Journal of Environmental Sciences (China), Vol. 2, No. 1, pp 117–124, 1990 ISSN 1001-0742

A new direction for the development of the paper industry

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(Received March 6, 1989)

Abstract—In order to reduce the increasingly serious environmental impact caused by wastewater from the paper industry, the municipality of Jinan plans to adopt a specialized production technology. The new technology will centralize pulp production and decentralize paper production. It is predicted that the new technology will greatly reduce the environmental effects of the paper industry. Perhaps it is a new direction for the development of the paper industry in China.

Keywords: pulp production; cooking black liquor; alkali recovery.

GENERAL SITUATION

The history of paper industry in Jinan, one of the most important paper producers and suppliers in our country, is more than 70 years long. Its annual output of machinemade paper is 500,000 tons. Many of its products are famous for their quality and rank among the best or good ones. However, most of the paper mills in Jinan are small or medium scale with their raw materials being mainly natural fibres such as wheat straw, cotton and linen. These factories use a large amount of chemicals and waste a lot of raw materials and energy resources, resulting in a large discharge of wastewater and other pollutants. Approximately 400 tons of water is needed to produce one ton of paper in Jinan, while the advanced standard in the world is only about 50 tons. According to the statistics issued by the investigations of pollution-creating sources in 1987, paper industry in Jinan discharges approximately 21,311,000 tons of wastewater per year, making up 61% of the total wastewater discharged by the light industry and 14% of the drainage in the whole city of Jinan with the pollution loading ratio being 18.6%.

Most paper mills in Jinan adopt alkaline pulping method. It produces black liquor which accounts for 90% of the pollution load of paper industry and is the most harmful source of wastewater. This wastewater, dark in color and foul in smell, contains alkali and organic pollutants. Major paper mills of Jinan are located on the banks of Xiao Qing River. Untreated wastewater directly or indirectly discharge into this river and causes serious water pollution.

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In order to reduce the increasingly serious environmental impact caused by wastewater from the paper industry, the municipality of Jinan plans to adopt a specialized production technology. The new technology will be centralize pulp production in Licheng County and decentralized paper production in existing factories. It also stimulates technological innovation and production in existing paper mills, promotes alkali recovery, saves resources and reduces environmental pollution. So it really is an optimal comprehensive plan.

The pulp mill produces bleached straw pulp and bleached cotton pulpboard. The daily output of straw pulp is 50 tons, and that of cotton pulp is 60 tons. The annual output of straw pulp is 17,000 tons, and that of cotton is 20,400 tons.

ESTIMATES OF THE ENVIRONMENTAL IMPACT OF CENTRALIZED PULP PRODUCTION

According to the pollution control plan suggested by " studies on pollution protection of Jinan Section of the Xiao Qing River" , Streeter–Phelps Equation and dilution ratio method, the present pollution of the Xiao Qing River has been calculated, and so the effect of the new technology on this river has been obtained by simulating calculation.

$$L = L_0 \exp(-K_1 \frac{x}{u}) \tag{1}$$

$$O = O_s - (O_s - O_0)\exp(-K_2 \frac{x}{u}) + \frac{K_1 L_0}{K_1 - K_2}[\exp(-K_1 \frac{x}{u}) - \exp(-K_2 \frac{x}{u})] \tag{2}$$

where L, O are BOD and DO of each section of river respectively (mg/L); O_s is saturated dissolved oxygen (mg/L); L_0, O_0 are BOD and DO of the beginning section respectively (mg/L); X is the length of a certain river section (m); U is the average velocity of flow in a certain river section (m/s); K_1 and K_2 are BOD degradation coefficient and reaeration coefficient respectively. Equations (1) and (2) represent the effect of pulp production on the environment by calculation and simulating before and after pulp production is centralized.

Recent pollution of the Xiao Qing River by calculation

There are four major paper mills in Jinan: Shandong Eastern Paper mill, Shandong Western Paper Mill, Jinan Paper Mill and Huang Tai Paper Mill. Their total discharge amount is 32,930t/d, of which the discharge from cooking black liquor is 15,930t/d (Table 1) and the total amount of BOD is as high as 7.77t/d. Black liquor flows into the Xiao Qing River through the Gong Shang River and the Qi Li River and amounts for 28% of the total BOD of the Xiao Qing River. Recent pollution of the Xiao Qing River has been calculated by total amount control method (Table 2).

Table 3 lists the figures got by simulating calculation to show water quality after pulp production process is moved away to suburban areas. When pulp production is stopped in

urban area, BOD of the Xiao Qing River will be reduced by 28% and the water quality in this river will be greatly improved.

Table 1 Discharge of paper industry in urban area

Mills	Discharge amount, t/d	BOD		TSS, mg/L
		Content, mg/L	Total amount, t/d	
Shandong eastern paper mill	Eastern outfall 8,000	214.6	1.72	620
	Western outfall 5,500 (wastewater from cooking)	202.3	1.11	1288
Shandong western paper mill	Southern outfall 9,000	213.5	1.92	66
	Northern outfall 4,680 (wastewater from cooking)	415.0	1.94	1236
Huang Tai paper mill	3,050 (wastewater from cooking)	504	1.54	

The influence of the pulp mill on the water environment

Pollution control of the new pulp mill should be designed, constructed and put into operation at the same time as the capital construction. The pulp mill is designed to adopt Kraft continuous cooking technique, use horizontal belt vacuum washers and commonly adopted at home alkali recovery technique. Technological parameters are: black liquor extraction ratio -95%, caulicization ratio -85%, total alkali recovery ratio -76%.1%. Advanced technique and equipment control the pollutants in the pulp mill. Anti-pollution system, installing equipment and capital construction are carried out at the same time. It has been estimated by simulating calculation based on Streeter–Philps equation that after alkali is recovered from the straw pulp-wastewater and the remaining pollutants undergo the primary treatment, the wastewater will be very close to the water environmental quality standard of the Xiao Qing River. The mixture of cotton pulp black liquor and straw pulp black liquor is not burnt either at home or abroad, so

cotton pulp does not undergo alkali recovery. Its wastewater undergoes the secondary treatment to come down to the discharge standard of the Xiao Qing River.

Table 2 Calculated figures of the recent situation in each section of the Xiao Qing River (Jinan section, mg/L)

Discharge system	Section number	Names of the start and finish point of each section	L_O	O_O	L	O
I	1	Multi-western suburb paper mill	2	10	1.738	9.88
	2	Western suburb paper mill–Xing Ji River	15.46	9.41	14.95	9.12
	3	Xing Ji River–Ji Luo main pipe	25.71	5.20	23.91	5.47
II	4	Ji Luo main pipe–Gong Shang River	24.78	4.4	24.39	4.59
	5	Gong Shang River–Xi Luo River	67.14	2.42	65.44	2.02
III	6	Xi Luo River–Dong Luo River	63.77	1.95	62.68	1.73
IV	7	Dong Luo River–Liu Hang Tou	60.82	1.76	60.03	1.58
	8	Liu Hang Tou–Qi Li River	57.91	1.62	55.77	0.992
V	9	Qi Li River Da Xing River	66.29	0.932	61.52	
	10	Da Xing River–Zhang Ma River	60.18		57.3	
VI	11	Zhang Ma River–discharge pipe	53.18		49.52	
	12	Discharge pipe–Han Chang River	53.91		49.76	
	13	Han Chang River–pulp mill	47.69		44.02	
	14	Pulp mill–Ya Wang kou	50.82		45.13	

Table 3 Water quality estimates of the Xiao Qing River after pulp production is moved away

Section number	Names of start and finish points of each section	BOD and DO content of start and finish section, mg/L			
		L_O	O_O	L	O
1	Multi western suburb paper mill	2	10	1.736	9.88
2	Western suburb paper mill –Xing Ji River	15.46	9.41	14.96	9.12
3	Xing Ji River–Ji Luo main pipe	27.71	5.20	23.91	5.47
4	Ji Luo main pipe–Gong Shang River	24.79	4.39	24.39	4.58
5	Gong Shang River–Xi Luo River	50.05	2.48	48.75	2.48
6	Xi Luo River–Dong Luo River	47.49	2.39	46.84	2.38
7	Dong Luo River–Liu Hang Tou	45.49	2.39	44.91	2.34
8	Liu Hang Tou–Qi Li River factory	43.74	2.34	42.13	2.07
9	Qi Li River factory–Da Xing River	50.68	1.96	47.29	1.25
10	Da Xing River–Zhang Ma River	46.24	1.40	44.01	0.99
11	Zhang Ma River–discharge pipe	41.29	1.44	37.97	0.38

ENVIRONMENTAL COST-BENEFIT ANALYSIS OF CENTRALIZED PULP PRODUCTION

The necessity and environmental cost-benefit of centralized pulp production

As our experience proves, in paper mills, whose annual pulp output is less than 10,000 tons, alkali recovery is not economical or practical. In 1978, Shandong Western Paper Mill introduced a set of alkali recovery equipment, which would be able to treat 15 tons of straw pulp per day, in order to deal with the black liquor produced during pulping. However, because of the small

capacity of the mill (straw pulp amounted to 60% of machinemade pulp), high viscosity of straw pulp black liquor, high content of silicon and low amount of heat produced, alkali recovery was quite difficult. Moreover, much land is needed for the decentralized treatment. Economic efficiency would be realized by pollution if alkali recovery were given up. So centralized pulp production is the best plan adopted by paper industry in Jinan to control water pollution.

Owing to centralized pulping, the existing paper mills will be able to expand and improve their equipment, popularize effective techniques of white water recovery and closed cycle system, and control BOD content in white water, which will bring associated environmental and economic benefits. As a result, all the wastewater in urban area can be controlled, and BOD content reduced by 11.1 ton per day (Table 1), which amounts to 40% of the total BOD content in the Xiao Qing River. The economic and environmental benefits equal the primary treatment of this river.

Economic benefit of alkali recovery during centralized pulping

The annual amount of alkali used in the pulp mills is 5,000 tons, that of alkali recovered 3,978 tons, and the cost of alkali recovery 534.5 yuan per ton. At present, the state price of alkali is 800 yuan per ton, market price 1,400 yuan. The annual profit of alkali recovery will be 1,060,000 yuan. Moreover, in order to produce one ton of market alkali, approximately 2,000 kW/h have to be consumed; 8,000,000 kW/h can be saved to produce 3,978 tons of alkali. Our national economy suffers lack of energy resources, and alkali is very much needed. So alkali recovery during centralized pulping will save a lot of raw materials of cooking black liquor and make waste materials reusable, thus saving expenditure as well as energy resources and eliminating environmental pollution.

Social benefit of centralized pulp production

The pulp mill is one providing raw materials and earning small profit. The economic benefit of its own is quite low. However, judging from the point of view of the whole Jinan and its paper industry, the benefit is remarkable.

(1) Centralized pulp production stimulates the development of paper industry in Jinan

It enables existing paper mills to expand and improve their production techniques. It also promotes the changes in production structure and thus enlarges the amount and assortment of their products. It is estimated that the whole paper industry will increase the output value by 80,000,000 yuan per year, and the profit tax 20,000,000 yuan.

(2) Centralized pulp production saves foreign currency and reduces the cost

By using straw and cotton pulp instead of part of wood pulp, the pulp mill saves 2,500 tons of wood pulp produced in our country or imported from foreign countries, so it saves $1,300,000 and 12,000 m^3 of wood and the cost is reduced by 2,700,000 yuan.

(3) Centralized pulp production solves the problem of the lack of pulp produced at home, smooths the contradiction between the supplies of and demands on the long-fibre pulp, reduces the amount of imported wood pulp, eliminates the pollution in Jinan and solves the problem

of water shortage. Moreover, the pulp mills make full use of the straw and short fibre cotton in the surrounding areas to increase the social benefit.

CENTRALIZED PULP PRODUCTION IS AN IDEAL WAY TO PREVENT AND CONTROL THE POLLUTION CAUSES BY WASTEWATER FROM PAPER MILLS

The equipment of paper industry in Jinan is backward and the environmental management is not perfect. Reusable material are not recovered or reused, a lot of raw materials are thrown away as wastes, and the result is serious environmental pollution. If paper factories were further developed, the contradictions between the production development and environmental protection would be more intensified. That is why we should think about how to improve our environment at the same time as production is developed. With the idea of " promoting treatment by the development of production and seeking development in treatment " as our guiding line, we have decided on the specialized method of " centralized production of pulp and decentralized production of paper"

Environmental, economic and managerial factors being considered, we have come to the centralized way of preparing pulp to replace the decentralized way. Alkali will be recovered, and the pollutants (70–90%) will be reduced in the course of production. So this is a very economical and practical way to coordinate environmental benefits and economic efficiency. To treat the pollutants discharged by the paper factories means to decompose " pollutants " (actually they are usable raw materials) into carbon, hydrogen and oxygen and reduce their amount to the " discharge standards" , it seems that the environmental quality demands are met, but in fact, we consume more energy to treat waste resulted from the backward technology and management. This is contrary to the principles of socialist construction in our country. Many of the advanced paper factories in the world treat pollution problems in the factories. Generally speaking, treatment within factory has certain economic efficiency. Even if it does not, this treatment is quite economic because the pollution problems is solved at the right time.

At present, most of the old paper mills in Jinan and of those built in the 70's are not equipped with anti-pollution equipment. To ensure the environment benefit of centralized pulp production, actions must be taken to deal with the factories with low profit, serious pollution and without anti-pollution measures. According to the pollution statistics of the Xiao Qing River, the small Western Suburb Paper Mill alone discharges 1.25t/d of BOD, and the BOD concentration of cooking black liquor is 290 mg/L. This wastewater cuts down the amount of dissolved oxygen in the Xiao Qing River to 2mg/L. Such kind of small-scale paper mill earns small profit, but its harm far surpasses its economic benefit. So the construction of small scale paper mills must be put under stick control. Only thus can the pollution of the Xiao Qing River caused by centralized pulp production be reduced by 30%.

While our national economy is being readjusted, it is more urgent that economic benefit,

rational distribution of industries and long range planning and renovation of enterprises be taken into consideration. Those factories which do not have enough raw materials, consume much energy, lose for a long time, cause serious pollution and are unable to solve their own problem or to bring about economic efficiency, should be closed, stopped, switched to manufacture other products or moved to other places.

To sum up, the pulp mill produces raw materials. Its profit is not high, but it will bring associated environmental, economic and social benefits by readjusting the structure of industries, developing paper industry and reducing environmental pollution. So centralized pulp production may be a new direction for the development of the paper industry in China.