circular Economy Action Plan for a Cleaner and More Competitive Europe, which in line with the European Green Deal aims to make the European economy greener. The action plan focuses in particular on the design and production system of goods to be used in the circular economy. The aim is to ensure that the resources used are kept in the EU economy for as long as possible.

The plan includes stricter recycling standards and binding targets for 2030 on the use and ecological footprint of materials. Specifically, the plan states that:

- **Sustainable products become the norm in the Union**: through special standards to be launched, products placed on the EU market will be designed to last longer, be easier to reuse, repair and recycle, and contain recycled materials as much as possible. There will also be measures to limit the use of disposable goods. Planned obsolescence and destruction of unsold goods is prohibited;
- **Empowering consumers**: i.e. providing them with information to encourage sustainable choices on how to handle goods;
- **Focus on sectors that use the most resources** and have a high potential for circularity, and in particular electronics, batteries and vehicles, packaging, plastics, textiles, construction and building, and foodstuffs, which will be the subject of special rules;
- **Reduce waste**: avoid waste production by processing end-of-life goods into high-quality secondary resources with an efficient secondary raw materials market. The Commission will examine the possibility of introducing a harmonized model for waste separation and labelling in the Union to encourage recovery and recycling on an industrial scale, minimizing costs.

Most recently, in February 2021, the European Parliament adopted a resolution on the new action plan for the circular economy, calling for additional measures to achieve a carbon-neutral, environmentally sustainable, toxic-free and fully circular economy by 2050. Stricter recycling standards and binding 2030 targets on material use and material footprint are also included.

In March 2022, the Commission published the first package of measures to accelerate the transition to a circular economy, as part of the Circular Economy Action Plan. The proposals include enhancing sustainable products, empowering consumers for the green transition, revising the Construction Products Regulation and a strategy on sustainable textiles.

In November 2022, the Commission proposed new EU-wide rules on packaging. These include a proposal to improve the design of packaging, provide it with clear labelling and encourage reuse and recycling. The proposal also includes a transition to bio-based, biodegradable and compostable plastics.

5-Which countries have developed a more optimal circular economy?

There are several countries that have adopted policies and measures to promote the circular economy and are leading in its development and implementation. Some examples are:

1. The Netherlands have been pioneers in adopting measures to foster the circular economy. In 2016, the Dutch government presented its national circular economy strategy, which includes a series of targets and measures to reduce material use and increase reuse and recycling.
2. Finland is another country that is leading the way in the development of the circular economy. In 2016, the Finnish government presented its National Circular Economy Strategy, which sets out a series of targets and measures for reducing waste and increasing resource efficiency.
3. Germany has also taken steps to promote the circular economy. In 2016, the German government presented its Circular Economy Action Plan, which includes a series of measures for waste reduction and increased resource efficiency.
4. Denmark is a leading country in the circular economy and has adopted policies and measures to encourage reuse, recycling and regeneration of materials. The country has set ambitious targets to reduce waste and increase reuse and recycling.
5. Japan is another country that is leading the way in the development of the circular economy. The country has set a series of targets and measures to reduce waste and increase resource efficiency, and has developed innovative technologies for recycling and materials recovery.
6. China is the world's largest waste producer, but it is also working to develop the circular economy. In 2020, the Chinese government presented its National Circular Economy Plan, which sets out a series of measures to reduce waste and increase resource efficiency.
7. The European Union has set ambitious targets for the circular economy and has adopted policies and measures to encourage its development. In 2020,

the EU presented its Circular Economy Action Plan, which includes a series of measures to reduce waste and increase reuse and recycling.

8. Although the United States does not have a national circular economy policy, some cities and states have adopted policies and measures to encourage reuse, recycling and regeneration of materials. In addition, the federal government has established a number of programs to encourage innovation in the circular economy.

These countries and regions are leading in the development of the circular economy and are adopting policies and measures to encourage its implementation. However, much remains to be done to achieve a truly circular and sustainable economy globally.

6-What is sustainable chemistry?

Sustainable chemistry, also known as green chemistry, is an approach to chemistry that seeks to reduce or eliminate environmental impact and improve efficiency in the production of chemicals. Sustainable chemistry aims to design chemical processes that are safer, more efficient and less toxic to the environment and human health.

In sustainable chemistry, principles such as atomic design, the use of safer reagents and solvents, waste reduction and improved production efficiency are used. In addition, the use of renewable sources and biomass-derived feedstocks is pursued, helping to reduce dependence on fossil fuels and mitigate climate change.

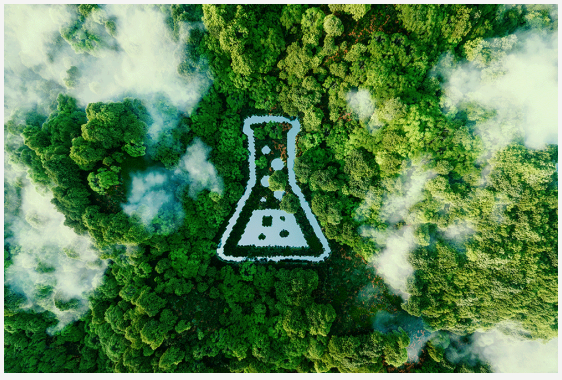
Sustainable chemistry is important to ensure that chemical production does not have a negative impact on the environment and to promote sustainable development. By implementing these principles, production efficiency can be improved, the use of hazardous materials can be reduced, and the environmental and social impact of chemistry can be reduced.
In addition, sustainable chemistry can also have economic benefits by reducing production costs and improving competitiveness in the marketplace. It can also foster innovation in the creation of new, more sustainable products and processes.

7-Can examples of sustainable chemicals be given?

There are several examples of sustainable chemicals that are used in a wide range of applications.
The following are some examples:

- **Bioplastics**: bioplastics are materials that are derived from renewable sources, such as corn, potatoes, sugarcane and other crops. These materials are biodegradable and do not pollute the environment.
- **Natural solvents**: some chemicals used as solvents, such as ethyl acetate and isopropanol, can be replaced by natural solvents, such as lemon oil and orange oil.
- **Eco-friendly detergents**: eco-friendly detergents use natural ingredients instead of harsh chemicals to clean clothes and dishes. These detergents are biodegradable and do not pollute the environment.
- **Organic fertilizers**: organic fertilizers are made from natural materials, such as manure or ground bones. These fertilizers do not contain synthetic chemicals and are safer for the environment and human health.
- **Plant-based adhesives**: Plant-based adhesives, such as gum Arabic and pine resin, are used in the manufacture of products such as plywood and drywall. These adhesives are biodegradable and do not pollute the environment.
- **Natural dyes**: natural dyes are obtained from plants, fruits and other natural materials. These dyes are more sustainable than synthetic dyes and do not release toxic chemicals into the environment.
- **Natural food additives**: Natural food additives, such as vitamin C and citric acid, are used in the food industry to preserve food and improve its taste. These additives are safer and more sustainable than synthetic additives.

Sustainable chemicals are those that are produced and used responsibly, without causing harm to the environment and human health. These products are becoming increasingly important in the chemical industry and other sectors as society seeks more sustainable and environmentally friendly solutions.



Importantly, the use of sustainable chemicals not only benefits the environment and human health, but can also have a positive impact on the economy. Many consumers and companies are demanding more sustainable products and are willing to pay more for them. In addition, innovation and development of sustainable chemicals can generate new employment opportunities and improve the competitiveness of companies.

In conclusion, sustainable chemicals are an important part of the transition to a more sustainable and environmentally friendly economy. There are many examples of sustainable chemicals today, and demand for these products is likely

to continue to grow as more sustainable practices are adopted throughout the supply chain.

8-What is the European strategy for the development of safe and sustainable chemicals? What are the objectives?

The European strategy for the development of safe and sustainable chemicals focuses on ensuring that chemicals used in the European Union are safe for both people and the environment.

The EU has set long-term objectives for its safe and sustainable chemicals strategy. Some of these objectives include:

1. Ensuring that all chemicals are used and produced in a safe way by 2030;
2. Reduce the use of hazardous chemicals in the EU by 50% by 2030.
3. Ensure that all chemicals are produced and used according to circular economy principles by 2030.
4. Increase the use of safer alternatives to hazardous chemicals by 2030.
5. Reduce greenhouse gas emissions from the chemical sector by 40% by 2030 and achieve climate neutrality by 2050.

To achieve these goals, the EU will continue to work closely with the chemical industry and other stakeholders, promoting innovation and investment in safer and more sustainable technologies, and strengthening international cooperation to address global chemicals-related challenges.

9-What has the European Union done so far?

The European Union (EU) has taken significant steps to improve the safety and sustainability of chemicals in recent years. Below are some of the important steps the EU has taken so far:

1. **REACH Regulation**: The EU introduced the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) Regulation in 2006 to improve the safety of chemicals. REACH requires companies to register substances they produce or import in quantities greater than one ton per year and provide information on their safety. REACH also allows for the authorization and restriction of hazardous substances.
2. **CLP Regulation**: The Classification, Labeling and Packaging of Substances and Mixtures (CLP) Regulation is an EU law that harmonizes the classification, labeling and packaging of chemicals. CLP was implemented in 2009 and is regularly updated to ensure that information on chemicals is accurate and up to date.
3. **EU Strategy on Safe and Sustainable Chemicals**: In October 2020, the EU launched its EU Strategy on Safe and Sustainable Chemicals, which aims to ensure that all chemicals are used and produced safely by 2030 and to reduce the use of hazardous chemicals in the EU by 50% by 2030.

4. **EU funding for research and innovation**: The EU has provided funding for research and innovation in safe and sustainable chemicals through programs such as Horizon 2020 and Horizon Europe.
5. **Evaluation and authorization of chemicals**: The European Chemicals Agency (ECHA) is responsible for evaluating and authorizing chemicals in the EU under the REACH Regulation. ECHA has evaluated thousands of chemicals and has identified those that may be harmful to human health and the environment.
6. **Implementation of the Paris Agreement**: The EU has ratified the Paris Agreement on climate change and has set ambitious targets to reduce greenhouse gas emissions. This includes the goal of achieving carbon neutrality by 2050 and reducing emissions by 55% by 2030 compared to 1990 levels.
7. **EU Plastics Strategy**: In January 2018, the EU launched its Plastics Strategy, which aims to address plastic waste and promote the transition to a circular economy for plastics. The strategy includes ambitious targets, such as ensuring that all plastic packaging is recyclable or reusable by 2030 and reducing the use of microplastics by 50% by 2030.
8. **Carbon footprint regulation**: The EU has put in place a number of laws and policies to reduce greenhouse gas emissions and address climate change. This includes the EU Emissions Trading Scheme and the EU Product Carbon Footprint Regulation, which will establish clear rules for measuring the carbon footprint of products.

In summary, the EU has taken a variety of steps to improve the safety and sustainability of chemicals. While there is still work to be done, the EU has demonstrated significant commitment to addressing chemicals-related challenges and promoting long-term sustainability.

Greening and digitalising the production of chemicals

What is the digitization of the chemical industry?

Digitization of the chemical industry refers to the incorporation of advanced digital technologies into chemical industry production and operations to improve the efficiency, quality, safety and sustainability of chemical processes and products.
Digitization of the chemical industry can bring significant benefits, including reduced costs, increased productivity, improved quality and safety of chemical products, and reduced environmental impact of chemical production.
In addition, digitization can also improve the chemical industry's ability to adapt to changing market demands and regulatory changes, which can increase its competitiveness and long-term sustainability.

In practice, the digitization of the chemical industry can include the implementation of advanced process control systems, the incorporation of sensors and devices connected to the internet of things (IoT), the adoption of data analytics and machine learning tools, the implementation of augmented and virtual reality technologies, and the use of digital platforms for collaboration and information sharing between companies and supply chain actors.
In summary, the digitization of the chemical industry represents an opportunity to improve the efficiency, safety, sustainability and competitiveness of chemical production through the implementation of advanced digital technologies in the industry's processes and operations.

What technologies are being used for the digitization of the chemical industry?

Some of the technologies that are being used for the digitization of the chemical industry include

1. Internet of Things (IoT): Network-connected sensors and devices allow plant operators to monitor equipment and processes in real time, which can help detect problems before they become major failures.

2. Augmented and virtual reality: Augmented and virtual reality technologies allow plant operators and workers to view chemical processes and operations in 3D, which can improve worker training and safety.
3. Process automation: Process automation can improve the efficiency and quality of chemicals by minimizing human intervention in production processes.
4. Digital platforms: Digital platforms can improve collaboration and transparency in the chemical supply chain, which can improve efficiency and reduce the risk of errors.

In conclusion, the digitization of the chemical industry is a trend that is accelerating globally, as more and more companies recognize the need to use digital technologies to improve efficiency and competitiveness. Some leading chemical companies are already leveraging digitization to improve their processes and operations, and the adoption of these technologies is expected to continue to grow in the coming years.

What are the goals of the digitization of the chemical industry with regard to sustainability?

The digitization of the chemical industry has several objectives in relation to sustainability, among them:

1. Improving energy efficiency and reducing greenhouse gas emissions: digitization enables real-time monitoring and optimization of production processes, which can help reduce energy consumption and minimize greenhouse gas emissions.
2. Reduce waste and improve waste management: Digital systems can help identify opportunities to reduce material waste and improve waste management, which can reduce the negative environmental impacts of chemical production.
3. Improve safety and reduce environmental risks: Digitalization makes it possible to monitor production processes and detect potential problems before they become real problems, which can improve safety and reduce environmental risks.
4. Facilitate the transition to renewable energy sources: Digitalization can help the chemical industry to integrate renewable energy sources into their production processes, which can contribute to the transition to a low-carbon economy.

In short, digitization can help the chemical industry reduce its environmental impact and improve its long-term sustainability.

What is the greening of chemical production? What technologies can be used for green chemical production?

The greening of chemical production refers to the implementation of more sustainable and environmentally friendly production processes. This involves reducing the use of natural resources and energy, reducing greenhouse gas emissions and minimizing the generation of waste and pollutants.

There are several technologies that can be used to green chemical production, some of them are:

1. Cleaner production processes: This approach involves the reduction or elimination of hazardous chemicals and materials in production processes, which reduces the amount of waste generated. Techniques such as catalysis, membrane separation and purification, and the use of alternative solvents can be used to reduce the amount of hazardous waste.
2. Renewable energies: Renewable energies such as solar and wind energy can be used to power chemical production processes, reducing the amount of greenhouse gas emissions.
3. Bioprocesses: Bioprocesses use microorganisms to perform chemical processes instead of using toxic chemicals. For example, the production of lactic acid using bacteria instead of hazardous chemicals.
4. Life cycle analysis: Life cycle analysis is a technique used to assess the environmental impact of a chemical from production to disposal. This technique can be used to identify areas where environmental improvements can be made in chemical production.
5. Use of renewable materials: Instead of using fossil feedstocks, renewable materials such as biomass can be used for chemical production. For example, the production of ethanol from corn or the production of succinic acid from biomass.
6. Recycling and reuse of materials: Recycling and reuse of materials can help reduce the amount of waste generated in chemical production. For example, recycling catalysts and reusing solvents can help reduce the amount of waste generated.
7. Wastewater treatment technologies: Wastewater treatment technologies can help reduce the amount of pollutants released into the environment. For example, biological treatment processes can be used to degrade organic contaminants in wastewater.

What strategies has the European Union adopted to digitize the sustainable production of chemicals?

The European Union (EU) has adopted several strategies to digitize the sustainable production of chemicals, with the aim of improving the safety and sustainability of chemicals in Europe. Here are some of the main initiatives:

1. REACH Regulation: The EU has implemented the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) Regulation, which aims to ensure that chemicals placed on the EU market are safe for people and the environment. REACH includes mandatory registration of chemicals, risk assessment and authorization for chemicals that present significant risks.
2. Chemicals Strategy: The EU has established a chemicals strategy that aims to reduce the exposure of people and the environment to hazardous chemicals, and to promote the use of safer substances. The strategy focuses on innovation, digitalization and transparency in the production and use of chemicals.
3. Sustainable Chemicals Industry Initiative: The EU has launched the Sustainable Chemicals Industry Initiative (SCI3), which aims to foster innovation and sustainability in chemicals production. The initiative

promotes the use of digital and automation technologies to improve energy efficiency, reduce waste and greenhouse gas emissions, and increase worker safety.

4. Digital Chemical Industry Platform: The EU has created a Digital Chemical Industry Platform, which aims to promote digitalization in the production of chemicals. The platform focuses on collecting and sharing data and creating digital tools to improve the efficiency and safety of chemical processes.
5. Horizon Europe: The EU has launched Horizon Europe, a research and innovation program that aims to fund projects and activities that promote digitalization and sustainability in different sectors, including the production of chemicals. The program has a focus on technological innovation and the development of sustainable solutions and is expected to contribute significantly to the advancement of the European chemical industry.
6. European Chemical Industry Alliance: The EU has created the European Chemical Industry Alliance, which aims to bring together the chemical industry, governments and other relevant stakeholders to address the challenges of sustainable chemical production. The alliance promotes collaboration and the exchange of knowledge and best practices and is focused on improving the sustainability and competitiveness of the European chemical industry.
7. Green Deal: The EU has presented the European Green Deal, a comprehensive plan to achieve a sustainable, carbon-neutral European economy by 2050. The Green Deal includes a specific focus on the chemical industry, with the aim of significantly reducing greenhouse gas emissions and promoting a more sustainable and circular production of chemicals.

Overall, the EU is taking a comprehensive approach to digitizing the sustainable production of chemicals, involving different stakeholders and promoting collaboration, innovation and transparency throughout the value chain. These initiatives are expected to contribute significantly to improving the safety, sustainability and competitiveness of the European chemicals industry in the future.

MODULE 1

Promoting safe and sustainable-by-design chemicals: Renewable materials

Background knowledge

Promoting safe and sustainable-by-design chemicals

In an ever-changing world, awareness of the environmental impact and safety of chemicals has risen significantly. The design of safe and sustainable chemicals has become an imperative, not only to preserve our environment, but also to protect human health. In this context, the focus on renewable materials has been highlighted as a fundamental way to promote safety and sustainability in the chemical industry.

The challenge of the chemical industry

The chemical industry plays a crucial role in modern society, providing a wide range of essential products for sectors such as health, agriculture, construction and technology. However, the production and use of conventional chemicals have often been associated with risks to human health and the environment.

The manufacture of conventional chemicals is based on materials derived from petroleum and other non-renewable resources. This brings with it challenges such as dependence on finite resources, generation of toxic wastes, and release of hazardous substances during the production and use of such chemicals.

In response to these challenges, a renewed focus on the use of renewable materials in the production of chemicals has emerged. The design of sustainable chemicals based on renewable sources has become a priority for industry, regulators and consumers.

What are renewable materials in the chemical industry?

Renewable materials, in the context of the chemical industry, refer to those materials that come from natural sources that are readily renewable or rapidly regenerated. These materials can include biomass, such as plants, microorganisms, algae and agricultural residues. The key advantage of these resources is their ability to regenerate at a rate that allows their continued use without depleting natural resources.

By using these renewable materials as raw materials for chemical manufacturing, dependence on non-renewable resources can be reduced and negative impacts on the environment can be mitigated. In addition, the use of renewable materials can lead to the production of chemicals with lower toxicity and a reduced carbon footprint.

The role of safe and sustainable design

The transition to safe and sustainable chemicals is not limited to simply using renewable materials. It also involves a comprehensive approach known as safe and sustainable design. This approach focuses on creating chemicals and

manufacturing processes that minimize risks to human health and the environment throughout their entire life cycle.
Safe and sustainable design involves assessing and minimizing risks from the conception and development stage of a chemical product through its manufacture, use and final disposal. This includes the careful selection of raw materials, the design of efficient production processes, and consideration of the toxicity and biodegradability of the resulting chemicals.

Benefits of sustainable chemicals

The adoption of sustainable chemicals has numerous benefits for both the environment and society at large. Some of these benefits include:

Reduced environmental footprint:

The use of renewable materials and safe, sustainable design lead to a significant reduction in the environmental footprint of chemicals. There is a decrease in greenhouse gas emissions and reduced dependence on non-renewable resources.

Improved human health:

Safely designed chemicals reduce exposure to toxic substances, which can have a positive impact on human health. Reduced risks of toxicity and allergies contribute to safer environments both at home and in the workplace.

Stimulating the circular economy:

The use of renewable materials encourages the transition to a circular economy by promoting the reuse, recycling and regeneration of resources. This can generate economic opportunities through the creation of new markets and supply chain innovation.

Challenges and future prospects

Despite significant progress, the widespread adoption of safe and sustainable chemicals based on renewable materials faces significant challenges. These challenges include the need to develop more efficient technologies for biomass extraction and processing, as well as improving the scalability and cost-effectiveness of manufacturing processes.
In addition, education and awareness of the benefits of sustainable chemicals are critical to encourage their adoption in the industry. Government incentives and policies that encourage research and development of sustainable technologies also play a crucial role in this process.
In conclusion, the drive towards safe and sustainable chemicals through the design of renewable materials is essential to address today's environmental and

health challenges. This approach not only promotes environmental preservation, but also drives innovation and economic development. Collaboration between industry, regulators, academia and consumers is key to accelerating this transition to a safer and more sustainable future for all.

Innovation and advances in the design of sustainable chemicals

The drive toward safe and sustainable chemicals has catalyzed a wave of innovation and technological breakthroughs. Research and development is underway to find more efficient, cost-effective and environmentally friendly solutions in renewable materials production and chemical design.

Emerging technologies

Numerous emerging technologies are revolutionizing the way renewable materials are produced and used in the chemical industry. Biotechnology, for example, enabling the genetic modification of microorganisms to produce specific chemical compounds more efficiently. Metabolic engineering and microbial fermentation are being harnessed for the production of a wide range of chemicals from renewable sources, such as bioplastics, biofuels and pharmaceuticals.
Nanotechnology is also playing a crucial role in enabling the creation of innovative materials with unique properties. Nanomaterials derived from renewable sources have the potential to be used in a variety of applications, from construction to electronics, thereby reducing dependence on non-renewable resources.

Interdisciplinary collaboration

Moving toward safe and sustainable chemicals requires collaboration among diverse disciplines, including chemistry, biology, engineering, economics and policy. Partnerships between industry, academia and governments are critical for knowledge sharing, joint research and policy development to drive the adoption of more sustainable practices.

Regulations and standards

Efforts to promote safe and sustainable chemicals are supported by the implementation of stricter regulations and standards. Regulatory agencies are taking steps to assess and monitor the safety and environmental impact of chemicals, thereby encouraging industry to adopt more responsible practices.

Awareness and education

Increased awareness of the benefits of sustainable chemicals plays a key role in their adoption. Educational programs and awareness campaigns targeting consumers, businesses and industry professionals are promoting greater understanding of the impacts of chemicals on the environment and human health. This is driving demand for safer and more sustainable alternatives in the marketplace.

Success stories and inspiring examples

The transition to safe and sustainable chemicals is already underway and significant progress has been made in several sectors.
Notable examples include:

Bioplastics and renewable polymers

Innovative companies are developing bioplastics from renewable sources such as corn starch, cellulose and vegetable oils. These bioplastics are biodegradable, reducing pollution from conventional plastics and reducing dependence on fossil fuels.

Biofuels and renewable energy

The production of biofuels from organic crops and waste has gained momentum as a sustainable alternative to fossil fuels. The use of renewable sources for energy generation is contributing to the reduction of carbon emissions and the mitigation of climate change.

Green chemistry in the pharmaceutical industry

The adoption of green chemistry principles in the pharmaceutical industry is driving more efficient and sustainable drug synthesis. Cleaner manufacturing processes and the reduction of toxic waste are being prioritized in the creation of drugs to improve human health

Conclusions

The drive toward safe and sustainable chemicals through the design of renewable materials is transforming the chemical industry toward a more conscious and responsible approach. Through the integration of innovative technologies, sound regulatory policies, interdisciplinary collaboration and public awareness, progress is being made toward a future where chemicals are not only safe and efficient, but also environmentally and human health friendly.
The transition to sustainable chemicals is an ongoing journey that requires commitment and collective action. Over time, it is hoped that the widespread adoption of sustainable practices and technologies will lead to a world that is more equitable, healthier and in harmony with the natural environment

Activity 1

From Grease to Green: Innovative Biodiesel Production from Used Vegetable Oil

Objectives

The production of biodiesel from used vegetable oil is an interesting project that contributes to environmental sustainability and waste reduction. Here are the general steps to carry out this experiment:

- Environmental sustainability: Produce a more environmentally friendly fuel that reduces greenhouse gas emissions.
- Waste reduction: Reuse used vegetable oil into a useful product instead of discarding it.
- Education and research: Infrared to the chemistry of transforming vegetable oils into biodiesel and its practical application.
- Safety awareness: Teaching about safe handling of products made hazardous in the process.
- Applications: Produce biodiesel to evaluate its use as an alternative fuel in diesel engines.

Introduction to the topic

What is Biodiesel?

Biodiesel is a renewable fuel made from vegetable oil or animal fats. It can be used in diesel engines with little or no modifications. Biodiesel is a cleaner-burning alternative to traditional diesel fuel, reducing greenhouse gas emissions and improving air quality.

What are free radicals?

Atoms consist of protons, electrons, and neutrons. Protons and neutrons form the nucleus, while electrons orbit in energy shells. Each shell has a specific electron capacity, and the electrons in an atom are called valence electrons. Carbon, with a valence of 4, can form four bonds with other atoms.

The problem with used vegetable oil

Used vegetable oil is a waste product that can be harmful to the environment if not disposed of properly. It can clog drains and cause pollution if dumped in landfills or waterways. However, with the right technology, used vegetable oil can be turned into a valuable resource.

Activity Details

Material

1. used vegetable oil (preferably used cooking oil).
2. Methyl alcohol (methanol).
3. Sodium hydroxide (NaOH) or potassium hydroxide (KOH) reagent as catalyst.
4. Round bottom flask and condenser to carry out the reaction.
5. Support and grid to hold the flask.

Duration

The duration of the experiment for biodiesel production can vary depending on several factors, such as the scale of the process, the efficiency of the equipment and the experience of the participants. In an educational setting, the estimated time to conduct this experiment could be at least two days.

Group Number

groups of 2 to 4 students

Instructions

1. Oil preparation:

- Filter and dehydrate used oil to remove particles and water.
- Measure the amount of oil used.

2. Transesterification:

- In the reactor, add a specific amount of methanol based on the molar ratio to the oil (usually about 6:1 methanol: oil).
- Add the appropriate amount of sodium hydroxide or potassium hydroxide as catalyst (about 0.3 to 0.5% of the weight of the oil).
- Place the flask in the flask holder and connect the condenser. Apply gentle heat to the mixture and make sure to maintain a constant temperature around 60-70°C for approximately 1-2 hours for the transesterification reaction to occur.
- This process converts the oil into biodiesel and glycerin, separating the two phases.

3. Phase separation:

- After the reaction, allow the mixture to settle to separate the biodiesel and glycerin phases.
- Use a centrifuge or decanting system to speed up the separation.

4.Washing:

- Wash the biodiesel with water several times to remove catalyst residues and other by-products.
- Agitate and separate the phases at each wash.

5.Drying:

- Dehydrate the biodiesel to remove any remaining moisture.

6.Filtration:

- Pass the biodiesel through filters to remove unwanted particles.

7.Storage:

- Store the clean, dry biodiesel in suitable tanks.

It is important to note that these are general steps, and the precise amounts of inputs and outputs will depend on the quality of the used oil and the efficiency of the process. In addition, large-scale biodiesel production would require more sophisticated equipment and processes. It is also important to take into account local and environmental regulations related to biodiesel production.
Also, it is important to note that this experiment involves the use of hazardous chemicals, such as methanol and sodium or potassium hydroxide, so it is essential to follow proper safety measures and conduct the experiment in a well-ventilated area. Also, be aware of local regulations on the production and use of biodiesel.

Activity 2

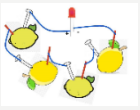
Power to Citrus: Unleashing the Electrifying Potential of Lemons

Objectives

Power to the Citrus is a revolutionary concept that has the potential to change the way we think about energy. By harnessing the power of lemons, we can create a sustainable and renewable source of electricity. Join us on this electrifying journey as we explore the possibilities of this citrus-powered future.
Demonstrate how electricity can be generated using lemons and learn about electricity production.

Principle of operation: This experiment demonstrates the principle of an electrochemical cell, which is a device that converts chemical energy into electrical energy through a redox (reduction-oxidation) reaction. In this case, lemons act as the electrolyte and zinc and copper nails as electrodes.

Introduction to the topic



The science behind citrus power

Lemons are a natural source of acid, which can be used to create a chemical reaction that generates electricity. This process is known as **electrolysis**, and it has been used for centuries to power everything from batteries to cars. By using lemons as our source of acid, we can create a sustainable and renewable energy source that is both affordable and accessible.

The power of lemons

Did you know that a single lemon can power a small LED light for up to 20 hours? Imagine the possibilities if we were to harness the power of thousands of lemons! With **Power to the Citrus**, we can create a citrus- powered future that is both sustainable
and electrifying

Applications of Citrus power

The potential applications of **Power to the Citrus** are endless. From powering small electronics to providing electricity to entire communities, lemons have the power to change the world.
Imagine a future where every home has its own lemon-powered generator, providing clean and renewable energy to all.

Activity Details

Material

- Zinc nails (also known as galvanized nails)
- Copper nails
- Copper wires
- A small LED bulb (available at electronics stores)
- Knife (for adults)
- A pair of gloves (optional, for handling the nails)

Duration: 30 mins to 1 hour

Group Number

groups of 2 to 4 students

Instructions

1. Cut a lemon in half to obtain two lemon halves.
2. Insert a zinc nail into one half of the lemon and a copper nail into the other half. Make sure the nails do not touch inside the lemon.
3. Connect one end of a copper wire to the copper nail and the other end to the long side of the LED bulb
4. Connect one end of another copper wire to the zinc nail and the other end to the short side of the LED bulb.
5. Observe how the LED bulb lights up due to the electric current generated by the lemons

Tips for trainer

- Explain how this experiment demonstrates the production of electricity through a chemical reaction between lemon and zinc and copper nails.
- Encourages discussion about electrical power generation and renewable energy sources.

Safety tips:

- This experiment is safe, but keep in mind that the end of the cloves being inserted into the lemon must be long enough to prevent them from touching the inside of the lemon.
- If a knife is used to cut the lemon, care should be taken and adult supervision is recommended for younger students.
- Make sure there are no open wounds on the hands when handling the nails.

This experiment is a great way to teach students about electrical power generation, the chemistry behind electrochemical cells, and how lemons, which are acidic, can act as electrolytes in a cell. It is also a fun introduction to energy science and renewable energy sources.

Activity 3

From Spuds to Sustainability: Crafting Bioplastics from Starch

Objectives

The objective of this experiment is to produce homemade bioplastic from starch and to understand the importance of bioplastics as a more sustainable alternative to conventional petroleum-derived plastics.

Introduction to the topic

What are Bioplastics?

Bioplastics are plastics made from renewable resources such as vegetable fats and oils, corn starch, and pea starch.
There are a more sustainable alternative to traditional plastics as they are biodegradable and compostable

The advantages of Starch-Based Bioplastics

Starch-based bioplastics have several advantages over traditional plastics.
They are **renewable, biodegradable and compostable**.
They also have a lower carbon footprint and can help reduce our reliance on fossil fuels

Activity Details

Material:

The following materials will be needed:

- Starch (can be potato or corn starch).
- Water.
- White vinegar.
- Glycerin (available in pharmacies).
- Food coloring (optional).
- Pot or saucepan.
- Spoon or spatula.
- Silicone molds or small containers.

Duration:

The practice may take 60 to 90 minutes, depending on the time needed to prepare the materials and let the bioplastic solidify.

Group Number

groups of 2 to 4 students

Instructions

1. In a pot or saucepan, mix 1 cup of starch and 1 cup of water. Stir well to make sure the starch dissolves in the water.
2. Add 1 tablespoon of white vinegar and 1 tablespoon of glycerin to the mixture. These ingredients will help make the bioplastic more flexible and resilient.
3. Optionally, you can add food coloring to the mixture to color the bioplastic.
4. Heat the mixture over medium-low heat, stirring constantly. You will see that the mixture thickens and acquires a consistency similar to that of a modeling dough.
5. Once the mixture has the right consistency, remove it from the heat and let it cool a little.
6. While the mixture is still warm, place it in silicone molds or small containers to shape the bioplastic. You can use molds of different shapes and sizes.
7. Allow the bioplastic to cool and solidify completely. This may take several hours, depending on the size and thickness of the bioplastic.
8. Once the bioplastic is completely solid, remove it from the molds and observe its texture and flexibility.

Conclusions

Through this experiment, we have produced homemade bioplastics from starch. We have observed how the ingredients combine and form a plastic material that we can mold. Bioplastics are a more sustainable alternative to conventional petroleum-based plastics because they are produced from renewable sources and are biodegradable. Experiments like this allow us to explore more environmentally friendly ways of using and producing plastic materials.

Tips for trainer

No specific personal protective equipment is required for this experiment, but it is recommended to work in a well-ventilated area and avoid contact with irritating chemicals or contaminants.

MODULE 2

STRENGTHENING THE EU'S OPEN STRATEGIC AUTONOMY: CHEMISTRY AND ENERGY.

Background knowledge

Strengthening the EU's open strategic autonomy (chemistry and energy)

1-What is meant by energy autonomy and why it is important to implement energy autonomy

Energy autonomy is "a concept of local energy generation, providing a self-sufficient power balance between demand and supply, in a desired time span and with the ability for stakeholders to self-determine energy provision in a sustainable, economically viable, and socially equitable way" (Juntunen and Martiskainen, 2021). Self-production, self-sufficiency, self-determination, environmental sustainability, economic viability, social equity. At different geographic scales, we can distinguish three types of energy autonomy: the first is energy autonomy at the household scale, the second at the community scale (such as neighbourhoods or small islands), and the third relates to the energy autonomy of a country (Bentley et al., 2019). The motivations behind energy autonomy, in fact, are diverse: independence from energy markets, stability in the face of fluctuations in energy prices, environmental and health concerns, as well as increased energy security, whereby energy supply and its production are made certain, especially in relation to the price and availability of energy raw materials, but also, when express reference is made to new renewables (wind and solar, above all), to overcoming their inconstancy and unpredictability.

2-What are the benefits of developing a functional chemical strategy

The public and the environment are less exposed to hazardous chemicals and benefit from safer products. Consumers can demand information about the hazardous chemicals in the products they buy. In addition, industry workers and other users of chemicals benefit from more accurate information on the risks of the chemicals they handle and how to use them safely. Industry is helped to comply with legislation. Innovative companies benefit from the need to phase out the most hazardous substances. Developing countries get information on how to handle hazardous chemicals safely.

3-What is the European Chemicals Agency (ECHA)?

ECHA's work aims to promote the safe use of chemicals. It implements innovative EU chemicals legislation, benefiting human health, the environment, innovation and competitiveness in Europe. At the same time, it helps companies comply with EU chemicals ordinances by cooperating with international organizations and stakeholders to promote the safe use of chemicals and by providing information on chemicals and their safe use through a single, free database. ECHA also works

with the European Commission and EU governments to identify substances of concern and make risk management decisions at EU level.

4-What is the EU's role in the development of energy sources?

The EU is the world's largest energy importer: it imports 54% of its needs at a cost of more than EUR 400 billion per year in 2015. Among the five states with the largest energy consumption, the least dependent on imports are the UK (37.4%) and France (46%), compared to Germany (61.9%), Spain (73.3%) and Italy (77.1%). 11 Member States are still below the 10% electricity interconnection target.

5-What are the main energy objectives of the European Union

Under the Energy Union (2015), the five main objectives of EU energy policy are to:

- diversify Europe's energy sources, ensuring energy security through solidarity and cooperation between EU countries;
- to ensure the functioning of a fully integrated internal energy market, allowing the free flow of energy within the EU by means of adequate infrastructure and without technical or regulatory barriers;
- improve energy efficiency and reduce dependence on energy imports, reduce emissions and boost jobs and growth;
- decarbonise the economy and move to a low-carbon economy, in line with the Paris Agreement;
- promote research into clean and low-carbon energy technologies and prioritize research and innovation to drive the energy transition and improve competitiveness.

6-What is circular energy? Why is it important? How has Europe acted to develop circular energy strategies?

The term circular energy refers to the reintegration action carried out within a given environment where material and energy resources that have already been used are reutilised, thus eliminating the concept of 'waste' and replacing it with terms such as 'recovery', 'recycling' and 'sharing'.
The benefits that circular energy offers us are:

- Decarbonization: Understood as a shift from fossil fuels to carbon-neutral renewable sources, resulting in a reduction of CO2 emissions into the atmosphere.
- Limitation of global average temperature as a direct consequence of decarbonisation
- Economic savings: It has been verified that using renewable energy in all sectors of the economy is the most economical solution (source LUT University and Energy Watch Group)
- Global growth: A further consequence of circular energy is the growth of the national economies of all countries around the world.

In order to achieve this, the European Commission on 1 February 2023 published a new document outlining its vision for a 'Green' Industrial Plan, which aims to transform the EU towards a net-zero economy and help the bloc meet its climate targets. Recently, even the IEA has spoken out with an official document 'Energy Technology Perspectives 2023' to offer "... indispensable guidance for government and industry decision-makers seeking to exploit the opportunities offered by the emerging new energy economy, while navigating uncertainties and safeguarding energy security." The European Commission intends to support the transition through a combination of financing, regulatory measures and a supportive framework for research and development. The plan emphasizes the need for strong partnerships between the public and private sectors, as well as between different industries and countries, to drive the transition to a net-zero economy.

7-What were the other main strategies and operations adopted by the European Union in the energy field?

Policymakers would have to be knowledgeable about firms and industries that generate knowledge spillovers, the relative amount of learning by individual firms from others and from their own experiences, the precise path of such learning over time and the magnitude of cost disadvantages at each stage in the learning process, and the extent to which early entrants generate benefits for future entrants. Article 194 TFEU makes certain areas of energy policy a matter of shared competence, marking a step towards a common energy policy. On 25 February 2015, the Commission published its Strategy for an Energy Union (COM(2015)0080) with the aim of achieving an Energy Union that offers EU households and businesses a secure, sustainable, competitive and affordable

energy supply. According to the drafted regulations, EU Member States are required to develop 10-year Integrated National Energy and Climate Plans (NEEAPs) for the period 2021-2030, report on progress every two years and formulate coherent long-term national strategies to achieve the objectives of the Paris Agreement.A fully integrated and properly functioning internal energy market guarantees affordable energy prices, provides the necessary price signals for green energy investments, secures energy supply and opens the least expensive path to climate neutrality.

Activity 4

Inflate a balloon with lemon juice

Objectives

The objective of this activity is to understand different chemical reactions (specifically the acid-base reaction)

Introduction to the topic

What is a chemical reaction?

A process that involves rearrangement of the molecular or ionic structure of a substance, as distinct from a change in physical form or a nuclear reaction.

Activity Details

Material

You will need the following items for the experiment:

- A compact bottle or jar
- Lemon juice
- Vinegar
- Baking soda
- Balloons

Explanation

When baking soda is mixed with vinegar, something new is formed. The mixture quickly foams up with carbon dioxide gas. If enough vinegar is used, all of the baking soda can be made to react and disappear into the vinegar solution.
The reaction is:
Sodium bicarbonate and acetic acid reacts to carbon dioxide, water and sodium acetate.

Duration

15 minutes

Group Number

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Instructions

1. Stretch the balloon a bit to make it easier to inflate.
2. Fill your jar or bottle about one quarter full with lemon juice.
3. Use a funnel to tip the bicarbonate of soda (baking soda) into the neck of the balloon.

4. Place the ballon over the top of the bottle. When you're ready tip the balloon up so the baking soda drops into the lemon juice.

As a result, the balloon will start to expand and inflate, as the gas ascends and fills it up.

Tips for trainer

- Stress the significance of precise measurements when adding the vinegar
- lemon juice, and baking soda. Small variations can affect the outcome of the reaction.
- Provide a simple explanation of the acid-base reaction that occurs between the vinegar (acid), lemon juice (acid), and baking soda (base) to produce carbon dioxide gas, which inflates the balloon.

Activity 5

The PH scale in food: "PHOOD"

Objectives

The objective of this activity is to study the characteristic property of density and begin to calculate concentrations)

Introduction to the topic

What is density?

The density of a substance is a characteristic property of it and is given by the amount of mass that occupies a certain volume.

What is concentration?

The concentration of a chemical substance expresses the amount of a substance present in a mixture.

Activity Details

Material

- 3 beakers
- One cup
- Food coloring (at least three different colors)
- Water
- Sugar
- Pipette
- Stirring rod
- Spoon or scale

Duration

60 minutes

Group Number

5/6 participants

Instructions

1. Put 50ml of water in each of the 3 beakers.
2. Add two drops of different food coloring to each of th with water.
3. In the first of the glasses, nothing else is added.
4. In the second of the glasses, add 3 tablespoons of sugar and in the third of the glasses, add 6 tablespoons of sugar. Stir both glasses until they are completely dissolved.
5. Take 30 ml of the first glass with the pipette and leave it in the glass.

Tips for trainer

- Introduce the concept of density as a characteristic property that relates mass to volume.
- Encourage the participants to predict how different concentrations of sugar will affect the density of the solution.
- Guide participants in calculating and comparing the densities of each solution by explaining the relationship between sugar concentration and density.

Activity 6

The pH Scale in Food: Fifty Shades of Red Cabbage

Objectives

The objective of this activity is to explain in a simple and engaging way the concepts of acidity and basicity. This is achieved through an inexpensive, colorful experiment, introducing a complex concept like pH in an accessible manner

Introduction to the topic

How can you tell if a substance is an acid or a base? By its PH

The values that this physical quantity can take range from 0 (very acidic) to 14 (very basic); the intermediate pH, 7, is called neutral pH and is what characterizes pure water.

how to measure pH?

The pH of a substance can be measured using special instruments, called pHmeters, but it can also be measured using litmus paper, which changes colour according to the degree of acidity or basicity of the solution in which it is immersed.

Activity Details

Material

- 1/4 of a head of red cabbage
- 1/2 liter of water
- Various test substances (with different pH values)
- Transparent containers (e.g., glass beakers)
- Knife, scissors, or grater with large holes
- Spoon or other stirring tools.

Duration

60 minutes

Group Number

5/6 participants per group

Instructions

1. Peel or grate the cabbage.
2. Put the cabbage into the water and boil it for about ten minutes so that you can see the water colour.
3. Strain the infusion, retaining the water, which is what you are going to use, and leave to cool.

4. Divide the cabbage water into as many containers as there are substances you want to test, choosing transparent containers so that it is easier to observe what is happening inside, uncoloured glass beakers will do.
5. Add a small amount of the test substances to the coloured water, stir with a spoon and watch the science magic in action.
6. Stir the mixture and observe the color changes, which indicate the pH level (acidic or basic).

Tips for trainer

- Explain the concept of pH as a scale ranging from 0 (very acidic) to 14 (very basic), with 7 being neutral.
- Encourage participants to predict the outcome before adding each test substance to the cabbage water.
- Use common household substances like vinegar, baking soda, and lemon juice for the test to make the experiment more relatable.
- Highlight the scientific principle behind the color changes: red cabbage contains a pigment called anthocyanin, which reacts to different pH levels.

Activity 7

Testing for Vitamin C: A Chemical Experiment

Objectives

The objective of this activity is to perform a chemical test to detect the presence of ascorbic acid, which is the chemical name for vitamin C

Introduction to the topic

What are vitamins?

Vitamins are essential organic compounds for all living organisms. They are categorized into fat-soluble (A, D, E, K) and water-soluble (C, B-complex) t Fat-soluble vitamins are stored in the body's fat for longer use, water-soluble vitamins are quickly utilized and excreted through urine.

What are free radicals?

Atoms consist of protons, electrons, and neutrons. Protons and neutrons form the nucleus, while electrons orbit in energy shells. Each shell has a specific electron capacity, and the electrons in an atom are called valence electrons. Carbon, with a valence of 4, can form four bonds with other atoms.

Activity Details

Material

- 1 cup of each: chopped pumpkin, acorn squash, and cranberries
- 1/4 cup distilled water (add more as needed)
- Cornstarch
- Cheesecloth or coffee filters
- Measuring cups or beakers
- Iodine drops
- Saucepan
- Stirring rod
- Test tubes or mixing containers
- Heat source

Duration

60 minutes

Group Number

5/6 participants per group

Instructions

1. Chop the pumpkin, acorn squash, and cranberries into small pieces (about 1 cup each). Place each in separate bowls.
2. Add 1/4 cup of distilled water to each bowl and stir. Let the mixture sit for 15-20 minutes.
3. Strain each mixture using cheesecloth or coffee filters, keeping them separate.

4. Prepare the indicator: In a 12-ounce container, mix 2 tablespoons of cornstarch with water to form a paste. Add 250 mL distilled water and bring to a boil, stirring constantly.
5. Pour 125 mL of the boiled starch mixture into a separate container and add iodine drops to turn the solution dark blue.
6. Prepare the test tubes or containers for testing with the strained liquids and observe the reactions.

Tips for trainer

- Begin by explaining the importance of vitamins, especially water-soluble ones like Vitamin C, in the body.
- Discuss free radicals and how antioxidants like Vitamin C help neutralize them.
- Guide participants on observing color changes, which indicate the presence of Vitamin C in the test substances.
- Encourage participants to hypothesize which fruit or vegetable contains the most Vitamin C.

MODULE 3

PROTECTING PEOPLE AND THE ENVIRONMENT FROM THE COMBINATION EFFECTS OF CHEMICALS

Background knowledge

Protecting people and the environment from the combination effects of chemicals

What is the importance of chemicals in our society? What is the connection between chemicals, health and sustainable development?

In our society, chemicals are very important because they represent pillars in technologies, products, and materials with low carbon emissions, so they influence our society a lot. They also have an economical factor since they are cheap and in a lot of products, to simply stop using them would have an impact on the different items we use in our daily life.

However, they also can be dangerous for health and environment and provoke serious diseases and issues such as cancer, malfunction of the immune system, respiratory system, endocrine system, reproductive system and cardiovascular system. It can also affect the capacity of the human body to accept vaccines and increase the vulnerability of the human body to face some diseases. Moreover, it can affect the development if a child is in contact with those. It affects the environment by being one of the key factors that put our planet in a dangerous situation, it increases this situation but also the climate change, and provokes ecosystem's degradation and loss of biodiversity.

We can resume the connection between chemicals, health and sustainable development by saying that the chemicals affect the health of humans and the environment. So to avoid this, people are developing sustainable chemicals to avoid the dangerous ones.

Where can we find combinations of chemicals?

We can find chemicals in a lot of products such as food (for example there is pesticides in fruits and vegetables), water, toys, cosmetics, furniture, textile, shoes but also health care products, medicines, baby equipment and even the air we breathe.

What is the regulatory approach toward an analysis of chemicals? How are the risks and effects of chemicals products calculated?

The regulatory approach to determine the dangerousness and chemical is an evaluation of single substances, chemical-by-chemical with a safety margin for the time of exposure and the beginning of exposure and the impact on environment and people. But there are concerns that this approach is not sufficient enough for security and to evaluate substances because it doesn't evaluate the combination of chemicals and because it is not systematic for every chemical. On the other side, it wouldn't be very useful or even possible to try and

evaluate every combination of chemicals since the number of possibilities is enormous.
The risks and effects are calculated following guidelines. Exposure to chemicals is a factor and their effects are monitored with hazard identification and comparative risk assessment tools. Also, with HBM -Human Bio-Monitoring) they have monitoring and surveillance tools.
Also, there are principles such as precautionary principle and "Polluter pays" principles that have to be respected by efficient chemicals policies and legislation. The "Polluter pays" principle is the public right to know the facts and intergenerational equity.

Would it be possible to have a world without toxic substances? How?

It would be possible to have a world without toxic substances but changes would need to be done like avoiding to cause damages to earth for the actual generations and the future ones, avoid the use of chemicals substances if it is not essential for the society, use chemicals in a safer and more sustainable way possible, promote ecological transition and grow an environment that doesn't need toxic substances.

What can we do more to use fewer toxic substances?

There are several ways to avoid the use of chemical products. First, it is important to make safer chemicals so, if necessary, chemicals would have a fewer impact on the body and on the planet. Also, reinforce execution and compliance of the European legislation during its life cycle ; production, commercialization, liberation and elimination is a key because it would have an impact on several countries and significantly reduce the danger of chemicals since everything would be controlled. Also, it is very important to set strict limits for the amount of chemicals allowed in the principal products that have chemicals such as food, water, air and manufactured products. It would be way better for health and the environment and since these are the principal products with chemicals would reduce their use a lot.
These are solution a large-scale but it is also possible to do some things at our scale on our daily life such as prioritizing food from bio agriculture, second-hand products clothes and shoes, be aware of the products contained in other products and find alternatives with for example cleaning products that most of them have can be substituted with natural cleaners, it wouldn't of course have the same impact for the planet but you would be able to control your health and if everyone tries to do some of these habits in a large scale it would mean a lot.

What are the risks of exposure to dangerous substances? What are the combinations of chemicals most dangerous? More used?

Chemical agents are present in many products we use on a daily basis. It is incredible to think how many dangerous chemical reactions can be created by

mixing substances that are commonly found in our homes. The health problems that can be caused by contact with such hazardous substances range from mild eye and skin irritations to serious effects such as cancer. The effects can be acute or long-term and some substances can have a cumulative effect. Some of the most common problems are: allergies, skin diseases, tumors, reproductive problems and birth defects, respiratory diseases, poisoning. Some dangerous substances present safety risks such as fire, explosion or suffocation. It is incredible to think how a simple mixture of bleach and vinegar can produce a toxic chlorine gas that causes irritation to the respiratory tract and eyes, but can also burn or cause death if not treated properly. The mixture of bleach and denatured alcohol also causes the formation of toxic chloroform which causes unconsciousness if breathed in for a prolonged time. Not to mention hydrochloric acid which can cause chemical burns if brought into contact with the skin.

What is the strategy of the European Union to use more sustainable substances? what initiatives have been implemented to decrease the risk of exposure to hazardous chemicals?

Human beings normally lead a life routine that brings them into constant contact with chemical substances, without even realizing it. These substances are present in hygiene products, in the food we consume, or in the electronic devices we keep in our homes. This condition of prolonged and continuous exposure can be potentially dangerous to human health, and in this regard the European Union has taken action in various ways to safeguard citizens and to prevent uncomfortable situations in the homes of European citizens. In fact, since 2009, the Council of Environment Ministers has issued communiqués on the consequences of the combination of chemicals, suggesting how to prevent certain uncomfortable situations and guide citizens towards safer lifestyles. This is done by setting important limits on the QUANTITIES and DOSAGE of substances in commonly used products. the Commission will identify priority mixtures to be assessed and ensure that the different strands of EU legislation provide consistent risk assessments for these priority mixtures.
Most recently, in March 2021, The Council approved a new chemicals strategy that sets out a long-term vision for the EU chemicals policy. The strategy aims to achieve a toxic-free environment with a higher level of protection for human health and the environment, including targeted changes to streamline chemicals legislation, replacing and minimizing substances of concern and phasing out the most harmful substances used for uses that are not essential to society.

What could be done to protect people and the planet of combinations of chemicals?

The European Environment Agency is working with partners internationally to build the knowledge base on the links between environment, health and wellbeing to work towards this end, the study of exposure to specific environmental stressors, including chemicals and their effects on health, comes into play.

These include issues such as antimicrobial resistance or changes in human exposure to chemicals in products. The EEA works with international networks of experts, including the European Commission, the WHO and the European Food Safety Authority, to identify emerging environmental risks.
The EEA provides a range of assessments and indicators on air pollution, chemicals and climate change adaptation.
The EEA is a partner in the HBM4EU initiative. The main objective of this initiative is to coordinate and advance human biomonitoring in Europe. HBM4EU will provide better evidence of citizens' actual exposure to chemicals and possible health effects to support policy-making.
The EEA also contributes to the Information Platform for Chemical Control (IPCHEM), which documents the occurrence of chemical substances and mixtures in relation to humans and the environment.

Which strategies can be used in order to develop more sustainable use of chemical substances?

The concept of 'safe and sustainable design' means that the processes used to create products must avoid, from the earliest design stages, the presence of chemicals with certain properties in certain dosages that can be harmful to the environment and humans. This means that if materials and products are safe during their entire life cycle, from production to disposal, they will also be safe when they are recycled. Indeed, recycling cycles of non-toxic materials are being sought to achieve environmentally sustainable disposal criteria to promote and accelerate the arrival at a clean circular economy.
So-called 'sustainable chemicals' for the digital green transition have also been identified. The European Green Deal adopted a new EU growth strategy, which laid the foundation for the EU to become a sustainable, climate-neutral and circular economy by 2050. It also set the goal of better health and environmental protection as part of an ambitious approach to combat pollution from all sources for a toxic-free environment. Chemicals permeate our daily lives, these substances are also the building blocks of low-carbon, zero-pollution and energy- and resource-efficient technologies, materials and products. Increasing the chemical industry's investment and innovative capacity for safe and sustainable chemicals will be key to developing new solutions and supporting both the green and digital transition of our economy and society.
In a clean circular economy it is essential to stimulate the production and use of secondary raw materials and to ensure that both primary and secondary materials and products are always safe. To move towards toxic-free material cycles and clean recycling and to ensure that 'recycled in the EU' materials become a global benchmark. In principle, the same limit value should apply to virgin and recycled materials as for hazardous substances.

Activity 8

Solar Food: Harnessing Sunlight for Snacks

Objectives

- Increase awareness and adoption of circular economy principles.
- Showcase and learn from countries that have made significant progress in adopting circular economy practices (such as the Netherlands, Finland, Germany, etc.)
- Promote initiatives that empower consumers with information to make sustainable choices.
- Encourage and support innovation in products, processes, and services to align with circular economy principles.

Introduction to the topic

What is solar cooking?

Solar cooking involves harnessing sunlight to directly heat or cook food, often through the use of solar cookers or solar ovens. These devices use reflective surfaces or concentrators to capture and focus sunlight onto the cooking vessel, allowing for a sustainable and environmentally friendly cooking method.

Activity Details

Material

- Cardboard pizza box
- Aluminum foil
- Plastic wrap
- Black paper
- Crackers
- Chocolate
- Marshmallows

Duration

45 minutes

Group Number

15 participants

Instructions

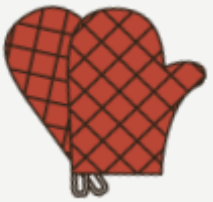
Objective: Demonstrate the potential of solar energy by making s'mores using a solar oven.

1. Introduction (10mins):
2. Solar Oven Construction (15mins):
    a. Cut a flap in the pizza box lid, leaving a border intact.

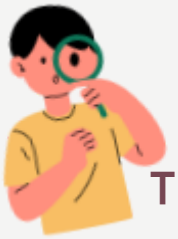
b. Cover the inner side of the flap with aluminum foil, securing it with glue or tape.
c. Line the bottom of the box with black paper.
d. Cover the opening with clear plastic wrap, creating a transparent window.

3. Assemble the S'mores (10mins):
   a. Prepare crackers, chocolate, and marshmallows for s'mores.
   b. Place the s'mores on a tray suitable for the solar oven.

4. Solar Cooking (10mins)
   a. Position the solar oven in direct sunlight, ensuring the foil-covered flap reflects sunlight onto the black construction paper.
   b. Place the tray of s'mores inside the solar oven and wait for them to melt.



5. Observation (15mins):
   a. Monitor the s'mores for changes in the chocolate and marshmallow consistency.
   b. Discuss the concept of solar energy and how it was harnessed for cooking.



TIPS FOR TRAINER

- Conclude the experiment by discussing the effectiveness of solar cooking.
- Encourage students to consider real-world applications of solar energy
-

Activity 9

DIY Water Filtration

Objectives

Understand water filtration basics, emphasizing the roles of sand, gravel, and optional activated charcoal and encourage consideration of DIY filter applications in various scenarios, fostering eco-conscious thinking.

- Evaluate how well the DIY water filtration system cleans water by comparing filtered and original samples
- Understand water filtration basics, emphasizing the roles of sand, gravel, and optional activated charcoal.
- Encourage consideration of DIY filter applications in various scenarios, fostering eco-conscious thinking.

Introduction to the topic

What is water filtration?

Water filtration is the process of removing impurities, contaminants, and particles from water to make it safe and suitable for consumption or other specific purposes. Filtration is a crucial step in water treatment and purification, addressing various types of pollutants that may be present in water from natural sources or human activities.

Activity Details

Material

- Plastic bottles (2 per student)
- Sand
- Small pebbles
- Activated charcoal (optional)
- Coffee filters
- Dirty water source (water mixed with soil or small debris)

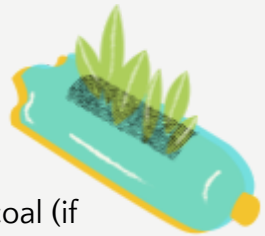
Duration

60 minutes

Group Number

15 participants

Instructions



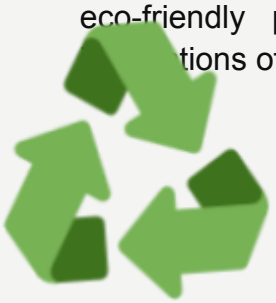
1. Introduction (10mins)
2. Bottle Preparation (15 minutes):
    a. Cut the bottom off one plastic bottle to create a funnel.
    b. Layer the second bottle with sand, gravel, and activated charcoal (if available) to create the filtration chamber.
3. Filtration Setup (10 minutes):
    a. Insert the funnel end of the first bottle into the neck of the second, creating a simple water filter.
    b. Place a coffee filter or cheesecloth inside the funnel to prevent sand and gravel from escaping.

4. Dirty Water Test (10 minutes):
    a. Pour water mixed with soil or small debris into the filtration system.
    b. Observe the water passing through the layers and collecting in the second bottle.

5. Observation and Discussion (15 minutes):
    a. Discuss the clarity of the filtered water.
    b. Compare the filtered water with the original dirty water.
    c. Consider the effectiveness of each layer in removing impurities.

Tips for trainer

- Remind participants to handle materials with care, especially when cutting bottles. Emphasize safety measures to prevent accidents during the experiment.
- Emphasize the project's relevance to sustainability and the importance of eco-friendly practices in water management. Discuss the broader ...tions of water filtration for environmental conservation.



Activity 10

DIY Paper Recycling

Objectives

- Enable participants to actively engage in the paper recycling process, from shredding used paper to forming and drying recycled paper.
- Foster comprehension of the environmental impact of recycling, emphasizing how paper recycling contributes to waste reduction.
- Encourage the adoption of sustainable waste management habits by showcasing the simple yet effective process of transforming used paper into recycled paper.

Introduction to the topic

What is DIY Paper Recycling?

DIY paper recycling, or do-it-yourself paper recycling, is a process where individuals or small groups take used paper materials and transform them into new paper products. This hands-on approach to recycling empowers people to actively contribute to waste reduction and environmental sustainability by reusing paper materials in a creative and practical way.

Activity Details

Material

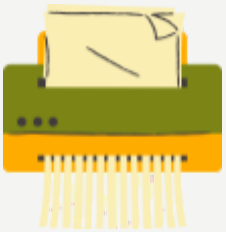
- Used paper (newspapers, magazines, scrap paper)
- Blende Large container
- Water
- Fine mesh or screen
- Sponge
- Rolling pin

Duration

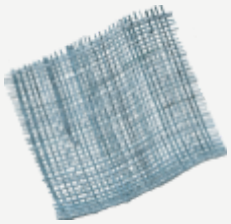
70 minutes

Group Number

15 participants



Instructions



1. Introduction (10 minutes):
    a. Discuss the environmental impact of paper waste and the importance of recycling.
2. Paper Shredding (10 minutes):
    a. Shred used paper into small pieces using a blender or paper shredder.
3. Paper Pulp Creation (10 minutes):
    a. Mix the shredded paper with water in a basin, creating a pulp.
    b. Use a blender for a finer pulp consistency.
4. Paper Forming (15 minutes):
    a. Place a fine mesh or screen into the pulp mixture.
    b. Lift the screen, allowing excess water to drain and forming a thin layer of paper pulp.
5. Pressing and Drying (15 minutes):
    a. Place the wet paper pulp on a flat surface.
    b. Use a rolling pin or flat tool to press and flatten the pulp.
    c. Carefully transfer the formed paper to a drying rack or clothesline.

6. Observation and Discussion (10 minutes)

Tips for Trainer

- If using tools like a blender or paper shredder, remind participants to handle them safely and provide guidance on proper usage.
- Relate the project to real-world recycling practices, discussing how initiatives like paper recycling contribute to larger sustainability goals.

MODULE 4

TOWARDS ZERO CHEMICAL POLLUTION IN THE ENVIRONMENT: THE CIRCULAR CHEMISTRY CONCEPT WITH A FOCUS ON ECOLOGY

Background knowledge

Towards zero chemical pollution in the environment: The circular chemistry concept with a focus on ecology

Chemical pollution is the pollution of the environment with chemicals that are not present there naturally. We can find chemicals everywhere, the products we use and also the food we eat is made up of chemical substances. Chemical pollution is a big problem which can affect the balance of the ecosystems. Chemical products are produced and meant to have functions in different fields, such as agriculture, medicine, cosmetics and products for the household. In the process of manufacturing, disposal or during the transport, the leakage of chemicals in the environment is common.

In the past few decades chemical pollution was very visible and, in the EU much better protection is happening against many harmful substances. However, the problem still exists, because from the 50s to the early 2000s, the global production volume of chemicals has increased more than 50 times. The number of synthetic chemicals on the EU market is around 100 000 with that number constantly increasing on a daily basis.

According to the European Environment Agency characterization of chemicals for their hazards and exposures can be divided into 4 categories:

- Extensively characterized, only 500 of those are extensively characterized for their hazards and exposures
- Fairly well characterized for their hazards and exposures, around 10 000 are fairly well characterized
- Chemicals with Limited characterization of their hazards and exposures are around 20 000.
- Poorly characterized chemicals for their are hazards and exposures are more than 70 000.

Examples of extensively characterized chemicals for their hazards and exposures include:

- Cadmium and cadmium compounds
- Mercury and mercury compounds
- Bisphenol A (BPA)
- Glyphosate
- Lead and lead compounds
- Phthalates

Examples of fairly well-characterized chemicals for their hazards and exposures include:

- Asbestos: It is connected with lung cancer.
- Benzene: can cause cancer, used in the production of plastic.
- Lead: Can cause problems in development in children.

Examples of chemicals with limited characterization for their hazards and exposures:

- Plant Protection Products(PPPs) - The toxicity and impact of those chemicals is not fully known. Some of the studies show their harmful effects, but about exposure the facts are not fully understood.
- Polycyclic Aromatic Hydrocarbons (PAHs) - The toxicity of those chemicals varies by the number of rings in the molecule. Benzopyrene is understood regarding exposure and hazards, but for many others this is not the case, which is why they are in the group of chemicals with limited characterization of hazards and exposure.

Examples of poorly characterized chemicals for their hazards and exposures include:

- Microplastics - The small plastic particles which come from the oceans to the soil. Their harmful effect include accumulation in animals and humans, but their long-term effects are not yet fully discovered.
- Pharmaceuticals and products for personal care products – They are chemical included into toothpaste, shampoo and deodorant. For them it is characteristic to be in the wastewater, yet their effects are not fully understood.
- Nanomaterials are used in many products like cosmetics and clothes but their potential impact on the environment and human health is poorly understood.

All this is really important because it puts pressure on the environment and people, and therefore the risk of harm. Such exposure to harmful chemicals, may cause many health effects, with respiratory and cardiovascular diseases, allergies and cancer as the most frequent health effects. The chemicals that are toxic affect the environment and our health through absorption, breathing, eating. The quality and fertility of soils is affected by chemicals like cadmium, lead, mercury. When the soil is less fertile and with less quality it affects the food we eat.
All ecosystems, animals are affected by the use of pesticides. Often, effects can be long term, its effects are not manifested immediately. The goal and the challenge is to maintain the human and economic benefits of chemical substances, but in the same time to minimize the side effects.

The chemical industry has become a major industrial sector in in recent years regarding resource consumption and environmental impact. Circular chemistry is a key enabler of circular economy. It is set to replace today's linear 'take–make–and then dispose' approach with processes that are different in a way that materials are continuously cycled back through for reuse, that way optimizing resource efficiency.

Circular chemistry is aiming to reduce waste and most important to minimize as much as possible the use of harmful chemicals. During all the processes health should have advantage over economic growth. This should be achieved by promoting sustainable and processes based on circular production.

At the moment the initiative is focused on reducing to depend on fossil fuels and harmful chemicals. As mentioned above, through circular chemistry we can achieve this goal, because in circular chemistry, the materials are reused and recycled. During all the processes health should have advantage over economic growth. This means to use materials that are renewable and non-toxic, and products that can be reused or recycle. This way many industries, especially pharmaceuticals, agriculture and textile industry will have better environmental impact.

In the pharmaceutical industry, circular chemistry can reduce the amount of waste generated by using microorganisms to produce drugs. In the agriculture sector, circular chemistry can promote sustainable farming practices the principle is the same, to minimize the use of chemicals. In the textile industry, which is one of the topic of our three activities, circular chemistry can help reduce water use and waste by upcycling clothes and another option is the usage of non-toxic dyes. It is based on short power point presentation about fast fashion’s bad effects and influence along with short video. It will be followed with an out of the box interactive swapping clothes event in which the students can learn about a lot about sustainable practices regarding textile.

In this theoretical part we will focus on chemical pollution of water, air and soil and circular chemistry solutions.

1. Water pollution - Water pollution is the contamination of water by substances which make the water unusable for drinking, cooking, cleaning, swimming and other activities. Chemicals are the main source of pollutants. In our activities we focus on clothes and water pollution. Clothes production means a lot of water, energy and different chemicals are spent, such as formaldehyde and synthetic dyes, which are later released in water and are harmful in many ways to people and animals. Textile waste is one of the biggest contributors in water pollution, when

disposed improperly. The solution is the use of second-hand clothes, in this way it is reduced the amount of waste generated and less water is used in production. All this is beneficial for the environment.

2. Soil pollution - Soil pollution is happening when chemicals, such as pesticides, fertilizers and heavy metals accumulate in solves at not allowed levels which are harmful for people and environment in general. The approach of circular chemistry is to design products, processes, and systems that minimize waste and preserve natural resources. Circular chemistry also eliminates the use of harmful substances and design products with a longer life cycle. All the above mentioned leads to preventing soil pollution in agriculture and similar industries which is beneficial for people, animals and environment.

3. Air pollution - Air pollution is the presence of substances in the air that are harmful to human health or the environment. Pollutants can come from industrial sector, transportation and energy production. Air pollution can cause serious health problems like lung disease, respiratory infections and even cancer. It contributes in climate change which is another important reason why we should work towards improvement. Circular chemistry focuses on designing chemical processes and products that promote sustainability and circularity. In this sense reducing the amount of pollutants released into the atmosphere during chemical processes is a way in decreasing air pollution. In this way, industries can contribute to cleaner air and a healthier environment.

To conclude, the goal of zero chemical pollution based on circular chemistry with a focus on ecology is essential for a sustainable world. Implementation of circular chemistry can promote a so-called closed-loop system, to help in reducing waste and minimizing the use of harmful chemicals. The key to achieving this is to change our mindset that gives priority to the environment over economic growth and promotes sustainable production processes.

In the following three activities, focused on pollution of water, air, and soil, the students will learn about chemical pollution of water, and air and how circular economy principles can contribute to reducing it. The first proposed activity is about Soap Preparation from Natural sources without using additives, which will emphasize the need of choosing biodegradable and above all, natural ingredients to reduce environmental pollution, in this case water pollution. It will be laboratory activity with the goal to learn about soap preparation, the so called cold method and to find out about the advantages of choosing natural ingredients for soap preparation.

The other two activities are also interactive, with quizzes and game-based learning which would encourage secondary school students of chemistry to be more engaged in chemistry lessons

Activity 11

Soap preparation in the lab as a way to understand circular chemistry

Objectives

The objective of this activity is:

- To raise awareness about the chemical pollution of water and how it affects the environment.
- To understand the need for circular solutions in order to reduce the impact of chemical pollution.
- To promote resource efficiency by showing that products like cooking oil, which can be transformed into soap.
- To encourage responsible behavior among secondary school students.

What is (the activity)?

The first proposed activity is about Soap Preparation from Natural sources without using additives, which will emphasize the need of choosing biodegradable and above all, natural ingredients to reduce environmental pollution, in this case water pollution. It will be laboratory activity with the goal to learn about soap preparation, the so called cold method and to find out about the advantages of choosing natural ingredients for soap preparation. Activity Details

Material

- Distilled water
- Sodium hydroxide (NaOH)
- Digital thermometer
- Safety goggles and gloves
- Coconut oil
- Olive oil
- Soap mold

Duration

120 minutes

Group Number

A class of high school students approximately 25-30

Instructions

Introduction (10 minutes)

Starting with the theoretical part of the topic, the educator presents the facts about chemical pollution, the issue about chemicals and what is circular chemistry. 2. Then, for better understanding of the presentation, the educator shares a video about circular chemistry.

https://www.youtube.com/watch?v=8yY5_akz6hU
https://www.youtube.com/watch?v=Ii0PV0a-wjQ
https://www.youtube.com/watch?v=mBfcdXd-mA8

- Emphasize that soap-making can be a practical example of circular chemistry if we choose sustainable ingredients.
- Introduce the safety measures to the students, such as wearing lab coats, gloves and safety goggles. Also, working in a ventilated area is essential.

Figure 1. Organic soap

Main part (50 minutes)

First, explain to the participants what are the advantages of using eco-friendly ingredients and why vegetable oil instead of fat oil.
Divide the class into groups of 4 students and provide each group with all the necessary ingredients for soap making, safety equipment and lab utensils.
Give instructions to the students about the soap recipe.

- It is recommended that the students measure 200 ml of coconut oil and 100 ml into different containers(heat resistant).

- Students should mix the sodium hydroxide with distilled water, while wearing safety goggles and gloves. **It is essential that the students add NaOH to water, not the opposite.**
- They stir it until the NaOH is dissolved and for the mixture to cool to 43-49 degrees.
- At the same time the two separate containers of olive oil and coconut oil should be warmed until the same temperature.
- The students should slowly add the mixture containing NaOH to the oils and mix continuously until the mixture thickens.
- Encourage the students to add natural colorants and essential oils, in order to add fragrance and visuality to their soap.
- Next, pour this mixture into soap molds. The soap should stay like this 24 to 48 hours in order to harden and to complete the saponification.
- After this period, the soap should be removed from the mold and stay in a cool and dry place for another 4-6 weeks.

In the end the teacher explains the importance of waste reduction and makes sure that the students use all the ingredients efficiently and minimize waste.

Figure 2. Preparation of soap in the laboratory

Soap Maturing and Packaging (5 minutes):

In this part the teachers explain to the students the maturing of the soap, which usually takes 4-6 weeks. The process takes this amount of time in order to allow saponification to complete and excess moisture to evaporate.
Regarding packaging, it is important that the students are taught to use biodegradable packaging, such as recycled paper or fabric, to reduce waste generation and pollution.

Quiz

1. How would you define circular chemistry?

   a. Can soap making be considered a circular process, if yes, why?
2. Can you share alternatives to regular soap making?
3. Can you share some ways to reduce waste and minimize the environmental impact of soap making?
4. Why is natural soap better for the environment?
5. How does regular soap contribute to water pollution?

Conclusion (10 minutes)

Teachers and all students together have short discussions on their experience with circular chemistry and soap-making.
Encourage participants to reflect on the importance of using eco-friendly ingredients and proper waste management to achieve zero chemical pollution in their daily lives.

Tips for trainer

For educator

- Gives clear instructions for each part of the experiment in order for everything to go great.
- Make sure that explains the topic in an interactive way which will engage students to ask questions and after a while they can draw logical conclusions.
- Ask open questions in order to start a discussion and at the same time encourage students to be curious and ask questions.
- Draws attention to the importance of safety measures and makes sure that the students follow all the safety guidelines.

  1. https://www.youtube.com/watch?v=8yY5_akz6hU
  2. https://www.youtube.com/watch?v=Ii0PV0a-wjQ
  3. https://www.youtube.com/watch?v=mBfcdXd-mA8
  4. https://gimmethegoodstuff.org/safe-product-guides/bar-soaps/
  5. https://www.mediamatic.net/en/page/371605/workshop-natural-soap-making

Activity 12

Air pollution and circular chemistry

Objectives

- To discuss the effects on air pollution and to learn about sources of air pollution.
- To learn about the principles of circular chemistry and how it can be applied in improving the situation with air pollution;
- To encourage critical thinking, problem solving and creativity in solutions on air pollution.
- To teach the students to observe and analyze data and also to develop practical laboratory skills.
- To collaborate and brainstorm in groups, teaching the children that collaboration is essential also in real life for all stakeholders in order to solve air pollution

Activity Details

Material

- Hydrogen peroxide solution (3%)
- Manganese dioxide (MnO2) as a catalyst
- Plastic water bottles (clean, dry and empty)
- Balloons
- Plastic tubing (cut into small pieces)
- Safety goggles and gloves
- Timer or stopwatch
- Water

Duration

90 minutes

Group Number

30 students divided in groups

Instructions

1. Introduction (10 minutes)

The teacher starts the lesson by opening discussion with students, with questions like: what do you think causes air pollution? Do you know some chemicals/substances that cause air pollution? For better understanding the

teacher shares a video about air pollution:
https://www.youtube.com/watch?v=sFA1bEBcZyA&t=59s

Main part (40 minutes)

The teacher explains circular chemistry principles, basic introduction about circular chemistry and what is circular chemistry. Then, for better understanding the educator shares a video about circular chemistry.
https://www.youtube.com/watch?v=8yY5_akz6hU

Next, the teachers introduce the main part towards zero air chemical pollution in the environment. It is a laboratory activity.

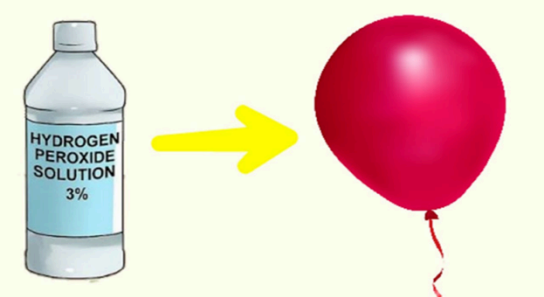
The activity is based on decomposition of hydrogen peroxide with a catalyst such as Mangan dioxide and followed by the decomposition of air pollutants such as NO2).

Before the reaction starts, the teacher asks the students what they think will happen, what is going to happen with the balloon, what changes they will observe and after the experiment to check if their predictions were correct.

Make sure that the classroom is properly ventilated and that safety precautions are met. Provide students with safety goggles and gloves.

Catalytic Decomposition of Hydrogen Peroxide:

- First, fill a plastic water bottle with about 100 mL of 3% hydrogen peroxide solution.
- Next, we should add the catalyst manganese dioxide powder to the hydrogen peroxide in the bottle.
- First, we should weigh appropriate manganese dioxide based on the volume of hydrogen peroxide to be used. The catalyst should be in appropriate amounts, if it is too little it might not facilitate the reaction, but if it is too much it is a waste.
- Second, the catalyst must be a powder. This must be done in order to increase the catalyst's surface area; you might need to crush it into a fine powder. The surface area of the catalyst is essential in catalytic reactions. This process exposes more active sites of the catalyst to the reactants, leading to more efficient catalysis.
- The reaction is the following: $2H_2O_2(aq) \xrightarrow{MnO_2(s)} 2H_2O(l) + O_2(g)$
- Put a balloon over the bottle to collect the gas produced.



The second phase is the breakdown of air pollutants:

- Remove the balloon and allow the gas in the bottle to escape. Now the bottle is filled with leftover oxygen and any other gasses present.
- Attach a small piece of plastic tubing to the mouth of the bottle and the other end of the tubing into a balloon.
- Add a small amount of vinegar with a syringe into the balloon, thus simulating air pollutants.
- There is a reaction between the vinegar and the remaining oxygen in the bottle. ($CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$).

Safety Measures

- Emphasize the importance of wearing safety goggles and gloves during the experiment.
- Ensure proper ventilation in the classroom.
- Avoid breathing in fumes directly. The reactions are safe, but students should not breathe the produced gasses.

To make the activity more engaging students are divided into 3 groups:

- The first group is asked to focus on the role of the catalyst in the decomposition of hydrogen peroxide (in this case the manganese dioxide);
- Second group, what is changed in the balloon during reaction and why?
- Third group, what happens with the leftover vinegar and oxygen?

This experiment is connected to the circular chemistry approach, and it is adapted to be understandable enough for high school students of circular chemistry. It allows them to understand how catalysts can contribute to decreasing air pollution, but at the same time it encourages interactive activities about sustainable chemistry practices.

Conclusion and quiz (20 minutes):

- The teacher summarizes all the reactions happening, summarizing the key role of catalysts, by promoting reactions that reduce waste and encourage resource efficient utilization.
- The teacher discusses and shares examples of how catalysts can be used to decompose pollutants and to prevent harmful gasses, like car catalysts.
- The teacher shares a quiz which will help students to reflect on their knowledge gained through this exercise.

1. **How can we connect circular chemistry to this laboratory activity on air pollution?**
   a) The activity shows the role of catalysts in circular chemistry.
   b) Circular chemistry is not related at all to air pollution.
   c) In this activity we learn about circular methods to purify air.
2. **What is the chemical equation for the decomposition of hydrogen peroxide using manganese dioxide?**
   a) $H_2O_2(aq) \rightarrow H_2O(l) + O_2(g)$
   b) $2H_2O_2(aq) \rightarrow MnO_2(s) \rightarrow 2H_2O(l) + O_2(g)$
   c) $H_2O_2(aq) + MnO_2(s) \rightarrow H_2O(l) + O_2(g)$
3. **Why do we use catalysts in the decomposition of hydrogen peroxide?**
   a) To change the color of the solution.
   b) To speed up the reaction, but to remain unchanged itself.
   c) To increase the volume of gas produced.
4. **Why is it important to crush the catalyst into a powder?**
   a) To increase the catalyst's surface area and improve its efficiency
   b) To increase the reaction temperature.
   c) To make the catalyst easier to weigh.
5. **Which gas is normally produced in the balloon when vinegar reacts with leftover oxygen?**
   a) Carbon monoxide (CO)
   b) Oxygen gas (O_2)
   c) Carbon dioxide gas (CO_2)
6. **How do sulfur dioxide and nitric oxides contribute to air pollution?**
7. **Which of the following is a major air pollutant?**
   a) Activated carbon
   b) Sulfur dioxide
   c) Carbon monoxide

Tips for TRAINER

For educator

- Gives clear instructions for each part of the experiment in order for everything to go great.

- Make sure that explains the topic in an interactive way which will engage students to ask questions and after a while they can draw logical conclusions.
- Ask open questions in order to start a discussion and at the same time encourage students to be curious and ask questions.
- Draw attention to the importance of safety measures and makes sure that the students follow all the safety guidelines.

Activity 13

Soil pollution and ways to decrease it using circular chemistry principles

Objectives

The objective of this activity is:

- To understand and raise awareness about the chemical pollution of soil and how it affects the environment.
- To understand the need for circular solutions in order to reduce the impact of chemical pollution.
- To learn about circular chemistry and propose creative and sustainable solutions.
- To develop practical laboratory skills, when the students do soil testing, and analyze the data collected.
- To brainstorm and develop critical thinking and problem-solving skills.
- To raise awareness about sustainable practices and how it can improve the environment's conditions.
- To introduce students into scientific methods, meaning they will collect data, analyze and interpret the results.

What is (the activity)?

The teacher starts the lesson with the high school students of chemistry by starting a short discussion if they know that the soil can be polluted and if they know they can share examples. To encourage discussion the students can share about what chemical elements or compounds cause this pollution or how we as individuals contribute in **reducing** the chemical pollution of soil.

Activity Details

Material

- Contaminated soil samples
- Organic compost or mulch
- Plant seeds (fast-growing species like radishes or clover)
- pH testing kit
- Water source
- Shovels or garden trowels
- pH adjustment materials (pine needles, wood chips, citrus peels)
- Safety equipment (lab coats, gloves, goggles)

Duration
90 minutes

Group Number
20 students of chemistry

Instructions

1. Introduction (10 minutes)
The teacher starts the lesson with the high school students of chemistry by starting a short discussion if they know that the soil can be polluted and if they know they can share examples. To encourage discussion the students can share about what chemical elements or compounds cause this pollution or how we as individuals can contribute to reducing the chemical pollution of soil.

- For better understanding later it is presented a video about soil pollution in order to raise awareness about the magnitude of the problem. (https://www.youtube.com/watch?v=wHcY-iFSYZM)
- Another short video is presented about the solution to soil pollution from the Food and Agricultural Organization of the United Nations.

https://www.youtube.com/watch?v=s1O3_0GKiEg

Main part (70 minutes)

Part 1. Major chemical pollutants of soil (10 minutes)
The teacher continues the lesson by explaining the major chemicals as soil pollutants that can be inorganic and organic.

- **Inorganic**: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), manganese (Mn), nickel (Ni), zinc (Zn), and radionuclides. These elements are naturally present, but in higher concentrations can be toxic for the environment and human health.
- **Organic**, can be divided into halogenated or non-halogenated (depends on or whether they contain atoms of halogen group) and to aliphatic and aromatic (depends whether they contain carbon-carbon double bonds).

The teachers explain the characteristics of the most important pollutants and on what depends on the duration of contamination, risk of harm and toxicity.
The teacher explains what circular chemistry is and how introducing this concept can help us understand sustainable solutions.

Part 2. Laboratory activity (60 minutes)
The activity is based on a circular chemistry approach for soil conservation.
Preparation of soil samples (20 minutes): Students collect samples from the garden and add coffee grounds for organic pollution, salt for salinity, plastic for plastic pollution. You add the samples in different containers and label it properly

according to the type of contaminants. Students are divided into 2 groups. Each of them gets different types of treatment.

Treatment (20 minutes):

The teacher explains the benefits of different treatments of soil, like organic pH levels adjustment (pine needles, wood chips, citrus peels). Students are assigned the treatment (pH, organic).
https://www.youtube.com/watch?v=gDaF_NQo2kA

Seed Planting (15 minutes):

Students from each group plant seeds in their treated soil samples according to package instructions. Each group gets with a packet of fast-growing plant seeds (e.g., radishes, lettuce, clover) that are suitable for the chosen time frame.
These seeds will serve as indicators of how well their chosen treatment approach affects soil health.

Observation and Discussion (20 minutes):

While we wait for seeds to germinate, engage in a brief discussion about circular chemistry and its principles.
Discuss the potential benefits of organic compost and pH adjustment on soil health and pollution reduction.

Seed Germination and Conclusion (20 minutes):

Depending on seed type, some germination may occur during this time. Take time to talk the role of healthy soil in supporting plant growth and ecosystem balance.
Conclude the activity by summarizing key points about circular chemistry and its application to soil health

Tips for trainer

Quiz about soil pollution:

1. Name 3 inorganic and organic compounds that pollute the water...
2. Why is circular chemistry important in addressing soil pollution?

a) It promotes more use of chemicals in soil
b) It focuses on creating new products
c) It provides solutions which are sustainable and are in the direction of reducing waste

3. What are the effects on human health and the environment caused by soil pollution?
4. How can we avoid soil pollution?

MODULE 5

PROMOTING SAFETY AND SUSTAINABILITY STANDARDS OUTSIDE THE EU: WASTE AS RECOURSE

Background knowledge

Promoting safety and sustainability standards outside the EU: Waste as recourse

Promoting safety and sustainability standards outside the EU involves implementing measures that ensure products and services meet certain safety and environmental standards. This is an important aspect of global trade as it ensures that products and services are safe for consumers and do not cause harm to the environment. One theoretical framework is the concept of sustainable development. This refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development involves balancing economic, social, and environmental considerations. To promote safety and sustainability standards outside the EU, it is important to consider the social and environmental impacts of trade and development. This can be achieved by implementing policies and practices that promote sustainable development, such as investing in renewable energy, reducing waste and pollution, and promoting fair trade.

In addition, the concept of international governance can also play a role in promoting safety and sustainability standards outside the EU. This involves creating international agreements and regulations that ensure that companies adhere to safety and sustainability standards in their operations and supply chains. For example, the United Nations has established the Sustainable Development Goals (SDGs), which provide a framework for sustainable development and promote the adoption of sustainable practices across various sectors. Overall, promoting safety and sustainability standards outside the EU requires a combination of corporate responsibility, sustainable development, and international governance. By implementing these frameworks, companies and governments can work together to ensure that products and services meet certain safety and environmental standards, thereby contributing to a safer and more sustainable global economy. Sustainable waste management means that we keep the materials in use for as long as possible and minimize the amount of solid waste that is disposed of in landfill or through incineration. But, nowadays the waste begins even before products are manufactured, therefore we are required to have a more detailed approach to sustainable waste management. The sustainable waste management has to emphasize the total lifecycle of a product in order to enable us to minimize the negative environmental, social, and financial impacts of 21st-century consumption. Sustainable waste management can provide us with different solutions to the problems waste causes. Here we would like to mention the 5R's, according to the 5R's prior to recycling 4 other actions should be taken: refuse, reduce, reuse, repurpose and then the final step recycle. If we implement the 5R's we can significantly reduce the amount of waste we generate.

https://www.roadrunnerwm.com/blog/the-5-rs-of-waste-recycling

With the economic development and improved qualities of life, quantities of biowaste are generated without proper treatment, which could result in not only resource waste, but also environmental pollution, which attributed to its own special properties such as high water moisture, high degradable organic substances and high nutrients. Recently, many methods have been used to recycle biowastes such as thermal treatment, anaerobic digestion, aerobic composting technology, and other effective approaches. These means could transform biowaste into organic fertilizer and biological energy. However, some byproducts could be generated during the process such as greenhouse gases (GHGs) during aerobic composting, residues (biogas residue and biogas slurry) during anaerobic digestion, and dust in the thermal process, which adversely affected secondary environmental pollution and thus restricted the acceptance of these methods. Therefore, it is essential to satisfy the requirements of zero waste to recycle biowastes in a sustainable way. In order to improve and make better use of these biotechnologies in actual production, more efforts must be made. In order to meet the needs of current technological innovation, under the support and leadership of the policies of various countries of the world, waste recycling and utilization are combined with new business models to meet the stable market demand, which can provide a safety guarantee and sustainable economic development.

The benefits of modern living lead to the creation of large amounts of waste. Economic growth and improved living conditions contribute to an increase in waste generation both in developed countries in Europe and in countries outside the European Union. Producing large quantities of waste leads to environmental pollution.

With economic development and improved quality of life, significant amounts of organic waste are generated without proper treatment, which can result not only in resource waste but also in environmental pollution. This is attributed to its inherent properties, such as high water content, highly degradable organic matter, and high nutrient content. Recently, many methods have been used to recycle organic waste, such as thermal treatment, anaerobic digestion, aerobic

composting technology, and other effective approaches. These means could transform organic waste into organic fertilizer and bioenergy. However, some byproducts may be generated during the process, such as greenhouse gases (GHGs) during aerobic composting, residues (biogas residue and sludge from anaerobic digestion), and dust in the thermal process, which negatively impact secondary environmental pollution, thus limiting the acceptance of these methods. Therefore, it is essential to meet the requirements for zero waste in order to recycle organic waste sustainably.
To improve and better utilize these biotechnologies in actual production, more efforts need to be made. In order to meet the needs of current technological innovations, recycling and waste utilization are combined with new business models under the support and leadership of policies in various countries worldwide, aiming to satisfy stable market demand, which can provide guarantees for safety and sustainable economic development.

Links and sources:

1. European Commission. (2011). A renewed EU strategy 2011-14 for Corporate Social Responsibility. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0681
2. United Nations Development Program (2021). Sustainable Development Goals. https://www.undp.org/content/undp/en/home/sustainable-development-goals.html
3. ISO. (2021). ISO 14001:2015 Environmental management. https://www.iso.org/standard/60857.html
4. ISO. (2021). ISO 45001:2018 Occupational health and safety management systems https://www.iso.org/standard/63787.html
5. World Business Council for Sustainable Development. (2021) What is sustainable development? https://www.wbcsd.org/Overview/Purpose-and-vision/What-is-Sustainable-Development
6. https://www.rts.com/blog/what-is-sustainable-waste-management/
7. https://www.sciencedirect.com/science/article/abs/pii/B9780323885119000033?via%3Dihub

Chapter 1 – Sustainable biowaste recycling toward zero waste approaches

Author links open overlay panelXiuna Ren, Tao Liu, Yue Zhang, Xing Chen, Mukesh Kumar Awasthi, Zengqiang Zhang

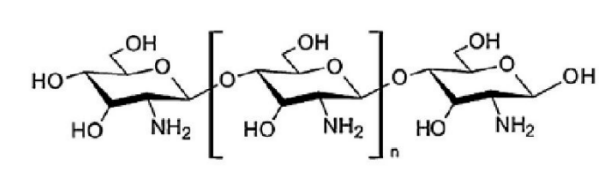
Biowaste as a Potential Source of Bioactive Compounds—A Case Study of Raspberry Fruit Pomace

Slađana Krivokapić,[1,*] Milorad Vlaović,[1] Biljana Damjanović Vratnica,[2] Andrej Perović,[1] and Svetlana Perović[1]

Activity 14
Bioplastics from orange peels

Objectives
The objective is to raise awareness about reusable and renewable waste while creating new materials, to reduce the problem of plastic waste that is suffocating the planet and contaminating the environment.

Introduction to the topic
What are biopolymers?
Biopolymers are polymers produced from natural sources. These can either be chemically synthesized from biological materials or biosynthesized by living organisms. These are made up of monomeric units bonded together by covalent bonds. These monomeric units form larger molecules. As biopolymers are derived from living organisms like plants and microbes, they are a renewable resource, unlike most polymers which are petroleum-based polymers.



Orange peels
Orange peels, which are the main by-product of the citrus processing industry, are rich in pectin, cellulose, and hemicellulose, but poor in protein (5.8%), and constitute approximately 50% of the fresh fruit weight.

Activity Details
Material
- Orange peels
- Blender
- Glass plate
- Glass stick
- Food Dryer
- Hydrochloric Acid (HCl)
- Glycerol

- Distilled water

REQUIRED PPE: Gown, gloves, goggles

Duration

The duration of the practice will be 60 minutes.

Instructions

1. INTRODUCTION

- Biopolymers are polymers produced from natural sources. These can either be chemically synthesized from biological materials or biosynthesized by living organisms. These are made up of monomeric units bonded together by covalent bonds. These monomeric units form larger molecules. As biopolymers are derived from living organisms like plants and microbes, they are a renewable resource, unlike most polymers which are petroleum-based polymers.
- In 2018, the United Nations Food and Agriculture Organization (F.A.O.) [1] estimated a world citrus production of 104.15 Mt, with 75.54 Mt corresponding to orange. During 2018, the largest orange producers worldwide were Brazil, China, India, USA and Mexico, achieving 58.10% of the total orange production. In the same year Mexico produced 4.74 Mt of orange, which represents 6.3% of the world total production [2]. Figure 1 presents the orange production of these countries compared to the world production from 2000 to 2018 [1]. In general, orange production is increasing year over year. The waste that are generated from the orange industry include seeds, pulp, albedo and peel. Some processes take advantage of the greater amount of the fruit and used the rest in different subprocess—cattle feed, essential oil and/or limonene extraction, as well as pectin's extraction are some of the trends applied to the orange residues. However, not all waste is used, resulting in non-hazardous waste with revalorization potential.
- Generally, biopolymers are degradable. They find use in various industries ranging from food industries to manufacturing, packaging and biomedical engineering. Biopolymers are promising materials owing to their characteristics like abundance, biocompatibility and unique properties like non-toxicity etc. With some nanosized reinforcements to enhance its properties and practical applications, biopolymers are being researched for its use in more and more ways possible.
- Orange peels (OP), which are the main by-product of the citrus processing industry, are rich in pectin, cellulose, and hemicellulose, but poor in protein (5.8%), and constitute approximately 50% of the fresh fruit weight

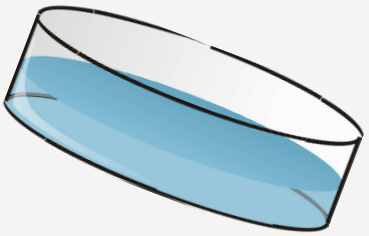
(Bampidis and Robinson, 2005 ▸; Mamma et al., 2008 ▸). This by-product has a high potential degradable dry matter in the rumen with a degradation rate of approximately 3.1% h−1, suggesting its high energetic value for ruminants (Silva et al., 1997 ▸).

- The essential oil (EO) is mainly obtained from the CS peel as a major by-product of the juice production process by a cold-pressing method that can provide the intact blend of compounds without losing the lighter, more volatile, components of the complex mixture that can be lost in the standard EO extraction procedure that is hydro distillation. The last one is mainly used in small-scale applications, for example in research laboratories.
  https://www.intechopen.com/chapters/75482

2. PROCEDURE

The orange peels are pulverized. Then, in order to remove the water, they are placed in a food drier at a temperature of 120°C for 10 minutes. To 25 g of the orange peel paste, while stirring constantly with a glass rod, 3 mL of 0.1 mol/dm3 HCl and 2 mL of glycerol are added. The resulting mixture is pulverized with distilled water (30 mL) using a hand blender and poured onto a glass plate. It is dried at room temperature for 48 hours or in a drying oven at a temperature of 40°C. The sample is peeled off the glass plate.

3. SHEET WITH ISSUES AND QUESTIONS:



- What is bio plastic?
- What kind of bio plastic did we produce?
- Could other resources be used to create bio plastics?
- How can we use the created material from bioplastics?

4.WASTE MANAGEMENT

Does not generate waste

Activity 15

Traction of pectin from apple peels

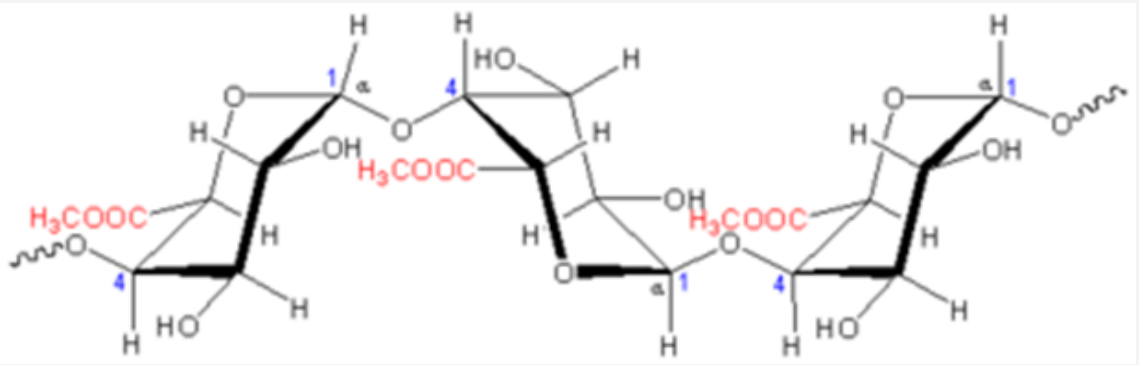
Objectives

The objective is to raise awareness about biowaste to create new materials

Introduction to the topic

What is pectin?

Pectin are highly molecular compounds like polysaccharides. They are found in the cells of plant tissue in fruits and vegetables along with cellulose.
Thanks to their colloidal property of foaming and binding water in themselves, they are very often used as regulators of the water regime in fruits and vegetables.
The richest source of pectins are the peels of citrus fruits, such as oranges, lemons, as well as apples, peaches , bananas , apricots, strawberries , green beans, carrots , peas , tomatoes , potatoes, etc.



Activity Details

Material

- *Raw material*: Apple peels
- *Equipment and devices:* Erlenmeyer flask (250 mL); a glass wand; dryer; mill; water bath; cotton gauze; filter paper; pH paper strips/pH meter
- *Chemicals:* Citric acid; Ethanol; Distilled water
- *REQUIRED PPE:* Gown; gloves; goggles

Duration

ESTIMATED DURATION – preparation time: 1 day or more for drying apple peels

The duration of the practice will be 60 minutes.

Group Number
20 students

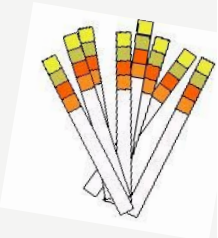
Instructions

Introduction
Pectin substances are highly molecular compounds and in their nature are very close to polysaccharides. These are a whole group of compounds that are found as a natural component in the cells of plant tissue. They are found in fruits and vegetables along with cellulose in cell membranes.

Thanks to their colloidal property of foaming and binding water themselves, they are very often used as regulators of the water regime in fruits and vegetables. The richest source of pectins are the peels of citrus fruits, such as oranges, lemons, lemons, as well as apples, peaches, bananas, apricots, strawberries, green beans, carrots, peas, tomatoes, potatoes, etc. From a chemical point of view, pectin is a methylene ester of polygalacturonic acid.
Pectin is used in the preparation of jams and marmalades, due to its ability to thicken and make a kind of gel consistency in combination with water. For this purpose, it also needs a certain amount of sugar and acid. It can also be used as a substitute for gelatin in the production of processed foods.

Step 1 – homework
Collect apple peels in your home for 1 week and put them in a sunny place to dry for several days.

Step 2 – In the school laboratory
- Apple peels are dried in an oven at a temperature of 60 °C for 1 h or in the shade for several days until they are dry, and ground in a mill.
- 5 g of the ground husks are measured in an Erlenmeyer flask and poured with 150 mL of distilled water.
- Checked the pH value of the mixture by using pH paper strips or pH meter. Correct pH value to 2 by adding drop by drop 0.1 mol /dm 3 HCl.
- The mixture is heated with constant stirring at a temperature of 80 °C for 1 h and filtered through filter paper or five-layer gauze. The resulting pectin filtrate is coagulated with an equal volume of 96% ethanol and left at a temperature of 4 °C for 3 h or overnight.
- Then, it is filtered through filter paper and the resulting precipitate is rinsed with 70% ethanol.



SHEET WITH ISSUES AND QUESTIONS
- draw the chemical formula of the pectin molecule

- explore what pectin is used for in the food industry and why it's important

MODULE 6
Overarching EU strategy and objectives for moving toward sustainable chemicals: Sustainable chemicals for circular economy

Background knowledge

Overarching EU strategy and objectives for moving toward sustainable chemicals (sustainable chemicals for circular economy)

In the 1990s, **green chemistry** (GC) emerged as a reaction to the clearly visible problems inherent to industrial chemistry impacts on the environment (Anastas and Warner, 1998). A set of 12 principles was then proposed to reduce or eliminate the use or generation of hazardous substances in the design, manufacturing, and application of chemical products.

In the late 1990s, a broader view differing from green chemistry was proposed - **the sustainable chemistry** (SC) - taking into account a broader impact on the environment and the 3 dimensions of sustainability (social, economic, and environmental). Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services (OECD, 1998) it also encompasses environmental and societal benefits by (Zunin et al., 2021):

- Avoiding the use of persistent, bio-accumulative, toxic, and otherwise hazardous materials.
- Using renewable resources and decreasing consumption of non-renewable resources.
- Minimizing negative social and environmental impacts of chemical processing and manufacturing.
- Providing technologies that are economically competitive for and advantageous to industry.

More recently **Circular Chemistry** (CC) (Keijler et al., 2019, Kümmere et al., 2020) expanded the scope of sustainable chemistry to the entire lifecycle of chemical products. Circular chemistry intends to optimize resource efficiency across the entire chemical value chains and enable a closed-loop, waste-free chemical industry. This can be done by:

- Keeping molecular complexity to the minimum and avoiding complex products
- Safe and recyclable by design chemical components
- Being responsible for a product throughout its life cycle,
- Ensuring traceability through product digital passports
- Adopting new business models “Chemistry as a service”
- Designing processes for optimal material recovery

The European Chemicals Strategy for Sustainability

The European Union has significantly contributed to the development of a more sustainable chemistry science and industry. The EU already has one of **the most comprehensive and protective regulatory frameworks for chemicals,** supported by the most advanced knowledge base globally. The framework includes almost 40 regulatory instruments, including the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), the Regulation on the Classification, Labelling and Packaging of hazardous substances (CLP) and amongst many others the legislation addressing the safety of toys, cosmetics, biocides, plant protection products, food, carcinogens in the workplace as well as legislation on environmental protection.

This regulatory framework is increasingly becoming a model for safety standards worldwide. However, since some chemicals still cause harm to human health, moreover chemical pollution is one of the key drivers putting the Earth at risk, and global chemicals production is expected to double by 2030, there is an urgent need to produce chemicals and materials which are inherently safe and sustainable, from production to end of life. This is the reason why in October 2020 **the European Commission published a "Chemicals strategy for sustainability"** as a key commitment of the European Green Deal.

In July 2020 t**he European Parliament adopted a resolution on the Chemicals Strategy**, stressing the need to develop 'safe and sustainable by design' criteria to help prevent and control pollution, improve the tracing of hazardous chemicals in products, and promote their substitution by safer and more sustainable alternatives. In March 2021, the **EU Council conclusions on the Chemicals Strategy** also call on the Commission to promptly develop, in cooperation with the Member States and in consultation with stakeholders, harmonized, clear, and precise definitions and, where adequate, criteria or principles for the concepts that are crucial for the effective implementation of the Chemicals Strategy, such as 'safe and sustainable by design' chemicals.

<u>The EU chemicals strategy</u>

The purpose of the strategy is promoting a **toxic-free environment**, where chemicals are produced and used in a way that maximizes their contribution to society including achieving the green and digital transition, while avoiding harm to the planet and to current and future generations. It envisages the EU industry as a globally competitive player in the production and use of safe and sustainable chemicals.

The strategy proposes a clear **roadmap for the transformation** of industry toward safe and sustainable products and production methods. The roadmap is lustrated in the figure below.

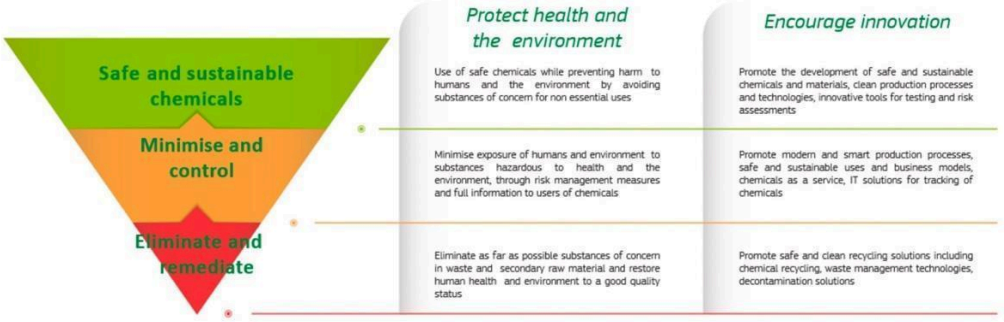


Figure: The toxic-free hierarchy – a new hierarchy in chemicals management

The Strategy is articulated in **4 main chapters:**

1. Innovating for safe and sustainable EU chemicals.
2. Stronger EU legal framework to address pressing environmental and health concerns.
3. A comprehensive knowledge based on chemicals.
4. Setting the example for a global sound management of chemicals.

Illustrating the whole content of the strategy is beyond the scope of this educational module, however, some topics are very relevant for secondary education, especially in the VET system. Moreover, the Strategy stresses the need to address safe and sustainable-by-design **skills mismatches** and competence gaps, and ensure adequate skills at all levels, including in vocational education.

The core concept of the strategy is indeed the "**safe and sustainable by design (SSD)"** approach to chemicals production. The EU will incentivize industry to substitute, as far as possible, substances of concern with safe and sustainable-by-design chemicals, including bio-based chemicals. A framework identifying criteria for safe and sustainable chemicals and KPIs to measure the industrial transition in this direction has already been developed by the Joint Research Centre (Caldeira er al, 2022). Financial and networking support will be also provided by the EC the ensure the development and commercialization, of SSD, materials and promote cooperation across sectors and the value chains.

Another strategic concept is "**safe secondary raw materials",** which means ensuring that substances of concern in products and recycled materials are minimized. This is particularly important for certain plastics and textiles and **chemical recycling** could play a crucial role in this process, provided that it has an overall positive environmental and climate performance. The EC will therefore introduce requirements for the use of secondary raw materials and also information requirements to track the presence of substances of concern through the product's life cycle. Investments to decontaminate waste streams, increase safe recycling are also planned.

Alongside actions concerning safe and sustainable chemicals, other actions aimed at **protecting people and the environment from harmful chemicals** and substances

of concern are envisaged by the EU Strategy. **The REACH and CLP** Regulations will be reinforced and complemented by methods to assess and manage chemicals in sectorial and Member States legislations, especially that regulating consumer products. the most harmful chemicals in consumer products will be banned, or allowed only where their use is proven essential. For instance, a system will be put in place to identify and ban **endocrine disruptors** in consumer products. Furthermore, **a risk management approach** will be developed, and integrated into the REACH, to ensure that consumer products, such as food contact materials, toys, childcare articles, cosmetics, detergents, furniture and textiles, do not contain chemicals that cause cancers, gene mutations, affect the reproductive or the endocrine system, or are persistent and bioaccumulative.

The "cocktail effect", that is the impact of the combination effect of several chemicals to which people are daily exposed, will also be taken into account for chemical risk assessments and management. The risk and hazard assessment of chemicals will be also improved by establishing a simpler and more transparent approach **called "one substance one assessment".** It will be a coherent approach across Member States using **a common open data platform on chemicals** to facilitate the sharing, access, and re-use of information on chemicals coming from all sources.

Another strategic action planned is **the phasing out the use of per- and polyfluoroalkyl substances (PFAS) i**n the EU to reach the objective "zero chemical pollution in the environment".

Per- and polyfluoroalkyl substances (PFAS) has gained special attention, due to the large number of cases of contamination of soil and water - including drinking water - in the EU and globally, the number of people affected with a full spectrum of illnesses and the related societal and economic costs. That is why the Commission proposes a comprehensive set of actions to address the use of and contamination with PFAS. The key ones are:

- **banning all PFAS as a group in** fire-fighting foams as well as in other uses, allowing their use only where they are essential for society;
- addressing PFAS with a group approach, under relevant legislation on water, sustainable products, food, industrial emissions, and waste;
- developing innovative **methodologies for remediating PFAS contamination** in the environment and in products.

A "**zero tolerance approach to non-compliance"** will reinforce the purpose of banning/restricting hazardous chemicals, by straightening the principles of **'no data, no market'** and the '**polluter-pays'** under REACH. Furthermore, the EU is committed to play a leading role globally by championing and promoting high standards in chemistry sustainability, and by **not exporting chemicals banned in the EU.**

References

Anastas P.T. and Warner, J. C. Green Chemistry: Theory and Practice. *Oxford University Press,* 1998.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of The Regions. Chemicals Strategy for Sustainability Towards a Toxic-Free Environment. COM(2020) 667 final.
Commission Recommendation of 8.12.2022. Establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials. C(2022) 8854 final
European Parliament resolution of 10 July 2020 on the Chemicals Strategy for Sustainability (2020/2531(RSP).
Council conclusions 6941/21 of 15 March 2021, Sustainable Chemicals Strategy of the Union: Time to Deliver.
Caldeira C., Farcal L., Garmendia, I., et al. Safe and sustainable by design chemicals and materials: Framework for the definition of safe and sustainable by design criteria for chemicals and materials, *Publications Office of the European Union*, Luxembourg, 2022.
K. Kümmere, J. H. Clark and V. G. Zuin. Rethinking chemistry for a circular economy. *SCIENCE*, 2020, 367, 369–370. DOI: 10.1126/science.aba4979.
OECD, Proceedings of the OECD workshop on sustainable chemistry, 19/PART1, 1998.
Zuin, V. G., Eilks, I., Elschami, M. , and Kümmerer, K.. Education in green chemistry and in sustainable chemistry: perspectives towards sustainability. *Green Chemistry*, 2021. DOI: 10.1039/d0gc03313

Activity 16

Dealing with "FOREVER CHEMICALS"
Supporting the EU Strategy for phasing out the use of per- and polyfluoroalkyl substances (PFAS)

Objectives

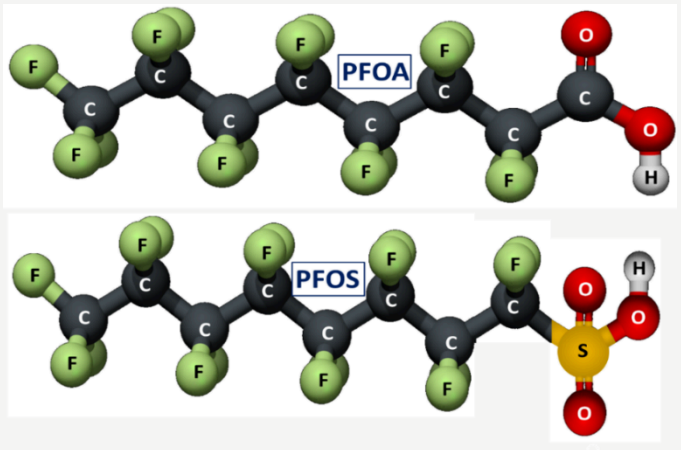
- Learning chemical theory about per- and polyfluoroalkyl substances (PFAS).
- Learning about risks related to PFAS and how they can be mitigated.
- Providing background information on the European Chemicals Strategy for Sustainability in relation to PFAS.
- Fostering critical thinking and other transversal skills.

Introduction to the topic

What are PFAS?

The term PFAS refers to a family of synthetic organic compounds consisting of a linear or branched alkyl chain, hydrophobic, of varying length (from 4 to 16 carbon units). These can be fully or partially fluorinated: in the first case, they are called "PERFLUORINATED" substances (e.g., PFOA and PFOS); in the second case, they are referred to as "POLYFLUORINATED" substances.
Pharmacological Research Institute "Mario Negri" of Milan

CHEMICAL STRUCTURE OF THE MOST COMMON PFAS

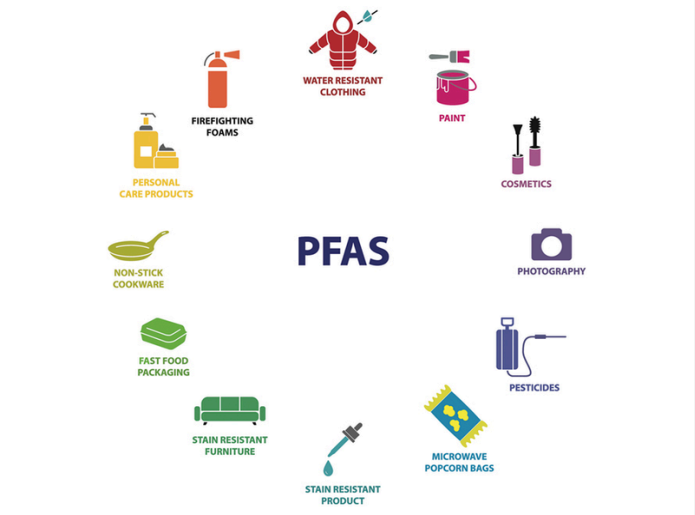


Perfluorooctanoic acid and Perfluorooctane sulfonic acid

CHEMICAL-PHYSICAL PROPERTIES

- THERMAL AND CHEMICAL STABILITY
- RESISTANCE TO ACIDS AND BASES
- RESISTANCE TO OXIDIZING/REDUCING AGENTS
- WATER AND GAS IMPERMEABILITY
- FIRE RESISTANCE
- LUBRICANT CAPABILITY

FIELDS OF APPLICATION OF PFAS



EXPOSURE TO PFAS

- Ingestion of contaminated water (30%)
- Ingestion of contaminated food (40%)
- Inhalation (7%)
- Environmental dispersion (23%)

CHARACTERISTICS OF PFAS

Chemically stable and resistant to degradation processes: persistence in soil, air, and water for years. PFOA and PFOS have bioaccumulative properties and persist in the human body without being expelled like regular toxins. They accumulate in the liver and adipose tissues, binding to blood proteins.

HEALTH RISKS

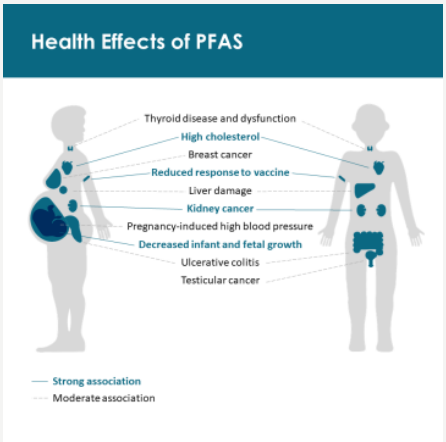
- Effects on the immune system
- Effects on the Endocrine system
- Carcinogenic and toxic effects on humans
- Negative consequences on fertility
- Risk of spontaneous abortion

- Damage to breastfed children and reduced immune response to vaccination
- Newborns, anomalies in the nervous system, circulatory system, and chromosome malformations

Restrictions on PFAS

The scale of PFAS pollution triggered some countries in 2020 (Germany, Denmark, the Netherlands, Norway, and Sweden) to begin preparing a broad PFAS restriction which was presented in 2023.
The European Chemicals Agency (ECHA) is currently (March 2024) working on assessing the massive number of comments the restriction proposal received from industry and organizations globally.
The EU has already started moving the needle with restrictions on some groups within the PFAS family, like the 2024 ban of PFHxA in food packaging clothing, and other uses.

PFAS contamination in Italy



Miteni, located in Trissino, was responsible for 97% of the 5 kilograms of PFAS discharged into the basin waters. The factory produced fluorine-containing intermediates mainly for the agrochemical and pharmaceutical industries.
In 2016, tests were conducted on part of the population living between the provinces of Vicenza, Verona, and Padua. These tests revealed a high concentration of chemical compounds in the blood, including PFAS.
In 2018, the company went bankrupt due to the contamination of the groundwater with PFAS like PFOA, GenX, and C6O4.

PFAS Contamination in Piedmont

Arpa Piemonte began analytical activity in 2009, monitoring the spread of PFAS in regional water bodies. A particularly contaminated area was identified around the Chemical Hub of Spinetta Marengo (Alessandria), where these substances are produced.
Starting in 2023, experimental activities are underway to detect PFAS in samples of gases, landfill leachates, sludge from purification processes, soils, and waste to verify the spread of these substances.

The contamination is no longer limited to the province of Alessandria but has also been found in other areas of the Metropolitan City of Turin and in Novara.

Decrees or draft laws regarding PFAS in Italy

The first law was enacted in 2015 and is based on a study conducted by the CNR, completed in 2013, on the environmental and health risks associated with PFAS contamination in major Italian basins.
The second law, implemented after the European directive (2020/2184), was recently approved in 2023, establishing limits for the presence of PFAS in drinking water, with particular attention to the sum of 24 different PFAS substances and the total of substances classified as PFAS.
However, the two Italian laws do not solve the problems because they do not ban the presence of PFAS.
However, the two Italian laws do not solve the problems because they do not ban the presence of PFAS.
In France, on April 4, 2024, a law was approved banning the use of PFAS in production processes starting in 2026.
It will cover food packaging, dental floss, baking paper, pharmaceuticals, medical devices, cosmetics, clothing, textiles, and furniture products.
For now, the law excludes pots and other kitchen utensils.
In Italy, we are still stuck with two laws that only signal and monitor the presence of these harmful substances in water for health and the environment.

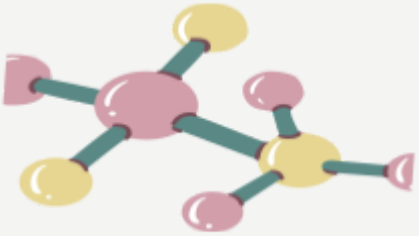
Treatment of PFAS-contaminated water

A team of researchers from the ENEA Center in Bologna is developing a new method using electronic plasmas, a technology based on a beam of electrons with controlled energy.
Essentially, the electron beam breaks the carbon-fluorine bond in PFAS, one of the strongest in organic chemistry. The result is the formation of fluorides, which are still pollutants but much easier to treat and remove.

Activity Details

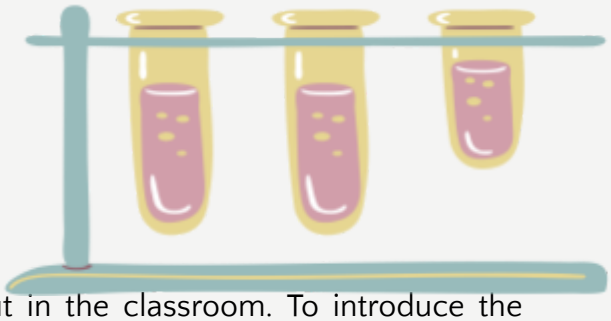
Material

- 2 Videos
- 1 PDF (Theory)
- 1 Activity instruction
- 1 Learning Assessment Test
- Teacher Guideline



Duration

Step 1 - in the classroom: .1h Theory + 1h group Exercise
Step 2 - outside the classroom: 3 h group work
Step 3 - in the classroom: 1 h presentation & discussion of group work.



Group Number
5-member groups

Instructions

General structure of the Activity
The activity is organized in 3 steps:

1. "Introduction to PFAS" is carried out in the classroom. To introduce the topic the teacher shows a video and then lectures students on PFAS. Afterwards, students divided in subgroups are asked to perform a small task. At the end of the lesson the teacher gives instructions on the additional task to be conducted by the groups after school.
2. "No PFAS Around". Each group carries out this task by preparing a service announcement about the dangers of PFAS to be presented in the classroom.
3. "Conclusions and evaluation". Group work is presented and discussed in the classroom with the teacher. A learning assessment test is administered by the teacher at the end of the lesson.

Activity Program and Materials

STEP 1 – in the classroom

Introduction to PFAS
Material: 2 videos

- "Forever Chemicals" https://www.youtube.com/watch?v=tqKEG5LxPiY
- "Forever Chemicals we do not want around" https://www.youtube.com/watch?v=lndgsT9tRrk

Lecture on PFAS
Material: ppt or pdf presentation

- What are PFAS?
  - The basics of PFAS
  - Chemical structures & properties
- Why and how are they used?
  - What are the advantages of PFAS?
  - Where one can find PFAS
- Risks related to PFAS
  - Human exposure to PFAS
  - Health implications
- What do we not know?
  - How many PFAS are around?

    - How do they interact with our body?
- What can we do?
    - Filtration and destruction
    - The EU strategy on PFAS

"PFAS free" alternatives (Task 1)

Material: short guidelines for teachers

Overall description

Since the best method of preventing PFAS compounds from entering the environment is to avoid, if possible, using materials that contain "forever chemicals". Students are divided into sub-groups and required to identify 3 items that they use daily that contain PFAS compounds then they are asked to find "PFAS free" alternatives to these items.

STEP 2 – outside the classroom

No PFAS Around (Task 2)

Material: short guidelines for teachers

Overall description

The students will be asked to create a public service announcement about the dangers of PFAS compounds accumulating in the environment in hopes convincing individuals to limit their exposure and use of PFAS compounds. They might create a YouTube video, Infographic, TikTok, or Twitter to present their announcement. In the video, they should inform the public about PFAS compounds and their uses, the dangers of PFAS compounds, and how limit exposure/use of PFAS compounds.

STEP 3 – in the classroom

Group works presentation and discussion

Material: short guidelines for teachers

Learning assessment test

Material: test + answer sheet

Further Resources

- The Movie "DARK WATER", 2005
- The article "The Chemistry of Convenience" by Max G. Levy
- A Guide to the PFAS found in our environment. https://cen.acs.org/sections/pfas.html

Activity 17

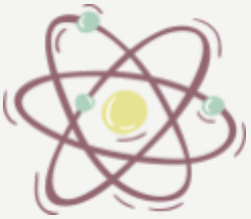
Chemistry in cosmetics: checking labels to go beyond brands and greenwashing.

Objectives

- Learning about basic chemistry of cosmetics
- Understanding ingredients and labels of cosmetics
- Learning about risks related to some chemicals in cosmetics
- Deciphering and assessing the label of a personal care product
- Fostering critical thinking and other transversal skills

Activity Details

Material



- 1 video
- 1 PDF (Theory)
- 1 Activity instruction
- 1 Learning Assessment Test
- Teacher Guideline

Duration

1. Lecture and discussion = 45 minutes.
2. Classroom Activity = 1 hour.
3. Homework = 1 hour

Group Number

Subgroup of 3 members for the activity

Instructions

Introduction

VIEDEO "The chemistry behind cosmetics"
https://www.youtube.com/watch?v=5G0OyeSI9FE

Lecture on

- Basic chemistry of cosmetics
- Understanding ingredients and labelling of cosmetics
- "Fragrance" labels: between trade secrets and safety
- Chemical concerns in cosmetics: the case of parabens
- Does "natural" mean safe? The case of oak moss
- Are cosmetics sustainable? The case of palm oil
- Relevant EU regulations for cosmetics

Typical ingredients explained

- **AQUA**: another term for water.
- **CI** [number]: A number with 'CI' in front of it is a colour index number which refers to a very specific ingredient – for a lipstick, for example – rather than just red or orange.
- **EXTRACT**: natural extracts from plants are common ingredients, but are mixtures of various compounds, which are difficult to standardize.
- **GLYCERYL**: in front of oleate, stearate or cocoate, is a type of glycerol used as an emulsifier and to help retain moisture.
- **PARABEN**: often attached to methyl, ethyl, propyl or butyl, is usually a preservative with a particular chemical structure. There has been debate about the safety of these chemicals due to hormone-disrupting effects and links to cancer.
- **PARFUM**: a fragrance or aroma compound, or a blend of these compounds.
- **SODIUM LAURETH SULFATE**: a widely used cleaning and foaming agent made from palm or coconut oil.
- **(NANO)**: used after an ingredient means that the ingredient has dimensions between 1–100 nm.

Chemicals of concern

What are parabens?

Parabens are several distinct chemicals with a similar molecular structure. Several are common in a wide array cosmetic and personal care product. **Methylparaben and propylparaben** are the most common of these. Parabens are most common in personal care products that contain significant amounts of water such as shampoos, conditioners, lotions and facial and shower cleansers and scrubs because **they discourage the growth of microbes**.

Health Concerns

Parabens are potential **endocrine disruptors** due to their ability to mimic estrogen. In cell studies, parabens have been found to weakly bind to estrogen receptors. Studies demonstrate that at sufficient concentrations, parabens can increase cell proliferation in human **breast cancer** MCF-7 cells, which are often used as a sensitive measure of estrogenic activity.

Found In	What to look for on the label
• Shampoos • Conditioners • Lotions • Facial and shower cleansers and scrubs	• Ethylparaben • Butylparaben • Methylparaben • Propylparaben • Isobutylparaben • Isopropylparaben • Other ingredients ending in –paraben

.

The mystery of a fragrance

Many products list "**fragrance**" or «**Parfum**» on the label, but very few name the specific ingredients that make up a "fragrance." This lack of disclosure prevents consumers from knowing the full list of ingredients in their products.

This protects companies from having to spill the secrets of their scents. However, protecting trade secrets leaves consumers in the dark and recent research suggests that many millions of **people are sensitive to fragranced products.**

All the ingredients that make up a fragrance do have to be assessed as part of a product's overall safety assessment.

Does natural mean safe?

Even though natural chemical are often perceived as safer than synthetic ones, safety does not depend on the natural, organic or man-made origin of the chemicals. For example, the EU regulation has banned some extracts of **the oak tree moss,** which were previously used for the perfume Chanel N°5, to protect consumers from potential **allergens and irritants** in fragrances.

There are also concerns about **the environmental impact** of the ingredient. Oakmoss is harvested from the bark of oak trees, and over-harvesting can lead to deforestation and loss of habitat for other species.

Are cosmetics sustainable?

Palm oil is a versatile vegetable oil that is ubiquitous in cosmetics and personal care products. It is beloved by the beauty industry for its high vitamin E content, texture-boosting fatty acids, and natural alcohols, which give it desirable emollient properties.

However, palm oil is an **unsustainable** ingredient. Demand for the product drives **deforestation** and destroys wildlife habitats in the diverse tropics. The farming

practices associated with the crop are notorious for **their considerable carbon footpri**nts and have been known to involve **child labour.**

ACTIVITY (IN THE CLASSROOM)

The students mimic a fictional meeting in which representatives of a risk assessment institute evaluate three different fictional brands of shampoo and scrutinize the labels for ingredients and allergens.

Organic Brand	High Street Brand	All natural brand
Aqua *Cocos nucifera* oil Sodium laureth sulfate Gyceryl cocoate Lauryl alcohol Methylparaben Sodium hydroxide Limonene Citral *Lavandula angustifolia* oil* *Rosa damascena* oil*	Aqua Sodium laureth sulfate Butylparaben Sodium chloride Parfum Glyceryl cocoate Sodium hydroxide Stearyl alcohol Citric acid Limonene Linalool	Aloe vera leaf extract Glycerin Coconut oil *Crambe abyssinica* seed oil Lemongrass herb oil Camellia leaf extract *Salvia sclarea* extract Xanthan gum Aqua Lemon peel Lavender oil

Students are asked to:

- identify ingredients with chemical names and those who have unclear wording
- understand ingredients purpose and assess label compliance with EU Law
- decide what brand provides enough information to conclude that the product is safe and EU Law compliant and can be launched on the market
- present an assessment report to the class.

HOMEWORK

Students are encouraged to: check the label of one personal care product they use at home; pick 3 ingredients; find the chemical formula; research about their functions and any potential concern; write a short report on the assessment.

DISCUSSION & EVALUATION

"Conclusions and evaluation". Group works are presented and discussed in classroom with the teacher and the latter evaluates them.

FURTHER RESOURCES FOR TEACHERS

Belova, N., & Eilks, I. (2012) Learning with and about advertising in chemistry education with a lesson plan on natural cosmetics – A case study. Chemistry Education Research and Practice. *DOI: 10.1039/x0xx00000x*

Activity 18

Assessing the environmental impact of the Haber Process and researching on more sustainable applications.

Objectives

- Understanding the chemical reaction involved in the Haber Process.
- Understanding the significance of the Haber Process in ammonia production.
- Learning about the environmental impacts of the Haber Process, such as greenhouse gas emissions, water pollution, and air pollution.
- Fostering critical thinking and problem-solving skills in the context of designing eco-friendly chemical processes.
- Facilitating discussions about the challenges and opportunities of designing eco-friendly chemical processes.

Activity Details

Material

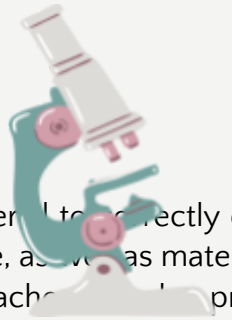
- 2 Videos + 1 PDF (Theory)
- 1 Activity instruction
- 1 Learning Assessment Test
- Teacher Guideline

Duration

1. lecture = 1h
2. Research = 45 minutes
3. Essay writing = 30 minutes

Group Number

Subgroup of 5 members for the activity



Instructions

STEP 1: BRIEF LECTURE

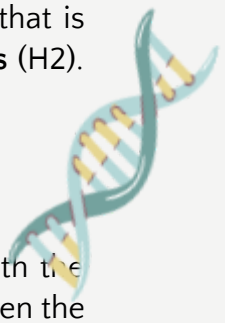
The teacher will provide students with the necessary material to correctly define the Haber Process, its applications and uses in everyday life, as well as material on the pollution produced by this chemical process. The teacher should provide students with handouts, flowcharts and diagrams defining the Haber Process and its impact on the environment.

Topics to be addressed in the lecture

- Description of the Haber Process,
- Description of its applications and uses in everyday life,
- Negative impact and pollution produced by the chemical process

The Haber process

The Haber process is a specific chemical reaction in industrial chemistry that is used to produce **ammonia** (NH3) from **nitrogen gas** (N2) and **hydrogen gas** (H2). The reaction is represented by the following equation:



$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$

The Haber process is a reversible reaction, meaning it can proceed in both the forward (left-to-right) direction and the reverse (right-to-left) direction. When the reaction is carried out under suitable conditions of temperature and pressure, it reaches a dynamic equilibrium. At this point, the rates of the forward and reverse reactions become equal, and the concentration of ammonia remains constant

Applications

In industrial applications, the Haber process is essential for the production of ammonia, which is a key component in the manufacturing of **fertilizers**, **explosives**, and various other chemical products. The Heber process has helped extensively with our crop production and made it possible to use less land and destroy fewer habitats.

However, ammonium-based explosives are in abundance due to the Haber Process and ammonia production has had many detrimental effects on the environment.

Impact & alternatives

The Haber process requires **high temperatures and high pressures** to achieve practical reaction rates. This results in substantial energy consumption and associated greenhouse gas emissions when the required energy comes from non-renewable sources. Moreover, the Haber process relies on **iron-based catalysts** to enhance the reaction rate. The synthesis, handling, and disposal of these catalysts can have environmental impacts.
Strategies to make the Haber process more green-friendly include (but are not limited to):

- **Developing more energy-efficient methods** for the Haber process, such as using alternative energy sources like renewable electricity or optimizing reaction conditions.
- Exploring alternative, more **sustainable catalysts**.

- Implementing strategies **to recycle unused reactants** and minimizing waste generation during the process can align the Haber process with green chemistry principles.

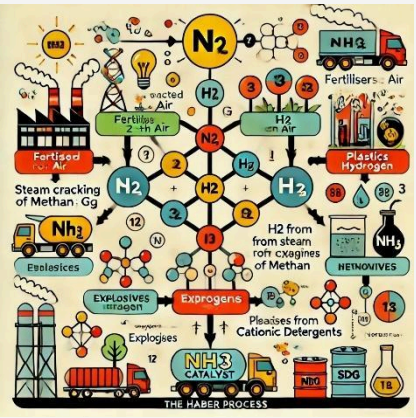
SUPPORTING VIDEOS

- VIDEO "The Haber Process & Its Environmental Implications" https://www.youtube.com/watch?v=FQunUEaNWCQ
- VIDEO "The chemical reaction that feeds the world"

STEP 2: ACTIVTIY – RESEARCH (30-45' MIN)

Students, divided into sub-groups, will have to research the different applications of the Haber process and the environmental impact of the process.
Students can use *diagrams*, *flowcharts*, or *handouts* to explain their proposed solutions for a greener Haber Process by incorporating green chemistry principles and innovative technologies.
They are required to reflect on the impact of Haber Process on the environment, society and economy. Then they will be asked to represent their understanding of these issues by using a **system thinking map.**

Students will be invited to **consider whether each element in their systems map had an impact on any of the SDGs.** Afterwards, they evaluate whether this impact could be positive, negative, or neutral through different colors.



STEP 3: SHORT ESSAY (30' MIN)

At the end of the assignment, the groups should write a short reflection on their experience researching and designing sustainable solutions for the Haber Process. They should **consider the challenges and opportunities of implementing green chemistry principles in industrial processes** and discuss the potential impact on global sustainability.

The groups will have to present their conclusions about the Haber process and its implications to the rest of the class. Discussion among students could be encouraged by the teacher.

The teacher will evaluate group and individual work according to the complexity and correctness of the presentation, and the involvement of each student in the project.

Engaging Schools in Communication activities

Activity 19

Organize campaigns to promote recycling and waste

Objectives

Organizing a recycling and waste reduction campaign in high schools requires a varied approach that involves raising awareness, changing behaviors, and implementing practical solutions. By taking these steps, high schools can promote a more sustainable environment and encourage students to become responsible citizens who are conscious of their impact on the planet.

Activity Details

Material

- Recycling bins
- Posters and flyers
- Materials needed for a compost site

Duration

3 months

Group Number

20 students and teachers

Instructions

High schools can organize campaigns to promote recycling and waste reduction among students and staff. This could include setting up recycling bins, composting systems, and educating students about the importance of reducing waste.

1. For example, high schools can set up recycling bins in strategic locations such as classrooms, hallways and outdoor areas to encourage students and staff to recycle. These bins should be clearly labeled to avoid confusion and contamination.
2. Another example is raising awareness through posters and flyers that is high schools can create posters and flyers to educate students and staff about the importance of recycling and waste reduction. These can be displayed in common areas and classrooms to increase awareness and promote behavior change.
3. And the last action can be to implement a composting program that is high schools can implement a composting program where organic waste such as food scraps and yard waste can be diverted from the landfill and turned into compost. This can be used as a soil amendment in the school's gardens or donated to a local community garden.

Activity 20

Host sustainability events: such an event can take place during the sustainability day on 26 October or Earth Day on 22 April

Objectives

By hosting sustainability events, high schools can engage students and the community in environmental action and education. These events can inspire students to become environmental leaders and change agents who promote sustainability in their daily lives.

- Environmental sustainability: Produce a more environmentally friendly fuel that reduces greenhouse gas emissions.
- Waste reduction: Reuse used vegetable oil into a useful product instead of discarding it.
- Education and research: Infrared to the chemistry of transforming vegetable oils into biodiesel and its practical application.
- Safety awareness: Teaching about safe handling of products made hazardous in the process.
- Applications: Produce biodiesel to evaluate its use as an alternative fuel in diesel engines.

Activity Details

Material

- Workshop materials,
- A place to host the event at
- Invitations

Duration

1. Preparation time: 2 weeks,
2. Actual event: 1 day

Group Number

20 students and teachers as well as a guest speaker

Instructions

High schools can host sustainability events such as Earth Day celebrations or Sustainability Day celebrations to raise awareness of environmental issues and promote sustainable practices.

The following steps can be taken in order to organize such an event:

1. Select a theme that proposes the school's sustainability goals and interests. The themes could include waste reduction, water conservation, energy efficiency or sustainable food.
2. Plan the event by determining the date, time and location of the event and decide on the activities to be included.
   Possible activities could include guest speakers, workshops, hands-on activities, and interactive displays.
3. Invite speakers, invite guest speakers who are experts on the selected themes to give talks and presentations on the topic. These speakers could include local environmental activists, sustainability professionals, and representatives from local organizations.
4. Workshops and activities, host workshops and hands-on activities that allow participants to learn about sustainability in a fun and interactive way. The workshops could include composting, gardening, cycling and sustainable cooking.