Economic analysis for solvent recovery system (solvent as cleaning liquid for the processing equipment)

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Abstract. The purpose of this paper is to aggravate more reuse and recover material in chemical or in any industry that use mixing process or cleaning equipment that use solvent. This study also gave new approach on sustainable solution that assess by economic advantage. In many industry solvents is used for cleaning the processing equipment’s to avoid cross contamination from one batch to the other, due to the solvent scrap is being generated in the cleaning process. In often times, this scrap has been thrown away since it is already contaminated with the products, so it is being considered as scrap. In order to minimize the scrap, recovery of solvent is one method to recover the solvent. For the research, the distillation process was proposed, so the contaminated solvent can be purified so it can be use again for cleaning, or in some case it can be also use again as raw material for products. The solvent recovery gives also cost advantage for the industry.

Keywords: Waste solvent, waste treatment, solvent for cleaning, recovery system, distillation

1. Introduction
As moving towards sustainable trend, the demand towards recycle and recover is increasing. Solvent (Isoparaffinic) is used to clean the processing equipment in this pilot project for: tanks, mixer, hopper, and piping. This cleaning is required to avoid contamination from one batch to the other. Since in one mixing line companies use it for multiple products which also require multiple raw material, therefore cleaning the equipment become a routine process. Most of the industries incinerate the waste solvents or send it to waste management companies for destruction to avoid waste handling and cross-contamination. It is not a cost-effective method and hazardous to the environment [1]. So, for this pilot project the usage of solvent recovery for purifying the contaminated solvent. At this pilot project, distillation process is use for the solvent recovery. As distillation estimated more cost effective and less energy consumption with other method for solvent purification.

An energy saving become a concern in the usage of solvent method [1-2], in addition, a significant effect of solvents on chemical processes, make a careful solvent selection become an important part in reducing process costs. Other factors should consider were a strict safety policy, environmental, and health regulation [2].

In several previous studies, solvents are widely studied. One of them are provide by Ahmad and Barton [3] who systematically develop a synthesis tools in order to prevent pollution for the usage of
solvent. The primary concern of their research are the effective re
cvery and recycling of solvent by
considering non ideal behavior of solvents caused by multicomponent azeotropic mixture. They also
develop an algorithm for characterizing the batch distillation composition simplex for multicomponent
system. Other studies provide by Tres et al. [4], they studied a solvent recovery from soybean oil/n-
hexane mixtures using hollow fiber membrane, while Gil [5] develop a process simulation with usage
of solvents as entrained. Lately, Braden and Joel [6] apply solvent liquefaction by two treatment,
cardboard (CB), PVC, and polyethylene (PE) as feedstock materials.

The objective of this studies to conduct an economic analysis for solvent recovery systemutilizing
waste material. In the following section, materials and method research was described. In Section 3 the
result study includingthe calculating of saving and discussion part can be found. Finally, a conclusion
study and future research are summarized in the end of paper.

2. Materials and method
In this research, a pilot scale system of solvent recovery system was installed. The pilot scale system
consists of (1) solvent recovery, (2) clean solvent storage tank, (3) piping from mixing tank and
storage tank to solvent recovery system and piping from solvent recovery system to solvent storage.
The detail of the figures is shown in Figure 1.

![Flow diagram of the mixing process](image)

Figure 1. Flow diagram of the mixing process

Figure 1 is the flow diagram of a common mixing process. It may varies from one industry to
another but the main process remain the same except for the pre-mixing. Some ingredients, due their
nature, may require more than one pre-mix. For the solvent recovery case, the more process needed
means the more solvent scrap that might be generated. As mention in the introduction, due to the
economic reason and low utilization issue, in most industries one mixing system may run many with
recipes, raw materials and ingredients, therefore cleaning the entire production line system.Cleaning
the entire system is a must have procedure, to avoid any mixing of the raw material. If contamination
occur it could lead to a disaster, since left-over material can contaminate the new produced batch.
Solvent is use for all product with solvent base. More product mix variants mean more change over
occur and more scrap can be generated. In addition, to the high product mix, the more process means
more equipment to clean and again more solvent scrap.

For this paper, based on the history, the cleaning process consumes 150 liter of solvent per week or
30 liter per day. The baseline is 30 liter/hr. for the development of the solvent recovery system, since
the recovery able to be conducted in the daily basis. Therefore, the distillation tank, pump, heat
exchanger is size up to 30 liter/hr.

The cleaning process took place in every step of process, where the equipment starting from the
mixing tank, then to the piping then to the storage tank. In order fully clean a tank, a high-pressure
spraying is required for doing the cleaning. The cleaning also may require more than one-time
flushing. For this pilot trial it requires two times of flushing. The more flushing or the more equipment
need to be clean in resulting more waste to be generated.
In addition, the investment for the solvent recovery must be based on the saving of the usage of the solvent. Disposal cost is also must be considered, so those two components cost are the basic cost for the investment evaluation (Table 1 and Table 2).

### Table 1. Solvent Usage

| Scenario                      | Option weight | kg |
|-------------------------------|---------------|----|
| Solvent usage for cleaning per week | 150           |    |
| Solvent usage for cleaning per year | 7200         |    |

### Table 2. Solvent cost

| Description                  | IDR   | US$ |
|-------------------------------|-------|-----|
| Solvent cost per kg           | 22000 | 1.62|
| Solvent disposal cost per kg   | 4688  | 0.35|

As mentioned, the distillation process is used for the solvent recovery, to separate all the contaminant of the previous mixing process. With distillation, the pure form of the solvent again obtained. Distillation is the separation of the constituents of a liquid mixture by partial vaporization and subsequent condensation, taking advantage of differences in volatility. A distillation process was used to recover the valuable chemicals from semiconductor industry discharge, which otherwise would have been lost to the environment [1].

Figure 2 is the schematic to separate solvent from the solvent waste that this pilot project uses.

![Figure 2. Process schematic to separate solvent from the solvent waste](image)
Furthermore, the idea of the research was to do an economic analysis whether or not implementing the solvent recovery system is a lucrative solution or not. The investment of the solvent recovery system was not only to be the cost of building the recovering system and installation, but the cost in operating it. In this case, the electricity usage and maintenance cost of the solvent recovery system also consider. Also, the cost of the heating oil which must be change after 2,000 hrs. The figure 3 shown a process for the pilot implementation of the solvent recovery system.

![Figure 3. Research method for the heat recovery system](image)

3. **Result and discussion**

3.1 **Study result**

Based on pilot project result, it found that solvent recovery system can generate 90% solvent from the waste. Analyze result showed that it turns out that the result is satisfactory, which means the recover solvent still have the same characteristic as Isoparaffinic. Given, the deduction that the recovery system has, there are 10% allowance factor for the savings calculation for the yearly savings. Therefore, the full saving of 150 kg as the weekly usage was not suggested, however 135 kg for the salving calculations was a better option. In addition, virgin solvent must be added for the monthly usage since the recover solvent could not fulfil the weekly requirement. For detail calculation please refer to Table 3.
Table 3. Salving calculation

| Investment. Building solvent recovery system + Installation: | IDR   | US$   |
|-------------------------------------------------------------|-------|-------|
| Total Investment                                            | 333,795,000 | 24,596.20 |

| Quantity of solvent being recovered:                        |       |       |
|-------------------------------------------------------------|-------|-------|
| Yearly solvent usage                                        | 7,200.00 | kg   |
| Allowance for recovery system (12%)                          | 864   | kg   |
| Yearly solvent recover                                      | 6,336.00 | kg   |

| Savings:                                                    | IDR   | US$   |
|-------------------------------------------------------------|-------|-------|
| Yearly savings from solvent recovery system                 | 169,092,000.00 | 12,459.80 |

| Operation cost of the solvent recovery system:              | IDR   | US$   |
|-------------------------------------------------------------|-------|-------|
| Monthly operations cost (Solvent Recovery system)           | 1,000,000 | 73.69 |
| Yearly Operation cost (Solvent Recovery system)             | 12,000,000 | 884.24 |

| Payback Period                                              | 2.12  | Years |

3.2 Discussion
Usage of solvent in manufacturing industry become a popular nowadays. Solvent selection is a key factor due to their substantial effects on process performance. Some research on solvents offers the efficiency between 45-90% [1]. The efficiency influenced by many things, such as a distillation method, physical properties, solvent design, the absorption operation window, and the catalyst [1, 2, 7]. This study not only proposed reuse and recover material in chemical or in any industry, the solvent design and the use mixing process or cleaning equipment also offered. Compare to other results it reveals the 90% result in generating solvent. The exploring new alternative solvents and design of solvents is essential to achieve the economic advantage, without compromising environmental aspects.

4. Conclusion
Based on the study, a calculation the solvent recovery system is proven to be a sustainable and an economical solution for mixing process. Although the payback period is 2.12 years, the advantages are still interesting due to the aspect of using reuse material and the ability in generated the solvent. Alternatively, company should make a less investment therefore the payback period can less than 2 years. In addition, the purity of the isoparaffinic is 80% therefore it can be used for equipment cleaning. Given the recover and recycle nature of the pilot project, it can be concluded that it is worthy investment, and it also promote the reuse of solvent for other industry. The solvent design and the equipment can utilized for other solvent liquid not only isoparaffinic. Further research to prove the ability of design and equipment is recommended to do, so a better design and process can be refined.

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