A ChemProfile

# Liquid-Liquid Extraction

ChemPro is a design-build company which provides conceptual process design, basic engineering packages, modular design and fabrication of new process units and revamping of existing facilities for its client base. We specialize in prefabricated systems and modular plants.

Chemical Separations (Recovery, Purification, and Gas/Liquid Treatment) are fundamental to most CPI process designs. We come from the original Chem-Pro Equipment Corp. and Glitsch International Inc., "the separations company." The ChemPro team is well versed in mass transfer, particularly in Distillation and Extraction and other chemical engineering unit operations. Separation equipment and systems are the heart of many of the modular systems that we have designed and/or built. A key ChemPro strength is its chemical separations expertise, and **Liquid-Liquid Extraction (LLE)** technology is a vital part of this core knowledge.

**Liquid-Liquid Extraction is often used to effect a chemical separation where distillation by itself is not feasible.**

LLE typically involves replacing a difficult or uneconomical distillation with two or more simple separations. A good example of this would be a solvent recovery operation where a high-boiling organic is present in low concentration in an aqueous stream. Due to energy considerations, it would be extremely costly to drive all of the water overhead in a distillation step. However, the high-boiling organic may be preferentially soluble in another solvent, which in turn has limited solubility in water. Separation of the high-boiling organic from this solvent would be relatively easy and similarly, removal of residual solvent from the water phase would be an easy operation. This is the perfect application for LLE.

The ChemPro team has a rich history in LLE. Typical ChemPro separation systems have multiple towers using various technologies, internals and media. In particular, systems utilizing LLE recovery, purification, or treatment systems include the extractor and its downstream stripping and recovery operations. These are typically multi-tower systems, employing multiple mass transfer technologies. Almost always, extraction is followed by downstream mass transfer operations to; 1) remove residual solvent from the raffinate and 2) separate the solvent from the extract, to be able to recycle the solvent. Sometimes, the system is more complex (usually where additional chemical components are present that act as contaminants to a single extraction step) and a multiple extraction train (two or more) is needed to first extract one component and then secondly to wash another component (or contaminant) from the extract.

**LLE can be a real competitive advantage when applied properly. ChemPro knows when, where, and how to apply LLE.**

**LLE is a powerful separation technique** which often is not fully understood or applied by most CPI engineers. Moreover, downstream mass transfer systems are critical to stable operation of the extractor. Remember this; **"The effectiveness of an extraction unit is only as good as the purity of the recycled solvent."** For the extractor to operate reliably, the purity of the recycled solvent must be tightly controlled. Therefore, designing the various circulation loops and the control schemes for all of these streams is an integral and crucial part of the total system design.

The extraction column/device chosen is equally important. Efficiency of the extraction equipment is largely dependent on two parameters; interfacial area created i.e. by agitation (since mass transfer occurs at the boundary between the two phases) and residence time (time that this phase boundary exists within the extractor).

Successful LLE system design depends on several key things;

- Choosing the best solvent to effect the desired separation - this selection process often involves consideration of:
  - solvents that may already be available at the plant site
  - solvents that have low toxicity and do not introduce additional hazards to the site/process
  - ease of downstream solvent recovery and recycle
  - effects of trace solvent present in the recovered product and what operations must be performed to remove these traces via raffinate stripping, etc.
  - a series of screening "shake-out" tests on the laboratory bench to determine the best solvent candidates for further testing
- Demonstrating the LLE separation scheme on a pilot plant scale:
  - the extraction must first be verified.
    - ♣ this is done in a pilot scale extractor, which is a scaled down version of the commercial unit and for which there exist predictable scale-up correlations
    - ♣ during this step sufficient quantities of extract and raffinate must be collected for verification of subsequent solvent recovery and raffinate cleanup steps
  - the solvent recovery operation needs to be verified, to fully understand the effect of recycle solvent quality on the primary extraction – often the extraction test is rerun using recycle solvent that has been collected
  - the raffinate cleanup may also need to be verified
  - the effects of temperature and pressure (inert gas blanket) may be investigated, based upon predictions from existing data and simulations
- Selecting/configuring the proper extractor for the application - considering;
  - scale up from pilot plant tests, diameter and number of equilibrium stages
  - mutual solubilities and interfacial tension between the immiscible liquids, droplet dispersion/droplet size, and the degree of agitation needed (all of which act to define interfacial area for the mass transfer to occur)
    - ♣ the ideal extractor should produce a uniform, predictable droplet size
    - ♣ too much shear can fracture droplets into a fine dispersion that requires longer disengagement times in the settling chambers after the agitation zone of the extractor and/or may cause undesirable entrainment issues
  - control of undesirable phenomena that degrade extraction performance
    - ♣ emulsions
    - ♣ "rag layer" formation
- Proper design of downstream stripping and recovery equipment and their controls

Our team not only understands LLE theory and knows the equipment, but also is thoroughly experienced in solvent selection and in the many details of integrating LLE into an extraction/distillation modular system.

LLE processes are all custom designed and most are perfectly suited for modularization, as complete prefabricated plants. Since ChemPro excels at both Distillation and LLE, and since we specialize in modular systems we are your ideal partner for systems utilizing LLE. The ChemPro team has knowledge to provide these things and more – the expertise to create just the right LLE system for its clients.

Throughout the CPI, there are numerous opportunities for effectively utilizing ChemPro's LLE capabilities; in solvent recovery, in metals/catalyst recovery, cleanup of organics from wastewater, removal and purification of acids (organic and inorganic), in caustic regeneration, in numerous chemical and refinery process operations, in pharmaceutical and fine chemicals purification, in food and beverage and in flavors and fragrances applications, and in environmental applications.

**Let the Pro's at ChemPro review your most difficult separations, to see if LLE may be the key to your own success story.**