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Reverse logistics in a pharmaceutical company: a case study[1]

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1 Introduction

Schering AG is a pharmaceutical company that was founded in 1871 in Berlin by the pharmacist Ernst Schering. During the past 128 years Schering has developed into an international pharmaceutical corporation with 145 world-wide subsidiaries and partnerships. In 1998 a staff of 22,043 (44% employed in Germany) contributed to revenues of DM 6.4 billion. The most important sales regions were the European Union (without Germany) with 28%, North America with 22%, Asia with 15%, Germany with 15%, and Latin America with 10% of the total sales. The largest single market is the USA.

Schering research and business activities focus on three areas that represent the Strategic Business Units. Fertility Control and Hormone Therapy (36% share of total sales in 1998) became the largest unit in 1997 due to acquisitions. The products of this area mainly serve to overcome acne, to prevent pregnancy, and to bridge the menopause. Therapeutics business unit (31% share of total sales) focuses on the treatment of leukaemia, multiple sclerosis, peripheral circulatory disorders, and thromboses. The Diagnostics business unit (23% share of total sales) produces contrast media that help to detect diseases in their early stages.

In Germany, Schering concentrates its activities in Berlin and Bergkamen. Berlin houses the headquarters and the research and development department. The production plants are located in Bergkamen.

The production of pharmaceuticals can be divided into three phases. First, so-called active ingredients are produced from raw materials at the chemical production facilities. In the following formulation stage, the active ingredients are combined with other substances in order to give them their dosage form. In the final phase, the goods are packaged and distributed to the customers. Mixing substances, packaging pharmaceuticals and distributing them is quite straightforward and can be done in a short time interval. The production of active ingredients, however, is very complex and time consuming. In this chapter, we discuss this production phase and especially two types of reverse logistics processes that are associated with it.

The first type of reverse logistics at Schering is the recycling of by-products that are obtained in many stages of the production process. The by-products often contain valuable materials. As a consequence, reusing them is economically attractive. Unfortunately, reusing does make production

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planning a lot more complicated. In this chapter, we will discuss these complications and the way that Schering deals with them.

The second type of reverse logistics is the reuse and recycling of impure solvents. Solvents are needed in many stages of the production process. After use, impure solvents are cleaned in a distillation facility and then reused, if this reuse option is economically attractive. If cleaning is too expensive, due to a high degree of pollution, then the impure solvents are thermally recycled (if possible). The remainder is disposed of.

There are other less important types of reverse logistics at Schering. Drums that are used for transporting and storing solvents, for instance, are reused several times. In this chapter, however, we restrict our attention to recycling of by-products and solvents. Both these types of product recovery belong to the field of rework. Interested readers are referred to Flapper et al. (2000).

2 Reuse and recycling of by-products

In many stages of the production process, by-products are generated. Many of those by-products are recovered, reducing the need for virgin materials. To give an impression of the importance of by-product recovery for Schering's chemical production, we present some global data from 1997/98. About 80 active ingredients are produced from approximately 10 raw materials. There are approximately 900 intermediate products of which 112 are by-products. About 630 tons of active ingredients are produced in total, resulting in about 14 tons of by-products. More than 90 % of these by-products are recycled.

2.1 Business drivers

The main motive for recycling by-products is economical. Most by-products contain enough valuable materials to make recycling profitable.

Another motive (for recovery activities in general) is the combination of care for the environment and of attaining an environmental friendly image. Since 1996 Schering participates in German Chemical Industry Federation's initiative "Responsible Care". The goals of that federation are to minimize the burdens for the environment caused by chemical industries. See Cefic (1997-2001). Schering tries to minimize, among other things,

- energy use,
- effluents, i.e. water for processing and cooling purposes,
- emissions,
- impure solvents, and
- waste consisting of used intermediate packages.

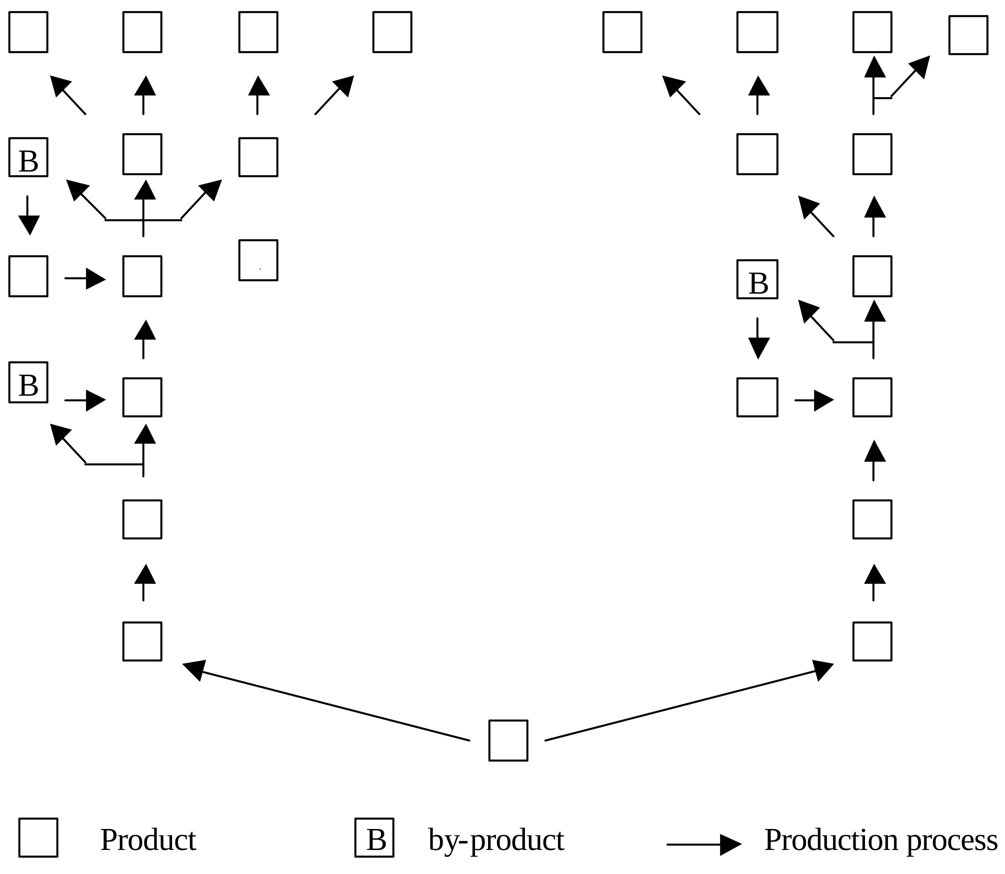
A Materials Flow Management project group is responsible for an effective execution of the different waste management tasks. Product recovery is a major issue in Schering's waste management activities.

A third motive (also for recovery activities in general) is provided by the legislators. Chemical industries in Germany face several binding legislation acts. The German Recycling and Waste Control Act forces industries to reduce their waste stream.

2.2 Description of the process of producing active ingredients

Figure 1 illustrates the typical production structure for active ingredients: long, diverging, and with cycles. It is long, because the production of active ingredients requires a large number of consecutive time-consuming production stages where chemical processes take place. It is diverging, since many (about 80) active ingredients are produced from a small number (about 10) of raw materials. Recycling the by-products leads to cycles. In Section 2.2, we describe how these cycles complicate production planning.

Figure 1: Typical production structure for active ingredient.



Many of the production facilities use multi-purpose machines. These machines are used for producing several (intermediate) active ingredients. When such a machine changes from one ingredient to another, it has to be cleaned in order to avoid cross-contamination. Cleaning machines is very expensive and can last an entire week. Hence, sequences of batches of some type of ingredient are formed. These sequences are called campaigns. Unfortunately, this causes large lead times. The accumulated lead time for the whole production chain from raw materials to active ingredients ranges from 3 to 15 months depending on the product route.

2.3 Planning and control

As was explained before, the recycling of by-products causes cycles in the production structure. Those cycles complicate production planning considerably. Standard planning methods like materials requirements planning (MRP) do not allow cyclic structures. The logistics department of Schering has therefore developed a Mixed Integer Programming (MIP) formulation of their production planning problem.

The MIP model uses a planning horizon of 3 years. Such a long planning horizon is needed, since lead times can be large, as discussed before. The horizon is decomposed into planning periods of one week for the first 18 months and periods of one month for the remainder. The MIP model finds the production schedule that minimizes the total set-up and holding cost during the entire planning horizon, under the restriction that expected demand is satisfied, and that machine and personnel capacities are not exceeded. The model is rerun every 3 months, in a rolling horizon mode. After running it, the production plants are informed about the optimal weekly production schedule for the first 3 months. The daily production planning is left to the production plants. We refer interested readers to Teunter et al. (2001) for a complete description of the mathematical model.

2.4 Information aspects

Most production planners at Schering are used to working in an MRP environment. Hence, the MIP formulation has been embedded in such an environment. The planners have to provide the technical bill of materials (BOM) with the correct routings for all the products and processes, and with the corresponding parameters. The decision support system (DSS) translates this BOM into an MIP formulation, and solves it. Hence, production planners need no knowledge of MIP, and can do all the planning in their familiar MRP environment.

3 Reuse and recycling of solvents

In this section we discuss the reuse and recycling of solvents in Bergkamen. Most active ingredients that Schering produces there require the use of solvents in one or more stages of the production process.

3.1 Business drivers

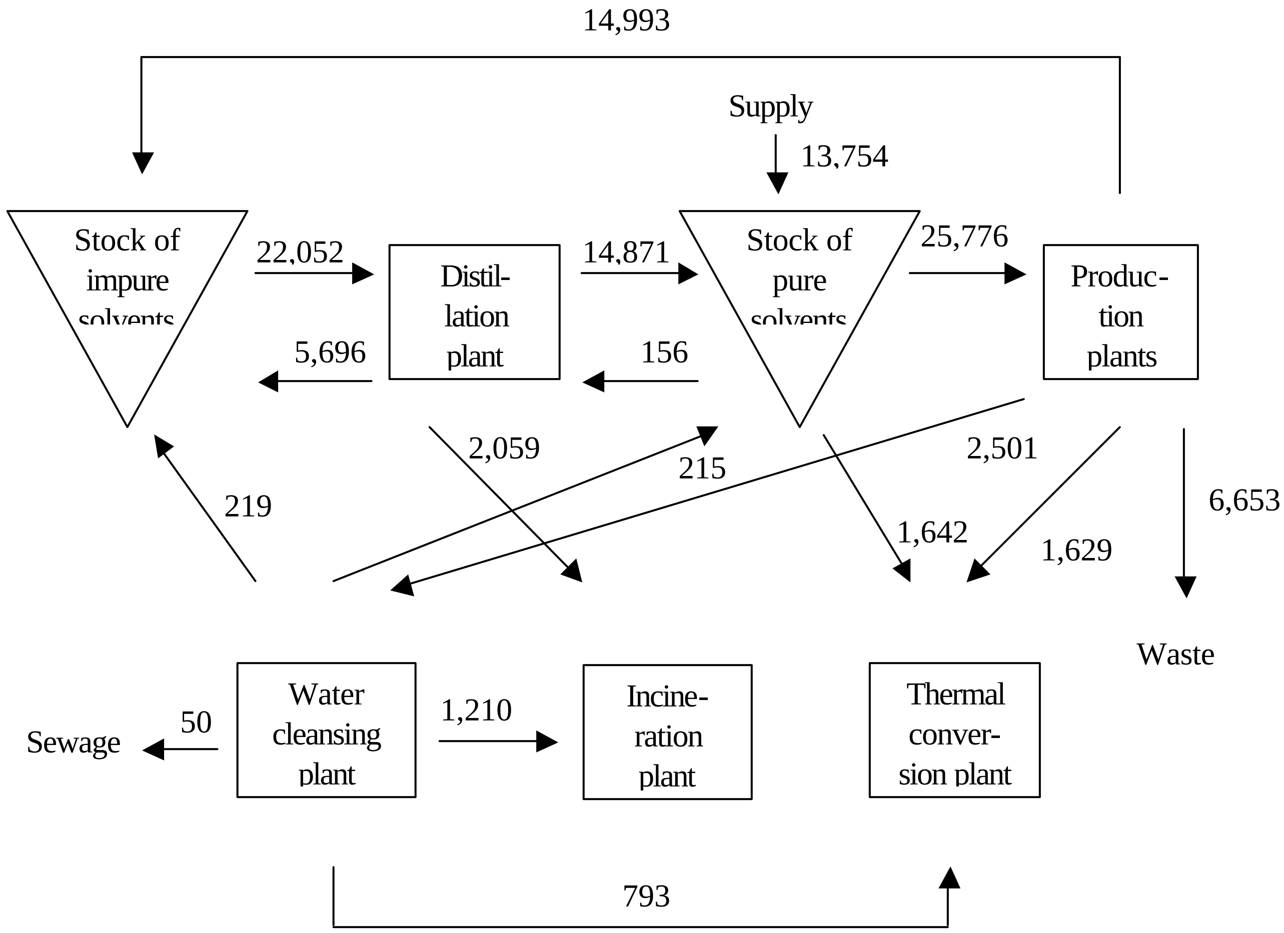
As for the recycling of by-products, the main motivation for recovering solvents is economical. But other motives like taking care of the environment also play a role (see Section 2.1).

3.2 Technical aspects

A graphical representation of the plants/sites in Bergkamen is given in Figure 2. That figure also gives the approximate number of tons of organic solvent that flowed between the different plants/sites in 1997 (all connected via pipelines above the ground). We remark that these are approximate flows, which explains the small flow inbalances. The smaller flows of non-organic solvents are omitted, since these solvents cannot be reused or recycled. Before discussing the plants/sites and flows in Figure 2 in detail, we shortly overview the whole system.

If a production plant needs more solvent, the necessary solvent is pumped out of the associated barrel from the stock of pure solvents. After being used for production, many solvents flow to the stock of impure solvents, where they stay until they can enter the distillation plant. The majority of solvents that leave the distillation plant, flow back to the stock of pure solvents and are reused. Some impure solvents flow to the thermal conversion plant, where they are used as fuel (this means that energy is recycled from the solvents). Other solvents, which cannot be used as fuel, flow to the incineration plant. In the water cleansing plant, solvents are filtered from the production/distillation process water.

Figure 2: The plants in Bergkamen and the approximate flows of solvents between them (in tons) for the year 1997.



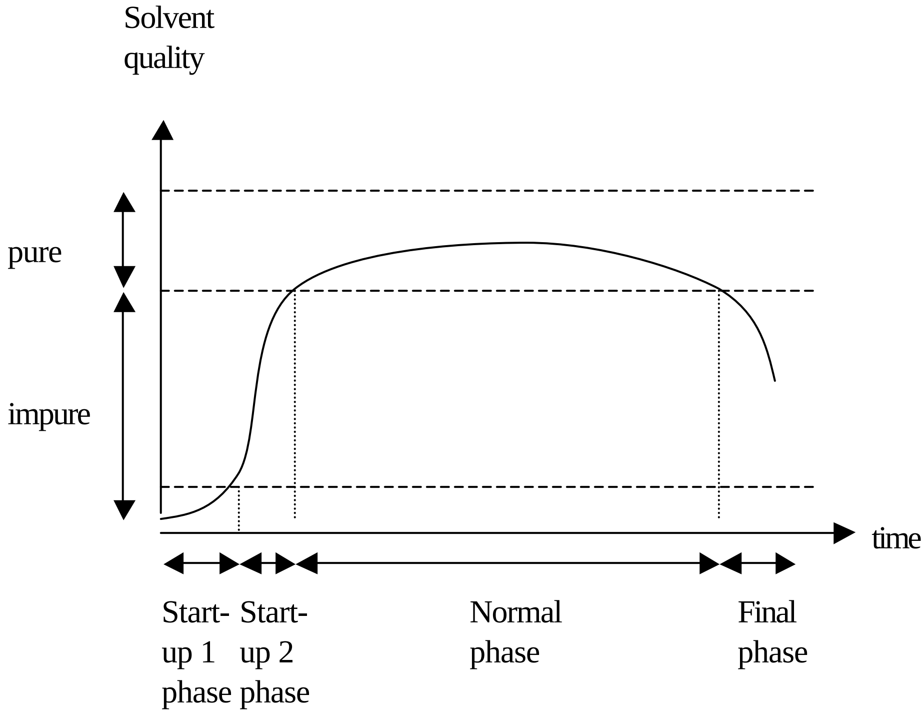
The production plants

At the production plants, active ingredients are produced. For the production of most of these active ingredients, pure solvents are needed. Hence, pure solvents (25,776 tons) flow from the stock of pure solvents to the production plants. After production, the solvents are no longer pure. Those impure solvents that will be reused (14,993 tons) flow to the stock of impure solvents. Those that will be thermally recycled (1,629 tons) flow to the thermal conversion plant. Production also leads to so-called process water containing some solvents. Hence, there is also a small (2,501 tons) flow of impure solvents to the process water cleansing plant. What remains is a waste stream of 6.653 tons of impure solvents that cannot be recovered in any way.

The distillation plant

In the distillation plant, impure solvents are transformed into pure solvents. The incoming flows at the distillation plant are the impure solvents (22,052 tons) that will be recovered, but also a small amount of pure solvents (156 tons) that are needed for the distillation process. In order to understand the outgoing flows, we need to describe the distillation process. When a certain amount of some impure solvent is distilled, the quality of the resulting solvent varies over time. This is illustrated in Figure 3.

Figure 3: The distillation process.



Just after starting the process, the quality is very poor. So poor indeed, that the solvent (2,059 tons) flows to the thermal conversion plant, where it will be used as fuel. The time period for which this holds is called 'Start-up 1 phase'. After some time, the quality improves to a level that makes the solvent too valuable to be used as fuel, but the solvent is still not pure. In this 'Start-up 2 phase' the solvent (5,696 tons) flows back to the barrels with impure solvents, and will be distilled again later. This phase ends when the quality reaches a purity threshold. Then the 'Normal phase' begins, during which the solvent (14,871 tons) flows to (one of) the barrel(s) for stocking pure solvent. Eventually, the quality will drop below the required level again. In the 'Final 'phase that then starts, the solvent (included in the 5,696 tons for Start-up 2) flows back to the barrels with impure solvents. Obviously, it is desirable to have a long Normal phase. Therefore, in the recent past, Schering has switched from batch distillation to continuous distillation for a number of solvents. With batch distillation, one can only distillate the amount of solvent that fits into a distillation tank. With continuous distillation, one can empty an (often much larger) barrel containing the impure solvent by continuously adding some of the impure solvent. Since switching from batch to continuous production has no considerable influence on the lengths of the Start-up phases and the Final phase, continuous production lengthens the Normal phase.

The process water cleansing plant

During the production of many active ingredients, water gets in contact with solvents. This leads to so-called process water that contains a small fraction of solvents. All process water has to be cleansed before it can be drained off. Hence, solvents that are contained in process water (2,501 tons) flow to the process water cleansing plant. During the cleansing process, the solvents are filtered out of the process water. Some of these are pure, but others are not. Hence there is a (229 tons) flow of pure solvents to the stock of pure solvents, and a (219 tons) flow of impure solvents to the stock of impure solvents. Most solvents obtained after cleansing, however, have a very poor quality. These solvents flow either to the thermal conversion plant (793 tons) or to the incineration plant (1,210 tons).

Thermal conversion plant

It is not always economical to clean and reuse a low-priced impure solvent. But it might still be attractive to recycle the energy that is contained in such a solvent. Hence, some impure solvents (1,629 tons) flow from the production plants to the thermal conversion plant. Also, some solvents that are filtered out of the process water (793 tons) flow to the thermal conversion plant. There, these solvents are used as fuel for generating steam that is needed for the production of several active ingredients. As fuel, solvents are about half as good as oil. That is, 1kg of oil and 2kg of solvent approximately lead to the same amount of energy. Sometimes, low-priced clean solvents also (1,642 tons) flow to the thermal conversion plant.

Incineration plant

Both during the distillation process and during the water cleansing process, some very impure solvents are obtained. These are considered as waste, since they cannot even be used as fuel in the thermal conversion plant. They lead to flows of respectively 2,059 tons and 1,250 tons of solvent to the incineration plant.

Stock of pure solvents

Pure solvents are kept in small drums and large barrels. Solvents that are only needed in very small amounts are kept in small drums. The same holds for perishable solvents. Other solvents are kept in one or more large barrels. Most barrels always contain the same type of solvent, but there are also some so-called multi-barrels. The size of most barrels is between 5 and 100 m^3. In 1997, the average stock was approximately 2 thousand tons with a value of DM 11 million (€ 5.5 million).

The reverse flow of cleaned solvents from the distillation plant (14,871 tons) covers 51% of the demand for pure solvents. An additional 1% (215 tons) is filtered from process water in the water cleansing plant. The remaining 48% (13,754 tons) of total demand is purchased from outside suppliers

The majority of pure solvents (25,776 tons) flow to the production plants. Small amounts of pure solvents are needed in the distillation plant (156 tons). Finally, some low priced pure solvents (1,642 tons) flow to the thermal conversion plant, where they are used as fuel.

Stock of impure solvents

As for pure solvents, a few impure solvents are stocked in small drums and most impure solvents are stocked in large barrels. Whether a solvent is kept in a small drum or a large barrel depends, again, on its demand rate and on its liability to perish. The largest part of the incoming (14,993 tons) flows originates at the production plants. Another large (5,696 tons) flow is that of distilled solvents that flow back from the distillation plant to the stock of impure solvents. Finally, there is a small (219 tons) flow of impure solvents that have been filtered out of the process water at the process water cleansing plant. These impure solvents all flow to the distillation plant.

3.3 Planning and control

In this section, we describe the type of policy that is used for planning the distillation of impure solvents, and for controlling the stock of both impure and pure solvents. We do not have sufficient information to discuss the planning and control of the water cleansing, thermal conversion, and incineration plants.

The supply of impure solvent and the demand for pure solvent from the production plants obviously depend on the production plans of those plants. Recall from Section 2.3 that the weekly production plans are fixed by the logistics department. Since the distillation facility is also informed about these plans, it roughly knows when impure solvents are supplied and pure solvents are demanded. The daily production planning, however, is done by the production plants themselves. The distillation facility is not informed about these plans, and hence they face unknown daily demands for pure solvents and supplies of impure solvents. They use the following policy for controlling the stock of both impure and pure solvents.

If the stock of some impure solvent reaches its critical level, then distillation is started as soon as a distillation tank is available. The critical level is approximately 80 percent of the size of the barrel containing the impure solvent. Since both the set-up cost and the set-up time associated with distilling solvents are very large, as much impure solvent as possible is distilled at once. Hence, either the amount that fits into the distillation tank (batch distillation) is distilled or the entire impure solvent barrel is emptied (continuous distillation).
In busy periods, it might take long before a distillation tank becomes available. If, as a result, an overflow becomes likely, then the inventory controllers try to prevent this by asking production plants to postpone the pumping of impure solvent to the almost full barrel.

If the stock of some pure solvent drops below its safety stock level, new solvent is ordered from an outside supplier. We do not have detailed information on how the safety stock level is calculated, but it depends on the demand rate and on the lead time of a solvent. The lead time varies from one day to several weeks, depending on the type of solvent.
In general, a full truckload of new solvent is ordered, since transportation costs are very large. For perishable solvents, however, smaller ordering sizes are used.

4. Concluding remarks

Schering spends considerable effort to undertake product recovery activities in pharmaceutical production. The two main recovery activities are by-product recycling and solvent reuse. The main driver for engaging in these activities is economical. Recovery leads to annual savings of approximately DM 25 million, which is about 8.5 % of the total production cost. This figure does not include additional savings due to reduced disposal quantities and additional costs due to investments in recovery equipment, of which we do not have reliable estimates. Furthermore, being engaged in recovery activities has additional benefits for Schering that are related to the reduced waste stream: production is in accordance with environmental legislation, the company builds an environmentally friendly image, and there is less strain on the environment.

The downside of the recovery activities is that they complicate production and inventory planning. Especially the added complexity of production planning, resulting from cycles in the production structure, is a disadvantage. A simple MRP approach, as commonly used in practice, is no longer applicable but has to be replaced by a more sophisticated planning procedure. Schering has developed an advanced decision support system which integrates a MIP procedure. Thus it turns out that reverse logistics also is a field which creates challenges for developing advanced planning systems in order to support practical decision making.

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