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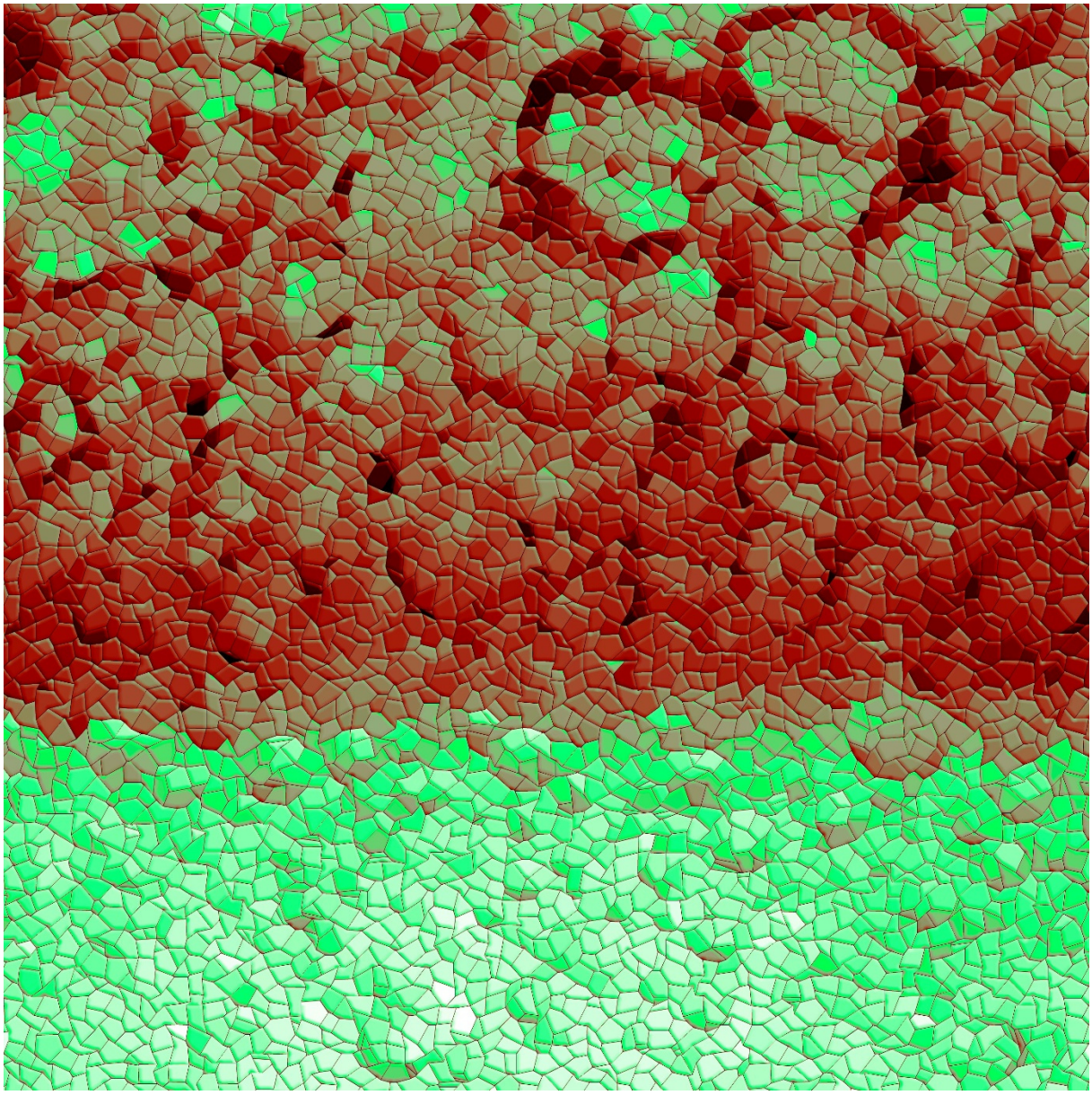
PEPs CHEMICAL ENGINEERING

Separation and Purification



2019

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Dear Reader

2019 appears to have rushed by in a hurry. The year has been full of new ideas and insights, many visits to conferences and after all a lot of work.

One major activity that used up quite some resources was the European tendering for the demonstrator in the PhosForYou project. Of course also our University is developing, which in turn means that the procedures are continually changing. In the first attempt only submission by paper was permitted. Unfortunately the most attractive supplier was a day late. But we were lucky, since the prices for all offers were too high anyway. Next attempt only digital submission was permitted. Since the companies had just learned that early paper submission is essential, this was quite a challenge not met by all. In a next round a specific digital signature was essential, which was not met by all potential suppliers, and only in the fourth round sufficient information was included in the invitation to tender that finally one offer was within budget and met all formal requirements. Thus, time went by and we are now formally almost at the end of the project. Luckily project duration has been extended slightly and we will hopefully be able to work a little faster than planned, since in our labs we had sufficient time to prepare...

Beside all the research on droplets, phase separation, reactive extraction, and mass transfer, this year was characterized by getting involved with Scientists for Future (S4F). Starting point was realizing that the contribution to last year's ProcessNet Jahrestagung with its consequences might be of broader relevance. As a consequence the idea and the concept of a book arose. In searching background information contact to Scientists for Future developed, which resulted in becoming active in the Aachen S4F group. During summer vacation the book was then finalized: Klima-Wende-Zeit finally appeared in October. Details can be found in the corresponding contribution to this report.

In parallel and in the following presentations associated to sustainability and the Grand Challenges of humanity were delivered. Interesting were the discussions with the audience after the presentations. Especially fascinating was that at the Silverberg high school in Bedburg near Cologne, the school is essentially exactly located where the North sea is expected to have its shores once the ice shelfs in Greenland and Antarctic melted. Some people find this even positive!

Fig. 1: Bedburg at the shores of North sea

Towards the end of the year we were visited by Professor Dr. Le Hung Anh from the Industrial University of Ho Chi Minh City, Vietnam, who is also co-supervisor of the research of Vu Dinh Khang. As a result, in the future the interaction between the two universities will be intensified.

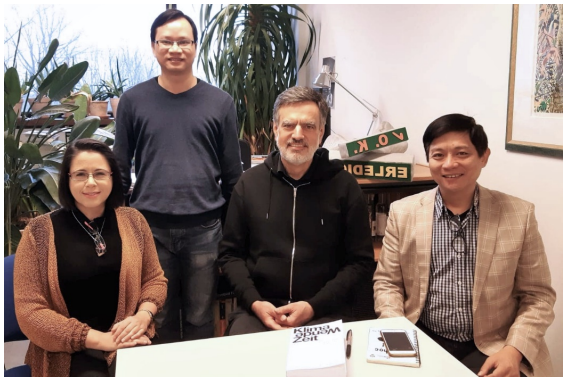

Fig. 2: Célia Joaquim-Justo, Vu Dinh Khang, Andreas Pfennig, and Le Hung Anh during the visit of the latter at ULiège

This were a lot of very different new experiences and challenges, which are mirrored also on the following pages, in which we present some details of our work.

So: Enjoy reading!

Andreas Pfennig

PULSE process: Process Development and P-Recovery at Lab Scale

Zaheer Shariff

The research work on the recovery of phosphorus (P) from sewage sludge began two years ago at ULiège under the Phos4You project which is jointly funded by Interreg North-West Europe and the Walloon Region. The P-recovery process being developed at ULiège is called PULSE (Phosphorus ULiège Sludge Extraction) process. The concept of the PULSE process is adapted from the PASCH process developed at RWTH Aachen. In the PULSE process, P is extracted from dried sewage sludge by acidic leaching. The leach liquor is then separated from the solids by filtration. As acidic leaching of P also results in dissolution of metals from the sludge, reactive extraction is used to extract the metals into the organic phase while P remains in the aqueous phase. In the final step, P is precipitated from the purified aqueous phase as calcium phosphate salts by raising the pH with addition of a base.

Cascaded Option Trees (COTs)

Cascaded option trees are used for developing and refining the PULSE process. In COT the information obtained from experimental results, solid-liquid equilibrium modelling and also literature are used to evaluate the different options for each of the unit operation of PULSE process. An example of the evaluation of drying unit operation which is the first step in the PULSE process using COT is shown in Fig. 1. The options to use wet sludge or dried sludge were evaluated against different criteria and graded accordingly. It is easier to transport and store dried sludge compared to wet sludge. With regards to operation cost, the leaching of just dewatered and not dried sludge requires more acid to reach the same pH of leaching as in the case of dried sludge. The cost of excess acid that would be required in case of wet sludge is almost the same or even more compared to the cost of energy required to dry the sludge depending on the drying technology used. Therefore, the operation cost in both cases would be similar. Further, with respect to P leaching efficiency, experimental results showed that the leaching of P from sludge dried in an oven without air circulation had slightly higher P leaching efficiency. With regards to filterability, in case of wet sludge the solids are very fine and block the filter almost immediately and addition of flocculants is also not effective at such a low pH. In case of dried sludge, the solids have inorganic-material like properties and size of the solid particles largely depends on the dried sludge crushing mechanism. If the sludge is not crushed very finely, it is easier to filter.

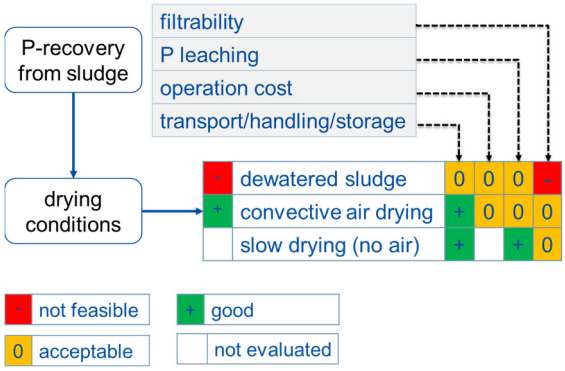

Fig. 1: evaluation of sludge-drying options using the methodology of cascaded option trees

Similarly, the cascaded option tree is applied to other unit operations in the PULSE process in order to assess which options are the best suited for our system.

Solid-Liquid-Liquid Equilibrium (SLLE) modelling

A solid-liquid-liquid equilibrium modelling tool has been developed in Matlab in order to compute the speciation of different species in liquid and solid phases at equilibrium. The data from the equilibrium modelling is used for better understanding of the experimental results and also process optimization. More information on the equilibrium modelling can be found in the annual report of 2018.

Lab-Scale Experiments

The effect of sludge drying on P dissolution was evaluated by leaching wet and dry sludge. The results showed no significant differences in the leaching efficiency. Further, the effect of acid type and pH on P leaching was also evaluated. As shown in Fig. 2, the leaching efficiency was only dependent on the pH and the type of acid used had no significant effect. The leaching of P evaluated using the SLLE equilibrium tool also shown in Fig. 2 by the solid line shows the same behavior. Some deviation in the modelling which is observed may be attributed to the P complexed with organic matter. Further, about 70% P leaching efficiency could be obtained with HCl concentration of 2 mol/L when the pH is already below zero. This leaching efficiency corresponded to the amount of inorganic P in sludge which was about 68% meaning that even at this low pH mostly inorganic P was leached from the sludge. P leaching was also tested with addition of oxidizing and reducing agents like hydrogen peroxide and sodium sulfite but no quantifiable changes could be observed.

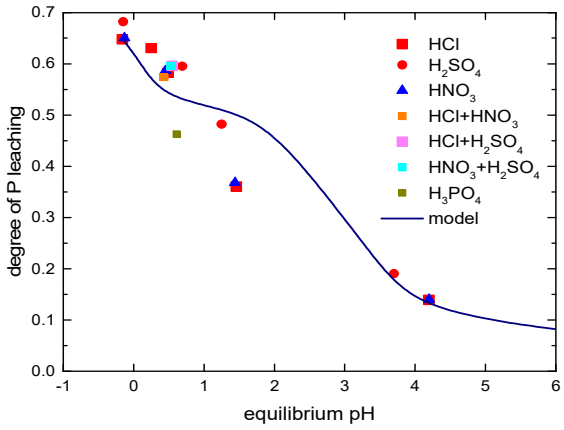

Fig. 2: P leaching from sludge

After experiments for leaching and filtration, reactive extraction of metals was evaluated with different extractants. As shown in Fig. 3, the extraction of metals was only efficient at low pH with Alamine 336 or a combination of Alamine 336 and other extractants.

In the next step, P in the aqueous phase was precipitated as calcium phosphate salts (CaP) by addition of sodium hydroxide. As the sludge leach liquor already contained sufficient calcium, there was no need for the addition of calcium during precipitation. Fig. 4 shows the precipitate obtained from lab experiments.

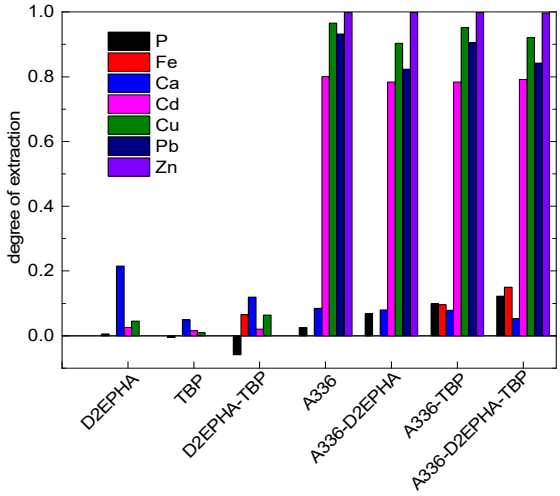

Fig. 3: extraction of metals from sludge liquor using different extractants

Fig. 4: precipitate obtained by PULSE process containing CaP salts

Acknowledgements

Samples of Ketrul D80 and Alamine 336 used in the experiments were supplied free of cost by Total Belgium and BASF Germany.

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Phosphorus Recovery: Potential Materials in Southern Vietnam

Khang Vu Dinh

Introduction

Southern Vietnam consists of two main areas: Southeast and Southwest (or called Mekong River Delta, MRD). It includes 19 provinces or cities in total, of which Southeast (SE) has 6 provinces or cities. This area is the focal point of Vietnam's economic development in the field of industrial production and services. Therefore, Southeast area is a densely populated region. According to the General Statistics Office of Vietnam (2018) the regional average population density is 725 people/km^2. Meanwhile, the Southwest (SW) has 13 provinces or cities with an average population density of 426 people/km^2. The population is mainly engaged in agricultural production. Especially, wet rice and aquaculture are the fields that bring great income to this area.

Many waste sources from production and living activities in the Southern region of Vietnam cause big obstacles for businesses and authorities in environmental protection. However, these waste sources can become valuable resources if considered in detail. Realizing this, the study focuses on potential waste sources for phosphorus recovery including sludge from centralized domestic waste-water treatment plants (DWWTP), sludge from rubber processing waste water treatment plants (called RP), waste from cattle farming (CTF) activities, pig farming (PF) and catfish (*Pangasius hypophthalmus*) farming (CF).

Objects

The main objective in this study was to identify the sources of waste as secondary raw material and to evaluate the potential for phosphorus (P) recovery. Basis are criteria obtained via data survey and analysis.

The Method

Research data were collected through a variety of sources, depending on the type of waste source. They was collected through the following main sources: (a) From General Statistics Office of Vietnam (GSO), The Food and Agriculture Organization of the UN Statistical Database (FAOSTAT), The Vietnamese Ministry of Natural Resources and Environment (MONRE), Vietnamese Ministry of Agriculture and Rural Development (MARD). The data obtained include input statistics such as population, pig, cattle head or catfish farming area and area planting rubber.

Raw material samples were collected according to the concentrated distribution of waste sources. Samples of sediment from catfish pond were taken from ponds in the MRD area, including 4 samples from ponds in An Giang (AG) province, 3 samples from ponds in Dong Thap (DT) province, and 3 samples from Ben Tre (BT) province. Five samples of pig manure were collected in Dong Nai (DN) province, and two from Ho Chi Minh (HCM), one in Ben Tre (BT) and one in Tien Giang. Similarly, cattle manure samples were collected from four provinces which have the largest cow population in the region including HCM, Tien Giang (TG), Tra Vinh (TV) and BT. Rubber latex processing industry is only available in the Southeast area, so the sludge samples from the waste-water treatment plant are collected in the provinces of DN, Binh Phuoc (BP), Binh Duong (BD) and Ba Ria Vung Tau (BRVT).

Fig. 1: Dewatered sludge from Rubber WWTP

The rate of domestic wastewater collected and treated is very low. HCM has the highest rate of wastewater collected and treated in the Southern region, but this rate has just only met about 21.2%. Meanwhile, most domestic

wastewater in MRD area has not been collected and treated (MONRE, 2018). In this study, sludge samples from DWWTPs were collected in HCM and BD.

The samples were air-dried at room temperature first, then dried at 105 °C. The dried raw material was crushed to be used for chemical analysis. ICP-OES device is used to determine the metal composition in samples, including P, Fe, Al and heavy metals.

The total P reserves that can potentially be recovered from the different waste sources are calculated based on input parameters from statistical data, sample analysis and separate factors corresponding to each type of waste source.

Result

Calculation results show that the potential waste sources have a large difference of P reserves. In 2018, the P reserves from CF was 48.46 t/d. This is roughly 3 and 5 times higher than that of cattle farming and domestic wastewater treatment plants, respectively.

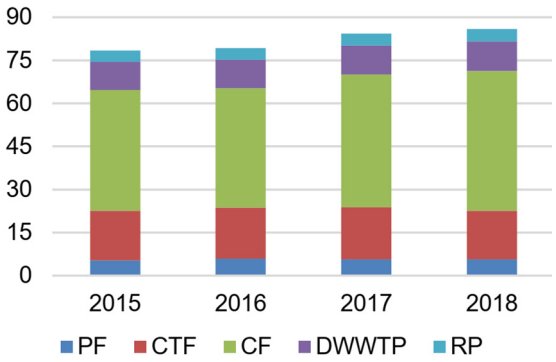

Fig. 2: Phosphorus reserve in potential sources in Southern Vietnam (2015-2018)

In 2018, total P reserves from waste sources are estimated at 31,276 tons. If these all P reserves are recovered, it could solve 3.85% of the nutrient phosphate for agricultural use or 6% of import quality in Vietnam in 2017. Currently, these waste sources are wasted, adversely affecting the environment without effective collection and recovery of P.

The distribution of P reserves among regions is quite obvious for sources of emissions from catfish farming and rubber processing industry. While catfish farming is concentrated in southwest only, rubber processing industry only exists in southeast area. The concentration of waste sources facilitates the collection and transportation of raw materials. This is also an important criterion to evaluate the overall potential for P recovery.

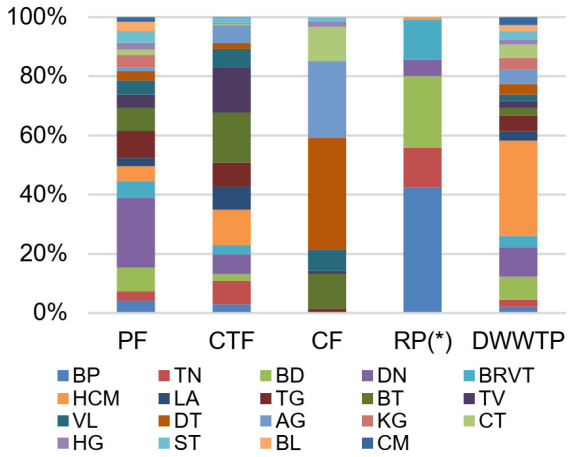

Fig. 3: Phosphorus reserve distribution, 2018

P reserves from pig farming and cattle farming are fairly evenly distributed in all provinces. This is explained by the strong growth of these activities at the household level. In general, phosphorus reserve from catfish farming and industrial rubber processing are concentrated in some provinces while others are widely distributed.

Acknowledgements

This work was carried out with the assistance of Nguyen Thi Tuyet Nhung, Nguyen Thi Yen and Nguyen Dang Khoa in collecting samples in the field.

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Solvent extraction and separation of rare earths and transition metals from secondary raw materials

Swagatika Satpathy

Introduction

The advancement of technology has led to an ever-increasing demand for transition metals and rare earths elements (REE) (Klinger, 2018). Large amounts of rare earths-based products sold and disposed of annually ensure the availability of recyclable material in these substances. Figure 1 shows some of the significant uses of different REEs. Research on the recycling of rare earths is directed towards three categories of end-of-life products: products containing phosphors, permanent magnets, and NiMH batteries. However, currently only 1% of the REEs is recycled in European Union (ERECON, 2015). This necessitates the need for implementing drastic steps to utilize waste to extract and recover REEs from secondary raw materials in order to achieve a circular economy.

The simple, rapid, and versatile nature of solvent extraction has made it an important technique for purification in multi-component systems. Over the recent years, focus has been given to efficient extraction of metals from these secondary sources. In spite of all the efforts made, several shortcomings have been noticed such as the use of toxic, flammable, and expensive diluents as well as high operating temperature decreasing the cost effectiveness of the process. Similarly, stripping with concentrated ammonia pollutes the environment. Process optimization and synergism have been carried out without paying attention to modelling and systematic optimization, respectively. These issues need to be resolved for practical implementation of the process in large scale.

This involves developing a methodology for optimal process design directed towards effective extraction and separation of REE and other metals from secondary raw materials. The diverse nature of secondary raw materials demands a more general approach, which allows adaption and optimization of the process for the specific waste to be treated. The process can be realized on large scale by taking into consideration various nature of possible urban-mining feedstock and work on aspects such as phase separation after extraction, fate of trace components, regeneration of extractant, explore the capability for re-extraction etc.

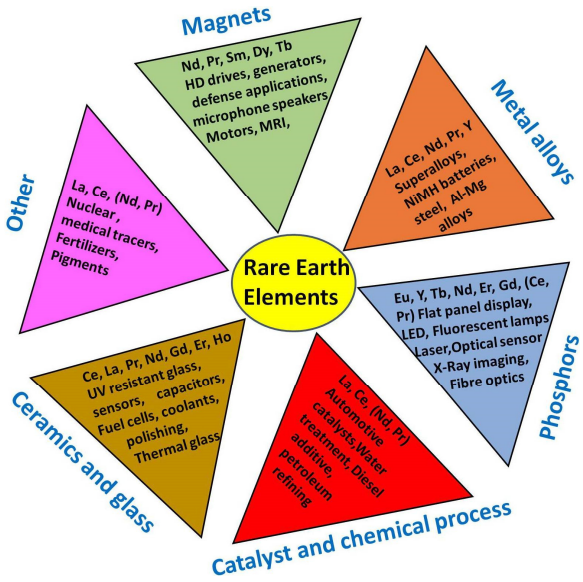

Fig. 1: Significant uses of different REEs (Eurare, 2019)

Methodology

Systematically planned experiments will be combined with detailed modelling to develop optimal processes to leach and separate the desired metal ions from secondary feedstock. This will be guided by a prototype of a cascaded option tree developed for such reactive-extraction processes for separation and purification of metals from leach liquor. Several commercial extractants, i.e. organophosphorous components, amines, ionic liquids etc. can be employed to explore the feasibility of maximum extraction and separation under various processing conditions like molarities of extractant, complexing agents, aqueous phase pH, nature of diluents used, organic to aqueous phase ratio, and temperature (Bednarz et al., 2014). Better elucidation of extraction regime and better design and development of the extraction process can be made possible by equilibrium and

mass-transfer experiments. It is apparent from the literature that usually combination of two extractants leads to improvement in metal extraction. Therefore, synergism, i.e. use of a combination of extractants, can be included as prerequirement to maximize extraction of metal ions. Stripping and regeneration studies allow effective separation of the metal ions into pure aqueous phase minimizing disposal of extractants and make the process cost-effective. Precipitation paves way for obtaining purified metal compounds. The different steps involved in the recuperation of metals from secondary raw materials (fluorescent lamps and NdBFe permanent magnets) is shown in Figure 2.

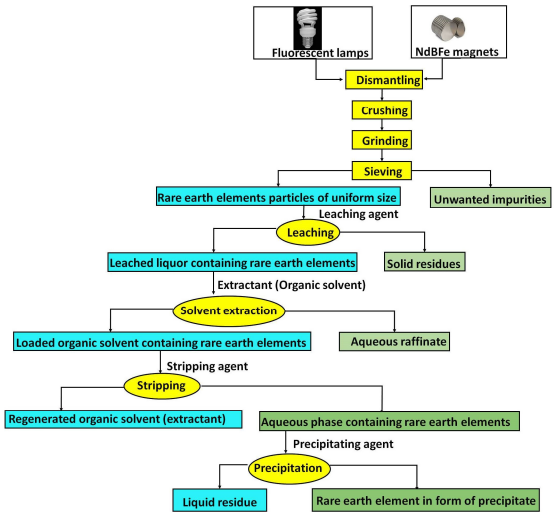

Fig. 2: Flowsheet showing different steps involved in the isolation of rare earth elements from secondary raw materials

The criteria for designing a technically feasible process for reactive extraction of different secondary raw materials are comparable. Therefore, a generalized or prototype cascaded option tree can be developed, which acts as a blueprint for the design of any such process. The concentration of the diluent and the nature of the extractant greatly influences the degree of extraction of the metals. The choice of diluent and extractant are vital for achieving maximum extraction, therefore they can be varied according to the suggested workflow and prototype cascaded option tree. The nature of diluent also strongly affects mass-transfer rates as well as ease of phase separation. This in turn determines technical equipment size. The efficiency of ionic liquids as an alternative for traditionally used extractants can be examined since they have interesting characteristics such as wide liquid temperature range and relatively low volatility. This is because they are organic salts comprising of organic cations and inorganic anions having melting point below 373 K. Likewise, complexing agents with salting-out effect lead to an increase in metal extraction into the non-polar organic solvent by reducing water activity. For each of the substance types (extractant, synergistic complexing agent, diluent and if required modifier) the available options of substance classes can be considered. For the extractants e.g. according to the different extraction mechanisms, for the diluents according to chemical nature, which influences polarity.

In a step of refinement, for the different classes different individual components maybe considered, as an example different cation exchangers and ionic liquids as extractants or individual alcohols as diluents. Thus, the result for a first test case leads to an optimal system that differs from that used to establish the modelling basis in the previous work packages. Study of temperature effect helps in gaining insight in to the enthalpy change as well as entropy change involved in the extraction process. Thus, these parameters need to be taken into account and fed into the modeling as well. The use of data modelling for generating an optimal process of solvent extraction simplifies the entire process of extraction of critical elements from secondary raw materials.

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Coalescence Model and Its Validation Using an Iso-Optical System

David Leleu

Motivation

Continuous and batch settlers are used in processes in order to separate liquid-liquid dispersions. Their design can be challenging, e.g. quantitatively predicting the remaining fraction of fine drops found at settler outlet as function of the operating conditions.

For batch-settler design, a numerical tool has been developed, which is based on considering the behavior of individual representative drops (ReDrop concept). This tool, which applies a Monte-Carlo method to solve the drop-population balances, allows to simulate the separation of liquid-liquid dispersions and thus to optimize the design of continuous settlers. Sedimentation and coalescence are evaluated for a sufficiently large ensemble of representative individual drops at each time step. The information obtained is then collected to determine e.g. the required settler size. In these simulations, the coalescence modeling is a major challenge due to the complex interactions of drops upon approach and coalescence.

Coalescence Model

As shown in Fig. 1, the probability that two drops coalesce depends on three contributions. The first is the frequency with which they meet, defined by the so-called collision rate. The second parameter is the bouncing probability. It characterizes the probability that the drops stay in contact during the time following the collision. If they are not, the collision leads to the direct bouncing without any chance to coalesce. The final variable influencing the coalescence probability is the efficiency with which the drops coalesce once they met. The coalescence efficiency in turn depends on the time, during which the drops stay in contact and the time they would need to coalesce (Leleu & Pfennig, 2019).

Dimple formation was assumed in expressing coalescence time. In the close-packed zone the drops are additionally deformed due to the hydrostatic pressure, which affects the contact area between the drops and thus the coalescence. Different expressions of the coalescence time were developed based on the drops surroundings.

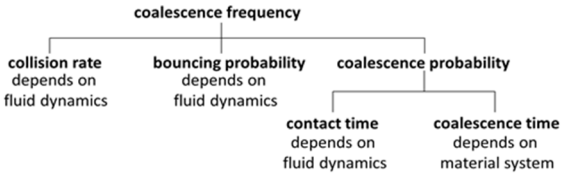

Fig. 1: Coalescence model

The coalescence model was developed in the framework of the ERICAA project. The coalescence model was published this year (Leleu & Pfennig, 2019).

Iso-Optical Settling Experiments for Model Validation

The coalescence time can be evaluated experimentally from any suitable settling experiment. Here, the experiments are conducted in the standardized settling cell of Henschke slightly modified within the ERICAA project, as shown on Fig. 2. It consists of a glass vessel with a capacity of 1L, with 2 shafts for stirring with 4 stirrers on each shaft. A SOPAT probe is used to measure the drop-size distribution in situ.

Fig. 2: Settling cell

Black plastic sheets, which surround the cell to avoid interferences of the video recording with surrounding light, are not shown on the photo. This black box is used also as a fume hood. Nitrogen flushing of the cell is possible for safety reasons. The experiments are recorded with a movie camera and for better contrast, a led panel is fixed behind the cell.

Each frame of a movie taken from a settling experiment is analyzed separately in order to get the averaged light intensity along the height of the settling cell. The overall evolution of the settling is then obtained by superimposing all the processed frames. An example is shown on Fig. 3.

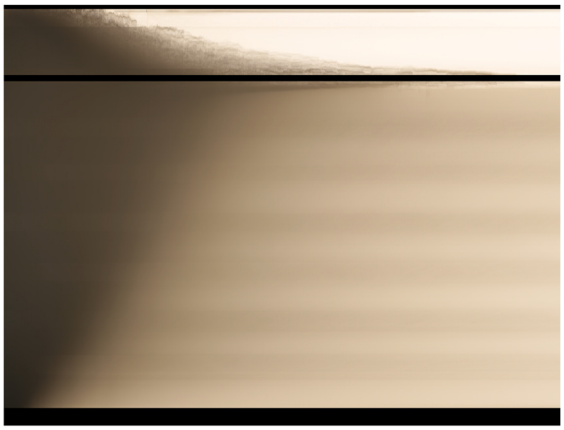

Fig. 3: Overall evolution of a settling experiment

From pictures similar to Fig. 3, the sedimentation and coalescence curves are clearly seen and quantified. This information is not sufficient for model validation, additional experimental data are mandatory for this purpose, e.g. local hold up measurement. However, due to different refractive index between the phases and due to coalescence, the holdup cannot be determined for usual systems. A solution is to use iso-optical systems, the two phases of which have the same refractive index. Thus, the drops interface is not visible.

The two-phase system was produced with three different chemicals and a dye is added to the system to color one of the phases to distinguish the drops. As the drop interface is not visible, the color intensity is then proportional to the local holdup with the Beer-Lambert law. Thus, to evaluate the proportionality factor of the Beer-Lambert law, special care for calibration is necessary to obtain reliable results.

The evolution of the holdup based on the color intensity is shown on Fig. 4. Some small zones of the cell shown as white bars cannot be quantified, namely at the bottom and top of the cell and around the interface.

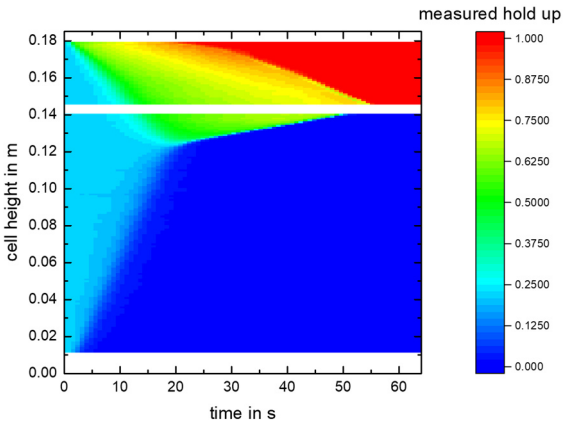

Fig. 4: Evolution of the local holdup based on a settling experiment with an iso-optical system

From Fig. 4, the building up of the close-packed layer can be observed as well as the evolution of the densely-packed zone. Long lag time has also been observed for a different settling experiment. This shows that small drops are present initially and coalescence of those small drops occurs in the first seconds of the settling. All of these observations will be used in the subsequent steps of model validation, which is currently in progress.

Acknowledgment

The ERICAA project was supported by the BMWi in Germany and the SOPAT probe was founded by The FNRS in Belgium.

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Getting Involved on Climate Change

Andreas Pfennig

Starting Point

As already mentioned in the foreword, this year was also characterized by getting involved. The presentation on bio-economy at the 2018 ProcessNet-Jahrestagung, which was after that also held in variations on other occasions, led to many discussions. One insight from these discussions was that a strong disparity exists between what is conventionally recognized about climate change and the actually required changes. Frequently the other Grand Challenges of Humanity are overlooked, which are concretized in the UN Sustainable Development Goals (SDGs).

At the same time, in the discussions it often gets quite emotional, where true facts and perceived facts get intermixed. This can also be realized in the Media, at least in Germany, where any initiative concerning sustainability is directly linked to climate change. Thus, replacing plastic bags and single-use plastic cups for the takeaway coffee with more sustainable options is regularly at least by some media introduced as step towards limiting climate change. Keeping in mind that a plastic bag or a plastic cup weigh only 10 to 20 grams while the average German consumes daily almost 9 kg of fossil resources, it becomes obvious that the contributions of plastic bags and plastic cups are minor. All the more so as the true saving is only a fraction of the weight, if the raw material and energy consumption of the alternatives that are believed to be more sustainable are correctly evaluated (UBA, 2019). For comparison, a single round-trip by plane from Germany to Bangkok or San Francisco leads to CO_2-emissions of 1.7 t. Accounting even for processing losses as well as fossil energy in production, the round-trip corresponds to a daily takeaway plastic cup for an entire life. The ratio gets even worse, if the CO_2-equivalents are regarded, since emissions by plane are more detrimental to climate than emissions at the ground by a factor of between 2 and 3.

At the same time many other aspects of life are linked to climate change in corresponding publications. Wynes and Nicholas (2017) find that one child less saves the parents 58.6 t CO_2 per year, which is a huge amount compared to the around 9 t per person in Germany. Similarly shift to less meat in nutrition is usually associated with climate change as well, since this reduces e.g. methane production significantly. Since reducing meat consumption still leaves the emissions from cows for milk production as well as the large contributions of rice production unchanged, the effect of omitting all meat in human nutrition would change greenhouse-gas emissions by possibly around 5%.

Considering all SDGs and the global system as a whole, it becomes obvious that the reason why certain changes in behavior are required to ensure sustainability are not appropriately perceived. The major reasons for limiting population growth is to reduce resource consumption and to limit emissions in general. A major aspect in this context is the sufficient food supply, i.e. the use of the limited resource land area. Already today 11% of world population are undernourished, even though agricultural productivity has been continually increasing during last decades. If world population continues to grow at currently projected rate, agricultural productivity can foreseeably not be intensified comparably. Thus undernourishment will increase fostering e.g. migration. Changing nutritional habits towards less meat and even animal-free food is important to master also exactly this challenge. The reason is the excessive land-area demand for animal-based food of 80% of food-production area compared to the relatively small contribution to calories supply of 17.5%.

New Book: Klima-Wende-Zeit

Realizing this demand for properly and systematically communicating these interrelations of the earth system lead to the decision to collect these insights in a new book: ‘Klima-Wende-Zeit’ (2019) (freely translated to English: Climate Change Age). The goal was to describe the major influences in a way comprehensible to a non-expert at the same time communicating also reasons for coming to the final conclusions. Thus every reader should in the end be able to understand, why certain

consequences are unavoidable, if we seek happy sustainable life for everybody.

An insight developed during the discussions and writing the book was that it is not sufficient for scientists to just inform policymakers about the bare facts. While this is the approach taken by the Intergovernmental Panel on Climate Change, this leaves the citizen uninformed, who should finally during elections make informed choices. That is at least the basic idea behind any democracy. If it is not scientists themselves, who deliver the information appropriate for the citizens to understand it, there will be significant freedom of interpretation of the facts and the resulting consequences for example by the politicians.

Especially the uncertainties in scientific description of climate change pose a significant challenge. How can guidelines be given, if the consequences of measures to master climate change cannot exactly be quantified? At second glance, this is of course not really an insurmountable challenge, since engineers hardly ever have exact information on all details of their designed equipment or processes. Thus, this situation is common to engineering sciences. 'Klima-Wende-Zeit' thus has the goal to present a user manual for our planet earth, which also gives the background information so that informed judgement by the reader is supported for everyday decisions as well as at elections, including discussion of uncertainties.

Scientists for Future

In preparing the book and during searching detailed information as the scientific basis of several aspects, contact was made to the Scientists for Future (S4F), scientists4future.org. S4F is a grassroots initiative where scientists understood in a rather broad sense coordinate to support the societal and political transitions required to reach sustainability. One main activity of S4F is to supply the initiative Fridays for Future with the required properly validated scientific facts. S4F has e.g. also been active for each of the global climate strikes organized by the Fridays for Future. Especially fascinating was the Summer Meeting of the Fridays for Future in Lausanne, where the young participants were posing their questions as they occurred in a shared document, which were then answered by appropriate scientists.

Getting involved in S4F also led to many new contacts and participation in events, which developed during the second half of 2019. Examples are presentations at schools supporting teachers in delivering details on climate change, its consequences, and how it is linked to the other SDGs. Another noteworthy event was the participation with a lecture to a Teach-In at the lignite-mining site Garzweiler, organized by the local group of Fridays for Future. The teach-In was also featuring Ralph Caspers known from TV and Antje Grothus, who is climate activist especially prominent in anti-coal initiatives. Meanwhile two series of presentations with discussions by the Scientist for Future in the Region Aachen are planned for the beginning of next year at the adult education center (Volkshochschule) and at the Burg Frankenberg.

Fig. 1: Teach-In at the lignite-mining site Garzweiler with Ralph Caspers

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Conferences in 2019

Zaheer Shariff

This year, our team participated in and presented our work at various scientific conferences around Europe. The different topics were for example coalescence modelling for settler design, the PULSE process for P-recovery from sludge, SLLE Equilibrium modelling, and bioeconomy. In addition to presenting the scientific works, conferences are always a great opportunity for young researchers to develop personal and presentation skills that they can learn from renowned speakers.

The year began with participation at the "Jahrestreffen der ProcessNet-Fachgruppen Phytoextrakte und Extraktion" in Switzerland where the team had two contributions in the form of a poster and an oral presentation. The conference focused on liquid-liquid extraction systems. In September, the team travelled all the way to Italy to participate in the "12th European Congress of Chemical Engineering" in Florence. This event is one of the largest gathering of Chemical Engineers across Europe and was organized over 4 days with more than three thousand contributions in the form of oral and poster presentation. Our team contributed 3 oral presentations at the ECCE.

In addition to participation at the conferences, we also had the pleasure of organizing the "5th European conference on Sludge Management (ECSM)" in Liège jointly with the team of Prof. Angélique Léonard. The conference was spread over two days with 27 oral presentations and 15 posters focusing on sludge management and nutrient recovery.

Fig. 1: 5th ECSM conference at ULiège

The 5th ECSM saw more than one hundred participants from 17 countries. Our poster on "Pulse process: recovery of phosphorus from sludge and its product quality assessment" was selected as one of the best posters by the jury.

The team then participated at the French congress "17ème Congrès de la Société Française de Génie des Procédés" in Nantes in October with three oral contributions. One of the contribution i.e. "Recovery of Phosphorus from Sewage Sludge and Subsequent Purification Using Reactive Extraction" was selected for a keynote presentation at SFGP.

Fig. 2: David Leleu presenting his work at SFGP

The last conference that the group participated in was the "Computer Aided Process Engineering (CAPE) Forum" in Liège. We once again contributed with three oral presentations.

We are looking forward to continue contributing again in 2020 by presenting the progress of our work and hope to find you in the audience for valuable feedback.

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Secondment of 6 months at the :Metabolon

David Leleu

Fig. 1: Panorama view from the top the landfill hill

The adventure at the :Metabolon – Bergischer Abfallwirtschaftsverband (BAV) has been continued in 2019, resuming the activities of our last visit in July 2017. The goal of our visit was to organize my secondment in the context of the Phoenix project, aiming at efficient utilization of bio-based resources, funded by EU in the framework of the Horizon 2020 program. The Phoenix project had the goal to promote collaboration between research units through environmental projects

:Metabolon is located in the region of Cologne two hours by car from Liège. The main activity at BAV is the waste recycling for industrials and for citizens. As a governmental organization, one of their additional tasks is to promote good waste management by the citizens, for example by organizing awareness campaigns for kids. Finally, BAV hosts a research group and has a strong collaboration with the University of Cologne. Their goal is to optimize the processes used on site, for example their waste-water treatment plant or their pyrolysis plant - both processes strongly linked to environment.

One of the issues at :Metabolon is their waste water. The rainwater is polluted because it comes into contact with the contaminated soils at the waste-dump site. This water has thus a high concentration of organics and inorganic components. The other waste water which needs to be treated is the liquid effluent coming from the pyrolysis plant. This water is highly polluted in organics.

Integrating a solvent extraction unit to their waste-water treatment plant can be an idea to decrease the concentration in the influent. My secondment was then to initialize this research project by modelling the effect of ions on the coalescence.

The presence of ions induces an electrostatic potential between the drops, which has a strong effect on their coalescence. This electrostatic potential is linked to the partition coefficient of the individual ions in the solution.

The partition experiments were designed in collaboration with the scientific staff at BAV, since they have a strong expertise on dyes, which was helpful for this specific project. Different partition experiments were done with different salts at different concentrations on a given two-phase system. Settling experiments were performed in parallel in order to link the coalescence behavior with the electrostatic potential. Results of this study will be published soon.

The Phoenix project thus allowed developing a working relationship for further joint projects. It was also a great experience for me to work in a different environment.

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Teaching in Oman

Andreas Pfennig

As established many years ago, this year again a course on Thermal Separation Processes was given at the German University of Technology (GUtech) in Oman, see Fig. 1. The number of students had been growing continually, so that this year more than 50 students participated, which is more than the Chemical Engineering students at the University of Liège.

Fig. 1: Thermal Separation Processes held at GUtech, Oman

The block lecture was scheduled during one week in April but was supported by skype lectures before and after that week of presence in Oman. One question was, if such distance learning would work out. Before starting the lecture, different platforms for delivering distance lectures had been tested. It quickly turned out that skype was offering sufficient means to present the lecture at good quality, if the sound was recorded with a microphone and the screen content transferred to Oman. The lecture consists of derivations as well as PowerPoint slides. The derivations are written with the digitizer pen on the touchscreen of the laptop, a Lenovo ThinkPad S1 Yoga using the program Journal. To avoid interference with accidental touching the screen with the fingers, input is only permitted with the pen. With a single click on the Windows button it is then possible to switch between presentation and the pages with the derivations. Together with the voice, this delivers all relevant information with sufficiently high resolution even if transferred via skype to Oman. On the Oman side the lecture was supported by interns, who took care of setting up the projector and establishing the connection. The skype communication was astonishingly stable, so that during all the skype lectures no quality problems occurred.

If delivering the lecture via skype would have a negative effect on the study outcome could be checked via the midterm exam, which covered topics taught only via skype. The outcome was quite comparable to those of midterms of previous years, which leads to the conclusion that distance learning has not necessarily negative effects on the transfer of knowledge.

Unfortunately during the lectures in Oman it was observed that a number of students were very actively watching and using their mobile phones during the lecture instead of observing the lecture and possibly taking notes. The consequences were unfortunately not so optimal with respect to the failure rate in the final exam, which was somewhat above that of previous years. Even after a repeat exam, which was given several weeks after the end of the course, this outcome unfortunately remained unchanged.

Thus, while distance learning has apparently no detrimental effect on learning outcome, this year other effects led to somewhat suboptimal results, which is currently still under discussion.

Fig. 2: Some of this year's students at GUtech, Oman

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An up to date list of publications is available at: https://orbi.uliege.be/ph-search?uid=U222548

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Replies to: A Last Word

Answer to an exam question by an undisclosed student, reported in last year's annual report:

Explain briefly how absorption works.
Which phases are contacted and in which direction occurs the mass transfer?

Comment by George De Bruyn:

Very 'charming' that answer from Your ' undisclosed student' about the direction of mass transfer in absorption, but in fact not so 'strange' –> just consider the 'flavors' of the quarks: up & down, top & bottom, charm & strange... Moreover, by crossing-out and interchanging the notions left/right, Your student showed he was not entirely sure, thus clearly demonstrating his acquaintance with Heisenberg's 'uncertainty principle'!!

I hope, he passed his exam !! [note: no, unfortunately he did not]

Comment by Oleg Pajalic:

In the Balkan area (meaning former Yugoslavia), the mass transfer is a fuzzy conception and there the mass-transfer just occurs. No-one knows why and how and no-one really cares !!!

Comment by Magdalena Bendova:

...let me complete the picture by saying that in Bulgaria yes may mean no, and no may mean yes, which has no influence on mass transfer whatsoever, but contributes to overall entropy increase.

Comment by Richard Darton:

...in most European countries mass transfer occurs from left to right; in Arab countries and Israel it occurs from right to left; in China, traditionally, it occurs from top to bottom; in Australia mass transfer is upside down. If you ask a British politician he will tell you that none of these options is acceptable. I suggest next year you ask about desorption, the correct answer being of course: "in desorption mass transfer occurs in the other direction".

Hope this helps.