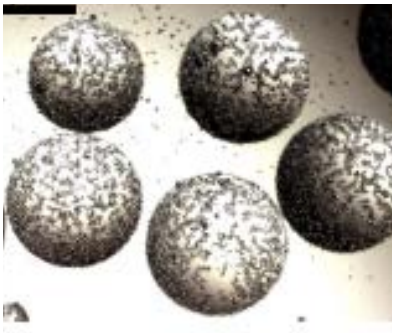
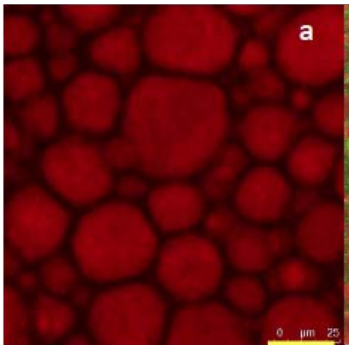
Formulation for designed functionality

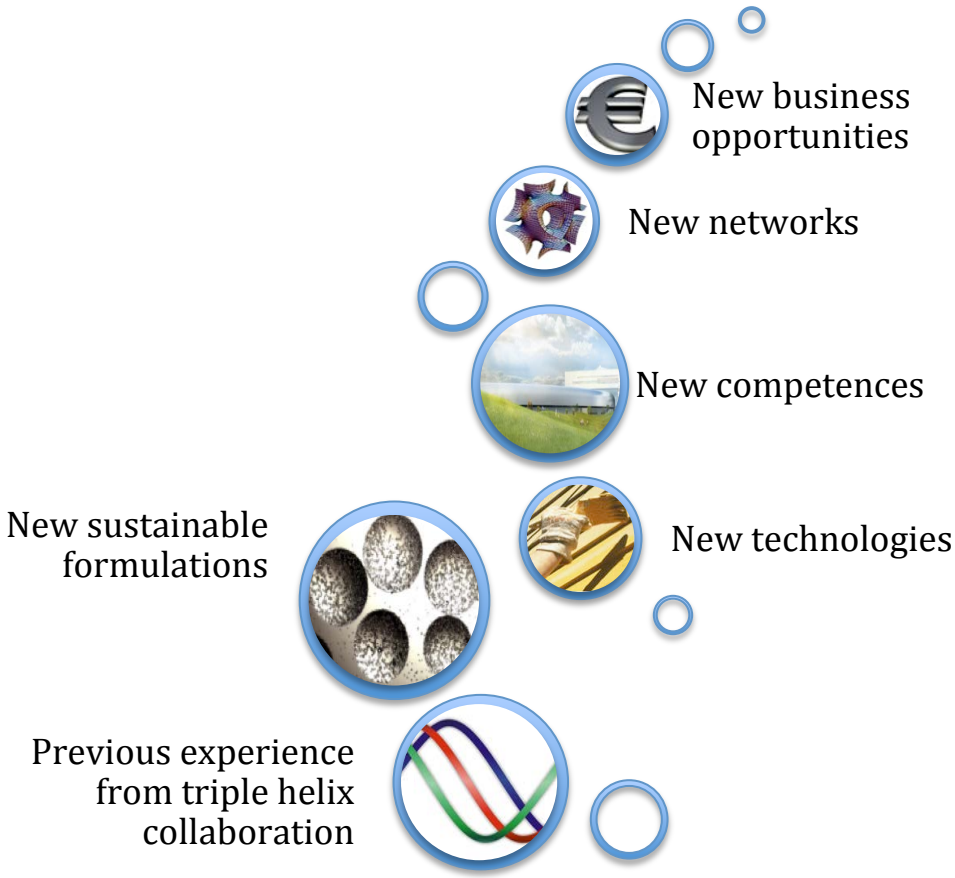
A strategic research and innovation agenda for industrial formulation in Sweden





Executive summary

Sweden needs a national agenda to strengthen the area of industrial chemical formulations, addressing the needs for strategic research, efficient innovation support, dedicated higher education and contract training in the area. The agenda proposes to create a national basis for coordinated research, innovation and education programs, based on growing industrial and societal needs for sustainable formulation development. Unlike other advanced European countries, such as England, France and Germany, Sweden still lacks generic "formulation science" as a coherent discipline. This is unfortunate, since formulation is key for numerous areas of national importance, including pharmaceuticals, paints, paper products, and specialty chemicals. However, the possibility to address this shortcoming is excellent, since Sweden can build on its internationally leading position within surface and colloid chemistry. At the same time, other important aspects of industrial formulation work need to be reinforced, e.g., the consequences of a chosen formulation design for product safety, perception, and regulatory aspects. Especially the latter aspects are important, since Swedish academy has not yet responded to industrial research needs originating from new regulations such as REACH and Quality by Design. Another important aspect addressed by the ReForm agenda is how such a development should take advantage of major infrastructure developments in Sweden, including MAX IV and ESS.



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1 The vision of ReForm

The vision of ReForm is that

- ***Sweden advances its position as an international stronghold for advanced formulation development, where competitive innovations provide increased economic growth***
- ***Formulation research and innovation leads to a society where chemical and life-science products contribute to a sustainable society with better health for man, and where products are based on renewable resources, produced and used in a sustainable way***

The ultimate vision of the ReForm agenda is the development and production, in Sweden, of new, innovative and expertly formulated chemical products that are sustainable, safe for man and environment, and energy-efficient. Successful (re-) formulation efforts along these lines will be essential for the future competitiveness of Swedish industry across several application areas and will, as an additional benefit, improve and update the image in society of modern chemistry and chemical industry. The latter will lead to a much-needed enhanced recruitment of chemistry students and teachers in the education system that, in turn, will guarantee the future supply of skilled and appropriately trained chemists to Swedish companies.

The vision of ReForm will come true through a national agenda for industrial (re)-formulation that coordinates all relevant actors in a unique partnership between academy, institutes, regulatory agencies, and industry across traditional industrial sectors. The ReForm agenda involves (i) cutting-edge strategic research, (ii) innovation support, and (iii) higher education and training. The agenda makes use of the long-standing and internationally recognized academic excellence of Swedish surface and colloid chemistry, but will also include new developments regarding perception, sensoric analysis, solid-state investigations and characterization methods. The agenda will, furthermore, efficiently use the advanced methodologies provided by ESS, MAX IV and other important research infrastructures to the benefit of formulation research.

2 The current status of Swedish formulation work

2.1 Why does Swedish industry need ReForm?

Formulations are mixtures of chemical components designed to achieve or improve functional performance. Formulations are key within a range of industrial areas and chemical processes. Typical formulation-related problems could be: controlling the drug release from pharmaceuticals, controlling the wettability/printability of paper, achieving surface adhesion, avoiding microbial growth in paints, controlling texture, taste and stability in food products.

Formulation work provides opportunities to bridge between traditional industrial sectors, since commonly encountered problems in different applications are often fundamentally the same. For example, concentrated dispersions (”particle systems”) have many generic properties, largely irrespective of their uses in, for example, skin lotions, low fat spreads, or surface coatings. This, in turn, means that a solution to a formulation problem can be transferred from one industrial area to another.

Within a broad range of application areas, knowledge in formulations and designed functionality is central from a competition perspective as a result of increasing demands for rapid and diversified development of new products that meet a large set of requirements from individuals as well as society at large. Industry faces new challenges through changes in quality and environmental preferences from consumers, a diversity of local requirements on a global market, as well as requirements from regulatory frameworks such as the European Union regulation for registration, evaluation, authorization, and restriction of chemicals (REACH). These several factors combined lead to an accentuated need for re-formulation work, that is, to replace formulation components with environmentally more attractive alternatives, ideally at improved formulation performance and reduced price. Although this development provides commercial opportunities, the threshold to introduce new products may be so high that promising innovations never reach the market. This is the case particularly for SMEs, which frequently lack competence and economic endurance to realize the formulation changes needed in final products.

Also from the perspectives of safety, environment, and sustainability, re-formulation work is important for Sweden and Swedish chemical industry. For example, 50% of all chemicals used in Sweden (80% by volume) are considered hazardous to the health. With a strongly increasing number of chemicals (the number of produced and imported chemicals at the Swedish market increasing by 64% between 1993 and 2005, currently amounting to 75000 chemical products based on 14000 chemicals) there are thus increasing concerns regarding sustainability (Kemisk industri ur ett ekonomiskt perspektiv, KemI, 2010).

So far, simplifying rules and guidelines, such as Scientific Advice, Fast Track, and Quality-by-Design – all well established within the pharmaceuticals area – have not seen corresponding measures for formulation development within the wider chemistry area. Companies therefore have to rely on themselves for extensive and costly development and evaluation work. Neither academy nor institutes in Sweden have sufficiently responded to the needs originating from environmentally and safety-driven (re-)formulation. An important reason for this is that *formulation science* is not an established concept in Sweden, neither in the education system not in society at large. This is contrary to the situation in, e.g., the UK, France, and Germany. Furthermore, despite a strong Swedish tradition in surface and colloid chemistry - the fundamental science underlying most of applied formulation science - there is only relatively modest research directed to the formulation technologies of tomorrow. Moreover, innovation support is fragmented between a range of different players.

Taken together, there is therefore a need for a national initiative within the area to facilitate environment-, energy-, and customer-driven formulation development in Swedish industry, cross-fertilization between industrial sectors for realization of new designed functionality, and education and training of the dedicated formulation experts and innovators required by industry. The present agenda seeks to establish a national coordinated effort within formulation science and industrial re-formulation work, encompassing *(i) strategic formulation science*, *(ii) innovation support,* and *(iii) education and training*, aiming at establishing formulation science as a focused research, innovation, and education area in Sweden.

2.2 What are the important challenges to be met by the ReForm agenda?

Some specific issues to deal with are the following.
- Increasing demands for safe and consumer-friendly products within areas such as food, pharmaceuticals, consumer chemicals, and cosmetics.
- Increasing needs to formulate products at reduced emission of green-house gases through a reduction of energy consumption and a replacement of chemicals based on petrochemicals.
- Strongly increased trade and consumption, which currently exceeds supply, leading to chemicals shortages and resulting price increases. This necessitates new chemicals and a switch to renewable sources, which accentuates the need for efficient re-formulation.
- Increased competition from China and other emerging nations. For example, the market share held by Asia without Japan has increased from 18% in 1997 to 30% in 2007, with China producing 3 times the volume in 2007 compared to 2000 (Kemisk industri ur ett ekonomiskt perspektiv, KemI, 2010).
- For localization of R&D investments, a key factor is the local research environment, influencing the recruitment of skilled personnel, possibilities for collaboration with academy and institutes, as well as partnership with innovative SMEs. Here, recent developments, e.g., at AstraZeneca indicate increasing difficulties to motivate investments in Swedish R&D.
- The dramatic changes in Swedish pharmaceutical industry, which have lead to a completely new landscape with a large number of small companies, needing new modes of collaborations between academy and industry.
- The current quite weak recruitment of chemistry students and future chemistry teachers at Swedish universities challenges the future availability of skilled chemists in Sweden.
- Swedish chemical industry accounts for only ~5% of Swedish participation in FP7, with AstraZeneca accounting for about 60% of these projects. Clearly, therefore, Swedish chemical industry is not utilizing the opportunities for funding and collaboration provided by EU (Kemisk industri ur ett ekonomiskt perspektiv, KemI, 2010).
- The need for new legislation that will support the development of products through sustainable re-formulation processes on an extremely competitive market. At the same time, the need, especially for small companies, to understand and efficiently work within the boundaries set by existing legislation.
- There are also challenges for the legislation and regulatory frameworks themselves, since current legislation, e.g., REACH, focuses on the chemical compound only, and neglects the physical form of the chemical. As identified, e.g., in the recent report *Säker utveckling! - Nationell handlingsplan för säker användning och hantering av nanomaterial (SOU 2013:70)*, REACH needs to be modified to address nanomaterials (i.e., colloidal systems). Most likely, a collaborative effort between industry, academy, institutes, and regulatory agencies can support this important development.

2.3 What is the potential for successful coordinated re-formulation work in Sweden?

Chemical industry is one of the largest industrial sectors in Sweden, providing about 17% of its export revenues (ca. 210 billion SEK in 2011), with some 5% from pharmaceuticals and related products, and about 10% from other chemical produce. In addition, numerous other industrial sectors rely heavily on chemistry and formulation, including paper industry (ca. 8% of Swedish export) and packaging industries. Dominating chemical industries in terms of numbers are i) pharmaceuticals and related products, ii) chemicals for paints, coatings, and adhesives, and iii) chemicals for detergents, hygiene products and the like (each about 20% regarding the number of companies). In total, chemical industry employs some 33000

individuals in Sweden (Branschanalys Kemi, VINNOVA 2013). Formulation plays a key role in Swedish chemical industry, which also has a strong position internationally regarding formulated products. The value of Swedish formulation industry seems not to have been estimated recently, but in the UK, the market value of formulated products was recently estimated to GBP1,000 billion (Chemistry Innovation KNT Strategy Report 2010). Formulation markets are strongly growing from an already considerable size, owing to increasing demands in emerging economies, related needs for regional formulation aspects, growing sustainability and safety awareness among consumers, and developments in production and branding. Given the above, a concerted effort on formulation in Sweden will have considerable positive effects from a Swedish economic perspective.

On the academic side, Sweden has a number of very strong research groups within surface and colloid chemistry, which are all part of the ReForm initiative. Surface and colloid chemistry is the most important scientific base for formulation work, and provides powerful tools for understanding complex formulations, transcending industrial sectors and facilitating implementation of formulation solutions from one area to another. Most of the senior researchers of surface and colloid science are internationally recognized, and a number of them are internationally leading, as evidenced by several prestigious research awards, a large number of publications in leading journals, and high citation numbers. This research has also resulted in several successful books used for undergraduate and graduate education, a good number of patent families, and several start-up companies. Moreover, during the last couple of decades, different constellations of the leading Swedish research groups in surface and colloid chemistry have been part of several large programs involving extensive industrial participation within the area, including two VINNOVA-supported "competence centers", CAP (Center for Amphiphilic Polymers from Renewable Resources) and SNAP (Center for Surfactants Based on Natural Products) (VINNOVA), two national research schools funded by the Swedish Foundation for Strategic Research, and the centers SuMo Biomaterials, Biofilms-Center for Biomaterials, and CODIRECT. On the fundamental side, there is the prestigious VR-supported excellence center OMM (Organizing Molecular Matter) that, in addition to fundamental science, has the expressed ambition to bridge fundamental and applied science in the area. In conclusion, there is extensive experience of running larger networks and research efforts within the participating groups and an established tradition of collaboration between industry and academy. Thus, there is a readiness to launch and support a unifying national programme such as ReForm.

Importantly, the Swedish research institutes have a range of broad activities in the formulation area. SP and its subsidiaries Chemistry, Materials and Surfaces, SIK, SP Process Development, and Glafo are highly involved in formulation-related research for a large range of different industries. Swerea and Innventia also have substantial activities within the formulation area. Together, the institutes have a very strong understanding of the formulation challenges for their respectively area. At the same time, the Swedish research institutes do not have the same resources as their European counterparts, for example the Dutch TNO. Thus, collaboration between Swedish institutes and academia is important to strengthen both parties.

3 The making of the ReForm agenda

Around 2010, ideas started to take shape among a core of individuals to launch *formulation* as research and innovation area of obvious strategic importance for Sweden. These ideas were to a significant extent triggered and inspired by activities connected with the *Formula VII* conference in Stockholm in 2010. The successful pan-European *Formula* conferences, taking place every three years, bring together industrial and academic formulation researchers across all application areas. Formula VII was organized by YKI (today SP Chemistry, Materials and Surfaces) together with the Swedish Chemical Society, and several Swedish researchers and groups participated actively both in the programme committee and as speakers in the conference itself. The following important conclusions were clearly driven home at this conference: 1) the increasing importance of innovative formulation science for a modern chemical industry, dedicated to environmentally friendly products and processes; 2) the strong overlap between central questions asked in industry and current research topics of academic surface and colloid science; 3) the fact that Sweden is lagging behind leading European countries in the education and further training of dedicated formulation scientists, ready to work in an industrial context.

The wider Swedish surface and colloid science community has a history of decades of national collaboration involving academic research groups, research institutes as well as industrial companies working together in research programs, graduate schools and EU networks. That this collaboration is highly valued by Swedish industry is proven by the fact that various coordinated initiatives have been taken directly by industrial companies over the years, aiming at national strategic and industrially relevant research programs in surface and colloid chemistry. Most recently, less than 10 years ago, there was such an initiative in connection with the call for VINNOVA VINN Excellence Centers. Various national forums for interaction have also existed through the years, such as the Surface and Materials Chemistry (previously Surface and Colloid Chemistry) division of the Swedish Chemical Society, which organizes a series of annual national conferences since 2001.

Despite the existence of an established national community, coordinated national research collaboration in the area has withered significantly during the last 5-10 years, largely due to a lack of larger national research programs in the area for Swedish researchers from academia and industry to engage themselves in. Instead, large efforts have been spent on the successful creation and consolidation of local centers of excellence (OMM at Lund University, SuMo Biomaterials in Gothenburg, and CODIRECT in Stockholm). For some research environments, such as that at Lund University, previous collaborations in larger programs with Swedish industry have to a large extent been replaced by bilateral collaborations in projects funded by large international companies, although active collaborations with small innovative companies – albeit with less funding – also exist. Nevertheless, the desire to revitalize national collaboration in the area has been kept alive, mainly among the more senior researchers throughout Sweden with personal experiences of previous fruitful national collaboration.

Given the background scenario described above, the call from VINNOVA and the Swedish Energy Agency to propose themes for Strategic Research and Innovation Areas was very timely indeed, and gave the several actors in the field something concrete to nucleate around. Following the call in April this year, things happened very quickly. An operative group, consisting of Martin Malmsten, Lennart Piculell and Marie Wahlgren, all with extensive long-term experience of successful academic-industrial collaborations, gathered to draft the embryo to the ReForm program. They contacted all major academic groups of relevance for

formulation science in Sweden, as well as relevant research institutes and several large and small companies for which formulation science is a core competence. The response was overwhelmingly positive. The current (but growing) list of the supporting companies and research groups is given in Appendix 1.

As soon as the VINNOVA support for the ReForm agenda proposal was granted in June 2013, intense work began along several lines. A steering group for the agenda work was created, with representatives from industrial companies, universities and one research institute. Two meetings, one virtual and one face-to-face, were organized with this group during September. A program for an on-going series of "focus group interviews" with industrial representatives was worked out with the help of the steering group, and launched during October. During the agenda work additional companies has shown an interest for ReForm and individual interviews with these have been performed. A summary of the learning's from the interviews is given in Appendix 2. Already in mid-August, a questionnaire was sent out to the academic research groups and later to the research institutes to review the status of Swedish research with relevance to formulation science. The results of these interviews are summarized in Appendices 3 and 4. Work on the first major application, for a so-called SIO programme, commenced in early October, and was carried out by the operative group with frequent and substantial input from members of the ReForm steering group. The agenda work has also included seminars aiming at initiating a dialogue around formulation issues, see Appendices 6-8. Based on this material an analysis of knowledge gaps within formulation was performed, Appendix 5.

4 Messages from ReForm companies

4.1 Specific innovation and research challenges

The following innovation challenges have emerged from the interviews conducted with the ReForm companies (Appendix 2).

- To find green substitutes for petrochemical-based materials.
- To find green substitutes to be used in protective films, e.g., in packing materials.
- To find new methods to remove unwanted by-products in the starting materials.
- To replace solvent-based systems by water-based systems (e.g., for adhesives/glues)
- To develop surfactant-free emulsions leading to safer pharmaceuticals and cosmetic creams.
- To utilize new formulation concepts, for example particle-stabilized emulsions.
- To develop platforms for in-vitro testing of new formulations.
- To find fast screening methods to evaluate formulations based on new materials.
- To develop methods for predicting stability and avoiding unwanted interactions.

The above innovation challenges translate to the following research challenges.

- Understanding how new compounds behave in complex products over time, e.g., interactions in a polymer- and surfactant-containing suspensions (as in paints).
- Designing particles that give desired surface or emulsifying properties.
- Develop strongly selective methods to achieve surface deposition of particles, and to design interfaces using polymers and surfactants.

- Understanding and controlling time-dependent processes at surfaces.
- Understanding the behaviour of nanoparticles in the GI tract.
- Measuring properties such as elasticity and softness of thin-films.
- Measuring particle sizes in concentrated formulations.
- Developing methods for in-vivo and in-vitro monitoring of the effects of formulations on biological membranes.
- How to use formulations to control friction forces for the development of new lubricants.
- Mechanistic modelling of the release of ingredients from formulation matrices.
- Hydration in the “almost dry" regime. The quite sharp appearance of "bulk-like" water in “dry” formulations at some characteristic relative humidity represents a point where both physical stability and chemical stability are generally lost.
- The hard-soft interface – formulation of “hard” materials by “soft” means, in order to control and manipulate hard components on the nanoscale.

4.2 Education and training

In the interviews performed during the agenda work, the companies have pointed out the need for education and training within formulation on all levels, from undergraduate programs to shorter courses for industry. The industry has furthermore pointed to the necessity that both graduate and undergraduate students acquire a better knowledge and understanding of safety and sustainability. The need for formulation engineers has also been addressed by the High Level Group on the Competitiveness of the European Chemicals Industry in their final report 2009, stating that “*To face today’s needs, the curricula for chemical engineers should adapt in parallel to the sector’s evolution, or even anticipate new needs, like the profile of ‘product engineers’ that should match the growing demand from the large number of formulators*”.

In the contacts with the different academic partners involved in the agenda, we have identified the following shortcomings in the current educational system.

- There are very few dedicated formulation courses that address formulation science on a generic level.
- There are few courses outside of the pharmaceutical and metallurgic fields that address powder technology.
- There are very few courses that on a systematic and advanced level cover requirements from authorities, environment and sustainable development.
- There are few courses open for industry or specific courses aimed at industry, with the exception of courses offered by the Swedish Pharmaceutical Society.

On the other hand, there exist considerable strengths within academia that could be used for further development.

- Application-specific courses offered in different vocational programs
    - Pharmaceutical formulation (Pharmacist, MSc)
    - Food Formulation (Master of Engineering)
    - Paper (Master of Engineering)
    - Metallurgy (Master of Engineering)
- A wide range of courses available in key fundamental subjects for formulation
    - Surface and colloid chemistry
    - Polymer engineering
- Several method courses relevant to the formulation, especially at the PhD level

- Scattering methods
- Microscopy and electron microscopy
- NMR methodologies (structure and dynamics)

4.3 Legislation and innovation support

Several of the interviewed companies highlight the need for a tougher legislation to promote the shift to a more sustainable society. At the same time, smaller companies need better insight into how to handle regulatory issues. Thus an on-going dialogue between companies and legislative authorities is important for the formulation community. Läkemedelsverket has been actively participating with input to this agenda and their newly formed organisation for External Relations and Innovation Support gives an example on how such support could be developed.

The innovation perspective is important in the agenda work. Part of this is to ensure that each application originating from the ReForm agenda will have a clearly communicated agreement on how to handle patents. During the discussions with the companies different models for open innovation have been brought up, and need to be followed up. For the smaller companies, support regarding key steps in the process of developing new products, such as scale up of production, is clearly desirable.

5 Plan for future actions

5.1 Implementation of the research agenda

The implementation of the agenda requires work along the following lines.

1. Industrially driven formulation research

- Identification of prioritized target areas for strategic formulation research through in-depth focus interviews, workshops, and seminars involving participants from academy, industry, and research institutes. Substantial initial work along these lines has already been performed in the making of this agenda (see the Appendices), but this must obviously be a continuous activity.
- Matching of Swedish research excellence with industrial needs in one or more coordinated programs.
- Coordinated research applications directed towards VINNOVA, KAW, SSF, Mistra and EU/Horizon 2020
- Individual project applications to, for example, VR and Formas.
- Joint/strategic efforts related to ESS and MAX IV, including coordinated research programs and experimental facility efforts.

Successful strategic research carried out in collaboration between academia and industry generally requires a mutual understanding of, and respect for, the boundary conditions under which the other partner operates. Companies cannot afford to engage themselves in research, however cheap the bill, that does not lead to new innovations/products or better processes. Good scientists, on the other hand, have both the desire and the obligation to do good science. However, the prospects for projects and research that satisfy all these boundary conditions are particularly good in formulation science, as evidenced by numerous previous examples.

2. Innovation support

- Developing IP and dissemination models to facilitate transfer of technical solutions of formulation problems from one industrial sector to another.
- Organizing a mentorship program for academic individuals wishing to pursue innovations.
- Involving the various university organizations for innovation support, as well as regional innovation offices, in the programme. It has become evident that the universities involved in the agenda organize their innovation support somewhat differently.
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3. Education and training

- Developing generic formulation science programmes at the Master and PhD levels, focusing on the combination of innovation and sustainability, transcending traditional industrial sectors.
- Developing a series of shorter courses directed to various application areas of formulation and/or various formulation types.
- Assessment of massive open online courses (MOOCs) as potential tools in formulation science.
- Arranging on-site training courses in formulation science for industrial personnel.
- Developing a joint academic/industrial program for Master projects to be carried out at participating industries.

4. Developing collaboration

- Organizing cross-competence collaboration in the formulation area in Sweden. This should build on and refine instruments developed in previous and existing centers of excellence and collaborative programmes. It should also incorporate various expertise in formulation evaluation related to, e.g., large research facilities, sensorics/perception, LCA, and eco efficiency.
- Strengthening collaboration with groups outside Sweden, especially other European groups. The already well-established collaboration within Medicon Valley, as well as the collaborations with European industry, are useful as a starting point.
- Developing closer ties with other areas important for formulation, for example toxicology, e.g., through collaboration with SweTox.
- Developing internet-based tools for dissemination and communication of developments.

5.2 Major applications

Several of the above work points clearly require additional resources in order to be pursued. More specific plans are, therefore, only meaningful to outline in detail in the contexts of, e.g., larger research applications, where the boundary conditions imposed by each particular call also have to be considered. The first application emerging from the ReForm agenda was the application for an SIO programme in the call launched on October 2, 2013, by VINNOVA, the Swedish Energy Agency, and Formas. Although the application was not granted, it went very far in the process, and the collaborative work with the application gave the ReForm participants an excellent opportunity to jointly think through more precise measures and to develop the necessary tools. This work will continue and develop as a second attempt for an SIO programme will be made in the call launched on June 3, 2014.

Although the SIO-programme format seems ideal for realizing the ReForm agenda on a full national scale, other potential sources of funding will be considered, such as SSF and EU/Horizon 2020. The ReForm agenda will also serve as a context and an inspiration for the submission of smaller focused project applications and proposals to various funding agencies.

5.3 Spreading the word and developing ReForm

As described above, joint work on securing long-term funding through major applications is perhaps one of the best ways to engage the various actors in concerted re-formulation work. The primary effort along these lines will be continued work towards realizing a ReForm SIO programme. Potential new partners will be identified and approached in this work, and actions such as focus group interviews, hearings or individual interviews will be taken in order to get input from all relevant organisations.

A series of events, such as seminars and conferences, have been and will be arranged as part of the ReForm work. Two successful half-day seminars (see Appendices 5 and 6) have already taken place with broad participation from academia and industry. *ESS and MAX IV - new opportunities in formulation research*, featuring seven expert talks and a concluding discussion, was held at Medicon Valley (co-arranger) in Lund in January with 68 registered participants. An open *Minisymposium on formulation science*, discussing challenges as well as recent progress was held at Kemicentrum in Lund in February, with an estimated participation of *ca.* 50. Finally, the title of the international annual Surface and Materials Science conference, arranged in Lund by the Swedish Chemical Society in October 2014 (Appendix 8), is *Realizing reformulation*. The list of speakers includes leading international scientists as well as key industrial and academic participants of the ReForm initiative. In connection with this symposium, a meeting will be arranged, open for participants and potential participants of ReForm, to discuss a second application for an SIO programme.

5.4 Education and training

Education and training programs essentially have to be funded by the Universities. Therefore, several measures to meet the educational needs in the formulation area can be taken independently of the work on applications for funding. External funding would be required, however, for larger initiatives such as national graduate schools.

There currently exist undergraduate courses and courses for industry that cover formulation in specific application contexts, but there are very few courses of generic character that address several industry areas. ReForm will be a center for developing generic courses within formulation that could be used on both national and international levels. This includes hybrids of so called MOOC (massive open online courses) and traditional education. Shorter MOOCs could be included as parts of the education in different undergraduate programs while also functioning as short stand-alone courses for professionals. Such MOOCs could be of interest in areas where the expertise is spread nation-wide and also outside the core of the Universities, for example in legislative authorities such as the Swedish Medical Products Agency. Examples include different aspects of legislation and sustainable product development as well as courses on advanced experimental techniques.

The ReForm participants could furthermore form a base for a national industrial research school in formulation. In addition to scientific courses in fields relevant to formulation, such a research school should also cover issues important for innovation and entrepreneurship. Many courses could be aimed at both PhD students and professionals from industry, which would increase the base of potential participants and, as an additional important benefit, provide excellent possibilities for networking and future recruitment.

There is a need for master programs in generic formulation science. Internationally there already exist a few such programs, for example, University of Greenwich and Glyndŵr

University in the UK and International Medical University (IMU) in Malaysia. The master program in Greenwich contains the following courses

- Case Study in Non-Pharmaceutical Formulations (30 credits)
- Pharmaceutics and Formulation (30 credits)
- Product Development, Manufacture and Control (30 credits)
- Pharmaceutical Analysis and Testing: Mathematics and Statistics (30 credits)
- Formulation Research Project (60 credits)

An important task is to identify the need for and the possible structure of a Swedish Master course in formulation, also making use of experience gained abroad. However, already now we can foresee that a Swedish Master would have different educational strengths than the programs, for example, in the UK. The Swedish Master would be based on the existing education tradition in Sweden, including the strength in surface and colloid chemistry and the future use of large-scale facilities (MAX and ESS) and, also, a tradition of including sustainability into educational programs. A tentative Swedish program could look as follows

- Methods for characterization and evaluation of formulations
    - NMR
    - Microscopy
    - Raman
    - Scattering methods
    - Calorimetry
    - Surface technologies
    - Chemometrics
    - QSAR/High throughput profiling and evaluation
- Special areas of formulation
    - Formulation for pharmaceuticals and cosmetics
    - Formulation for foods
    - Formulation of fine chemicals
    - Formulation for paper and pulp

Appendix 1. Companies, organizations and research groups supporting the ReForm

Table 1 A short description of the companies behind the Agenda

Company	Contact person	Size	Description of core business
AkzoNobel Functional Chemicals	Leif Karlson	L	AkzoNobel is a leading global paints and coatings company and a major producer of specialty chemicals.
AkzoNobel Wood Finishes and Adhesives	Peter Herder		
AkzoNobel Pulp and Performance Chemicals	Michael Persson		
AstraZeneca R&D Pharaceutical Development	Staffan Schantz	L	AstraZeneca is a global innovation-driven biopharmaceutical company specializing in the discovery, development, manufacturing and marketing of prescription medicines
Bioglan	Birgitta Svensson	SME	Bioglan AB is a contract development and manufacturing organisation with more than twenty-five years of experience in research, development, manufacturing and marketing of pharmaceuticals
Camurus	Fredrik Tiberg	SME	Camurus provides innovative nanoscale drug-delivery systems for development of high-value therapeutics.
CR Competence	Anna Stenstam	SME	The vision of the company is to, in as many ways as possible, act as a true bridge between academia and society
McNeil	Katarina Lindell	SME	McNeil Consumer Healthcare provides top quality, over-the-counter healthcare products
MIP	Ola Karlsson	SME	MIP Technologies develops designed resins for customers requiring extraordinary separations in various scales and application areas
Perstorp	Kent Sörensen	L	World leader in various sectors of the specialty chemicals market
SCA Hygiene Products	Jennie Andersson	L	SCA is a leading global hygiene and forest products company that develops and produces sustainable personal care, tissue and forest products.
Sol Voltaics	Johan Borgström	SME	Sol Voltaics improves the efficiency of energy capture, generation and storage using miniscule amounts of novel nanomaterials.
Speximo	Malin Sjöö	SME	Sustainable stabilization and encapsulation technology
Statoil lubricants	Thomas Norrby	L	For more than 20 years, Statoil has consciously invested in developing lubricants to meet the ever-increasing requirements for performance while having minimal negative impact on our environment.

Table 2 Organizations that supported the first application for an SIO programme

Läkemedel	**Kemi**	**Biotech, livsmedel, konsulter och övriga**	**Forskningsorganisationer**
Aerosol Scandinavia AB	Svenska Aerogel AB	SweTox	Innventia
Bioglan ABA community for formulation	AkzoNobel Functional Chemicals	Solve Research & Consultancy AB	SP Techn. Research Inst.
Camurus AB	AkzoNobel Pulp and Performance Chemicals	Orkla Foods Sweden	Lunds universitet
Enza Biotech	AkzoNobel Industrial Coatings	Biogaia AB	Malmö högskola
Galenica AB	AkzoNobel Surface Chemistry	Probi AB	Chalmers
Magle AB	BIM Kemi AB	CR Competence	Göteborgs universitet
McNeil AB	Dafo Fomtec AB	Medicon Village	Stockholms universitet
Moberg Pharma AB	Gipeco AB	Packbridge	KTH
MVIC	MIP Technologies AB	Region Skåne	Uppsala universitet
QPharma	Perstorp AB	Spexímo AB	Max IV Laboratory
SoBi	Sol Voltaics AB	Källbergs Industri AB	ESS AB

Table 3 Description of research groups participating in ReForm

Organisation	**PI**	**Number of senior scientist represented**	**Publications PI**	**H-value PI**	**Triple helix experience**
KTH	Per Claesson	12	272	47	Director of SNAP
KTH	Lars Wågberg	3	224	33	
GU	Johan Bergenholtz	3	49	21	Adjunct scientist, AstraZeneca R&D
SU	Lennart Bergström	8	155	32	YKI and director of The Brinell Center–Inorganic Interfacial Engineering
Chalmers	Anette Larsson	15	56+7 patent	13	Worked at Astrazeneca Head of SUMO
MAH	Thomas Arnebrant	9	160	27	Pharmacia, Ferring, YKI and director biofilm research center
LU	Lennart Piculell		168	37	Director of CAP
LU	Marie Wahlgren	6	54	19	Worked at Ferring AB
UU	Martin Malmsten	3	235	39	Head of YKI, worked at AstraZeneca, founded Dermagen AB and XImmune AB

Appendix 2. Summary of focus group interviews to date with the ReForm companies

A central activity of the Agenda work was a series of so-called focus group interviews with the industrial partners. Such interviews are made with groups of 3-6 participants and contain both individual reflections on questions and discussions in the larger group. This gives the possibility to identify both common grounds between the industries and possible differences between different companies or product areas. Apart from the actors supporting the Agenda, interviews and input have also been given by the following companies: Arla Foods, Medicon Village, Orkla Foods Sverige, Aerosol Scandinavia, Moberg Pharma, BioGaia, QPharma, Medicon Valley Inhalation consortium, and SoBi. Below is a summary of the answers given to the key questions asked during the interviews.

Q1 In what way is formulation a part of your core business, and how do you define formulation?

One thing that stands out is that all the companies see a direct link between formulation and product. To a direct question given in one of the interviews, the answer was that there always had to be product relevance in formulation research. Despite this product focus, the companies saw no problem in defining formulation as a very generic activity, where the knowledge readily transcends different industrial sectors. Several of the companies highlighted the importance of gaining knowledge from other industrial sectors when addressing their own formulation problems. A number of the companies work with other industries as customers, and one of their key challenges was to understand how their product works in the customer's formulation. Also from this perspective there is an added value of an agenda that transcends different industrial sectors.

The companies pointed out that formulation is strongly connected to understanding the raw materials, the process conditions and the customer demands. Several companies mentioned the necessity to understand product quality and how this changes with time. The companies also made the distinction that formulation is 'the mixing of components in the absence of chemical reactions', while in some cases chemical reactions could still be essential for the function of the formulated product when it is finally used.

The primary formulation challenges for the interviewed companies were dispersion and emulsion stability, film formation, adhesion, understanding texture and rheology, controlling release of active compounds, understanding the interactions of the formulation with biological systems (for example targeting formulations to specific cells) and toxicology, and understanding how formulations interact with surfaces and at interfaces. A few companies also addressed the need to understand solid-state properties of their formulations and the transitions occurring in a dry formulation upon wetting. As one of the companies pointed out, many formulations are powders containing very low amounts of water but our understanding of the low-water systems is still sketchy at best.

Nearly all companies emphasized the need to understand how their formulations change with time. Many of the companies also expressed the need for methods that can predict long-term stability from short-term investigations. Such methods exist that work reasonably well for chemical degradations but are difficult to find for changes in physical/chemical properties, since the type of changes that occur in a formulation might vary drastically with, for example, temperature.

Q2 What is the key area that a national agenda within formulation should address?

The interviews so far have given different perspectives on this question. Companies in one of the interviews emphasized the need for visions with a formulation agenda. They would like to identify where an agenda could make a difference when it comes to building a sustainable society. Visions regarding formulations based on renewable resources and products free from organic solvents where highlighted. This group pointed out that for such an agenda to work it is important to include all the links in the value chain, for example the ingredient manufacturer and the developer of consumer products. Other interviewed groups focused more on innovation and research challenges and highlighted the need to understand complex formulations and the need for faster and smarter development strategies for formulations. For one company it was important to perform efficient formulation work with limited amounts of (precious) materials. The discussion also brought up the need for high throughput evaluations of formulations. The need for efficient platforms for in vitro screening in order to reduce the need for in vivo/toxicity studies was also highlighted. Several groups brought up issues about how to go from idea to commercial production, involving aspects such as scale-up, economical boundary conditions in commercial production (for example the prices of ingredients) and understanding legislation. They saw that these types of issues could be especially important to address in the education part of the agenda. Several of the companies pointed out the need for a stronger environmental legislation to push innovation forward and that the lack of such legislation is preventing green products from being competitive on the market.

AstraZeneca and CR Competence highlighted the need for research on solid-state properties of water-poor formulations. AstraZeneca also mentioned targeted delivery as a key point of interest. They and AkzoNobel also greatly valued close collaboration in PhD projects, both as an excellent way for collaboration between industry and academia and as a way to secure future competence in Sweden.

One illustration on the generic aspects of formulation is that two interviewed companies with completely different type of products (Mölnlycke and Statoil) brought up the need to find technologies allowing the development of formulations free from bactericides/preservatives.

Q3 *What are the needs of research in the field of formulation available today based on your activity?*

Here we will list a few of the more specific issues that the companies brought up. One reflection was that it was interesting to see how companies working in completely different product fields brought up the same scientific issues.

- The need for a better understanding of interactions between individual formulation ingredients and entire formulations with interfaces. As examples, the companies mentioned complex sets of interactions that can allow the diffusion of certain formulation ingredients into a surface material, where the latter could be either living tissue (for example skin) or a soft, porous material such as wood or paper. Also interactions between formulations and hard surfaces were addressed, especially with regard to adhesion.
- The need to understand behaviour of concentrated colloidal systems, and especially tools to investigate such formulations without diluting them.
- The need for technology platforms for high throughput evaluation of products

- The need for platforms to perform in vitro screening of safety and performance issues before going into animal or human trials, especially as a measure to reduce the number of the latter trials.
- The need for quantitative sensoric models. As was described by some of the companies, several parameters used today to evaluate the behaviour of formulations (for example 'nice skin feel') are too subjective and ill-defined to be useful in modern optimization models such as multivariate analysis. For faster development of products more robust evaluation methods would be needed.
- The need to develop preservative- or biocide-free solutions at high water activity
- The need to understand what happens with formulations during transitions, for example from a very low to a higher water content.
- Targeted delivery of a drug
- The use of nano-cellulose in formulation science
- Pickering emulsions
- The formulation of biological molecules, for example protein and peptide drugs
- Methods to evaluate toxicity of nanoparticles

Q4 How should the collaboration between companies, academia and society be organized to work well from your point of view?

One of the key issues that the companies brought up was that they find it problematic to be too open in collaborations if they are sitting at the same table as their competitors. However, on a direct question they agreed that competing companies could collaborate on platforms, for example on in-vivo methods, which would not be a core part of their business model. If a research program is based on the agenda one has to handle how competing companies could participate, for example by creating smaller subgroups around different issues. Another issue that needs to be handled is patents.

Especially the larger companies described a situation where they have several offers to participate in collaborations with universities in different forms. They where very clear with that they only choose to participate in collaborations where they see real added value. To be able to see such values it is important for them to be part of the problem formulation and to be active during the project. Several companies have positive experience of industrial PhD students as a fruitful form of collaboration. The companies also pointed out that genuine trust and respect between the participants is essential, and that a true understanding of each other's working conditions is at least as important as the project description. It must be a true win-win situation; both the participating industries and (academic) researchers must see the value of what they are doing from their own perspective and in their own context.

Several of the companies pointed out the need for different types of collaboration including PhD projects, but also shorter projects lasting, for example, for a couple of months. One example could be that an industrial researcher did a shorter period of research work at a university. Important for such short periods of work is that the visiting industrial researcher should not have to reveal commercial strategies while working in the university laboratory. It was mainly the small companies that expressed the need for shorter research projects.

In the follow-up interviews several companies brought up the need of having academic partners for dialogue around early ideas for development. They also emphasized, stronger than in the focus group interviews, the need for a community within formulation. Several companies expressed an interest not only for the collaboration between academia and industry

but also an emphasis on the transfer of knowledge and ideas between companies. One example could be the participation of companies that can sell characterization competence.

It was also proposed that it could be useful with an innovation/research broker that could match industrial needs with the right research group. In one of the interviews we discussed how *open innovation* could be a part of the agenda work. Several of the companies (AkzoNobel, Statoil, AstraZeneca and Perstorp) have their own platforms for open innovations. AkzoNobel described a process for open innovation where the company lets 3-4 universities compete (against certain payment) to solve an industrial problem that the company previously failed to solve. The winning university will then get as a bonus a larger sum of money than the other participants. The company receives ownership of the innovation that is linked to their own applications, other aspects of the innovation are free for the participating university scientists to continue to explore.

At two of the interviews technology transfer was discussed. The companies that had been involved in the VINNOVA-supported excellence center SuMo pointed out that they had appreciated how SuMo worked with implementation and thought that a new initiative could further develop implementation methods. SuMo works with a dedicated committee for implementation and this is something that could be implemented also in initiatives taken by ReForm.

During the interviews it was also emphasized that the leader of a larger research collaboration is very important. This person must be able to truly understand the industrial needs as well as innovative research and has to be able to balance and satisfy the needs of the different participating partners.

Q5 What skills do you need in your company, and how well does existing educating and training match these needs?

Although some companies where not recruiting right now, due to the current economical climate, all of them saw a need for new recruitment within formulation already in a rather short-term perspective. One company pointed out problems connected with retiring experienced researchers representing vast amounts of accumulated knowledge. There is a need to recruit employees both at bachelor and PhD levels. In fact, one major incentive to participate in industry-academic collaborations is to secure the availability of good future employees. One of the companies mentioned that it is beneficial if the companies are actively involved already in the recruitment of the PhD student in a joint project, since this will make them more committed and likely to employ this person later.

The companies expressed quite different views on what is needed for a bachelor level recruitment. The smaller companies often pointed out the need to employ someone with a more dedicated formulation background, while the larger companies mainly require someone with the a solid and broad fundamental chemistry background, who can then be further trained within the company. All companies, however, emphasize the need for good basic knowledge. One of the industries pointed out the need for a better training and understanding of safety and environment issues among both PhD and undergraduate students. They are looking for people with a mind-set where safety is always a part of how you conduct your work.

A few of the companies mentioned the problem of requiting students to chemistry and saw it as one of the responsibilities of an agenda, and the participating partners, to also work on this issue.

There was also a discussion about the need of courses for industrial researchers. The smaller companies pointed out the problem with costs (time and money) connected with participating in such courses. The use of internet-based education for industry was proposed as one possibility to address this problem. On the other hand, several of the persons interviewed stressed the positive aspects of courses where you meet others in person, which might get lost in IT-based courses. Some companies were interested in the possibility to use joint courses for industry and PhD students, but this would require that the courses where conducted and scheduled in such a way that it worked also for industry (especially time management).

Appendix 3. Survey of Swedish academic research of relevance for formulation

1. The process

In order to survey current formulation-related academic research in Sweden, a short questionnaire was sent out to all participating academic groups asking them to

- List formulation-related research projects
- List key collaborators for these in academia and industry
- Identify internationally leading research groups
- Identify missing partners for the ReForm Agenda work
- List courses and programs within the formulation area

The groups were asked to identify and contact all suitable groups within their respective universities, thus not restricting the survey to surface and colloid chemistry groups only, but including also related research. The questions were deliberately phrased quite openly to allow for differences in opinion on what should be considered as "formulations", in an effort to locate both the center of gravity and the boundaries of current research within the area, as carried out by the present constellation. Indeed, the answers differed somewhat between academic groups. Nevertheless, from the summaries and lists provided by the academic groups it was possible to arrive at an overall picture of current research activities, as well as recent developments, within formulation in Sweden.

2. Overall summary

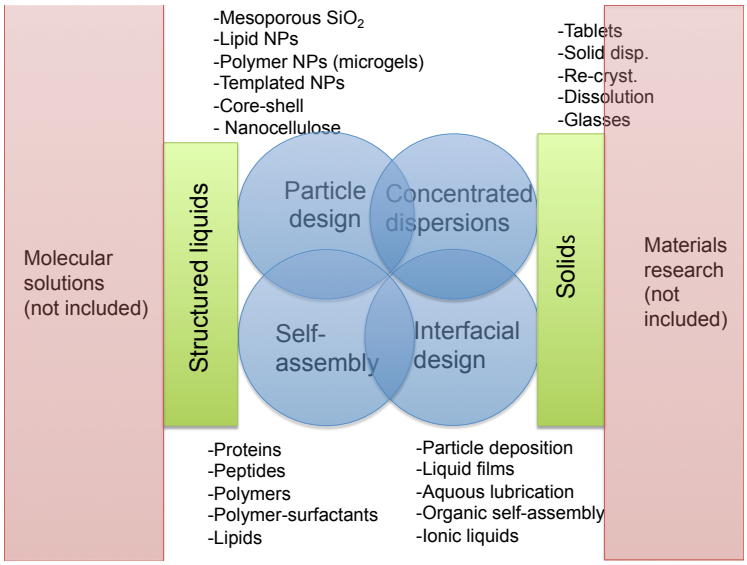

Figure 1. Current academic research in Sweden covers most key areas of surface and colloid chemistry, including particle and surface design, (concentrated) dispersions, self-assembly, and many others, spanning from structured solutions to concentrated semi-solids.

All academic groups in the core of ReForm have considerable research activities on colloid and interface chemistry. Their research focuses on properties of dispersed systems (particles, droplets, bubbles) and self-assembly structures formed by amphiphilic compounds (surfactants, polymers, proteins, peptides…), but also on the design of particles and surfaces.

In contrast, none of the groups have substantial activities on the synthesis of novel formulation excipients (preservatives, stabilizers, etc). All major universities within ReForm have extensive research on solid systems (polymer materials, food powders, ceramics, metals, etc), but the vast majority of this work is focused on materials research with other aims, with no clear formulation dimension. Exceptions exist, however, as exemplified by research for the design of novel paints, polymer composites, paper coatings, solid pharmaceuticals and ceramics. Nevertheless, an important result of the survey is that the present core constellation well covers systems spanning from structured solutions and semisolids and interfaces, with considerable less activities on formulations based on simple solutions and on materials research.

3. Survey of formulation-related research

From this overall identification of the center of gravity of the formulation-related research of the groups participating in ReForm, the following identification of current research activities could be identified (NPs=nanoparticles; μgel=microgel; API active pharmaceutical ingredient; ()=less formulation-oriented):

Lund University

Particle design
- Mesoporous SiO_2 NPs
- μgels
- μgel-templated particles
- Core-shell NPs
- Lipid NPs
- Pickering emulsions

Self-assembly
- Polymer-surfactant
- Protein self-assembly (casein)
- (Peptides)
- (Surfactants)
- Lipids
- Protein-polymer, protein-lipid

Concentrated dispersions
- Proteins
- μgels
- Core-shell NPs

Solids
- Cellulose dissolution
- Matrix erosion/tablet dissolution

Interfacial design
- Surface deposition of particles
- Coatings from porous particles
- Lipid-based films

Chalmers & Gothenburg University

Particle design
- Inorganic NPs
- Polymer NPs
- (Mechanism of NP formation)
- (Electrocatalytic NPs)

Self-assembly
- Polysaccharides
- Polymer-surfactant
- (Surfactant)
- NPs at very high ionic strength

Dispersions
- Release from particles, paints & coatings

Solids
- Pharmaceutical solids
- Models of drug release from tablets
- Cellulose materials

Interfacial design
- Polymer/surfactant

Several large-scale materials projects related to formulation (SuMO, etc)

Royal Institute of Technology

Particle design
- Nanocellulose
- Polymer(/surfactant) NPs
- Dendrimers

Self-assembly
- Surfactant
- Polymer
- Polymer-surfactant
- Protein self-assembly (MAP)
- Nanocellulose

Interfacial design
- Polymer-surfactant
- Nanocellulose
- (Protein coatings)
- (Organic coatings)

Molecular solutions
- (Ionic liquids)

Stockholm University

Particle design
- Micro- and mesoporous particles
- Nanocellulose
- Size- and shape-selective NPs
- Core-shell NPs

Self-assembly
- Inorganic NP assembly
- Nanocellulose self-assembly
- Lipids/cell membranes

Concentrated dispersions
- Nanocellulose

Interfacial design
- Porous & dense coatings for implants/dental
- Pickering foams

Solids
- Dissolution of zeolites
- New phases

Molecular liquids
- Ionic liquids

Uppsala University

Particle design
- μgels
- Core-shell NPs
- Mesoporous SiO_2 NPs
- Lipid NPs

Self-assembly
- Polymer-surfactant
- Polymer-protein/peptide
- (Protein self-assembly)
- Lipids

Solids
- Tablet formation
- Matrix erosion/tablet dissolution
- Solid dispersions
- Re-crystallization/polymorphs
- Ceramic depots

Only facility in Sweden with a wider pharmaceutical formulation activity/perspective

Malmö University

Particle design
- Mucoadhesive formulations

Self-assembly
- Lipid self-assembly and film formation
- Humidity effects in lipid systems
- Surfactant adjuvants
- Protein self-assembly

Solids
- Hydration of dry formulations

Interfacial design
- A series of aspects related to films for topical delivery
- Proteins/biofilms
- API-coated implants
- Lubrication and thin films

Numerous related projects within Biofilms-Center for Biointerfaces

4. Research on self-assembled systems

Self-assembly has been at the core of both surface and colloid chemistry and of formulation science for decades. Essentially all Swedish academic groups have extensive experience in this area, spanning from surfactants to block copolymers and polymer-surfactant systems. In parallel with an increasingly better understanding of the self-assembly of such systems, there has been a notable shift, during the last 5 -10 years, from fundamental surfactant research to applications of surfactants and block copolymers ("polymeric surfactants") in formulations, biomedicine, and advanced materials. Importantly, Sweden has a strong international position in the area, and particularly in the context of surfactants and polymers based on renewable resources, e.g., through previous long-term initiatives (CAP, SNAP). Additionally, current focus is placed on increasingly complex self-assembly system (polymer-surfactant, protein, peptide), of considerable importance for a wide range of formulations and other application areas.

5. Research on dispersion and concentrated dispersions

Traditionally, research on (dilute and concentrated) dispersions has focused on interparticle interactions for controlling colloidal stability, as well as on the effects on structure formation and mechanical properties of such systems (e.g., in ceramic green bodies, paper coatings, or latex paints). During the last few years, focus has shifted gradually towards the use of such systems for designing new types of advanced materials. Examples include particle-stabilized (Pickering) emulsions and foams, advanced building block for concentrated dispersions (microgels, core-shell NPs, nanocellulose, dendrimers…) and protein-based materials.

6. Research on particle and surface design

A notable development among several of the groups is that increasing attention is paid to particle design. This represents a shift in attention towards "tailoring" nanoparticles of interesting properties, either by themselves in dilute dispersion, or in concentrated systems in bulk or at interfaces. Examples of this development ranges from inorganics, such as mesoporous SiO_2 and various metal and oxide nanoparticles, to organics, such as microgels and lipid nanoparticles, and various hybrids, such as core-shell NPs. There is a corresponding and analogous increased attention paid to the design of macroscopic surfaces, e.g., for the control of friction, adhesion and corrosion, often focusing of water-based systems and systems from renewable resources.

7. Research on solids

Particularly within the pharmaceutical area, research on solids goes hand in hand with formulation research, e.g., in relation to stabilization of the amorphous state (solid solutions, solid dispersions…), control of hydration kinetics in lyophilized formulations, and disintegration of tablets. These areas are currently well covered by the research groups jointly. Also in seemingly different application areas, related research is performed aimed at applications in ceramics and advanced materials. Nevertheless, dry formulations (e.g., particle formation through various lyophilization techniques) could benefit from a stronger effort in Sweden, given their technical importance.

8. Other developments

In all the mentioned areas of Swedish research, the focus on water-based systems remains unchallenged, and considerable emphasis is placed on materials (surfactants, polymers) from renewable resources. Additionally, in all areas discussed above, increasing attention is paid to biological systems (proteins, peptides, lipids…), e.g., relating to mucoadhesive formulations and protein-based surface modifications for corrosion control in particle and surface design, topical drug delivery systems in dispersions, protein- and peptide-based materials in self-assembly, and lipid-based nanoparticles for drug delivery applications in particle design, to mention a few. Also common to all these areas is a development towards an increasing degree of sophistication of the experimental methods, including advanced spectroscopies (e.g., NMR), synchrotron-based SAXS, novel scanning-probe microscopies, and various neutron-based methodologies, to mention a few. This includes also a well-established presence of several of the participating groups at international facilities for neutron- and synchrotron-based research. In parallel to this development towards increasingly advanced experimental methodologies, the area is characterized by an increasing convergence between experiments and modeling, facilitated, e.g., through coarse-grain modeling, rewarded by the Nobel Prize in chemistry 2013.

9. Collaborations

All groups have broad networks of academic collaboration partners, spanning from medical researchers, microbiologists, pharmaceutical scientists, dentists, material engineers, soft matter physicists and many more. This is natural due to the multi-faceted nature of surface and colloid chemistry, with natural interfaces to biology, advanced materials, and environmental research. In addition, all groups have extensive industrial collaborations, both with big companies and with SMEs. Collaborations cover a wide range of industrial sectors (paints, foods, pharmaceuticals, personal care, speciality chemicals, paper, etc). Despite this,

and despite the opportunities provided by surface and colloid chemistry to transfer a technical solution to a formulation problem from one industrial sector to another, no broader formulation-related program/activity exist today. In fact, none of the academic groups currently has a clear strategic line regarding formulation efforts, or even bring forward research primarily motivated by re-formulation triggered by regulatory/legal or other issues. Taken together with the strong international position of Swedish surface and colloid chemistry, this point to a considerable untapped potential if these groups were to be coordinated in a concerted formulation effort.

Appendix 4. Formulation work at Swedish research institutes

RISE, Research Institutes of Sweden, is a network of research and technology organizations, wholly or partly owned by the Swedish state. The research institutes within RISE focus on industrially applied research and innovation and is an important link between academia and industry. Besides performing bilateral, confidential contract research with industry the research institutes play an central role in setting up and coordinating larger project consortiums funded by agencies such as EU, VINNOVA, Formas, and Mistra within strategic research areas. RISE consists of four corporate groups, SP Technical Research Institute of Sweden, Swerea, Innventia and Swedish ICT Research and their subsidiaries.

The Swedish research institutes have a range of broad activities in the formulation area, where SP and its subsidiaries SIK, SP Process Development and Glafo are highly involved in formulation-related research for a large range of different industries. Swerea and Innventia also have substantial activities within the formulation area. A number of focus areas for the formulation related activities at the Swedish research institutes have been identified and is briefly summarized below.

Particle design: This research area comprises the development and characterization of functional particles (inorganic or organic) for various applications, including foods, pharmaceuticals, paints, composites, paper, printing, and ceramic processing. Particle sizes varies from the nanometer to the micrometer size range and include magnetic nanoparticles, MOFs, mesoporous silica particles, nanocellulose, hydrogel and latex particles as well as lipid- and surfactant self assembly systems.

Powder Technology: The area of powder technology involves various drying methodologies including freeze-drying, spray-drying and spray-freeze drying as well as technologies for characterization of powders. One aspect is reformulation of liquids to dry powders to increase stability. Strategies to control the particle morphology and dissolution of powders are of specific importance to pharmaceutical and food industries. In close association to the area of powder technology is the area of microencapsulation as well as coating technologies for particles and powders.

Dispersions: Dispersed systems including emulsions, foams and pastes is an important research area for a broad range of industries. This research area comprises understanding of the interfacial behaviour in these types of systems and utilization of this knowledge for development of functional products. Specific focus is on stability of dispersions as well as production technologies for the systems. In addition, development of methods for characterization of dispersed systems and interaction with other components is prioritized.

Peptide and protein formulation: Formulation of proteins and peptides is an increasing area within specifically pharmaceutical, biotech, medtech and food industry. This area includes the formulation of these structures in liquid, solid or semisolid formulations in order to increase stability and performance in products. In addition, the interfacial behaviour of these molecules is an important area for research in order to understand and control interaction with other components in the formulations and interaction with surrounding surfaces.

Reformulation: Replacement of excipients, reducing the number of components and transformation to formulations based on materials from renewable resources while maintaining (or improving) the performance is an increasing requirement both from a regulatory as well as a consumer perspective. These aspects are a central part of this area, in

addition to stability improvement, solubility enhancement and formulation of poorly soluble substances.

Controlled delivery: Efficient control of delivery and release will greatly enhance the effectiveness of functional ingredients in a diverse range of products. In addition, controlled delivery can reduce unwanted side-effects. This is highly relevant for pharmaceutical applications, but also for environmental, consumer and industrial applications. Utilizing recently developed tools for various, new applications as well as developing new technologies for controlling delivery and release is central within this area. Special focus is on controlled release coatings, functional matrices and release in formulations.

Perception delivery: The area perception delivery concerns understanding the relationship between perceptual properties, focusing on tactile and oral perception, and formulation properties (composition, structure, interfacial behaviour). Within this area focus is on food, pharmaceutical formulations (oral and topical) and consumer products as well as formulations for specific patient groups (elderly, children) and formulations for surface modification to control perception.

Institute	Key activities	In more detail
SP	-Development and characterization of formulations for pharma, food, nutraceuticals, home, personal care and paint applications. -Controlled delivery of active substances -Perception delivery -Formulation of poorly soluble substances -Control of nano-and microstructure in formulations/ phase transitions in formulations/Stability -Reformulation -Nanoformulations (inorganic/organic) -Active coatings	Emulsions & foams - particle stabilized emulsions and foams Gels – Hydrogels, lipid and surfactant self assembly, liquid crystalline phases Powder technology - spray drying, freeze-drying Protein and peptide formulation – adsorption to surfaces, antifouling Porous particles (mesoporous silica, MOF) Microencapsulation Advanced techniques to study collidal dispersions and interactions with surfaces Synthesis, surface modification and dispersions of nanoparticles Surface modification Analytical chemistry applied in the evaluation of formulations, functions, stability and other parameters.
SP Process Development	-Formulation of Pharmaceuticals -Liquid formulations	Nano- and microsuspension, particle characterization, solid-state, dissolution, prediction of solubility, prediction of human exposure from formulation release, solubility enhancement, stability in formulation
SIK	-Microstructure-mass transport relationships in soft biomaterials and foods -Formulation of bio-based barriers -Structure design of hydrogels and emulsions -Phase separation and gelation in confined geometries -Microstructure-functionality/property relationships in foods and soft biomaterials -Mechanical and rheological properties of soft biomaterials	-In-line characterization using ultrasound techniques -State-of-the-art equipment to determine mechanical and rheological properties -Advanced quantitative and in situ microscopy techniques to determine material -response as a function of temperature, forces, injection of enzymes etc. -High-end microscopy techniques to characterize microstructure at several length scales from nanometers up to millimeters
Glafo	-Formulation of glass -Increase technical functionality -Substition of hazardous chemicals	Reformulation to exclude antimony and cadium from glass Improve strength, conductivity and photon conversion.

Institute	Key activities	In more detail
SWEREA IVF	-Formulations for ceramic processing -Formulations in thermoplastic materials and coating pastes. -Wet surface treatment and painting -Substitution of chemicals -Including chemical issues in LCA	Suspensions and pastes of colloidal ceramic particles - tape casting, slip casting, injection moulding, extrusion, 3D printing. Functional fillers -conductivity, anti-bacterial, stiffness/strength, flame retardancy Coating pastes for textiles-wear resistance, conductivity or optical special effects. Functional coatings -humidity protection for composites
Innventia	-Use of nanocellulose in different application -Latex in paper making and composites	
Acreo Swedish ICT	- Material characterization (magnetic materials). - Characterization of physical properties such as pH, viscosity, humidity, reologi, biofilm formation -Development of inks for printed displays.	-Very sensitive system for characterization of the magnetic properties of materials -Very good competence in the magnetic field

Appendix 5 Analysis of knowledge gaps

Key formulation areas and technology efforts

Background

Based on information collected in focus group interviews with participating industries, institutes, and regulatory agencies; research surveys for universities and institutes; and strategic discussions within the ReForm steering group, a prioritized set of formulation areas has been identified to focus on initially. The criteria used in the selection process have been potential business and environmental impact, recent scientific progress, and expected output and impact of a joint partnership such as ReForm. The prioritized areas include *concentrated dispersions*, *emulsions*, *self-assembly systems*, and *water-poor formulations*. In addition, key aspects spanning several of these formulation types, notably *cocktail effects*, *formulations at interfaces*, *tailoring interactions with biological systems*, *antimicrobials*, *responsiveness*, and *novel methodologies* for studying structure and dynamics of concentrated systems, provide a complementary dimension by which a matrix synergy can be obtained.

Prioritized formulation types

Concentrated dispersions and macromolecular solutions

Concentrated dispersions of either organic or inorganic nanoparticles play an important role in a wide range of products and industrial applications, including latex paints, paper coatings, ceramics, powder metallurgy, various foods products, wastewater treatment, and pharmaceuticals. In many ways, problems regarding concentrated dispersions are the same as for concentrated solutions of proteins, which are important for several applications such as pharmaceutics, modern detergents, food additives and as precursors in green-tech processes. From a technical/scientific perspective, critical aspects for the successful use of concentrated dispersions include control of i) particle interaction for controlled dispersion stability, ii) 3D dispersion structure, iii) dispersion rheology, interfacial spreading, and film formation, as well as iv) loading, distribution, and release of components (drugs, flavours, anti-oxidants, antimicrobials, etc) to/within/from such concentrated dispersion.

Within the context of environmentally and safety-driven reformulation, concentrated dispersions also offer opportunities to reduce the volume of solvent transported and to facilitate recycling. However, increased use of concentrated systems requires that they remain stable and allow solvent to be added prior to use, or to be removed on recycling. Such applications of concentrated dispersions therefore offer additional challenges related to triggerability, allowing solvent to be removed, added, or both. Within ReForm, these challenges will be met by incorporating current research and know-how on the design of several novel types of nanoparticles (NPs), including microgels, core-shell particles, nanocellulose, novel inorganic and hybrid NPs, dendritic NPs, porous NPs, anisotropic NPs, protein and lipid NPs. Such novel dispersion building blocks offer new opportunities to replace organic solvents by water, responsiveness to a wide range of parameters (temperature, ionic strength, pH, specific ions, reducing conditions, etc), as well as an increased control of incorporated guest molecules. At the same time, their wider use in industrial formulations and formulation products require additional R&D efforts to fully master effects of particle deformation, anisotropic interactions and particle self-assembly in concentrated systems. Efforts on toxicology, life-cycle analysis, and other environmental aspects are also needed to complements physicochemical and design studies, and other functional evaluation.

Emulsions

Also for emulsions (liquid droplets dispersed in another liquid), much of current industrial interest, as well as challenges in environmentally driven re-formulation, concern concentrated and responsive systems, replacing environmentally questionable solvents (ideally with water) and, also, replacing petroleum-based formulation components (excipients) with equivalent ones based on renewable resources. As a consequence of this, novel emulsifiers and stabilizers of emulsions have attracted considerable interest in recent years.

A prominent example of the above is so-called Pickering emulsions, i.e., emulsions stabilized by nanoparticles, which provide dramatically improved stability compared to emulsions formed by surfactants, polymers, or proteins, and also allow very concentrated systems to be reached, and even solvent replacement in preformed systems. As such, Pickering emulsions offer very interesting opportunities in environmentally driven reformulation. However, while effects of some parameters in Pickering emulsion design are becoming understood (for instance, nanoparticle size and dielectric properties, interfacial tensions, and particle packing density on the liquid-liquid interface), much remains to be clarified for more complex particle stabilizers, including core-shell and other deformable particles for facilitated particle packing at the liquid-liquid interface, aniosotropic (amphiphilic or Janus) particles for particle self-assembly and responsive surface activity, and porous particles for facilitated guest molecule transport through the liquid-liquid interface.

A concerted effort on the above is expected to allow the design of novel particle-stabilized emulsions, providing opportunities to replace environmentally detrimental solvents in a wider range of emulsion products (fuels, lubricants, …) with environmentally more friendly alternatives, and to introduce possibilities to stabilize and destabilize emulsions through various triggering mechanisms. This will allow the amount of solvent to be reduced during transport or provide a tool for simple but efficient component recycling.

As for concentrated dispersions, the efforts on emulsion structure, stability, and dynamics thus go hand in hand with those on particle design, ultimately aiming at allowing a stabilizing nanoparticle system to be selected from desired emulsion specifications (droplet size, nature of disperse and continuous phase,..), which is currently possible to some extent for surfactant stabilizers through the so-called HLB scale. While long-term structural aspects are of interest, emphasis in emulsions lie primarily on dynamics, including droplet formation, droplet coalescence, and convection and diffusion for transport and release of guest molecules, ideally also in a process environment.

Water-poor formulations

Somewhat related to concentrated dispersions and emulsions, but still providing distinct challenges, are semi-dry or water-poor formulations. Such formulations are very important in a range of applications, including foods (lyophilized powders of coffee and other beverages, soups, etc.) and pharmaceuticals (tablets, injectables, etc.). In addition, they could open up new avenues to dramatically reduce solvent or water content for formulated products during transportation, or to recycle formulation components or guest compounds. For such highly concentrated systems, where the water or solvent content is only a few percent or less, both the active components (e.g., drugs) and the formulation components enter into a complex regime of quenched dynamics, arrested states, and solid phase transitions. Despite the industrial importance of such systems, the understanding of these phenomena for complex formulations is still quite poor, as is the understanding of key factors determining structure

and controlled functional performance of lyophilized formulations obtained by spray-drying, freeze-drying, supercritical precipitation, or some other method. Understanding the effects of gradual solvent addition and the solvent transport (dissolution) in such systems is also of great importance. Here, additional efforts are needed to clarify factors determining amorphousness, nucleation and phase transitions at low water activity, particularly from a kinetic perspective.

Research activities should involve both simple, idealized water-poor formulations and more complex formulations, such as dispersed systems (emulsions, dispersions), surfactant-, lipid- and polymer-based excipients, and self-assembly structures for improved formulation performance.

Self-assembly systems

Through previous concerted efforts, the understanding of self-assembly systems as formulation components is good, and Sweden holds an internationally leading position in the area, not least within the areas of surfactants and amphiphilic polymers in general, and those from renewable resources, in particular. During the last decade, there has also been considerable progress on mixed polymer-surfactant systems and mixed surfactant systems. Currently, research on self-assembly is broadening to new types of systems, and much effort from the participating universities and institutes is now devoted to understanding self-assembly of peptides, proteins and other biological macromolecules, as well as amphiphilic nanoparticles.

Since the function of biological macromolecules, and especially proteins and peptides, depends sensitively on conformational changes, aggregation, and complexation with formulation excipients, these are aspects of pivotal importance for formulations of peptide and protein drugs (e.g., therapeutic antibodies or enzymes). Protein, peptide, and other biomacromolecular drugs represent well over a hundred products on the market they constitute the majority of new drugs discovered during the last few years, and roughly half of all drug candidates in clinical trials. Knowledge on the design of formulations for such drugs is key for the further development of the entire pharmaceutical area since it is required for delivery systems other than parenteral infusion solutions or freeze-dried injectables. Potential alternative administration routes include both inhalation particles/droplets, topical creams, and injectable depots. Protein and peptide self-assembly will therefore be investigated for a wide range of systems, including surfactant-, lipid-, and polymer structures, emulsions and various nanoparticles (nanogels, core-shell, etc).

Both for formulation stability reasons and in order to achieve in situ triggerability by excess water in the human body after administration, special attention will be paid to systems with a moderate-to-low water activity (dry, semi-dry, or concentrated formulations). Hence, there will be considerable overlap and possibilities for synergy between activities on drug design and those focused on technical self-assembly formulations. To strengthen this cross-fertilization, the activities in this area will also cover technical enzyme formulations of major importance for, e.g., detergent products. The research and know-how developed in this activity will thus have good opportunities to be implemented in a wide set of formulation products and processes containing sensitive guest molecules.

In a separate effort, the self-assembly of novel nanoparticles (nanogels, core-shell NPs, nanocellulose, amphiphilic NPs, porous NPs etc.) as formulation components will be investigated, with particular focus on amphiphilic NPs. Like surfactants, such amphiphilic NPs can self-assemble into both discrete aggregates and essentially infinite structures both in

solution and at interfaces. By tailoring factors such as amphiphilicity, size, and shape, such systems furthermore offer opportunities to combine the superior stability of Pickering emulsions (see above) with sensitive triggerability by various parameters.

Technology efforts spanning different formulation types

Responsive systems

A key aspect to consider in formulation design, mentioned repeatedly above, is that of responsiveness, i.e., the possibility to trigger structural and dynamic transitions so that the formulations change their properties in a desired and predicted manner. Such transitions can be used, e.g., to induce destabilization of a formulation after usage to facilitate recycling, or to accomplish a desired structure formation in a surface coating. Analogously, they can be used to concentrate a formulation prior to transport, to reduce the amount of solvent used or, in fact, to enable a change of the solvent itself in preformed formulations. In personal care, food, and pharmaceutical products, triggerable transitions may also be desirable after intake and/or administration in order to achieve improved bioavailability, sustained exposure, or sensoric attractiveness.

A wide range of triggers are possible to use to induce transitions, the most frequent ones being temperature, ionic strength, and pH. In addition, various more specialized approaches are possible using, e.g., specific ions, specific metabolites, reducing conditions and even external fields (light, magnetic field, ultrasonics). Since the design of such transitions has elements of a generic nature, addressing them in a technology development effort spanning essentially all types of formulations is expected to be fruitful.

Cocktail effects

A second area of generic importance for much formulation development is that of “cocktail effects”, i.e., effects of mixtures of compounds. As exemplified by a typical personal care lotion, which contains numerous active components for moisturizing or wetting and for providing antimicrobial functionality, good smell, efficient debridement etc., many formulations are indeed very complex systems. This means that there are risks for unexpected antagonistic effect or function loss, but also opportunities for functional synergies. Thus, through smart combinations of known systems, both excipients and active components, formulation designs may be obtained even for very challenging system requirements.

From the perspective of environmental reformulation, cocktail effects represent a major hurdle for the replacement of both unwanted solvents with water and petroleum-based formulation excipients by renewable equivalents, since the risk of malfunction increases with the number of formulation components and actives. Embracing cocktail effects for technical formulations is therefore of central importance for ReForm, and indeed at the very heart of formulation science itself.

Formulations at interfaces

A third area of generic importance for the application of many formulation types is that of the behaviour at interfaces. In a latex paint, defect-free packing and subsequent film formation of the polymer particles is required after application. Another example is a tablet coat, used for controlling drug release rate from tablets. Surfaces may also cause unwanted formulation transitions at interfaces, e.g., inducing phase separation of formulated food products or highly

unwanted aggregation and conformational changes in protein drugs. Controlling formulation properties and behaviour in solution is therefore frequently not enough. As the investigation of concentrated formulations at interfaces is quite challenging, there is thus a need for methodological development in the area.

Fortunately, there are important generic aspects spanning several key formulation types, such as the localization and packing of particles (including droplets and aggregates) at interfaces, the effect of surface active formulation excipients (surfactants, polymers, lipids) on these processes, the spreading of concentrated dispersions/droplets at interfaces, the uptake of solvent from different bulk phases in the interfacial structures, and many others. Through focusing on such aspects, a well as on experimental methods for investigating these issues, a technology effort spanning a wide range of formulation types is expected to efficiently complement formulation-specific activities.

Tailoring interactions with biological systems

Especially in pharmaceutical applications, but also in medical technology, cosmetics and food applications, there is a need to achieve very specific interactions in a biological system. One key aspect is to target the formulations to specific organs or cells, for example cancer cells instead of healthy human tissue. Another aspect is targeting a specific part of the GI tract, for example probiotic food targeting the large intestine. Here, synergies can here be reached through platform activities, spanning different formulation types. One important aspect for tailoring interactions in biological systems can be to trigger changes of the formulation at the site of delivery. Thus, responsive systems might be of interest for targeted delivery. However, also very specific interactions, involving antibodies or other specific ligands, might be important. A better understanding of such systems in vitro is often achieved by methods used in the study of interactions of molecules with surfaces.

Antimicrobials

Antimicrobials and antiseptics represent a class of additives of particular importance for many formulation types. Considering the rapidly growing problems with resistance development in bacteria and other pathogens, combined with increasing problems relating to the release of such compounds into the environment, it is important to specifically address antimicrobials as formulation components in a dedicated effort. By controlling antimicrobial-excipient interactions, as well as its effects on microbes, the amount of antimicrobial can be reduced, and a wider range of antimicrobials can be used. Through designed triggerability, formulations can also be designed to allow more efficient removal in wastewater plants, or to degrade more efficiently if released into soil or water reserves, again reducing the contribution to resistance development from technical formulations. Apart from formulation efforts described above, this area also requires microbiological and analytical chemical studies in order to monitor antimicrobial effects for relevant pathogens, as well as mode-of-action studies addressing, e.g., synergistic effects between formulation components regarding bacterial membrane rupture, oxidative stress, and metabolic inhibition.

Novel methodologies

The current investments in the large facilities Max IV and ESS will give considerable opportunities for understanding formulations better. The seminar and hearing on this subject organized by ReForm gave several examples on how these facilities can be used, for example, to understand the structures of concentrated emulsions.

We note, however, that advanced lab-scale methods highly relevant to the field are also continuously developing, including methods for imaging, advanced light and x-ray scattering, surface studies, rheology and advanced spectroscopy which enable the study of both the structure and the dynamics of molecules and particles in formulations. Research leading to the use of novel methods in the study of formulations is of importance. This includes fast methods to study both in vivo and in vitro interactions with biological systems (for example screening for toxicological effects), possibilities to study concentrated formulations (especially dispersions), and methods to study kinetics in formulations. In the later case methods that can predict changes in formulations during prolonged storage is of high commercial interest, since normal stress methods, using, e.g., high temperature and/or humidity, are less informative for formulation systems where such external stresses induce phase changes that do not occur under normal storage conditions.

Appendix 6

ESS and MAX IV – new opportunities in formulation research

A half-day open seminar for industrial and academic researchers

January 9, 2014, 13.00 - 17.00
Medicon Village, Scheelevägen 2, Lund

Confirmed Speakers

Heloisa N. Bordallo, Niels Bohr Institute, University of Copenhagen
Marité Cárdenas, Nano science center, Dept. of Chemistry, University of Copenhagen
Andrew Jackson, ESS, Lund
Sven Lidin, Polymer and Materials Chemistry, KILU, LTH, Lund University
Christoph Quitmann, MAX IV Laboratory, Lund University
Adrian Rennie, Materials Physics, Dept. of Physics & Astronomy, Uppsala University
Peter Schurtenberger, Physical Chemistry, KILU, Lund University

Background and scope

Increasing societal demands for environmentally friendly, sustainable, innovative and increasingly complex chemical products and production processes represent great challenges to be met by future advanced formulation science. This scenario is common for a wide variety of formulated products (pharmaceuticals, foods, paints/glues, paper, detergents, personal care products...).

At the same time, advanced experimental methods are emerging that can contribute to meeting these challenges. In Sweden, the future large-scale facilities *MAXIV* and *ESS* will provide new opportunities for advanced formulation science. The purpose of this half-day seminar, featuring a series of expert lectures and a concluding discussion, is to highlight these opportunities.

The seminar is arranged by *ReForm* in collaboration with *Medicon Village* (see enclosed map and the website http://www.mediconvillage.se/en). *Reform* is a current initiative to create a national strategic programme for formulation science in Sweden, involving strategic research, higher education, training, and innovation support.

Registration deadline December 19

The seminar is free of charge, but *prior registration is required.*
Please register *no later than Thursday, December 19* by e-mail to
Helena Persson <helena.persson@fkem1.lu.se>

Practical

Coffee will be served, but no lunch. Medicon Village has a lunch restaurant *Café Inspira* open from 11.30 on week days. For transport and parking, see enclosed information.

Program committee

Lennart Piculell, Ulf Olsson, Peter Schurtenberger, Martin Malmsten

Appendix 7

Minisymposium on Formulation Science

Thursday, February 27, 13.15 - 17.00

Lecture hall K:B Kemicentrum

Background

Chemical formulation problems are ubiquitous, and often crucial, in industrial products and processes. The challenges are amplified by urgent needs for raw materials based on renewable resources, and less environmentally demanding processes and ingredients. Interestingly, similar challenges, and the same basic scientific questions, typically appear in widely different formulation contexts. To provide top-quality education and research in generic formulation science is, therefore, an important task for academic chemistry departments. Yet, paradoxically, "formulation science" as a generic discipline is not well established in Sweden. To adress the above issues, there is an ongoing national initiative, supported by a large number of academic groups, industrial companies and research institutes to create a national strategic programme to promote formulation science in Sweden. This half-day seminar of lectures is part of the latter initiative, and presents a variety of examples of problems and methods of interest in current formulation science.

Program

13.15 *Introduction & welcome*

13.30 *Bubbles, snot and slime*
Peter Griffiths, University of Greenwich, UK

14.00 *Formulating the future. The tricks of the trade of tomorrow's technology*
Stefan Ulvenlund, Colloidal Resource, Lund

14.30 *Controlling the skin barrier through topical formulations*
Emma Sparr, Physical Chemistry, Lund University

15.00 *Coffee*

15.30 *Controlled release formulations based on cellulose derivatives*
Anette Larsson, Chalmers, Gothenburg

16.00 *How to please the consumers - formulation challenges in food science*
Björn Bergenståhl, Food technology, LTH

16.30 *Magnetic resonance characterization of formulations*
Daniel Topgaard, Physical Chemistry, Lund University

17.00 *End*

Appendix 8

Realizing reformulation

- A symposium on surface and materials chemistry

22-24 October 2014 in Lund, Sweden

Formulations are advanced mixtures of chemicals, designed to achieve or improve functional performance. Formulation science is highly interdisciplinary, encompassing surface and colloid science, material science, chemical engineering, biotechnology and so on. The challenges are ubiquitous in industry, where examples include formulating a pharmaceutical drug into a pill that dissolves in the right place and at the right speed in the body, formulating pulp to make efficient use of cellulose fibres in paper, formulating a paint that also has antimicrobial functions, or formulating a freezable low-fat mayonnaise. The challenges that one faces in these and other applications are often closely related to fundamental problems in in surface- colloid- and material-chemistry. **2014 Symposium on surface and material chemistry is devoted to the broad topic Realizing Reformulation, focusing on generic aspects of formulations that are relevant to many different applications.**

INVITED SPEAKERS

Thomas Arnebrant, Malmö University, Biofilm research center, Sweden
Odille Aubrun-Sonneville, L'ORÉAL, Paris, France
Vance Bergeron, Ecole Normale Supérieure de Lyon, France
Lennart Bergström, Stockholm University, Sweden
Joke Bouwstra, Leiden university, the Netherlands
Katarina Edwards, Uppsala University, Sweden
Anette Larsson, Chalmers University of Technology, Sweden
Jayne Lawrence, King's college, London, UK
Mika Lindén, University of Ulm, Germany
Mariagrazia Marucci, AstraZeneca, Mölndal, Sweden
Lennart Piculell, Lund University, Sweden
Lovisa Ringstad, SP Technical Research Insitute of Sweden, Sweden
Mark Rutland, KTH Royal Institute of Technology, Sweden
Anna Stradner, Lund University, Sweden
Ishi Talmon, Technion-Israel Institute of Technology, Israel
Fredrik Tiberg, Camurus, Lund, Sweden
Christine Vauthier, Université Paris Sud, France
Peter Wilde, Institute of Food research, Norwich, UK

Young scientists and AkzoNobel prize winners

Romaine Bordes, Chalmers University of Technology, Sweden
Hanna Dahlenborg, SP Technical Research Insitute of Sweden, Sweden
Sara Frykstrand, Uppsala University, Sweden
Kevin Roger, Lund University, Sweden
Yolanda Hedberg, KTH & Karolinska Institutet, Sweden
Samuli Ollila, Aalto University, Finland

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