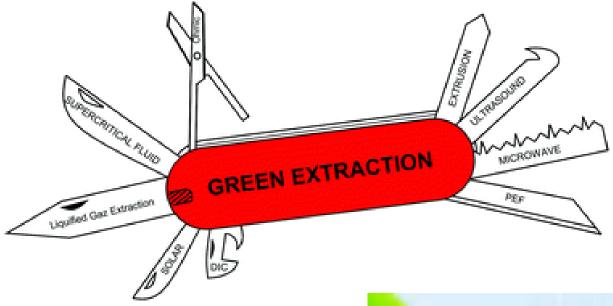
# MUNI PHARM



# **Green Chemistry**



### **Green Chemistry**

- = sustainable chemistry
- design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances and waste
- environment friendly
- cost-effective
- renewable plant resources
- alternative solvents
- reduction of energy consumption

#### **Green Chemistry Principles**

#### Green chemistry principles

#### 1. Prevent waste

2. Maximize atom economy

3. Design less hazardous chemical synthesis

4. Design safer chemicals and products

5. Use safer solvents and reaction conditions

6. Increase energy efficiency

7. Use renewable feedstock

8. Avoid chemical derivatives

9. Use of catalyst

10. Design for degradation

11. Analysis in real time to prevent pollution

12. Minimize the potential accidents

#### **Green Practices**

 Care about potential hazardous compounds and reagent

One step procedures

 Energy, and reagent consumes evaluation

Reduction of waste

#### **Old Practices**

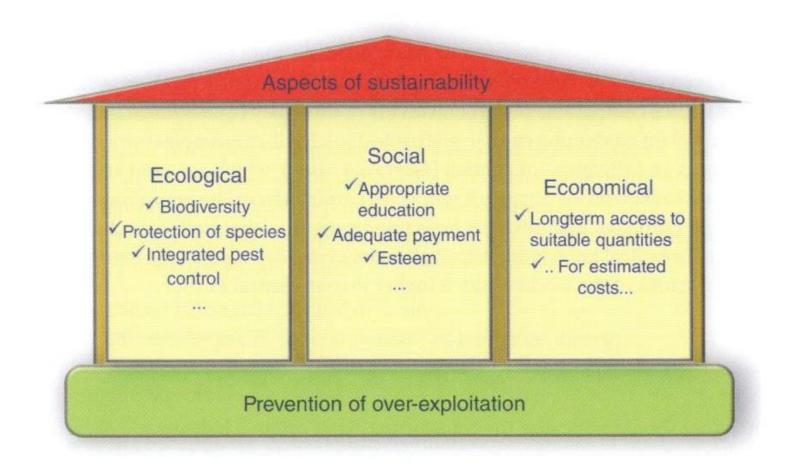
- · Use of toxic reagents
- Multistep procedures
- No energy, no reagents consume considerations

 Accumulation of waste for external treatment

#### **Sustainable Processes**

- Social sustainability = the ability of a social system to function with a level of well-being
- Environmental sustainability = the ability of the environment to provide a level of environmental quality and to assure that no species becomes endangered or even extinct
- Economic sustainability = the ability of an economy to assure a defined level of economic production

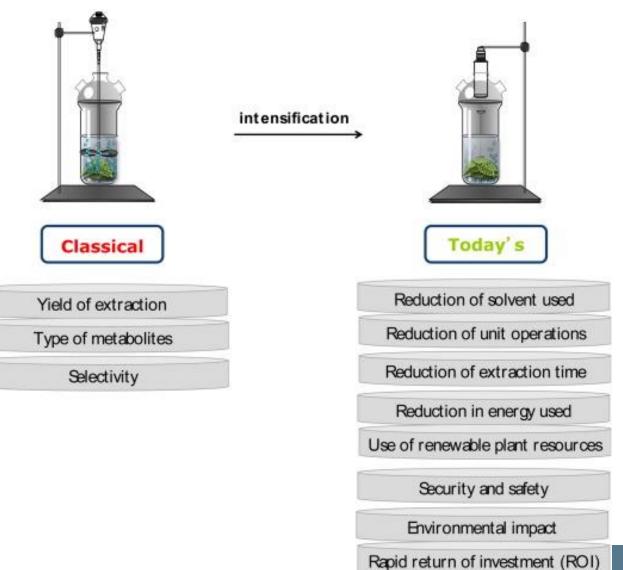
### **Pillars of sustainability**



### **Green Extraction Principles**

- Innovation by selection and use of varieties of renewable plant resources
- Use of alternative solvents, principally water or bio-based solvents
- Reduction in energy consumption by energy recovery, using innovative technologies
- Manufacture of coproducts instead of waste to include the bio- and agro-refining industries
- Reduction in unit operations, favoring safe, robust, and controlled processes
- Aiming for a non-demand and biodegradable extract without contaminants

#### **Green Extraction**



## Innovation by Selection of Varieties and Use of Renewable Plant Resources

- Proper selection of feedstock biomass
- Breeding
- Seed production/Vegetative propagation
- Crop rotation
- Choice of cultivation location
- Fertilization
- Organic farming
- Diseases and pests

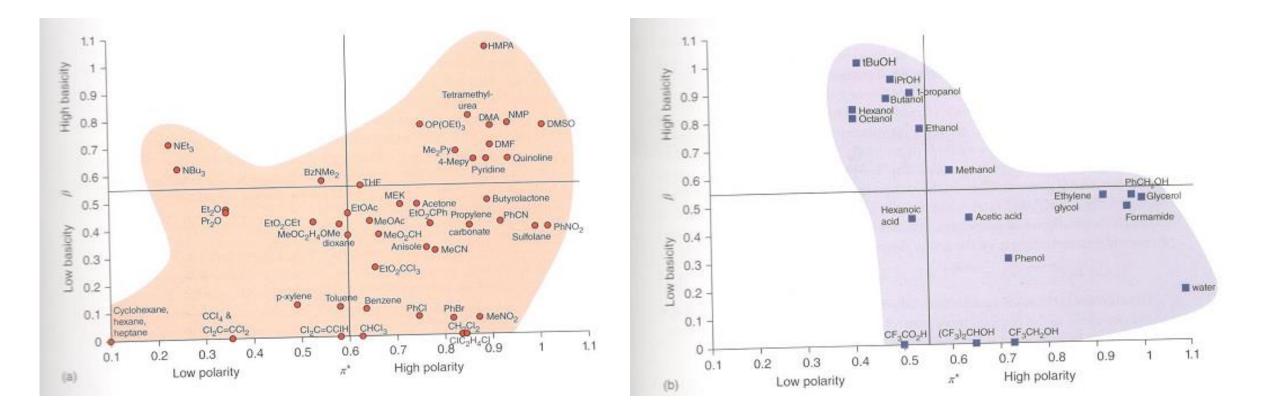
### **Use of Alternative Solvents and Agro Solvents**

 Chemically inert, nonflammable, temperature stable, and of low or negligible corrosiveness

HSE (health, safety, environment)

Bio-sourced/bio-based solvents are not necessarily "green"

#### **Physical properties of solvents**



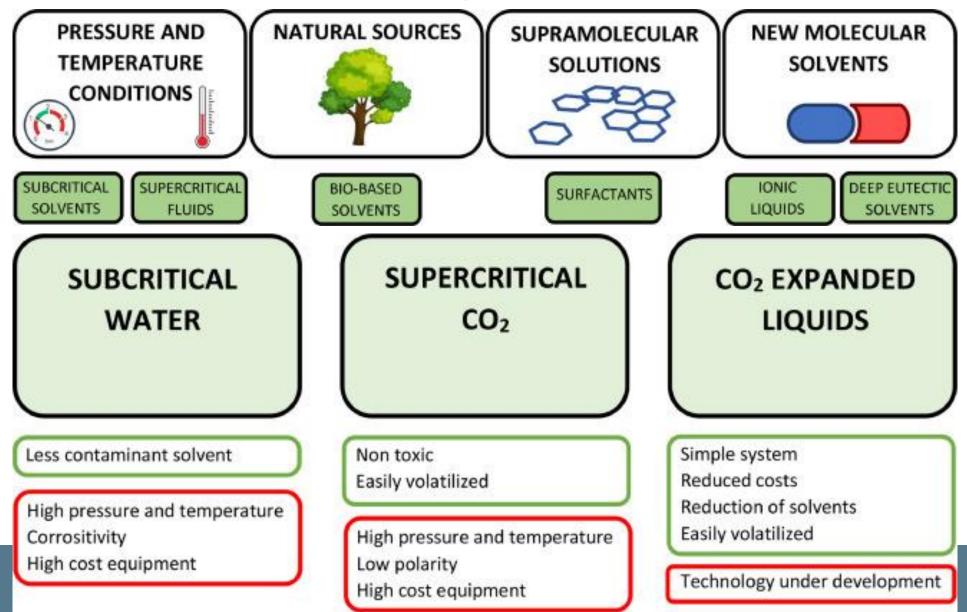


### **Alternative green solvents**

- Subcritical water
- Supercritical fluids
- Bio-based solvents
- Surfactant-based solvents
- Deep eutectic solvents
- Ionic liquids

ARMENTA, Sergio, et al. Alternative green solvents in sample preparation. *Green Analytical Chemistry*, 12 2022, 1: 100007. DOI: 10.1016/j.greeac.2022.100007

#### **Alternative green solvents**



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### **Production of Coproducts Instead of Waste**

• An effort to use as much as possible

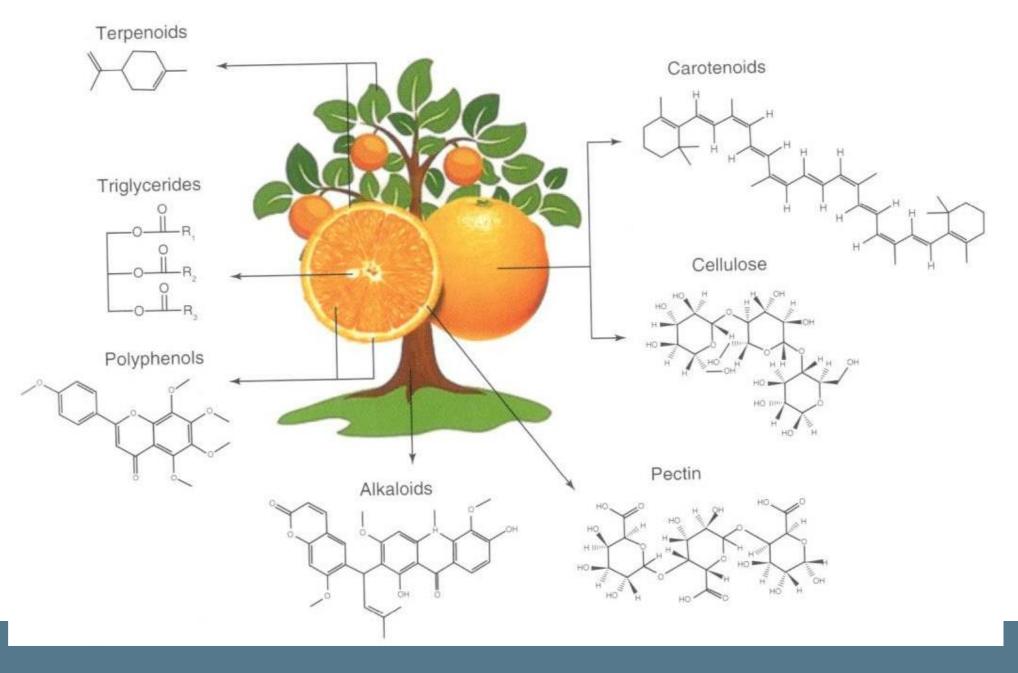
- Coproduct = product manufactured along with a different product, in a process in which both are required in the production of another product
- By-product = output other than the principal product(s) of an industrial process;
  usually an undesirable product of low value

• (see *Citrus* example)

## Prioritizing a Non-denatured and Biodegradable Extract without Contaminants

Resulting safe extract

- Without residual solvents
- Without contaminants from raw material
- Without denatured compounds due to drastic extraction conditions (= artifacts of separation procedure)



#### **Study literature**

- Green extraction of natural products : theory and practice. Edited by Farid Chemat Jochen Strube. Weinheim: Wiley-VCH, 2015. xviii, 363. ISBN 9783527336531.
- KUSUMA, Heri Septya; ALTWAY, Ali; MAHFUD, Mahfud. Solvent-free microwave extraction of essential oil from dried patchouli (*Pogostemon cablin* Benth) leaves. *Journal* of Industrial and Engineering Chemistry, 2018, 58: 343-348.
- ARMENTA, Sergio, et al. Alternative green solvents in sample preparation. *Green* Analytical Chemistry, 2022, 1: 100007.