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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Corn Syrup and Corn Starch

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Abstract

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992). The WMAC team at Colorado State University performed an assessment at a plant that produces corn syrup and dry corn starch. Corn is processed by wet milling and refining into the desired products. The team's report, detailing findings and recommendations, indicated that the largest quantities of waste are generated by the regeneration of the ion-exchange columns used in the production processes and that significant savings could result from extending the life of the fractionator resin.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

Introduction

The amount of waste generated by industrial plants has become an increasingly costly problem for manufacturers and an additional stress on the environment. One solution to the problem of waste generation is to reduce or eliminate the waste at its source.

University City Science Center (Philadelphia, PA) has begun a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the in-house expertise to do so. Under agreement with EPA's Risk Reduction Engineering Laboratory, the Science Center has established three WMACs. This assessment was done by engineering faculty and students at Colorado State University's (Fort Collins) WMAC. The assessment teams have considerable direct experience with process operations in manufacturing plants and also have the knowledge and skills needed to minimize waste generation.

The waste minimization assessments are done for small and medium-size manufacturers at no out-of-pocket cost to the client. To qualify for the assessment, each client must fall within Standard Industrial Classification Code 20-39, have gross annual sales not exceeding $75 million, employ no more than 500 persons, and lack in-house expertise in waste minimization.

The potential benefits of the pilot project include minimization of the amount of waste generated by manufacturers, and reduced waste treatment and disposal costs for participating plants. In addition, the project provides valuable experience for graduate and undergraduate students who participate in the program, and a cleaner environment without more regulations and higher costs for manufacturers.

Methodology of Assessments

The waste minimization assessments require several site visits to each client served. In general, the WMACs follow the procedures outlined in the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC staff locate the sources of waste in the plant and identify the current disposal or treatment methods and their

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associated costs. They then identify and analyze a variety of ways to reduce or eliminate the waste. Specific measures to achieve that goal are recommended and the essential supporting technological and economic information is developed. Finally, a confidential report that details the WMAC's findings and recommendations (including cost savings, implementation costs, and payback times) is prepared for each client.

Plant Background

This plant produces high fructose corn syrup and dry corn starch. It operates 24 hr/day, 365 days/yr to process over 8 million bushels of corn. Approximately 265 million lb/yr of corn syrup and 100 million lb/yr of corn starch are produced.

Manufacturing Process

The two major processes in this plant are wet milling and refining. Those processes are described in the following sections.

Wet Milling

Corn kernels are first softened by steeping in warm water. The steep water dissolves salts, soluble carbohydrates, and protein in the corn. The softened kernels are degerminated in a milling process that tears the kernels apart and extricates whole corn germs. This process yields a pulpy material that contains germ, starch, gluten, and fiber. The germ is recovered using hydroclones, dried, and sold for processing into corn oil.

The remaining slurry containing starch, gluten, and fiber undergoes additional milling to release the rest of the starch from the fiber and then to separate the fiber from the gluten and starch. After washing to remove additional starch, excess water is removed from the fiber by pressing and drying. Steep water and broken corn are added to the dried fiber and the resulting mixture is sold for use as cattle and dairy feed.

Centrifuges are used to separate the gluten from the starch slurry. The gluten is thickened by removing excess water and then dried in rotary vacuum filters to a cake-like consistency. The gluten is further dried to a granular form for sale as a pet food additive.

Refining

The remaining starch slurry from the wet milling process serves as the starting material for this company's two major products—dry corn starch and high fructose corn syrup. The slurry is washed with fresh water in a counterflow system and fed to a holding tank. Some of the slurry is drawn from the tank into the refinery for processing into corn syrup. The balance is processed into dry corn starch by a sequence of centrifuge drying, mixing, heated air drying, and cyclone air separation. The resulting corn starch is sold to a local brewery.

In the refining process, three enzymes are used in a series of operations to convert the starch slurry into fructose. Starch granules are broken down into chains of dextrose molecules by the first enzyme. The second enzyme breaks down the dextrose chains into individual dextrose molecules. Insoluble materials and unconverted starch are filtered from the dextrose solution in rotary drum vacuum filters. After filtering, colored particulate matter is removed in a carbon column.

The dextrose solution is then sent through a set of ion exchange columns that remove metal salt impurities from the solution. Water is removed from the solution in an evaporator before the third enzyme is added. That third enzyme converts the dextrose into fructose. The resulting fructose follows a process similar to the one for the dextrose solution—decolorizing, ion exchange, and evaporation.

Some of the fructose goes to a finishing evaporator yielding 55% high fructose corn syrup. That grade of corn syrup is sold or reserved for blending. The rest of the corn syrup is further enriched in a fractionator that uses calcium resins to remove remaining dextrose and impurities from the corn syrup. Deionized water is then used to dilute the syrup to the highest grade produced (90%). The 90% high fructose corn syrup is sold or blended with the 55% high fructose corn syrup to yield 75% high fructose corn syrup, the other grade produced by this plant. The corn syrup is sold to various clients in the soft drink industry.

The largest volume waste streams do not result from the production process itself, but from regeneration of the ion exchange columns used in the production process and from the treatment of city water for use in the production process. Hazardous lab wastes are generated in the test lab, but these wastes are minor in volume.

A simplified process flow diagram is given below.

Existing Waste Management Practices

This plant already has implemented the following techniques to manage and minimize its wastes.

- Cation exchange resins that are used in dextrose processing are treated with a brine solution that keeps the products of the resin regeneration solution. Without that treatment, an undesired byproduct precipitate (gypsum) would form.
- Sulfuric acid solution that is used to regenerate cation exchange resins is a mixture of fresh acid and reclaim acid.
- The water that is used to rinse the ion exchange resins prior to regeneration ("sweet water"), which contains residual carbohydrates, is given to local pig farmers instead of being processed through the wastewater plant.
- Spent diatomaceous earth from the rotary drum vacuum filters used to remove insoluble materials and unconverted starch from the dextrose solution is added to animal feed instead of being landfilled.

Waste Minimization Opportunities

The type of waste currently generated by the plant, the source of the waste, the quantity of the waste, the waste management method, and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunity for waste minimization that the WMAC team recommended for the plant. The minimization opportunity, the type of waste, the possible waste reduction and associated savings, and the implementation cost along with the payback time are given in the table. The quantities of waste currently generated by the plant and possible waste reduction depend on the production level of the plant. All values should be considered in that context.

It should be noted that the economic savings of the minimization opportunity results from the need for less raw material and from reduced present and future costs associated with waste treatment and disposal. Other savings not quantifiable by this study include a wide variety of possible future costs related to changing emissions standards, liability, and employee health.

Additional Recommendations

In addition to the opportunity recommended and analyzed by the WMAC team, additional measures were considered. These measures were not completely analyzed because of insufficient data, minimal savings, implementation difficulty, or a projected lengthy payback. Since one or more of these approaches to waste reduction may, however, increase in attractiveness with changing conditions in the plant, they were brought to the plant's attention for future consideration.

- Reduce the quantity of chemicals used during regeneration of the cation and anion exchange columns in the fructose and dextrose lines. Initially it was thought that excessive amounts of chemicals were used during the regeneration process. Further investigation determined that the quantities of chemicals used were well within industry standards.
- Investigate the cause of the resin breakdown in one of the fructose ion exchange columns.
- Install a reverse osmosis unit to treat the wastewater from the flushing of the ion exchange resins used to treat incoming city water; recycle the treated water.

This research brief summarizes a part of the work done under Cooperative Agreement No. CR-814903 by the University City Science Center under the sponsorship of the U.S. Environmental Protection Agency. The EPA Project Officer was **Emma Lou George**.

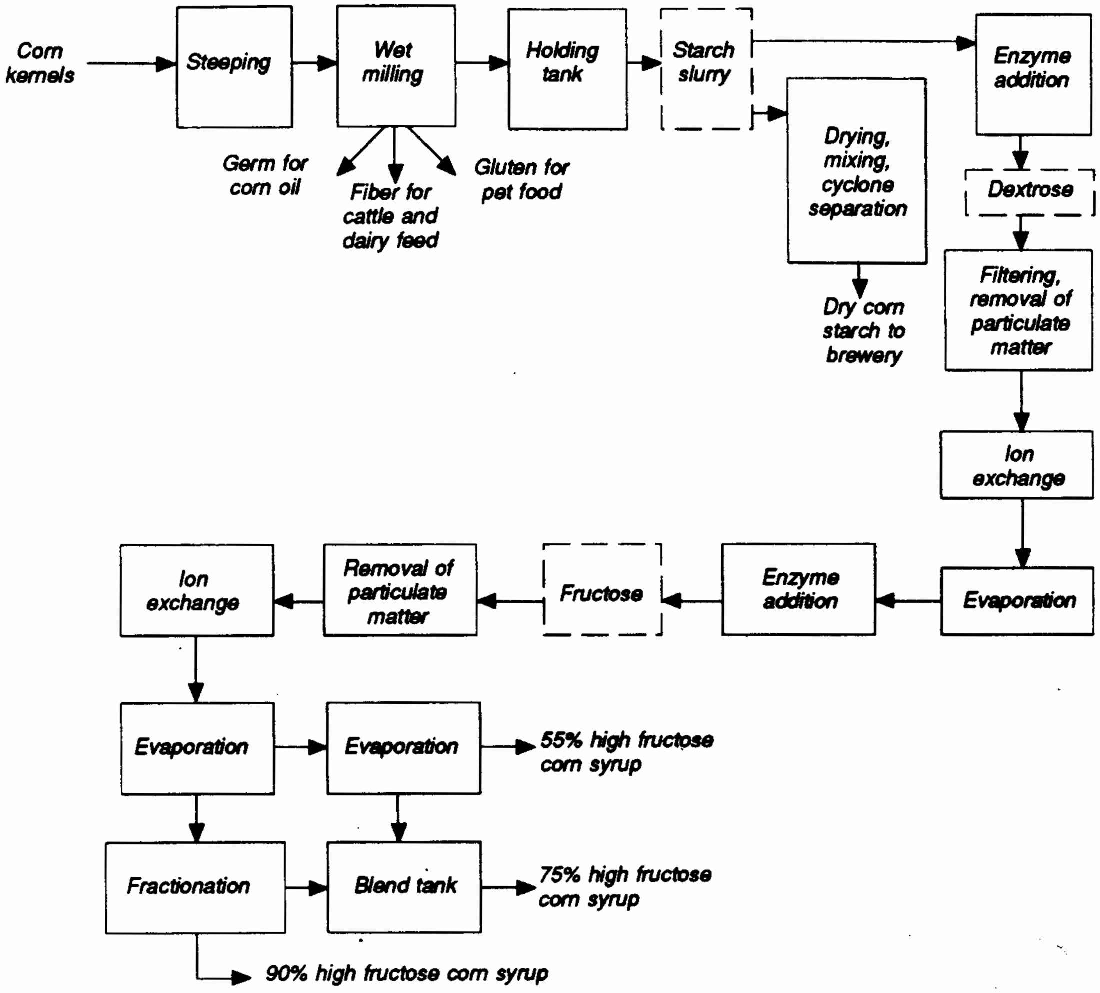

Figure 1. Abbreviated process flow diagram.

Table 1. *Summary of Current Waste Generation*

Waste Generated	Source of Waste	Annual Quantity Generated (lb)	Waste Management Method	Annual Waste Management Cost*
Spent cation resin	Dextrose ion exchange	8,750	Shipped to landfill	$15,630
Cation regeneration liquid	Dextrose ion exchange	257,000,000	Balanced; discharged to onsite ponds	346,000
Sweeten-off rinse water	Dextrose and fructose ion exchange	36,900,000	Balanced; discharged to river	3,320
Spent anion resin	Dextrose ion exchange	25,700	Shipped to landfill	109,090
Anion regeneration liquid	Dextrose ion exchange	229,000,000	Balanced; discharged to onsite ponds	79,700
Anion caustic cleaning liquid	Dextrose ion exchange	3,320,000	Balanced; discharged to onsite ponds	12,100
Spent water softener resin	Water softening	1,590	Shipped to landfill	2,290
Water softener regeneration liquid	Water softening	25,740,000	Balanced; discharged to onsite ponds	2,050
Spent mixed-bed cation resin	Fructose ion exchange	9,180	Shipped to landfill	18,430
Cation regeneration liquid	Fructose ion exchange	100,000	Balanced; discharged to onsite ponds	3,480
Spent mixed-bed anion resin	Fructose ion exchange	16,300	Shipped to landfill	74,760
Anion regeneration liquid	Fructose ion exchange	392,000	Balanced; discharged to onsite ponds	32,900
Regeneration rinse water	Regeneration of ion exchange resins	66,900,000	Balanced; discharged to onsite ponds	9,720
Spent fractionator resin	Fractionation	98,200	Shipped to landfill	286,330
Fractionator regeneration liquid	Fractionation	2,400	Balanced; discharged to onsite ponds	0
pH adjustment reagents	Wastewater treatment	4,400,000	Balanced; discharged to onsite ponds	9,680
Waste laboratory chemicals	Test laboratory	290	Shipped offsite for incineration	4,140

* Includes waste treatment, disposal, and handling costs and applicable raw material costs.

Table 2. Summary of Recommended Waste Minimization Opportunity

Minimization Opportunity	*Waste Stream Reduced*	*Annual Waste Reduction*		*Net Annual Savings*	*Implementation Cost*	*Simple Payback (yr)*
		Quantity (lb)	*Per Cent*			
Extend the life of the fractionator resin by reducing the O_2 content of the incoming deionized water by installing a degasifier. Oxygen degrades the resin in the fractionator.	*Fractionator resin*	*49,100*	*50*	*$139,280*	*$306,250*	*2.2*