Economy and Environment Program for Southeast Asia

An Assessment of Paper Mill Wastewater Impacts and Treatment Options in Vientiane Capital City, Lao P.D.R

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An Assessment of Paper Mill Wastewater Impacts and Treatment Options in Vientiane Capital City, Lao P.D.R

Contents

AN ASSESSMENT OF PAPER MILL WASTEWATER IMPACTS AND TREATMENT OPTIONS IN VIENTIANE CAPITAL CITY, LAO P.D.R.

Kaisorn Thanthathep[1], Phousavanh Douangphila[2] and Somphone Khamphanh

1.0 INTRODUCTION

1.1 Background

River systems play a crucial role in local livelihoods since they provide water for agricultural production. The rapid increase in the number of factories impacts these river systems both positively and negatively. While industrial growth provides local communities with employment and income, it also causes air pollution and contaminates river systems because of industrial wastewater discharge.

Pulp and paper mills are among the industries that cause air, water, and solid waste pollution, all of which impact livestock, agricultural production and local livelihood. At the time of this study in 2005, there were six pulp and paper mills operating throughout the country. Five were located in Vientiane Capital City and one in Vientiane Province. Compared to those in neighboring countries, these were small-scale pulp and paper mills with less than 200 tonnes of output per day. Among them, only the one in Vientiane Capital City had installed a wastewater treatment system. However, this did not operate full-time to save on energy and costs.

Given that most of the Lao people relied on streams and rivers for their water consumption, the government recognized that the quality of water in these bodies was crucial, especially to the lives and livelihood of poor villagers. Therefore, in accordance with the Millennium Development Goals, the government set targets in order to improve the local people's access to safe drinking water by the year 2015.

The Socio-Economic Development Strategy up to the year 2020 and the Five Years Plans 2001–2005 and 2006–2010, the National Growth and Poverty Eradication Strategy, the National Environment Strategy up to the year 2020 and the Action Plan 2006–2010 highlight the importance of the sustainable use and management of natural resources, specifically water. Furthermore, the Environment Protection Law (EPL), the Water and Water Resources Law and the regulation on wastewater discharge forbid any water pollution and recommend that the private sector be responsible for the environmental damage and the related social and economic effects that result from their industrial activities, specifically from wastewater and air emissions[3].

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[2] Researcher at ETC
[3] The Ministry of Industry and Handicraft issued the Industrial Waste Discharge Regulation on 31 November 1994 and updated it in October 2005. In addition, the Environment Impact Assessment Implementation Regulation for both the industrial and handicraft (cottage industry) sectors was issued in December 2005.

While it is recognized that the country's economy generally benefits from the operation of paper mills in terms of employment and income for local communities, the persistence of environmental problems caused by their wastewater is nevertheless a major issue that the same communities continue to complain about.

1.2 Case Study: KPS Paper Mill

The KPS Paper Mill, which was the target of this study, is located in Ban Illai, Nasaythong District, Vientiane Capital City. The plant uses sodium carbonate (Na_2CO_3) or sodium hydroxide (NaOH) (or cold soda) mixed with sulfur (S) to deepen the yellow color of the paper it manufactures and exports to Taiwan. The factory operates 24 hours a day, 6 days a week. Working hours are divided into three shifts. Machinery maintenance and checking take place on Saturday evenings. Production is continuous throughout the whole year. About 150 workers work at the factory, 45 of which are female.

The KPS Paper Mill has not installed any wastewater treatment system although it is stipulated in the factory's project document. Wastewater is discharged into a series of ponds and overflows into the adjacent Houay Say Khao Stream without any appropriate treatment to reduce the biological oxygen demand (BOD) or chemical oxygen demand (COD) concentrations in it (Figure 1). The effluents change the water color of the Houay Say Khao, which has turned from its natural limpid color to brown and dark grey with an unpleasant sulfur odor. Furthermore, due to heavy storms in June 2005, the wastewater ponds were broken and a large volume of wastewater overflowed directly into villagers' fish ponds and rice fields.

Affected villagers have blamed the factory owner's lack of responsibility for their dead fish and the bad color and quality of the stream water. The factory's wastewater has also been blamed for the skin irritation suffered by the villagers and negative impacts like soil degradation which affects rice yields. Due to the poor quality of the stream's water, villagers claim that it is no longer suitable for fishing, swimming, and washing clothes as it was before the factory commenced operation.

KPS compensated the villagers for the loss of fish and damaged rice fields but is doubtful about being able to improve the quality of the water of the Houay Say Khao Stream so that it may return to its original color. In 2005, in an interview with the researchers of this study, the factory owner cited high water treatment costs and said that he was willing to pay if concerned government institutions could help him find an appropriate and reasonably priced water treatment system technology. There have been few studies on the benefits of clean production in the industrial sector in Lao PDR, namely paper mills, garment factories, tanneries and cement plants. They are preliminary studies that do not look into the costs of appropriate wastewater treatment technologies and how these compare with the costs of environmental damage caused by the paper mills.

The local authorities have requested the Science Technology and Environment Agency (STEA) and its branch in Vientiane Capital City to advise the KPS factory on the appropriate actions to take to minimize its negative impact on the environment and, if possible, to restore the Houay Say Khao Stream to its initial color and quality. Without relevant information on the costs of both the environmental damage and potential wastewater treatment system, however, the STEA cannot provide the needed advice. The social costs of not installing a wastewater treatment system also need to be known. This study attempts to address these information gaps.

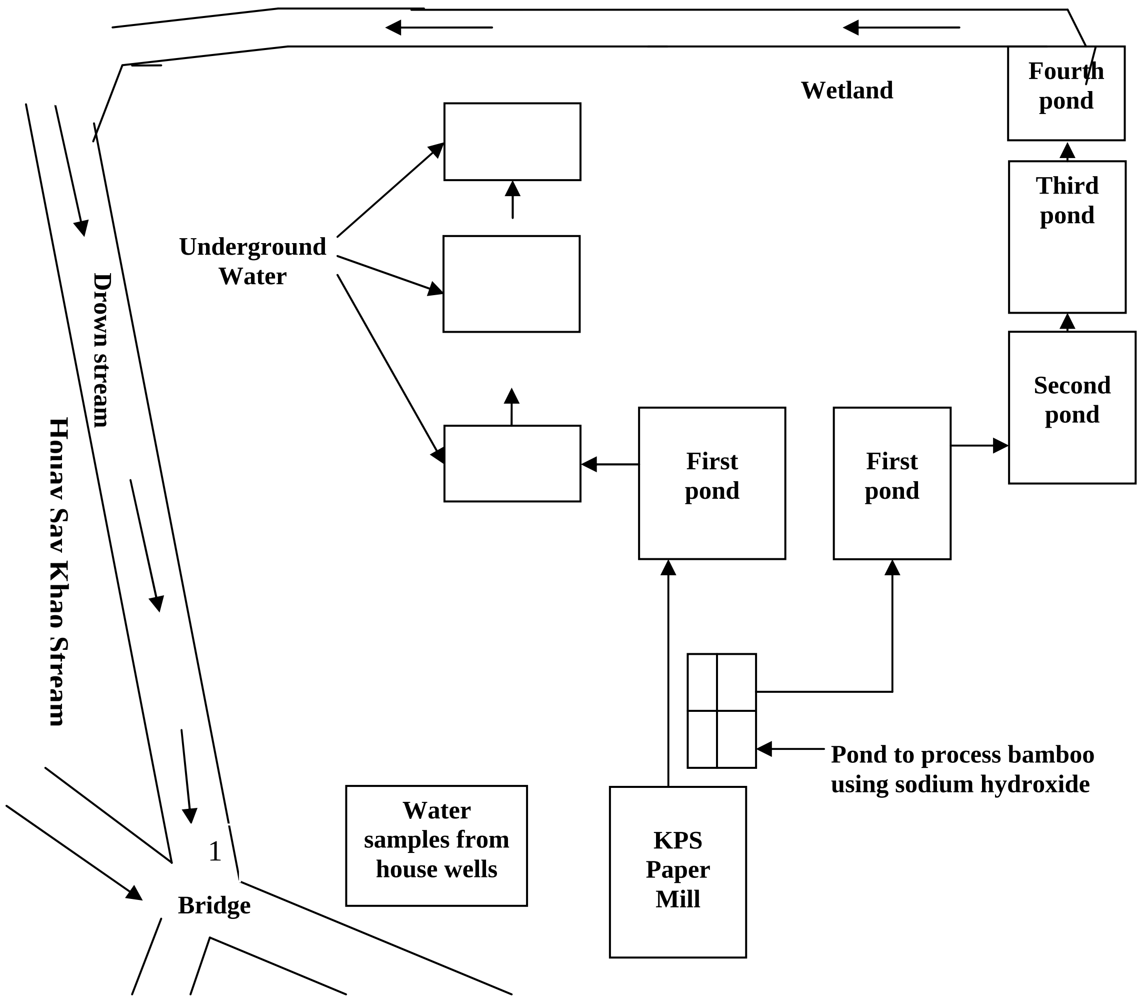

Figure 1. The pollution of the Houay Say Khao Stream by the KPS Paper Mill

1.3 Research Objectives

The study's overall objective was to analyze the cost of environmental damage caused by the KPS Paper Mill and perform a cost analysis of possible waste treatment options for the mill.

The specific objectives were:

a) To present the main social and environmental issues arising from the operations of the KPS Paper Mill;

b) To identify the nature and extent of environmental damage caused by the KPS Paper Mill;

c) To undertake a cost-effectiveness analysis of the wastewater treatment options for KPS; and

d) To provide relevant policy recommendations to concerned institutions and authorities on the waste management of paper mill plants in the country.

2.0 RESEARCH METHODOLOGY

2.1 Estimating the Impact of the Water Pollution Caused by the KPS Paper Mill

To estimate the economic impact of the water pollution caused by the KPS Paper Mill, a household survey was conducted in Ban Illai Village to collect information on sales revenue from fish and rice before and after the factory started its operations. In this study, cost-effectiveness analysis was used to identify the appropriate wastewater treatment technology to reduce the BOD levels in the wastewater discharged by KPS (Table 1).

Table 1. Cost and effectiveness analysis for the KPS Paper Mill

Cost and effectiveness	**Alternatives**	
	Option A	**Option B**
Cost Measure (wastewater treatment cost in USD)	AA $	CC $
Effectiveness measure (reduction of BOD)	BB kg a year	DD kg a year
Cost-Effectiveness Ratio (cost of overall treatment per kg of BOD reduced)	$\frac{AA}{BB}$	$\frac{CC}{DD}$
Economic-Cost Ratio (kg of BOD reduced per USD)	$\frac{BB}{AA}$	$\frac{DD}{CC}$

Two approaches were adopted to estimate the economic values of the environmental damage from the KPS Paper Mill, i.e., the "before" and "after", and "with" and "without" approaches. Originally the research design only covered Ban Illai Village. However, recognizing the villagers' limitation in recalling information before the establishment of KPS, it was decided that a control village had to be identified. Thus, Ban Numkeng was chosen as the control village and included in the household survey. It has a similar socio-economic and physical setting as Ban Illai being about five kilometers away in the same district, and represented a situation without the wastewater problem.

2.2 Sources of Data

o *Survey of affected communities*

Primary data was collected through personal interviews with households in Ban Illai. They were asked about the impact of the pollution of the Houay Say Khao Stream on their health, agricultural practices, and daily activities. They were also asked about the compensation they expected from the paper mill owner, what they thought the owner's responsibilities should be, and the actions they expected the local authorities to take in order to manage the current situation and to prevent the same situation from happening again in the future.

o *Key informants survey*

The authorities of Ban Ilay Tay and Ban Ilay Neua in Saythani District were also interviewed. They were asked about the duration and extent of the environmental damage caused by the KPS Paper Mill, their reactions to this, the response of the plant owner vis-à-vis the damage caused, and the local communities' reaction to the situation and their expectations regarding the local government's actions.

o *Secondary data through literature review*

Literature on wastewater pollution and methods was reviewed. Of particular interest were studies related to wastewater laws and technology treatment options in Lao PDR and other countries. Local laws and regulations on wastewater management were also reviewed.

2.3 Data Collection

The research team was divided into two for the data collection. The first team focused on the assessment of the current situation of the six paper mills in Vientiane Capital City and Vientiane Province while the second team concentrated on the affected area and local people (see steps below).

2.3.1 Focus group discussions

Focus group discussions (FGDS) were organized to discuss key issues and identify data gaps. The discussion was attended by external experts in the field of environmental economics, the local villagers and village leaders, and the appropriate district-level state officials.

2.3.2 Key informant interviews

The team visited the KPS factory to conduct in-depth interviews and collect information on the factory's operations and wastewater management. The teams were assisted by environmental engineering consultants, Dr. Richard J. Frankel and Ms. Kimyen, who were both working at STEA under the SEM II Project.

2.3.3 Questionnaire design

The survey questionnaires used in gathering data from the local households and the factory owner were drafted based on the information gathered through the FGDs. The Environment Research Institute (ERI) Director helped improve them. A workshop was also organized to present the study's objectives to the participants and to ask them for their feedback and comments on the content and organization of the questions.

2.3.4 Sampling in the target and control villages

There are about 500 households in Ban Illai Village. A sample size of 222 households was determined using the formula below, at the 95% confidence level.

$$n = N/[1+Ne]^2$$

$$n = 500/[1+500(0.05)]^2 = 222$$

where

n = sample size
N = total number of households in the village
e = desired margin of error

Ban Numkeng was selected as the control village in order to compare the impact of the change in the water quality of Houay Say Khao Stream on the villagers' welfare. The selection criterion was that the control village should have characteristics similar to Ban Illai except that it should have no wastewater pollution problems. Forty households were interviewed in Ban Numkeng; the survey was randomly conducted on every third household.

2.3.5 Water sampling

ERI researchers, with technical assistance from chemical experts, analyzed the discharged wastewater. Water samples were collected from village ponds and the stream. Water quality, especially the effluent water discharged from the KPS Paper Mill, was periodically monitored in the rainy season. The parameters analyzed included BOD, COD, TSS and pH.

3.0 RESULTS

3.1 Socio-economic Profile of Target and Control Villages

Among the 222 households interviewed in Ban Illai, the largest group of respondents (38 per cent) was in the 51 to 65 years age group (Table 2). Fifty-four per cent of the respondents were women.

Generally, the respondents' level of education was low, particularly among the female respondents. Around 22 per cent of the respondents were illiterate. Despite the fact that both villages are located in the capital city of the country, only a very small percentage of the respondents had university-level education and no one held a masters or doctorate degree. Most of the local villagers, however, only finished primary school.

Table 2. Respondents' age distribution

Age	Frequency	Percentage
18-30	33	14.9
31-40	50	22.5
41-50	55	24.8
51-65	84	37.8
Total	222	100

Source: field survey

The majority of the respondents interviewed were farmers (47 per cent). The stream was their main source of surface water. Another 27 per cent were housewives, 9 per cent were traders, 6 per cent were workers, and 5 per cent were state officials (Figure 2). Some 4 per cent said they were unemployed and only 2 per cent owned a private business. Most of the villagers fished in the stream. The main sources of income were agricultural production and aquaculture.

For the control village, Ban Numkeng, most of the respondents were women in the 31 to 50 years age group. Their education and occupation profiles were similar to those of the respondents in Ban Illai. Around 15 per cent of those interviewed were illiterate and more than one-fourth of the respondents attended primary school only. More than 70 per cent earned their income through agriculture.

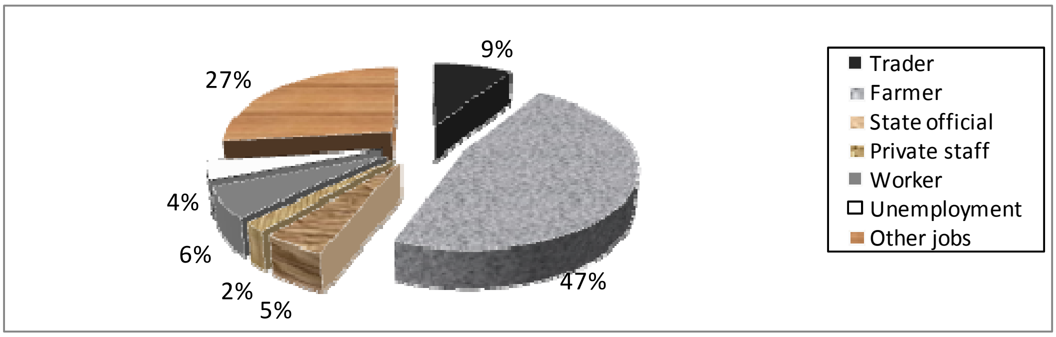

Figure 2. Occupational profile of Ban Illai respondents

3.2 The Impact of Water Pollution

3.2.1 Impact on fishing activities

Chemical contamination and reduced levels of oxygen have deteriorated Houay Say Khao Stream's water quality and lowered the survival rate of its aquatic animals (namely, shrimp, fish, shellfish, and snails), which are the local residents' main sources of protein. Villagers believe that some aquatic species can no longer be found in the stream because they either could not survive in the contaminated waters or they have migrated elsewhere.

Ban Illai respondents were asked to recall the fishing situation before the factory was established as well as since its operation. Taking into account the time that had passed and the toll this may have taken on the accuracy of the respondents' testimonies, this information was compared with that from Ban Numkeng respondents. Data on the fishing activities and the income they generated at both sites were compared to determine the extent to which the reduction in fishing activities was due to the deteriorating water quality.

According to the data collected, it was found that most of the respondents (78.8 per cent) depended on the stream for fish before the KPS Paper Mill was set up (Table 3). This indicates that aquatic resources were abundant in the past.

Table 3. Number of local people fishing in the stream before the KPS Paper Mill was established

	Earn money from fishing	Did not earn money from fishing
No. of households	175	47
Percentage	78.8	21.2

Source: Field survey. N = 222.

Figure 3 shows the fish catch volume before and after KPS was established in 1997. During the rainy season, the average fish catch per fishing household before 1997 was around 63.92 kg/month. After the factory started operating, this volume declined to around 2.28 kg/month. During the dry season, the average fish catch per fishing household was around 43 kg/month. Since the factory's operation, this has reduced to 1.32 kg/month.

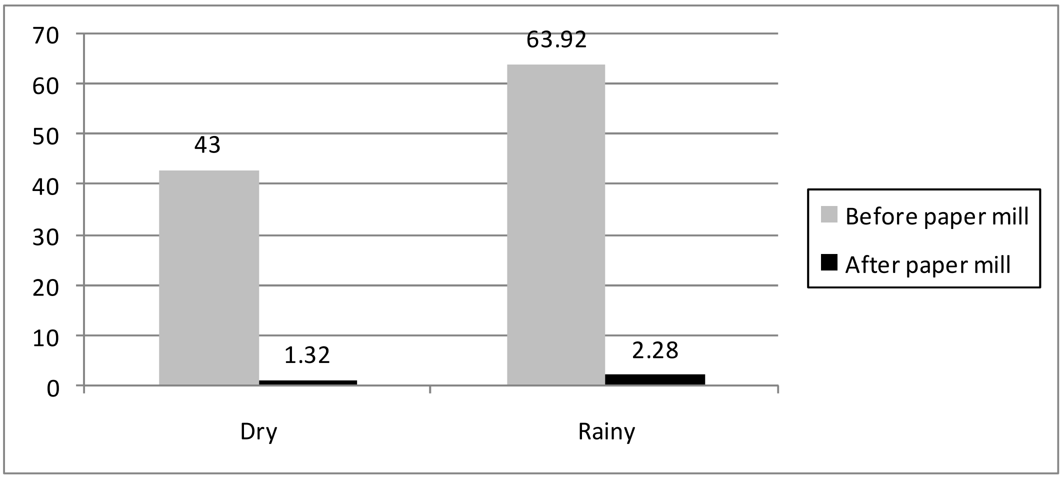

Figure 3. Average fish catch per fishing household during the dry and rainy seasons (kg/month)

3.2.2 Impact on agriculture

Almost 90 per cent of the respondents grew rice and used water from the stream for irrigation. The harvested rice satisfied household consumption needs and was also sold for income. Besides growing rice, the locals also maintained vegetable gardens near the stream. The most common vegetables planted were cabbage, snake bean, lettuce, corn, tomato, pepper, garlic, pumpkin and mushroom. The respondents reported that the color of the vegetables had changed because of the wastewater discharged from the paper mill and that the polluted water had also lowered their fishery stock.

The respondents also said that the hazardous wastewater had contaminated the soil and adversely affected agricultural production by slowing down the growth of the crops. Table 4 below shows Ban Illai's rice and vegetable output before and after the KPS Paper Mill's establishment. The rice output was estimated by converting the number of rice sacks into the kilograms. Vegetable output was estimated based on the price of the vegetables consumed and sold annually. Rice and vegetable farmers grew these crops every year.

Table 4. Rice and vegetable production

	Rice production (kg)		Vegetable production (kip)	
	Before paper mill	After paper mill	Before paper mill	After paper mill
Average	1,891	1,621	778,235.29	629,549.02
Total	270,400	231,900	39,690,000	32,107,000

Source: Field survey

3.2.3 Impact on the household sector

Most of the locals still relied on the Houay Say Khao Stream. None of the village households had access to a sanitized water supply due to the village's distance from the main city. Thus, Ban Illai was perceived as a poorly developed village.

The stream's low water quality has led to an increase in the use of chemicals to kill bacteria, which in turn has increased the cost of producing water. Although the polluted water was perceived to be potentially harmful to the local community, causing skin irritation, stomachaches, and lung problems among others, many villagers had no access to alternative water sources. Even the groundwater was believed to be contaminated.

However, it was not entirely clear whether the paper mill was the only cause of the water contamination. Two-fifths of the respondents believed that the village stream was still very clean. They believed that the water quality had changed because of the increase in population and household waste. There were small factories nearby but these did not discharge wastewater into the river. A slight odor emanated from the stream, but during the rainy season, no bad smell was detected.

Livestock drank water from the well and village stream. Before the paper mill was established, local households had various water sources (Figure 4). Eighty per cent got water for domestic consumption from the well near the stream. The villagers used water from the wells to wash clothes and take baths. Around 48 per cent got their water from the stream. A smaller percentage (4 per cent) used ground water.

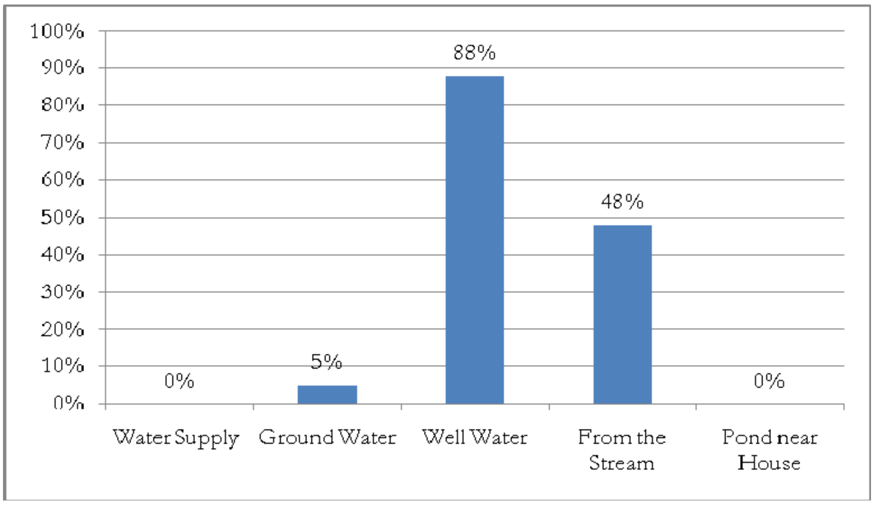

Figure 4. Sources of water for households before the KPS Paper Mill was set up

Figure 5 shows the impact on household water supplies once KPS started its operations. The reduction was slight because there were no alternative water sources.

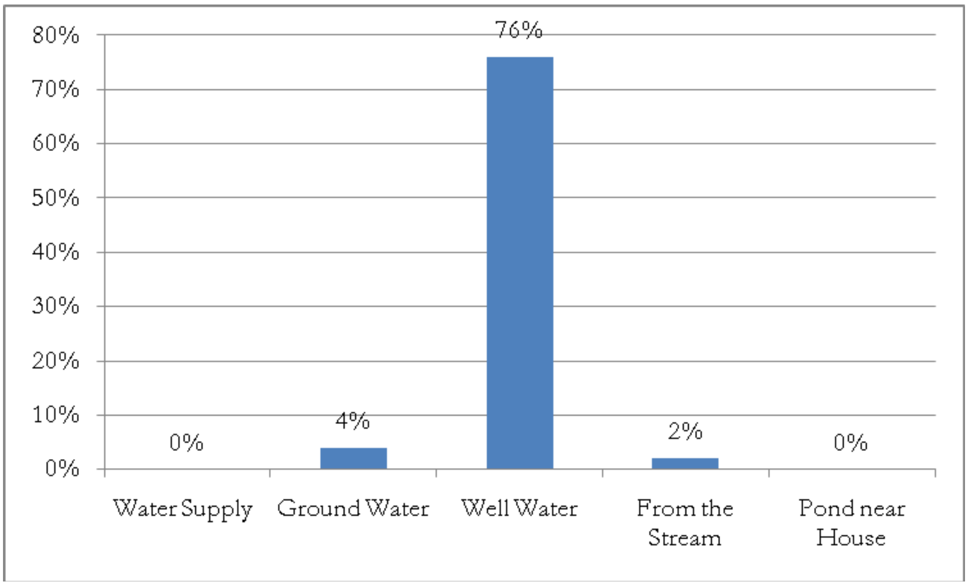

Figure 5. Sources of water for households after KPS was set up

The survey data does suggest that the establishment of the paper factory changed the way villagers used water from the stream (Figure 6). According to the Ban Illai villagers, the most serious problem they had with the factory was the odor from the wastewater it discharged followed by the contamination of the stream by the hazardous chemicals in the wastewater. Based on the survey data, before the operation of the paper mill, the respondents did not experience any of these problems. Therefore, it was indisputable that the factory's operations had had a negative impact on the stream.

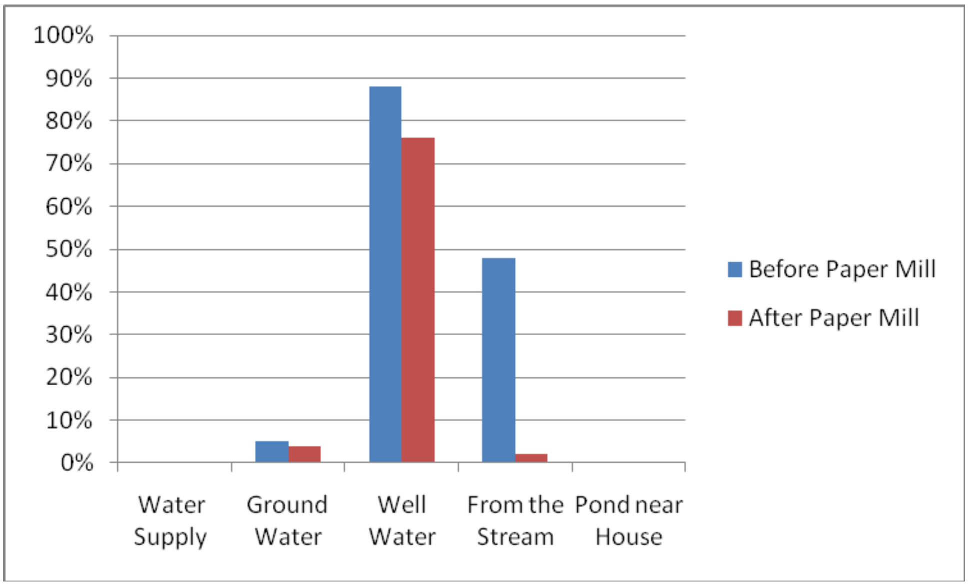

Figure 6. Sources of water for households before and after the establishment of KPS

The contamination did not only damage the environment; there were also financial costs. Ten years ago, the local people could consume water from the river. Now, they had to seek alternative water sources for drinking and for other household uses at additional cost. However, the poorer ones had no choice but to continue using water from the stream and risk illness. This suggests that the contamination of the stream also had social costs.

The factory changed the way the stream was used. After it started its operations, the number of households who used and consumed water from the stream and the well declined dramatically from 48% to 2%. There was also a slight decline in the use of underground water.

There was a considerable difference between the purchase of drinking water from the drinking water factory before and after the paper mill factory's operation. The average amount of drinking water purchased increased threefold from 4.30 gallons to 12.36 gallons/month.

Table 5. Volume of drinking water purchased from the drinking water factory before and after the establishment of the KPS Paper Mill

	Before paper mill (gallon/month)	**After paper mill (gallon/month)**
Average per household	4.30	12.36
Total water consumption	835	2,422

Source: Field survey

3.3 Analysis of the Economic Value of the Adverse Impacts of Wastewater Pollution

Based on the assumption that the two villages had very similar characteristics apart from the presence of wastewater pollution, the environmental impact of the KPS Paper Mill was assessed by looking at the differences in fish loss and drinking water consumption. Vegetable production was not included in the comparison because only a few households in Ban Numkeng engaged in this.

3.3.1 Fish loss due to water contamination

The difference in the volume of fish caught in the two villages was significant (Table 6 and Figure 7). The average volume of fish caught per fishing household in Ban Numkeng was 21.45 kg/month while that in Ban Illai, it was only 1.8 kg/month. The Ban Illai respondents believed that the decline in fish catch was largely due to the wastewater KPS discharged into the stream.

Table 6. Volume of fish caught per fishing household in the target and control villages

	Ban Illai (kg/month)	**Ban Numkeng (kg/month)**
Rainy season	2.28	22.93
Dry season	1.32	19.98
Average	1.8	21.46

Source: field survey

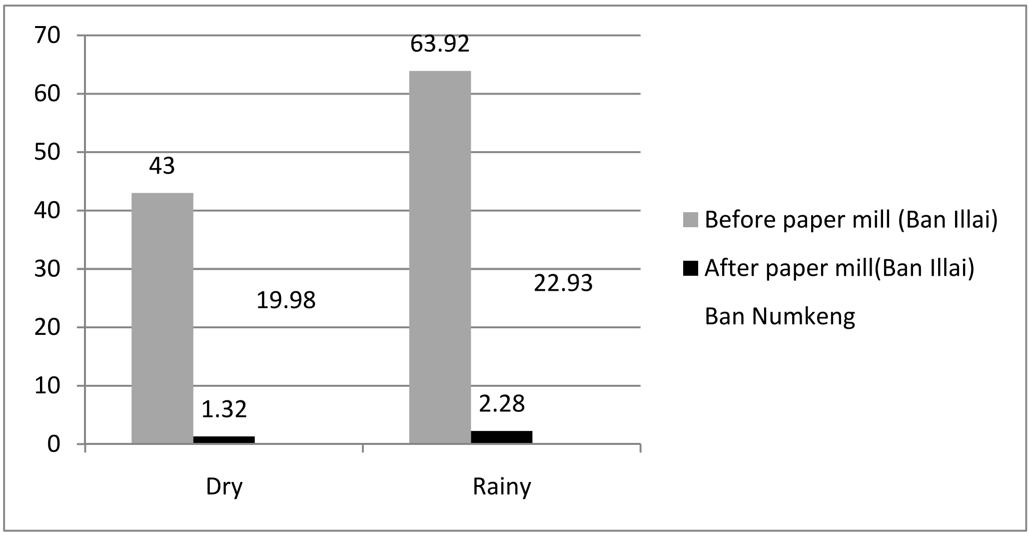

Figure 7. Volume of fish caught per fishing household in Ban Illai and Ban Numkeng (kg/month)

The villagers also believed that their fish ponds were seriously affected by the wastewater discharged by the factory because many fish had died. KPS has compensated the villagers for this many times but the villagers feel that the amount is not sufficient.

Based on the comparison of the two villages, it is apparent that the wastewater KPS discharges has seriously damaged the environment and affected fishing activities. Our survey found that around 80 per cent of the Ban Illai households were affected. Using the average fish catch for both the rainy and dry seasons, the total loss was estimated by multiplying the average volume of fish caught per month with fish prices[4]. The difference in revenue between the two villages was used to represent the monetary loss in fish output due to changes in water quality. The total revenue loss from the depleted fish resources was estimated to be USD 148,210/year (Table 7), estimated to be about USD 375/household/year.

Table 7. Fish catch in Ban Illai and Ban Numkeng per fishing household

	Ban Illai	**Ban Numkeng**
Rainy season (kg/month)	2.28	22.93
Dry season (kg/month)	1.32	19.98
Average (kg/month)	1.8	21.46
Monetization (kip) (monthly value)	28,636	341,328
1 year (kip)	343, 632	4,095 936
Total for 395 hh	USD148,210 (USD375 per fishing hh)	

Note: Average market price of fish = 15,909 kip (USD 1.6).

3.3.2 Reduction in rice output due to water contamination

The difference between the rice yields in the two villages was compared to determine the impact of wastewater contamination on rice production. Figure 8 shows that Ban Numkeng's average rice yield was about 2,211.5 kg/farming household in the

[4] Calculated from the market prices of various kinds of fish found in the stream.

rainy season. The average rice yield in Ban Illai was much lower at 1,621.5 kg/farming household.

The Ban Illai respondents believed that the contaminated water in their rice fields was the cause of their low annual harvests. The water that flowed into the local farmers' fields was mainly from the stream. Some of it came from the local reservoir. Local farmers usually planted rice twice a year while some planted it only once a year. The impact of the wastewater on rice yields varied depending on the field's distance from the stream. The water in the fields also irritated the farmers' skin, emitted an unpleasant odor, and was dark in color.

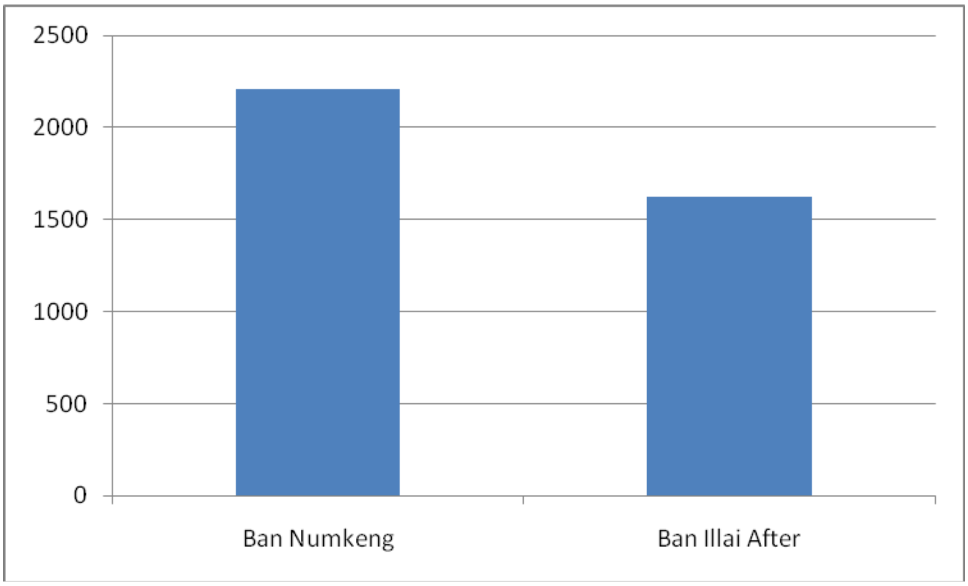

Figure 8. Rice yields in Ban Illai and Ban Numkeng (in kg/household/month)

The process used in computing the monetary value of the loss of fish resources was followed in monetizing the loss in rice yields. As shown in Table 8, the rice output in the two villages was multiplied by the market price of paddy. The difference in revenue reflects the monetary value of the impact of water pollution on rice production, which was estimated to be USD 118/year.

Table 8. Difference in rice production between Ban Illai and Ban Numkeng

	Ban Numkeng	**Ban Illai**	**Unit/month/household**
Rice output	2,211.5	1,621.5	kg
Monetization	4,423,000	3,243,000	kip
Difference in rice production	1,180,000 kip or USD 118		

Note: Market price of rice = 2,000 kip (USD 0.2) per kilogram. 1 USD = 10,000 kip.

3.3.3 Health impacts

The factory's wastewater had also affected the local villagers' health. However, many impacts had been reported. Moreover, the impacts were limited to the villagers who used the stream for fishing, rice growing, and vegetable production. These villagers reported suffering from allergies, skin irritation, breathing difficulties, and nausea. Because of these, they generally avoided going near the stream or using its water.

Figure 9 shows the negative impacts of wastewater discharge on the local people's health. The most prevalent ailment experienced was allergies and skin irritation. The very poor were the most vulnerable as they had no choice but to continue using the stream water for their daily activities. The following ailments were also identified as having been caused by the wastewater pollution: stomachaches, trachoma, nausea, and breathing difficulties. However, some who lived along the stream and depended on it did not consider these ailments to be related to water pollution. Others said that seasonal illnesses, such as the cough and flu, were not clearly associated with the pollution from the paper mill's wastewater.

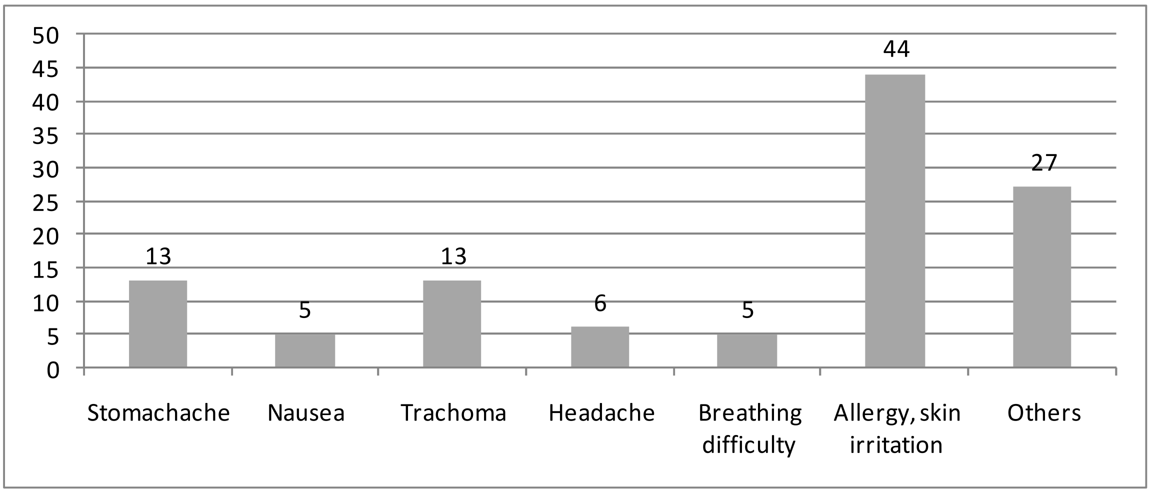

Figure 9. Ailments experienced by the Ban Illai villagers
Note: The figures show the frequency.

3.3.4 Estimating the total economic loss

The estimated fish and rice output losses were strongly perceived by the respondents to be caused by the paper mill's wastewater discharge. The estimated costs of these losses were scaled-up to determine the overall economic loss from the contaminated water in the village. Based on the statistics that 80 per cent of Ban Illai households earned their living through rice growing and fishery, it was determined that the total economic loss for the whole village was USD 190,905/year or about USD 408/household per year (Table 9).

Table 9. Total economic loss at the village level

Number	Sample	Total	Economic loss/household/year (USD)	Economic loss for the village per year (USD)
Households	222	500		
Fishermen	175	395	375	148,125
Rice farmers	160	360	118	42480
Total			408	190,905

4.0 KPS PAPER MILL OPERATIONS AND WASTEWATER PRODUCTION

The results of the wastewater sample analysis showed that the quality of the wastewater and surface water in Ban Illai did not pass the effluent standards (Table 10). There is a need to treat the wastewater from the paper mill before it is discharged into the environment. If no appropriate treatment system is adopted, the environmental damage will become worse and the stream will eventually die. The poor water quality not only affects the local people's livelihood; it also affects the survival of the aquatic animals and other life forms depending on the ecosystem.

Table 10. Effluent standards and samples

Factors	Effluent standard	Effluent sample
BOD	30 mg/l	130 mg/l
TSS	30 mg/l	293mg/l
PH	6 – 9.5	7.64

4.1 Factory Survey

4.1.1 Production and wastewater generated

Using a series of three high pressure (HP) pumps, KPS pumps water from the Houay Khao Stream to the factory for production purposes. The water is stored in three underground buffer tanks. Another three HP pumps are used to supply water from the tanks to the production process. There is no treatment for the supplied water. The factory uses electricity from the national electricity grid. The cost of energy consumption is about 20 to 25 million kip/month. The factory has no electrical generator. Two boilers supply steam for the paper-making process, which consumes 7,500 liters of dense oil every four days.

The KPS Paper Mill is an integrated pulp and paper factory. The raw material processed is bamboo, which is reduced to chips by a cutter. For delignification, the chips are immersed in a series of five tanks containing caustic soda, an alkaline solution. Sulfur is also added. The retention time in the delignification stage is five to eight days. After immersion, the chips are removed manually and placed in a grinder. The pulp produced in the grinder station is mixed with recycled paper (which includes rejects and surplus paper) in a water tank. After screening, the mixture is transferred into the paper-making machines. The finished paper is then colored, cut and stamped before being packed for export. The flowchart of the production line is given in Figure 11.

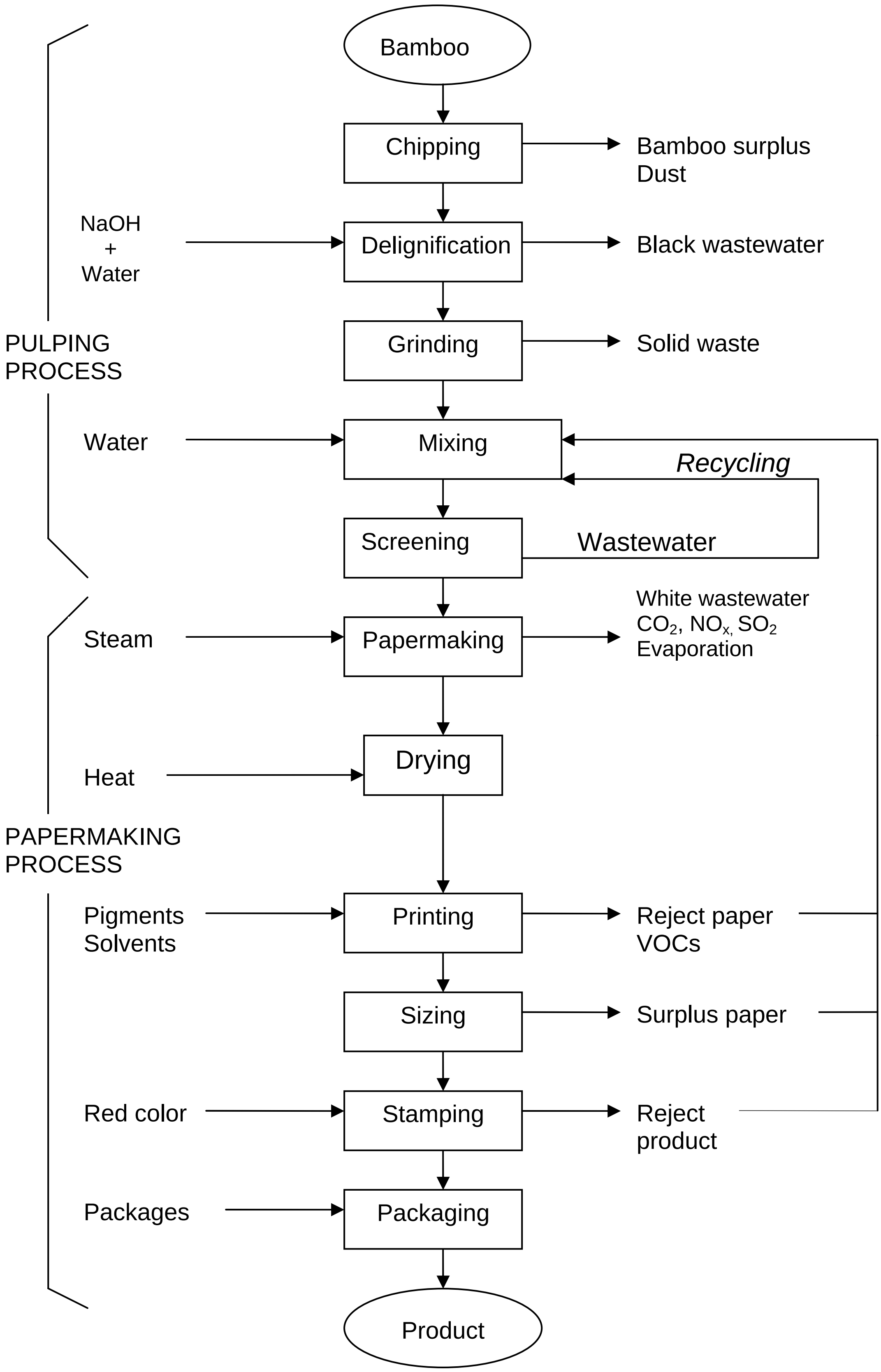

Figure 11. Flowchart of the production line in KPS Paper Mill

The overall consumption and emissions/discharge levels of the factory are shown in Table 11 in terms of amounts per tonne of paper produced.

Table 11. Average inputs and outputs from the KPS Paper Mill per tonne of paper produced (July 2007)

INPUTS			**OUTPUTS**		
Raw materials	**Amount**	**Unit**	**Product**	**Amount**	**Unit**
Bamboo	3,000	kg/t	Joss paper	1500	tonne/area
NaOH	123	kg/t	**Emissions**		
Sulfur	40	kg/t			
Black coloring	1	mg/t	NO_x		
Aluminum hydroxide	2	kg/t	CO_2		
Methanol	36	l/t	SO_2		
EAC	8	l/t	VOCs		
Glue	8	kg/t	Dust		
Red coloring	0.2	kg/t			
Water consumption			**Discharge**		
Surface water			Black	1.8	cum/t
			White		cum/t
Energy			**Solid waste/ Residue**		
Fuel oil	370	l/t	Reject paper	2.4	kg/t
Wood			- Hazardous waste (e.g., used oil, mixture of solvents, contaminated cloths) - Bamboo surplus - Sludge		

4.1.2 Wastewater discharge by KPS Paper Mill

There are two types of wastewater from the factory: 1) black wastewater from the delignification stage of the pulping process; and 2) white wastewater from the paper-making process. Only the black wastewater is discharged directly into the local stream.

The black wastewater is discharged into a series of ponds in the factory through two separated pipeline systems. Some of the ponds are full of biomass and solid waste. No protective layer covers the bottom of the ponds to prevent contamination of the groundwater. The risk of overflow from the ponds is high, particularly during the rainy season. In fact, the ponds were damaged in June 2005 due to heavy storms and a large volume of wastewater overflowed into villagers' fish ponds and rice fields.

Table 12 reveals that the contaminants in the wastewater are higher than the standards. Thus, mitigation solutions and efficient treatment methods to minimize the negative environmental impacts of the discharge are necessary.

Table 12. Pollutants in the wastewater in the factory's ponds

Parameters	**Unit**	**White wastewater discharged**	**Black wastewater discharged**	**Maximum allowed (Industrial Wastewater Discharge Regulation 326/MIH)**
pH		10	9.23	6 – 9.5
Color	CU	160	14,000	-
BOD5	mg/l	135	475	90
COD	mg/l	3,238	7,040	-
TSS	mg/l	292	6,435	60
TDS	mg/l	2,572	15,548	3,500
Cl-	mg/l	404.9	1,410	500

Notes: pH = level of acidity/alkalinity; BOD5 = Biochemical Oxygen Demand; COD = Chemical Oxygen Demand; TSS = Total Suspended Solids

5.0 TECHNOLOGICAL OPTIONS FOR TREATING WASTEWATER

During the last factory visit, the research team observed that there were many leakages in the water supply pipelines and chemical spillage in the plant. However, the amount of water consumed by the factory could not be estimated. The factory used three high pressure water pumps 24 hours a day. In any event, before applying any wastewater treatment, the factory should minimize its water consumption and control spillage. Due to their different characteristics, white and black wastewater should be treated separately as described below.

5.1 White Wastewater Treatment

The white wastewater from the paper-making process contains a lot of fibers. Collection and reuse of the fibers will help the factory reduce the quantity of raw material. Moreover, the treated effluent can be recycled for use at the mixing stage of the pulping process. Recycling would significantly reduce water consumption and the flow of discharged wastewater.

Suggested treatment alternatives are (i) dissolved air flotation and (ii) sedimentation to clean/remove the fibers from the effluent.

i) Option 1: Dissolved air flotation

The principle of flotation is to use pressurized air to float fibers to the wastewater surface. Figure 11 illustrates the steps of this process.

- Description: Air is dissolved in the wastewater under several atmospheres of pressure, followed by a release of the pressure to atmospheric level. The entire flow is held in a retention tank under pressure for several minutes to allow time for the air to dissolve.

The pressurized flow then enters the flotation tank where the air will escape out of the solution through minute bubbles throughout the entire volume of the liquid. Through this process, fibers will also float to the surface of the water and will be collected by a skimming operation and then dewatered in a filter press. The entire treated effluent will be stored in a buffer tank for reuse in the process. The pressed solid will be returned to the pulp mixing stage. Wastewater from the press will be returned to the equalization stage.

- Cost estimation: The capital investment is approximately USD 23,000 for a Lao paper mill with a capacity of 2,500 tonnes per annum and an existing average product quantity of 1,200 tonnes per annum[5]. The operating cost of the system, including labor, is approximately USD 4,560 – 6,000/year. These costs can be used as a reference for KPS, which has an existing product quantity of 1,500 tonnes per annum, with the possibility of expansion in future.

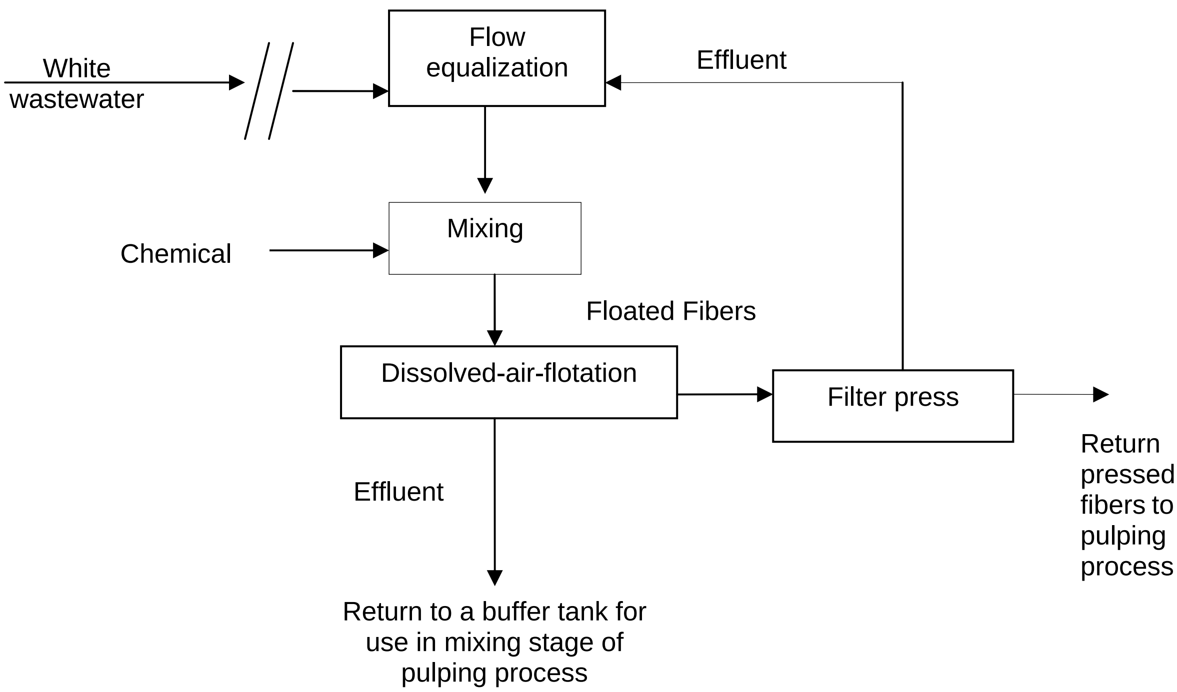

Figure 12. Flow chart of the dissolved air flotation treatment process for white wastewater

ii) Option 2: Sedimentation

The other option for white wastewater treatment is sedimentation, which involves the separation of suspended particles from the water through gravitational settling. Figure 12 illustrates the steps in this process.

- Description: Chemicals, usually aluminum salts, are added to the wastewater to make the fibers settle. Flocculants are used to make the particles settle faster. The particles are collected from a clarifier and then dried/dewatered by a filter press.

[5] Source: Cleaner Production (CP) Team. 2003. A white water treatment and recovery system at Asia Paper Mill B.S., Hatsayfong District, Vientiane, Laos.

- Cost estimation: The capital investment is estimated at approximately USD 43,500 for a Lao paper mill with a capacity of 2,500 tonnes per annum and an existing average product quantity of 1,200 tonnes per annum[6]. The operating cost of the system, including labor, is approximately USD 6,360/year. These costs can be used as a reference for KPS.

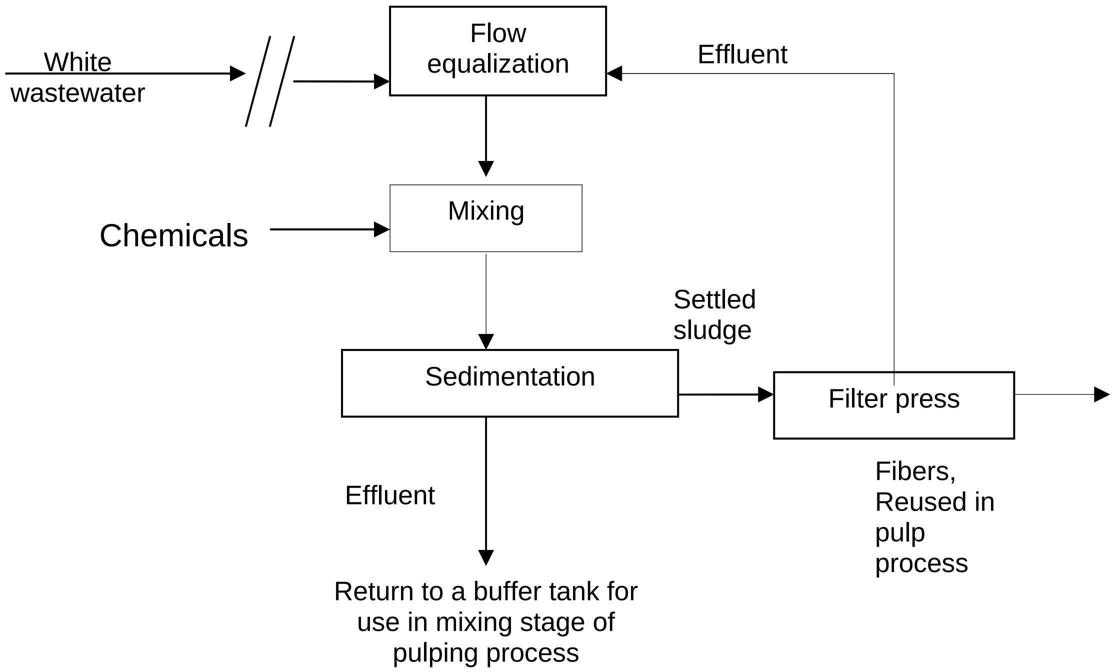

Figure 12. Flow chart of the sedimentation treatment process for white wastewater

The summary of the investment and operation costs for the alternatives in treating white wastewater namely, dissolved air flotation and sedimentation, are shown in Table 13.

Table 13. Investment and operation costs of the white wastewater treatment system alternatives

Costs	**Option 1: Dissolved air flotation**	**Option 2: Sedimentation**
Investment cost	USD 23,000	USD 43,500
Operating cost	USD 4,560 – 6000	USD 6,360

5.2 Black Wastewater Treatment

Typical characteristics of black wastewater from delignification are high pH, high COD and TSS. It is necessary to apply an ‘end-of-pipe’ treatment technology to reduce the contaminants in the effluent to meet discharge standards.

[6] Source: Cleaner Production (CP) Team. 2003. A white water treatment and recovery system at Asia Paper Mill B.S., Hatsayfong District, Vientiane, Laos.

The integration of chemical precipitation and biological treatment is proposed to treat the black wastewater. Chemical precipitation will remove most or at least, part of the suspended solids and some of the COD to protect the biological treatment from excessive loads and shocks and will provide more cost efficient purification of the effluents. Biological treatment is carried out for the removal of the dissolved and remaining suspended contaminants of organic matter/substances, which is achieved by biological degradation.

Swedish pilot plant studies on biological treatment combined with chemical precipitation have shown that a reduction rate of 80–90% of COD can be achieved.

Two options are proposed to treat the black wastewater from KPS. Both have the same first stages, namely, screening, equalization, precipitation, flocculation, and clarification. The only difference is method of bio-treatment; one uses activated sludge while the other uses stabilization ponds.

i) Option 1: Biological treatment with activated sludge

- Description: The activated sludge plant consists of two main units, the aeration tank and the secondary clarifier (sedimentation tank). The first stage involves the aeration tank. Here, the effluent is treated with a culture of micro-organisms (activated sludge), present in high concentrations. The retention time is about 15-48 hours. The sludge is later separated from the water in the clarifier. Most of the sludge is recycled back to the aeration tank to maintain the high sludge concentration there. A small part of the sludge, corresponding to the net growth, is removed from the system as excess sludge. Oxygen is put into the aeration tank using mechanical aeration equipment. Figure 13 illustrates the activated sludge treatment process.

- Cost estimation: The investment cost will be approximately USD 113,000 for the KPS Paper Mill, which has a product quantity of 1,500 tonnes per annum. Operation costs should be around USD 9,400/year.

ii) Option 2: Biological treatment using stabilization ponds

- Description: After the primary treatment and chemical precipitation process, the effluent goes into a three-stage stabilization pond system. There are two parallel treatment process trains. In the case of emergency or during repair, it is possible to isolate them. Figure 14 illustrates the process of this treatment technology.

  The first stage of the three-stage stabilization pond system involves the anaerobic ponds. The primary function of these ponds is to separate the solids in the incoming wastewater through sedimentation. The solids, which sink to the bottom of the deep ponds, will form a sludge layer. This layer will undergo anaerobic digestion. The digestion process reduces the volatile solid content in the sludge and the overall sludge mass thereby rendering it stable and more suitable for subsequent agricultural use after drying. The concrete bottom zone is fully lined with high density polyethylene (HDPE) liner.

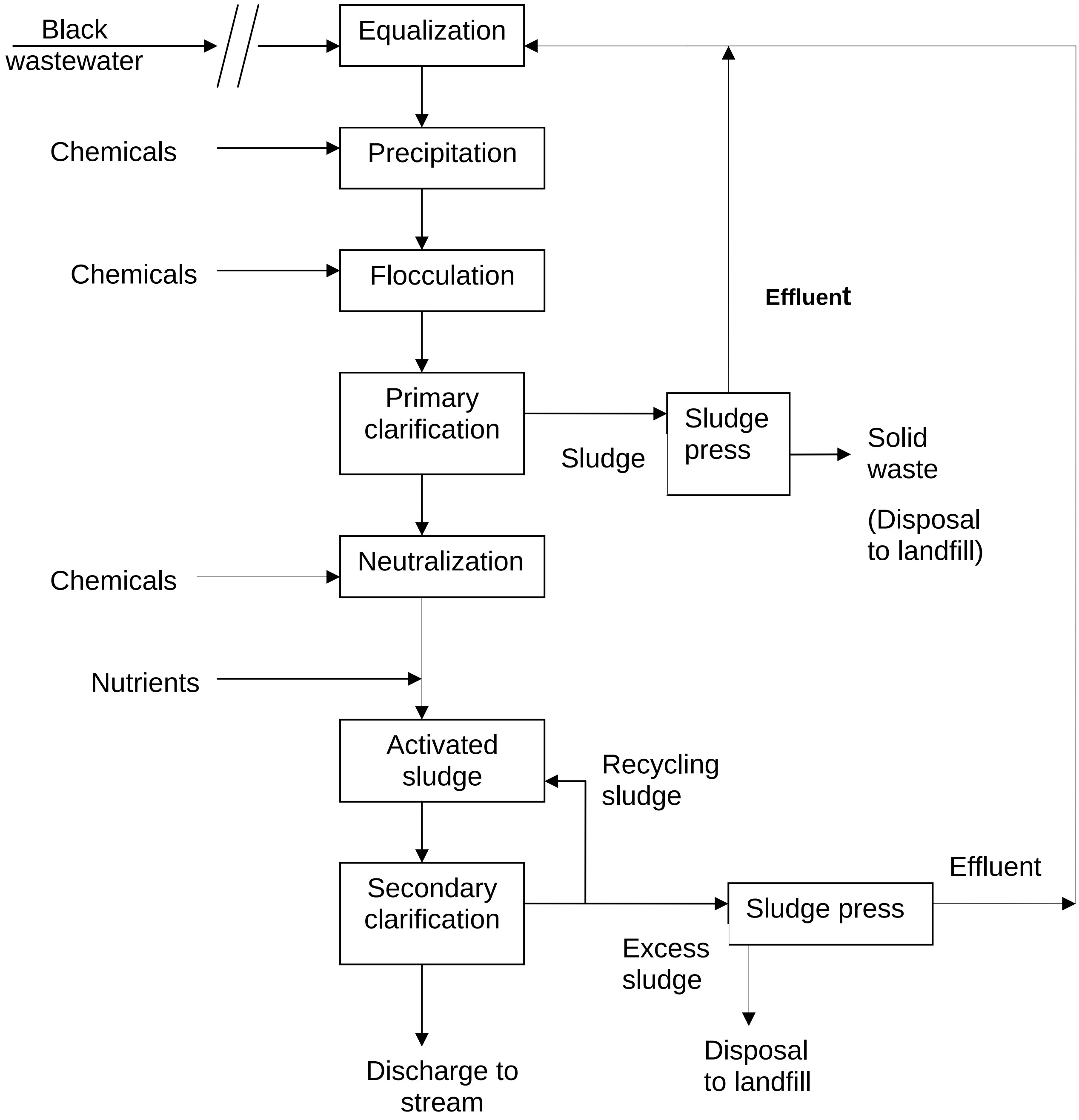

Figure 13. Flow chart of the black wastewater treatment process using activated sludge

The facultative ponds represent the second stage of the stabilization pond system where the aerobic biological oxidation of organic matter through bacterial cell growth takes place. The cellular matter created eventually dies and settles at the bottom of the pond where it is anaerobically digested by bacteria. The bottom of the pond will be anaerobic while the middle of the pond will change in oxygen content on a daily basis, depending on the oxygen quantity released by the green algae growing on the water's surface. The facultative ponds use a combination of surface transfer of oxygen by wind action and oxygen released by algal growth processes to sustain oxidation demands.

No mechanical aeration is installed. This emphasizes the importance of pre-aerating the influent wastewater using a cascade aerator before it enters the facultative ponds. The facultative ponds are fully lined (both on the bottom and sides) with HDPE liner material. This liner ensures that the groundwater below is not contaminated by the wastewater in the ponds.

The final stage of the three-stage stabilization pond system takes place in the maturation ponds. The primary function of the maturation ponds is to disinfect the wastewater through ultraviolet (sunlight) light penetration into the shallow depths of the pond. The ponds in each train ensure a high level of disinfection. The secondary benefit of maturation ponds is the 'polishing' and clarification of the treated water prior to final discharge. Although some degree of biological oxidation does occur, this is not significant if compared to the biological oxidation activity in the facultative ponds. Only the side walls of the maturation ponds are lined with HDPE liners. The bottom can also be lined if the budget is not limited.

It is also necessary to supply air to the wastewater to support the organic digestion process before the water enters the facultative and maturation ponds.

- Cost estimation: The system requires a large area with earth basins, which KPS has. Investment in this system will cost approximately USD 45,500 (excluding the cost of aerators) for the KPS Paper Mill, which has a product quantity of 1500 tonnes per annum. Operation costs will amount to USD 7,600/year.

Table 14. Comparison of the two treatment options for black wastewater*

Factors	Activated sludge	Stabilization ponds
Investment costs	Approx. USD 113,000	Approx. USD 45,500
Operation costs	Approx. USD 9,400	Approx. USD 7,600
Effluent removal efficiency	85 – 98% BOD removal 60 – 85% COD removal	40 – 85% BOD removal 30 – 60% COD removal
Land area	Small	Large
Smell	Possible to control	Cannot control; causes bad odor sometimes
Operating skill required	Technician needed	Technician not needed

*Based on technical experts assessment

Although the stabilization system for wastewater treatment has lower investment and operational costs, it has a somewhat lower capacity to remove contaminants. The technology requires a large land area and basin volume, but this is not a problem for KPS. Effluent foam and odor problems can sometimes be encountered. Sludge removal and disposal can also generate problems.

The advantages of the activated sludge system are its potential for very high treatment efficiencies, the possibility of controlling the process (particularly oxygen consumption), and a relatively low space demand. Among its disadvantages are its high investment and operational costs, its relatively high vulnerability to disturbances and, consequently, the risk of operational instability without any protective measures, such as an equalization basin.

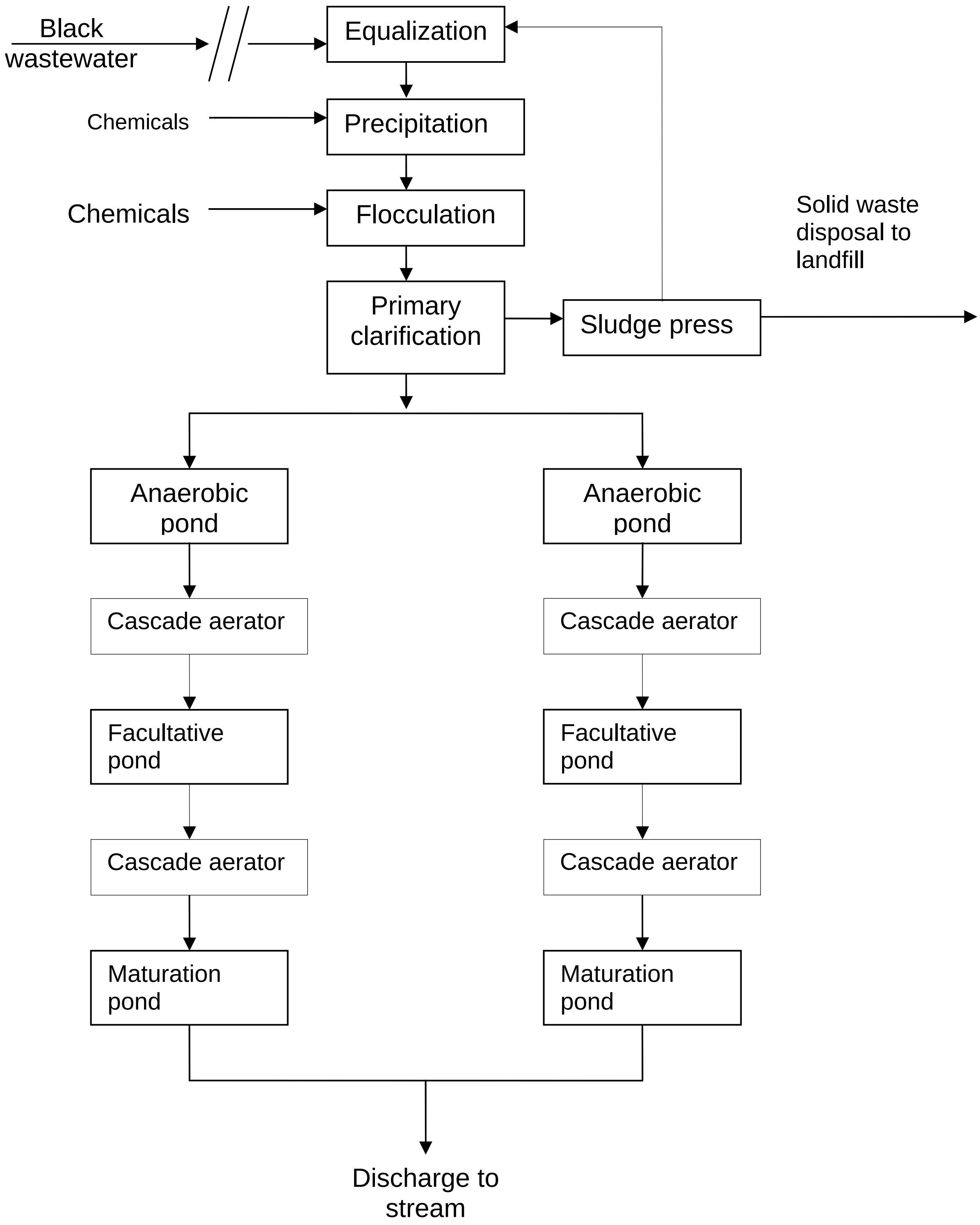

Figure 14. Flow chart of the black wastewater treatment process using stabilization ponds

5.3 Cost-Effectiveness Analysis

The amount of water used in the paper mill was estimated by STEA environmental engineer to be between 6-10 cubic meters per tonne of paper. The scenario of 10 cubic meters of water consumption per tonne was used in calculating the cost-effectiveness of the various wastewater treatment options.

The BOD produced in the factory was estimated based on the analysis of a sample of about 475 mg/liter or 0.475 kg/cubic meter of wastewater taken from the KPS Paper Mill. This number was multiplied with the water consumption of 10 cubic meters/tonne. With a paper production of five tonnes/day and 312 working days, the total paper production was estimated at 1,560 tonnes/year. The BOD was estimated by multiplying the amount of BOD in 10 cubic meters/tonne of water and the total paper used in a year as presented in Table 15 below.

Based on the characteristics of KPS, the proposed wastewater treatment technologies are presented in Table 16 below. Each option removes BOD from black wastewater differently. The overall treatment cost per kilogram of BOD is estimated at USD 17.95 for Option A (activated sludge) and USD 11.37 per kilogram of BOD for Option B (stabilization ponds). In other words, a USD 1.00 investment in wastewater treatment can reduce 0.06 and 0.09 kilogram of BOD using Options A and B, respectively.

Table 15. Annual BOD produced by KPS Paper Mill

Factors	Quantity
BOD	475 mg/l or 0.475 kg/m^3
Water	10 m^3/t
BOD and water	4.75 kg/t
Paper use per day	5 tonnes per day
Work days per year	312 days a year
Total paper used per year	1,560 tonnes/year
BOD per year	7,410 kg/year

Table 16. Cost-effectiveness analysis

	Option A	Option B	Unit
Wastewater treatment cost	122,400	53,100	US dollar
BOD removal	92%	63%	percentage
BOD (kg a year)	7,410	7,410	kg a year
Effectiveness measure (BOD reduced)	6,817.2	4,668.3	kg a year
Cost-Effectiveness Ratio (cost of overall treatment per kg of BOD reduced)	17.95	11.37	USD/kg
Economic-Cost Ratio (BOD reduced per USD)	0.06	0.09	kg/USD

6.0 CONCLUSIONS AND RECOMMENDATIONS

The volume of wastewater discharged from the KPS Paper Mill will be significantly reduced once the factory adopts cleaner production technologies that minimize water use and recycle treated white wastewater. The proposed black wastewater treatment technologies will reduce the remaining impacts of the factory's wastewater to the environment. A USD 1.00 investment in wastewater treatment can reduce 0.06 and 0.09 kilogram of BOD using activated sludge and stabilization ponds as treatment options.

The cost estimates are based on the available technologies which are used in pulp and paper factories in Europe and other countries. In order to calculate the treatment plant design costs, it was necessary to measure the volume of the white and black wastewater as well as analyze wastewater samples in order to have detailed and accurate data of the inlet effluents.

In implementing an effective wastewater management system, the following measures are recommended:

- Apply cleaner technologies to minimize water consumption and reduce generation of wastewater at the source. (These solutions are not detailed in this document.)
- Install/build a treatment system for the recycling of white wastewater.
- Install/build an appropriate treatment plant for black wastewater.
- Set up monitoring plans for the management of the system and to keep track of the water quality.
- Install a proper information network system.
- Determine pollution sources.
- Involve the local community in the establishment of the wastewater system.

The government should also strengthen its capacity to regulate and monitor industries in order to ensure that they perform the necessary wastewater treatment. It should take the following measures:

- Implement regulations to control the use of water sources.
- Implement regulations to ensure that polluters mitigate the pollution caused by the discharge of their wastewater.
- Assist polluting industries in finding appropriate wastewater treatment solutions.
- Determine clear categories of water sources by type, quality and standard to be used for different purposes.
- Involve the local people in decision-making.

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