ELSEVIER

Journal of Hazardous Materials 38 (1994) 207–216

JOURNAL OF HAZARDOUS MATERIALS

Testing of a waste generation prediction model in the paint and lacquer industry

R. Olbina[a,*], M. Hafner[b]

[a] *Risk Reduction Engineering Laboratory, US Environmental Protection Agency, 26 W. Martin Luther King Drive, Cincinnati, OH 45268, USA*

[b] *COLOR – Paint, Lacquer and Resin Industry, C. kom. Staneta 4, 61215 Medvode, Slovenia*

Received 10 October 1993; accepted in revised form 20 February 1994

Abstract

A framework of a coating production and waste generation in COLOR – Paint, Lacquer and Resin Industry is outlined. A mathematical model of industrial production and waste generation system is presented. Parameters of the system are precisely defined. Data collection, organization and evaluation of the model testing are shown. A waste generation prediction model is applied in COLOR, and cost analysis of coating production generating waste is determined.

1. Introduction

Paint and lacquer production processes have been identified worldwide to cause impacts on the environment [1]. Groundwater contamination caused by COLOR – Paint, Lacquer and Resin Industry, Medvode, Slovenia, and daily problems influenced by a lack of locations for temporary waste storage and its final disposal [2] (Slovenia has not yet got hazardous waste processing facilities nor special/secure landfills for hazardous waste disposal) have forced COLOR management to pay attention to more efficient waste management. The decision was made to reduce hazardous waste generation by applying waste recycling through the introduction of the thin-layer evaporation technology. This process enabled then to use recovered solvents as well as the remaining sludge as secondary raw materials, and save considerably [2]. However, the costs of waste quantity generated and managed as well as materials loss through release have still remained unidentified. Therefore, a framework for data collection in coatings production and its waste generation has been set up with the cooperation of COLOR management. These data have been used to identify

* Corresponding author. Fax: (+1-513) 569-7111.

SSDI 0304-3894(94)00030-K

production and waste generation parameters and to estimate primarily costs of waste generation, management, release and final disposal.

2. COLOR coating production and waste generation

Coatings are a complex mixture of polymer binders, pigments, fillers and many different additives with organic solvents or water for application in many different and/or specific purposes. The main coating components and additives are selected in a way to ensure a stable dispersion of required characteristics during production, storage and application processes. Coating production is a batch process. Pigments and fillers are dispersed first inside binders and solvents during the process of dissolving in dissolvers, and then by grinding in sand mills. Final mass homogenization and color shading is done in mixing vessels. After quality control, produced coatings are packed and stored [3].

According to Rooney [4], points of waste generation and/or physical material losses in paint and lacquer industry recognized from the total quality management point of view, are presented in Fig. 1. Most of the dissolvers and mixers in coating production are kept open during production, and evaporation of organic solvents is strong and easily detectable. Pigment powder, emitted during the charging process is trapped in cyclones and sent back to production lines. Waste paper bags

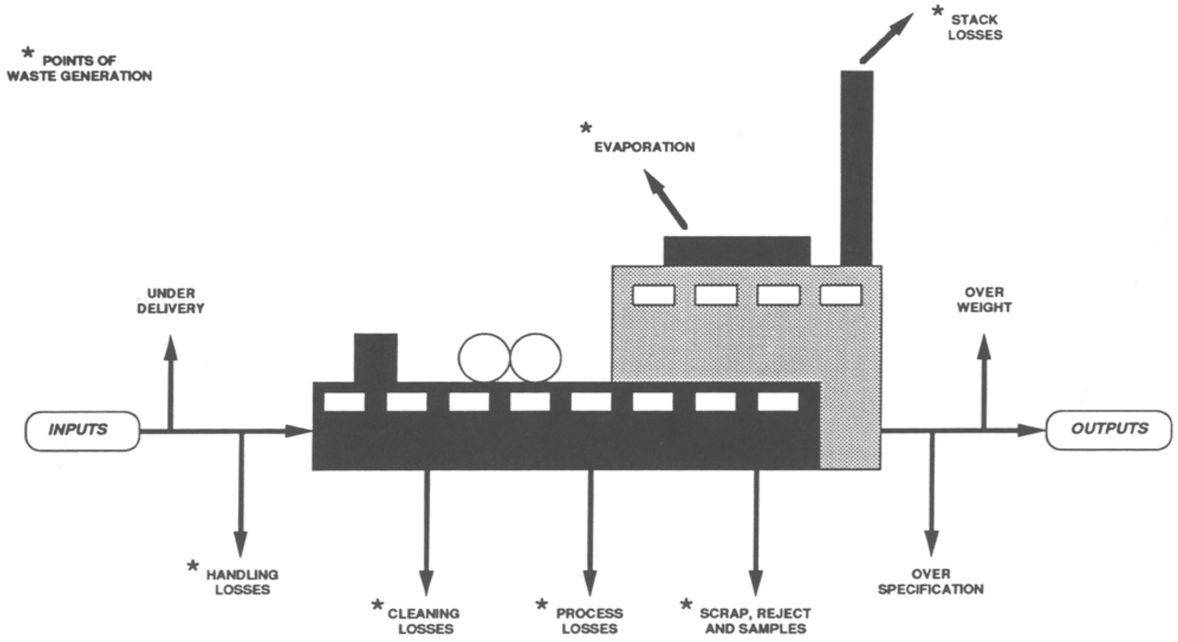

Fig. 1. Points of waste generation and/or physical material losses in paint and lacquer industry (according to Ref. [4]).

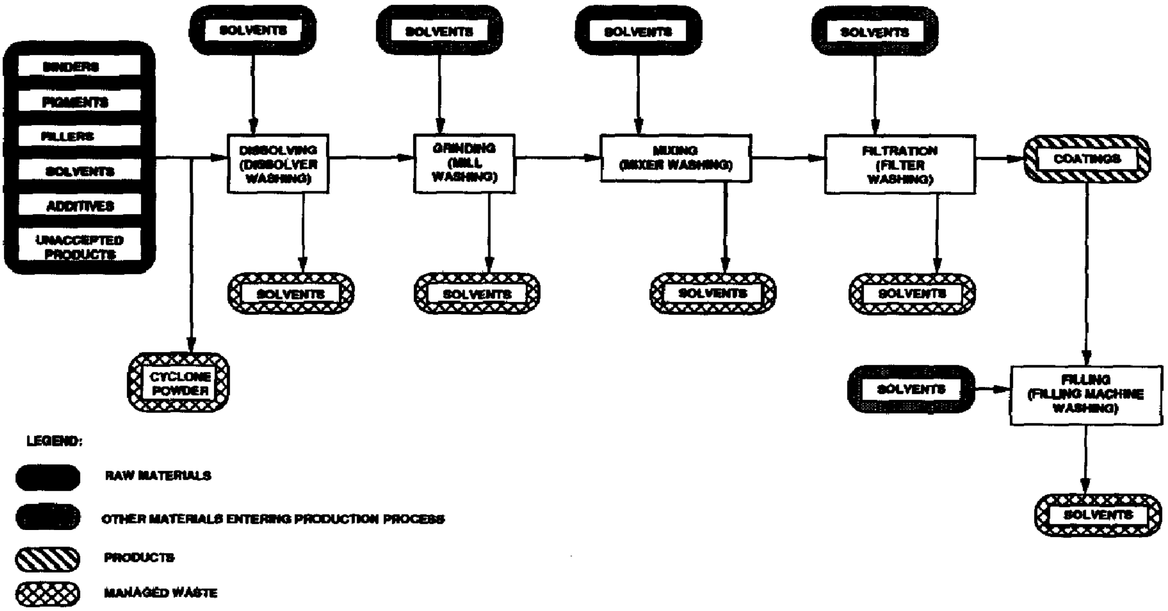

Fig. 2. Waste management in the COLOR coating production.

contaminated with hazardous chemical materials (especially heavy metals as the main constituents of pigments) are collected for disposal. The major quantity of waste is generated while cleaning dissolvers, mills, mixing vessels, filters and filling machines [3]. Specifically, during each main step of coatings production, waste is generated. A simplified scheme of coatings production indicating waste-generating points is shown in Fig. 2.

Waste generated by washing process at different points of generation is collected and then recycled jointly to recover solvents. Recovered solvents are used for washing process, while the remaining sludge is used for lower-quality coating products.

3. Data handling

Table 1 and Fig. 3 give an example of the EXCEL tabular and graphic presentations of a factual data base on the quantities of raw materials and other materials entering the production process, quantities of products produced and waste managed [5]. Data handling was carried out as follows [5]: (i) experimental time interval of data collection was first set to 22 working days (a month); (ii) data in the experimental set were results collected by COLOR employees daily; (iii) data were recorded daily and stored in the company computer; (iv) data were retrieved and sent to the Faculty of Science and Technology to be used for testing of waste generation prediction model; (v) data were organized as a factual data base in EXCEL computer program for further processing.

To obtain the data needed for system factors determination, data retrieval of daily recorded parameters was done. Data were then analyzed and the following was

Table 1

Material balance recording (raw materials, other materials, products and waste) daily production/generation flow (in kg). An example of data for January 1991

Production process name: Coating production

Date	21.1	22.1	23.1	24.1	25.1	28.1	29.1	30.1	31.1	Total
Raw materials										
Binders	41224.00	21650.00	13396.00	2044.00	23790.00	2455.00	18313.00	15740.00	28774.00	167386.00
Pigments	10080.00	3000.00	1000.00	1440.00	1000.00	2280.00	9846.00	9514.00	15234.00	53394.00
Fillers	1210.00	2875.00	3040.00	3470.00	2340.00	260.00	4285.00	4335.00	8880.00	30695.00
Solvents	850.00	6970.00	720.00	830.00	4570.00	1210.00	8170.00	5695.00	1345.00	30360.00
Additives	1545.00	2740.00	1.00	1322.00	0.00	805.00	15293.00	1635.00	1510.00	24851.00
Unaccepted products	2400.00	0.00	2400.00	0.00	2952.00	0.00	0.00	356.00	0.00	8108.00
Water										
Total	57309.00	37235.00	20557.00	9106.00	34652.00	7010.00	55907.00	37275.00	55743.00	314794.00
Other materials entering production process										
Equipment washing solvents	0.00	1740.00	3700.00	0.00	0.00	1360.00	0.00	170.00	4930.00	11900.00
Products										
Coatings	26536.00	39352.00	33146.00	25839.00	23734.00	29800.00	27955.00	33866.00	33866.00	274094.00
Waste										
Solvents	1720.00	3460.00	2800.00	5590.00	5290.00	1100.00	4600.00	3600.00	5660.00	33820.00
Working days	1	2	3	4	5	6	7	8	9	

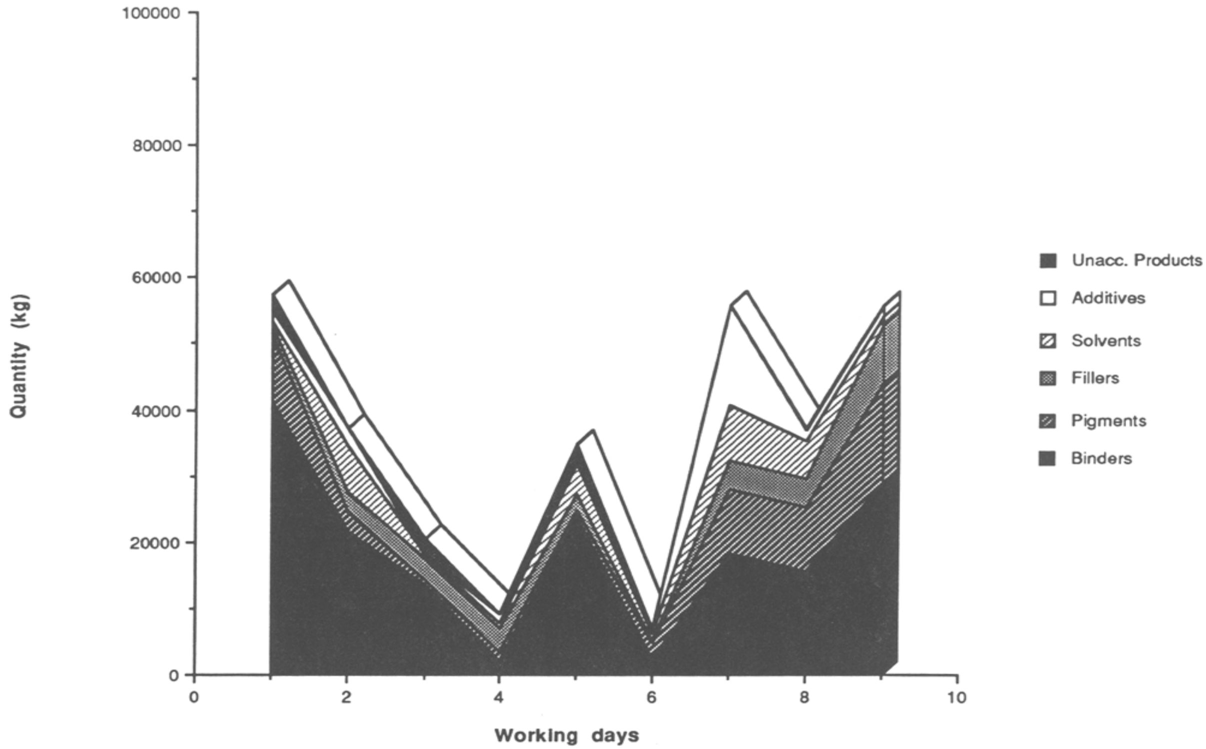

Fig. 3. COLOR – raw material consumption for January 1991.

concluded [5]: (i) coating production cycle is not uniform – each product type has its own production time; (ii) percentage of raw material components entering production varies from one product type to the other product type; (iii) cleaning of each machine is irregular in time and/or frequency and occurs only when a new type or lighter coating shade has to be produced, or in case if the equipment maintenance is needed.

Fig. 3 shows a large fluctuation in data values daily. Therefore, an actual, cumulative value on the quantities of raw and other materials entering the production process, coatings produced, and waste generated, are taken into account for the system parameter definition.

4. Waste generation prediction model

In order to determine system behavior more accurately, data on quantity of raw materials and other materials entering the production line in the time interval of 99 working days (4.5 months) were collected (Table 2). Quantity of products produced and waste solvents managed can be found in Table 3.

Time framework for system parameter determination [5,6] was defined based on the work of Baetz et al. [7], the law of conservation of mass and the developed

Table 2
Quantities of raw and other materials entering the production process

Parameters	kg
1. Binders	1478596
2. Pigments	377508
3. Fillers	815119
4. Solvents	283257
5. Additives	189650
6. Unaccepted products	94084
7. Water	95859
Total (1–7)	3334073
8. Equipment washing solvents	81300
Total (1–8)	3415373

Table 3
Quantities of products and waste solvents

Parameters	kg
Coatings (products), P	3210451
Waste solvents, g	133200

mathematical model, presented schematically in Fig. 4 (in what follows $rm = rm_1 + v$, representing all materials entering into the production process).

The following system factors for COLOR coating production were calculated [6].

$$\text{Production factor: } U = \frac{P}{rm} \approx 0.94,$$

where P is quantity of products produced.

$$\text{Waste management factor: } M = \frac{g}{rm*(1-U)} \approx 0.65,$$

where g is quantity of waste managed.

$$\text{Waste recycling factor: } R = \frac{s}{rm*(1-U)*M} \approx 0.98,$$

where s is quantity of recovered secondary raw materials.

Material balance and waste recycling by thin-layer evaporation technology provided the following data in the observed time interval (Table 4).

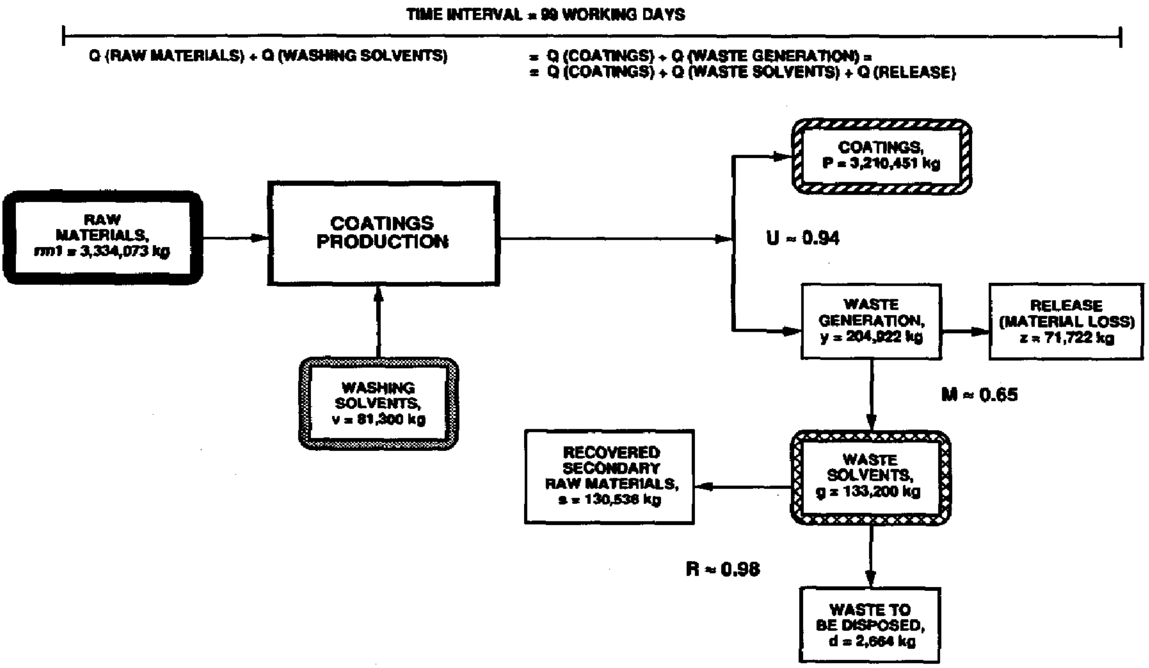

Fig. 4. Material balance in the COLOR coating production.

Table 4
Quantities of waste generated and recycled

Parameters	kg
Waste generated, y	204922
Recovered secondary raw materials, s	130536

Table 5
Quantities of released and disposed waste

Parameters	kg
Release (material loss), z	71723
Disposed waste, d	2664

Using data on waste generation, defined factors and recovered secondary raw materials (recovered solvents and remaining sludge), the quantity of emitted waste from the whole production process, and waste to be disposed were determined as given in Table 5.

Table 6
Raw material prices[a]

Average prices	\$/kg
1. Binders	1.49
2. Pigments	3.17
3. Fillers	0.13
4. Solvents	0.49
5. Additives	3.41
6. Unaccepted products	2.63
7. Water (m^3)	0.32 (\$/m^3)
8. Distillation process	0.56

[a] Prices of some items do not necessarily correspond to the real situation, but are used as an example.

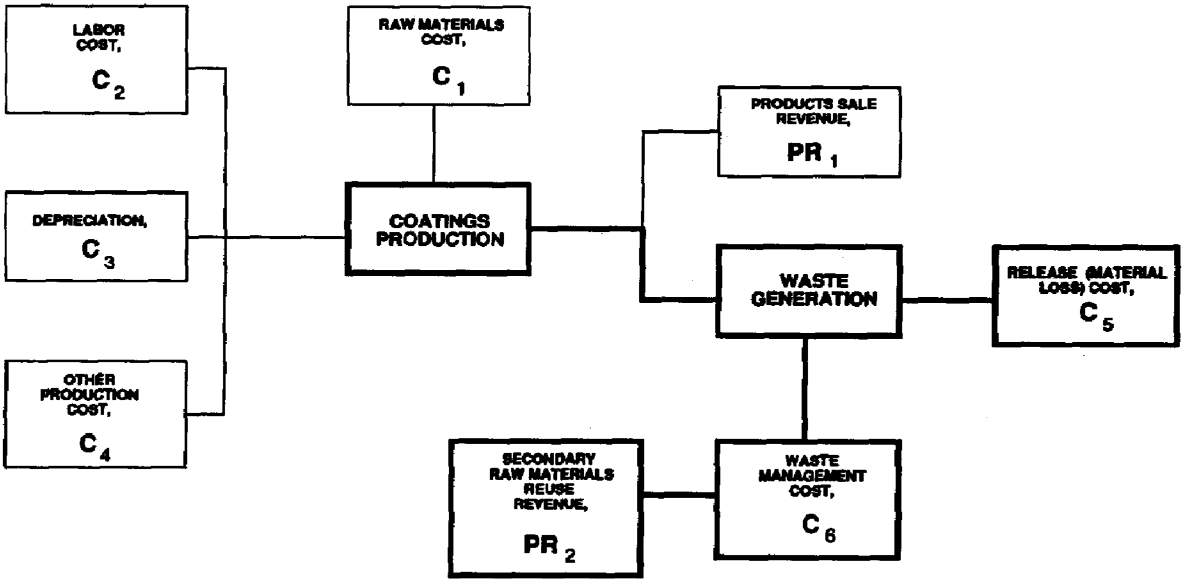

Fig. 5. Revenues and costs of the COLOR coating production and waste generation system.

5. Costs of COLOR coating production

The average price of raw materials used (calculated in USD) is shown in Table 6. The average products sale price is \$2.63/kg.

Fig. 5 represents revenues and costs which were taken into consideration for determining the overall profitability of the COLOR coating production. COSTS (production time = 99 working days) are shown in Table 7. It should be noted that the cost of material loss through release (C_5) is introduced to indicate a material loss due to inadequate coating production operation and maintenance. This quantity of

Table 7
The COLOR coating production costs

Cost type	Definition	$
Costs of raw materials, C_1	Raw material quantity × raw material price	4540053
Labor costs, C_2	Number of employees × average wage × number of working days	480338
Depreciation of machines, C_3	Number of machines × average machine price × rate of depreciation	303915
Other production costs, C_4	Number of other production activities × average price	295946
Cost of materials loss through release, C_5	Material quantity × material unit price	35413
Waste management costs, C_6	Number of management activities × average management activity price	32257
Total costs	$C_1 + C_2 + C_3 + C_4 + C_5 + C_6$	5687922

Table 8
The COLOR coating production revenues

Revenue type	Definition	$
Revenue on product sale, PR_1	Products quantity × products average price	8427434
Revenue on secondary raw material use/sale, PR_2	Secondary raw material quantity × average price	64452
Total revenues	$PR_1 + PR_2$	8491886
Profit	Total revenues − total costs	2803964

material should otherwise be incorporated into products and should gain corresponding revenues. Revenues (production time = 99 working days) and profit are shown in Table 8.

6. Conclusions

By precisely identifying parameters of the industrial production and waste generation system (in this case, coating production) and by using the waste generation prediction model, it was possible to determine quantities of raw and other materials entering the system and quantities of products produced and waste generation. By determining the quantity of waste generated (identified by waste management practices) and by applying the model, quantity of material loss through release (in this case emission) was estimated.

The waste generation prediction model was tested in an industry recognized as a hazardous waste generator. COLOR management intends to set up the same system to identify quantities and costs of waste generation and its management for other divisions. Its next step will be to minimize waste generation, especially of material loss through release, by applying better production and maintenance strategies.

Acknowledgements

The authors thank the University of Ljubljana, Faculty of Science and Technology, and the Slovenian Research Community for the support of the work as well as to COLOR – Paint, Lacquer and Resin Industry for the cooperation and the data they kindly provided. The authors also express their sincere thanks to the Pollution Prevention Branch of the US EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH for suggestions and comments in the preparation of the article.

References

[1] National Painting and Coatings Association, Paint Pollution Prevention Program Policy Statement, Pollution Prevention Bull., 1 (1990).
[2] R. Olbina, A. Cizerle and D. Krnel, Specialized bibliographic database on waste and wastewater management (CDS/ISIS 2.3 Information Storage and Retrieval System), on-line IZUM, University of Ljubljana, Faculty of Science and Technology, Ljubljana, 1991, 4000 documents.
[3] M. Hafner, COLOR production process, Internal COLOR Paint, Lacquer and Resin Industry documentation, 1990, 10 pp.
[4] C. Rooney, Start paint defect prevention now!, Eur. Coatings J., 6 (1991) 218–228.
[5] R. Olbina, Computer supported modelling of hazardous waste management, Dissertation, University of Ljubljana, Faculty of Science and Technology, 1991.
[6] R. Olbina and D. Dolničar, Development of a computerized supported model of industrial production and waste generation system, Internat. J. Environ. Studies, 45 (1993) 29–41.
[7] B. W. Baetz, E. I. Pas and P. A. Vesilind, Planning hazardous waste reduction and treatment strategies: An optimization approach, Waste Management Res., 7 (1989) 153–163.