

Cost-benefit analysis of the recovery of carbon disulfide in the manufacturing of viscose rayon

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LIANG YX, QU DZ. Cost-benefit analysis of the recovery of carbon disulfide in the manufacturing of viscose rayon. *Scand J Work Environ Health* 11 (1985): suppl 4, 60–63. Constraints in the management of occupational hazards include problems with technical feasibility and costs of control measures. A pilot investigation of the effectiveness of a carbon disulfide (CS₂) recovery system in the manufacturing of viscose rayon by means of cost-benefit analysis was conducted at a Shanghai viscose rayon factory. The annual amount of carbon disulfide recovered with the new system reached approximately 1 500 t in 1982. It is estimated that the company has made a net profit of 1 million yuan (about USD 500 000 at the time of the study) per year from this system (almost equal to 10 % of the production value of the factory). This study documented a control measure that was both effective in reducing a hazard for workers and economically beneficial to the company.

Key terms: recovery system.

The Shanghai Number 12 Viscose Rayon Factory was built in 1960 and began operation in 1961. It is one of the largest artificial fiber manufacturers in Shanghai with a current capacity to produce about 10 000 t of fiber per year.

Processes in rayon making

The major raw materials for making viscose rayon are wood pulp, sodium hydroxide, and carbon disulfide (CS₂). In producing viscose rayon, carbon disulfide serves as a “vehicle” in catalyzing the change of amorphous α -cellulose from wood pulp into the fibrous form for use in the textile industry. Two critical processes are xanthation and acidification-coagulation. During xanthation, carbon disulfide is added and interacted with alkalized cellulose to form a brownish syrupy liquid known as viscose. A process of acidification transforms the soluble xanthated cellulose into useful fibers, and most of the carbon disulfide added is released. It is advantageous to recover the carbon disulfide, released from fixed sites of the acid bath, for both economic and occupational health reasons.

An enclosure system is generally used for xanthation for controlling the carbon disulfide vapor that escapes. However, during the spinning (in an open bath), stretching, and cutting of the fiber, there are often major hazards because carbon disulfide is released from the fiber being scattered about; enclosure is difficult. The airborne concentration of carbon

disulfide in the spinning and cutting sections of this factory was elevated in proportion to the increment of rayon production and carbon disulfide use during 1961–1971, even though some preventive measures were employed. The average carbon disulfide concentration in these two sections was approximately two to nine times the current maximum allowable concentration (MAC) for carbon disulfide in China (10 mg/m³) (figure 1).

Consequently, cases of carbon disulfide poisoning were easily found during periodic health surveillance. The rate of carbon disulfide poisoning, based on the nationwide diagnostic criteria documented in China, was 10.6 % (38/360) in 1968, 11.3 % (42/372) in 1970, and 3.8 % (15/400) in 1972. Half of these cases occurred among workers in the spinning and cutting sections.

In addition the ambient air of the area around this factory, used for residential and for agricultural purposes, was polluted by factory exhaust with much carbon disulfide (table 1). The company had to pay at least 1 000 yuans (1 yuan = approximately USD 0.50 at the time of the study) per year to the local farming brigade to compensate for reduced agricultural production caused by carbon disulfide pollution.

Table 1. Airborne carbon disulfide (CS₂) concentrations in the area around the factory (1968).

Distance from factory (m)	Average CS ₂ concentration (mg/m ³)	Multiple of the ambient air standard ^a
500	0.14	3.5
1 000	0.10	2.5
1 500	0.05	1.3
2 000	Trace	.

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^a The standard for CS₂ in ambient air in China is 0.04 mg/m³.

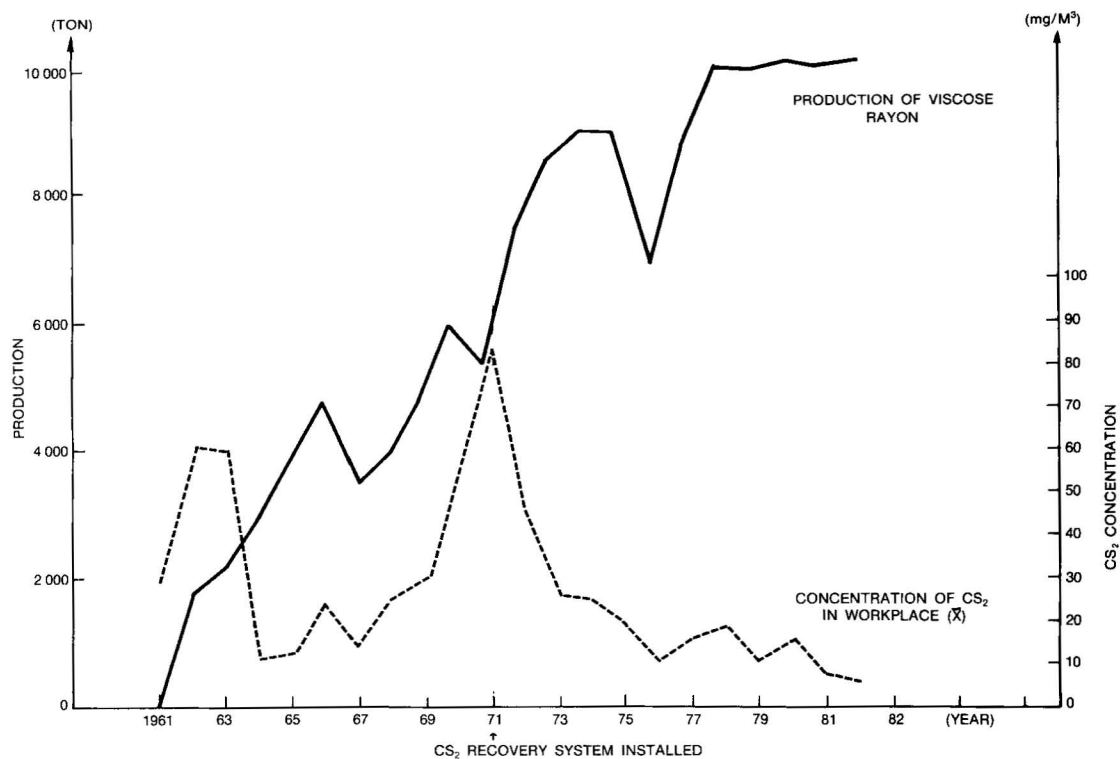


Figure 1. Carbon disulfide (CS_2) concentration of the workshop before and after the recovery system was installed.

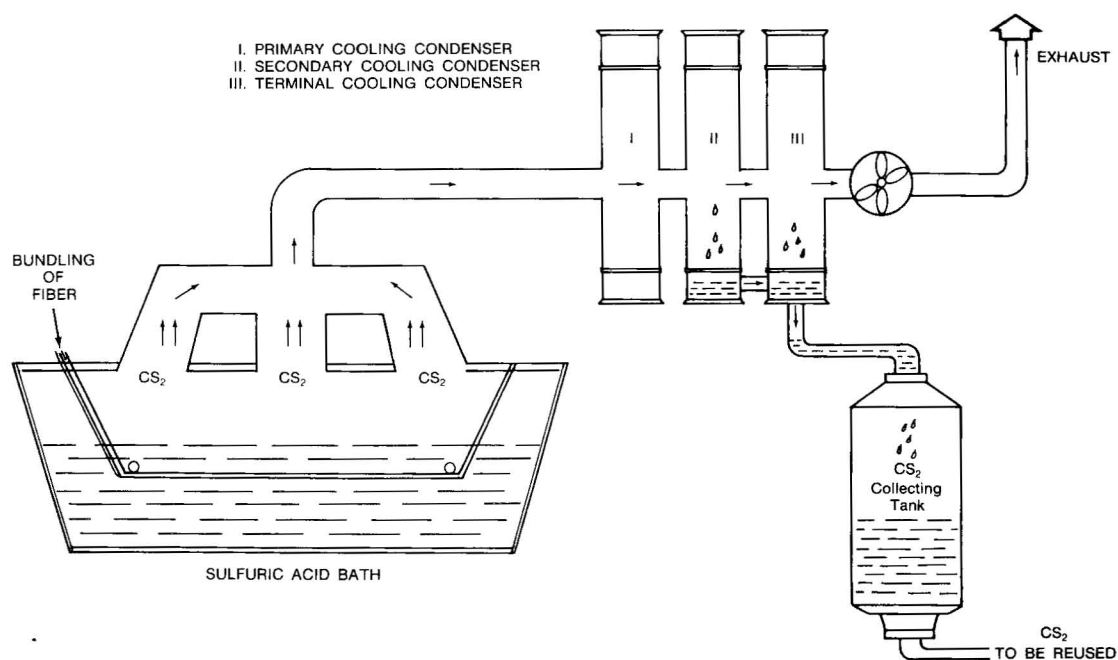


Figure 2. Schematic diagram of the carbon disulfide (CS_2) recovery system.

Table 2. Suspected cases of carbon disulfide (CS₂) poisoning observed during 1974–1982.

Year	Number of workers examined	Number of suspected cases	Prevalence of CS ₂ suspected poisoning (%)
1974	372	19	5.1
1976	400	16	4.0
1978	359	14	3.9
1980	402	14	3.5
1982	377	11	2.9

Table 3. Cost-benefit analysis for 1972. (1 yuan = approximately USD 0.50 at the time of the study)

Cost	Benefit (annual increment of income from reduced expense)
1. Expenditure for the installation of the recovery system 46 000 yuan	1. Profit from the carbon disulfide recovered 472 500 yuan (315 t × 1 500 yuan)
2. Maintenance fee (20 % of the investment of installation) 9 200 yuan	2. Medical expense recovery 4 500 yuan (30 t × 150 yuan) ^a
3. Electricity consumption fee (25 % of the investment) 11 500 yuan	3. Workdays not lost (output value) ^b 90 000 yuan (30 t × 1 000 yuan × 3)
	4. Compensation of the loss in agricultural production 1 000 yuan
Total	66 700 yuan
Net Profit	501 300 yuan

^a There were 30 patients, on the average, per year before the recovery system was installed. Each patient had to be hospitalized for several days and treated for three months at home, for a total cost of 150 yuan for medical care.

^b According to the average production level, each worker creates 1 000 yuan of output value per month.

Table 4. Comparison of the recovery rate of carbon disulfide (CS₂) during 1972–1982.

Year	Amount of CS ₂ used (t/year)	Amount of CS ₂ recovered (t/year)	Recovery rate (%)
1972	1 494.9	315.5	21.1
1973	1 824.0	627.6	34.4
1974	1 885.1	753.0	39.9
1975	2 947.9	1 245.5	42.3
1976	2 120.1	940.0	43.7
1977	2 634.3	1 190.0	45.1
1978	3 013.7	1 290.1	42.8
1979	3 222.0	1 377.1	42.7
1980	3 277.0	1 343.6	41.0
1981	3 212.0	1 549.1	48.2
1982	3 294.0	1 587.5	48.2

Therefore, before 1972, the factory faced problems of carbon disulfide poisoning among workers, pollution inside and outside the plant, and loss of carbon disulfide and, as a result of both, money.

New approach for controlling carbon disulfide

Since 1972, special efforts have been made to control the hazardous carbon disulfide vapor by a combined system of exhaust ventilation and recovery. The recovery of carbon disulfide is achieved, after the capture of the vapor in the ventilation system pipe, by three successive cooling condensers and a collection system (figure 2). By the early 1980s the average rate of recovery reached 48 % of all carbon disulfide added in production.

Efficiency of the recovery system

Outcomes of carbon disulfide recovery are satisfactory in the following aspects:

1. The air concentration of carbon disulfide at workstations has been dramatically reduced even though rayon output and carbon disulfide use have remarkably increased. The average airborne carbon disulfide concentration at workstations fell to below the MAC in 1981 (figure 1).

2. The prevalence of carbon disulfide poisoning has been controlled, a reflection of improvement in the work environment. No proved case of carbon disulfide poisoning (with both subjective neurosis symptoms and signs of peripheral polyneuropathy) has been diagnosed since 1974, although a few cases of suspected poisoning (with subjective neurosis symptoms only) still need follow-up (table 2). Medical care expenses have, as a result, been saved.

3. The emission of carbon disulfide from the factory to the atmosphere has been effectively controlled by the recovery system, and carbon disulfide is no longer detectable in the area around the factory. As a result, no further compensation has been requested by area farming brigades.

4. In addition to reduced medical care expenses resulting from decreased carbon disulfide poisoning and production losses due to ill workers absent from their jobs, much extra profit has been made from the reuse of recovered carbon disulfide. The amount of carbon disulfide recovered was 315 t in 1972 when the recovery rate was about 22 %. At that time, 1 t of the compound cost 1 500 yuan. The total amount of profit from the recovery of carbon disulfide was 472 500 yuan. After the initial investment, the cost of periodic maintenance, and the electricity fees are subtracted and the benefits of control are added, the net profit from the recovery system was 500 800 yuan in 1972 (table 3). In 1982 the recovery rate increased to 48 %, twice what it was at the beginning, and the total of carbon disulfide recovered also increased due to the increment of carbon disulfide added (table 4). It is

estimated that the company's annual extra profit due to the system is now over 1 million yuan, which is approximately 10 % of the total value of the factory's output per year.

Although there may often be conflicts between industrial development and occupational safety and health, this report illustrates that this need not always

be the case. The encouraging approach developed at the Shanghai Number 12 Viscose Factory is an excellent model illustrating that the needs of industrial development and of occupational health can effectively coincide. Hopefully, the successful experience of this factory can be extended to others in order to create conditions both more productive for the company and safer for the workers.