Feasibility Study of Gallium Recycling by Phytoextraction with Lemna minor

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Background

The scarcity of geological deposits and the increasing demand bear a high supply risk of gallium on the long term. Thus, the investigation and development of a regaining process is of tremendous importance to prevent a supply shortfall. One potentially applicable recycling method could be a phytoextraction process which remove contaminants from soil or water into harvestable plant biomass. In this context, it is well known that the duckweed *Lemna minor* is capable of accumulating aluminum, which is a group 13 element, thus showing similar chemistry as gallium. The advantage of duckweed is mainly related to the high potential for installing a continuous extraction process as it can be easily cultivated and harvested in hydroponic systems. The results of the first experiments show a Ga^{3+} fraction of up to 10 % which is 100 to 1000 times higher compared to the mineral bauxite or the Bayer liquor. This figure is sufficiently encouraging to further follow the path of Ga recycling by phytoextraction.

Criticality Screening

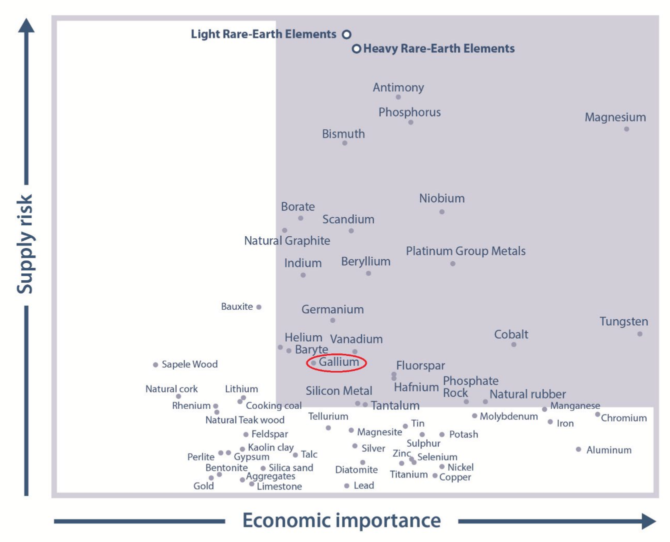


Fig. 1 Criticality screening of resources for the EU (2017) (amended from [1])

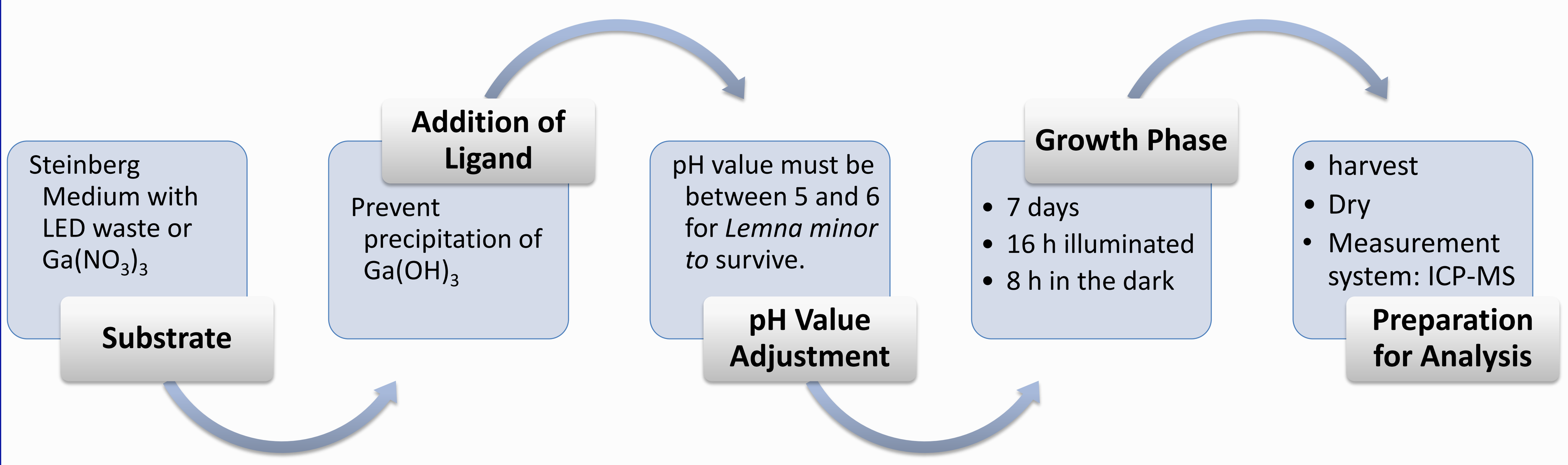
Advantage of the Solution Approach

- Environment friendly process
- 100 to 1000 times higher concentrated gallium compared to the mineral bauxite or the Bayer liquor
- Recycling of waste products → counteracting the problem of waste and minimizing its entry in the environment
- Counteracting the Ga supply risk for Germany

Novelty of the Solution Approach

- Extraction of Ga and other elements like In via phytoextraction process
- Leaching via complexing agents
- Higher the concentration by plants
- Generated ammonium salts as by-products from III/V semiconductor hydrolysis can be used as fertilizer

Experimental Settings



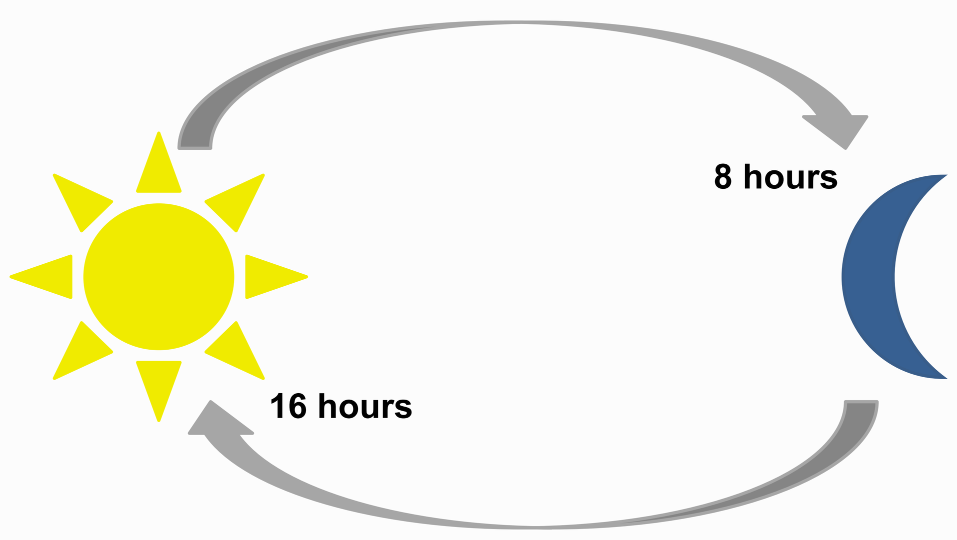


Fig. 2 Day and night cycle

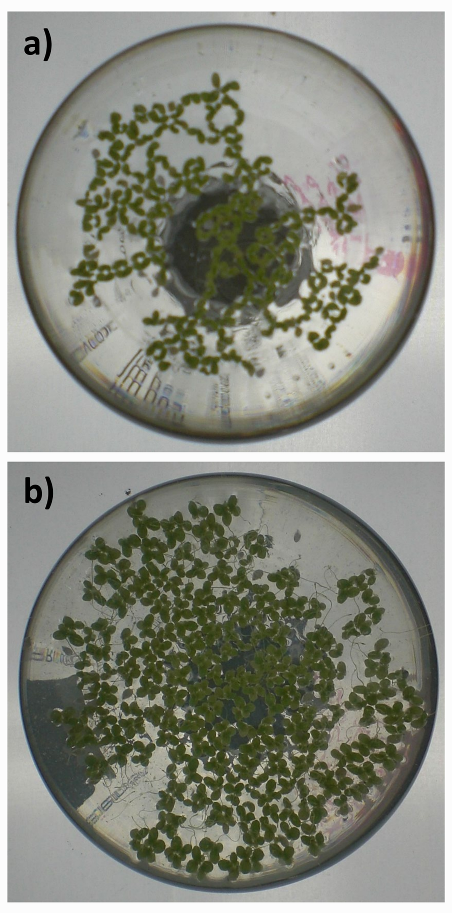


Fig. 3 Duckweed a) at starting point and b) after 7-days accumulating Ga^{3+}

Results

- **Accumulation**
  - *Lemna minor* accumulate Ga^{3+} in the transport tissue xylem
  - Highest Ga^{3+} concentration in Sample 3 (0.03 g/L) with 101 g/kg
  - Remaining samples are showing a close to linear behavior due to Ga^{3+} concentration in the ashes

➡ Lemna minor can accumulate Ga^{3+}

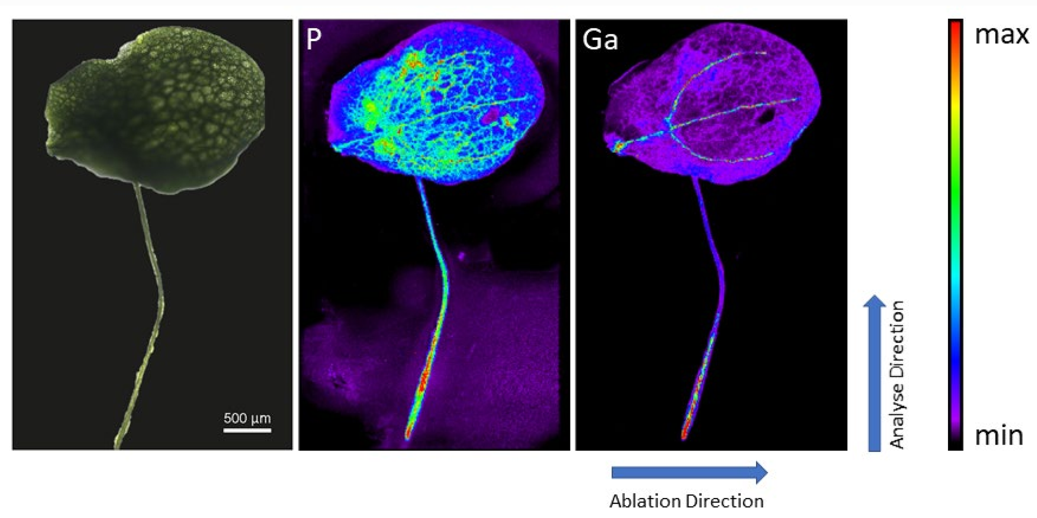


Fig. 4 LA-ICP-MS Analysis of Ga Accumulation in *Lemna minor* (Figure created by Maximilian von Bremen-Kühne, WWU Münster)

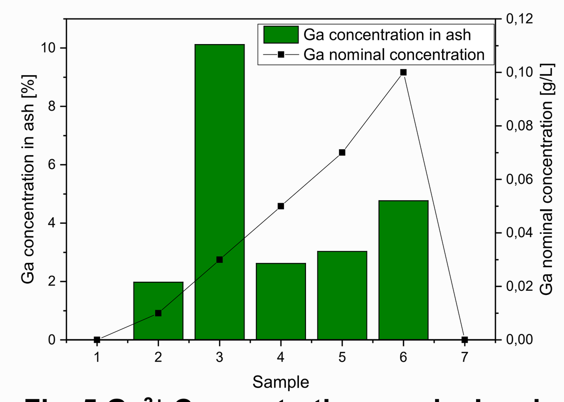


Fig. 5 Ga^{3+} Concentration nominal and measured in Ashes [2]

- **Growth rate**
  - Sample with 0, 10, and 30 mg/L Ga^{3+} show a negative growth rate within the first days
  - Strong increase of growth rate during following day at all samples
  - Some reach saturation at the end

➡ No negative impact of gallium. The negative growth rate might be caused by stress to the plants by the preparation process

➡ Saturation effect is caused by covering nearly the whole surface area

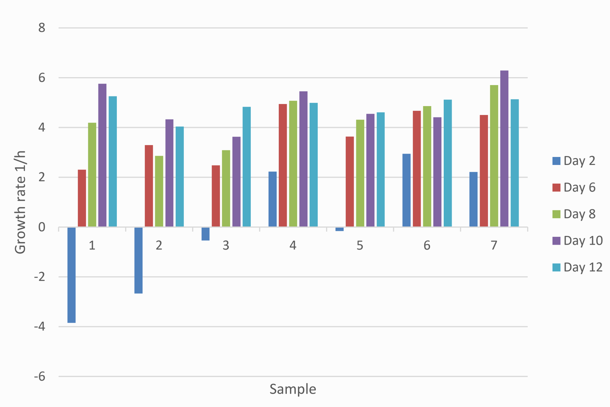


Fig. 6 Growth Rate of *Lemna minor* [2]

Conclusions

- *Lemna minor* is able to accumulate a certain amount of gallium
- Amount of accumulated gallium is not linear to the gallium solution concentration → Mechanism of accumulation of gallium is rather complicated and influenced by yet unknown parameters
- The finding of an optimal gallium concentration of 10 or 30 mg/L has to be confirmed

Literature

[1] https://new-mine.eu/eu-raw-materials-week/
[2] Simon Korte, Thomas Jüstel, Jonas Michels, and Thomas Schupp; Feasibility Study of Gallium Recycling by Phytomining with *Lemna minor*; 2019, DOI 10.13140/RG.2.2.20601.01123