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Alternative wastewater treatment strategies

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INTRODUCTION

It is very often assumed that on-site wastewater treatment in general is more economical and involves less complicated technology than centralized wastewater treatment. Although this assumption is surely correct in many practical cases, it must not be generalized. It depends on the specific situation of an individual case whether the appropriate solution is on-site or centralized wastewater treatment. This is demonstrated by the following case study, where centralized wastewater treatment offers both, lower cost as well as simpler technology.

The case study shows a situation which is very frequent in developing countries: the planning area is a fast developing industrial area on the outskirts of a metropolis. Besides the industrial area the planning area also includes a residential and commercial area. The surrounding land is still used for agriculture. Some parts of the stormwater and treated wastewater from the new builtup areas are discharged to irrigation canals. This situation has already resulted in the occasional pollution of irrigation water.

Six alternatives for centralized wastewater treatment and on-site wastewater treatment were compared. The comparison includes the cost of the different alternatives as well as an assessment of the technology involved. The following paragraphs give first a description of the planning area and of the design criteria, on which the alternative systems are based. Then the alternatives are compared in economical as well as in technical terms.

THE PROJECT AREA

An overview of the project area is given in Fig. 1. The area is located in a flat river basin. The climate is tropical with a mean monthly temperature between 20.5°C in December and 29.9 °C in April. The sub-soil conditions are marked by several layers of clay and a groundwater level close to the surface. Wastewater infiltration, therefore, is not possible. The bearing capacity of the sub-soil is very low and all heavy

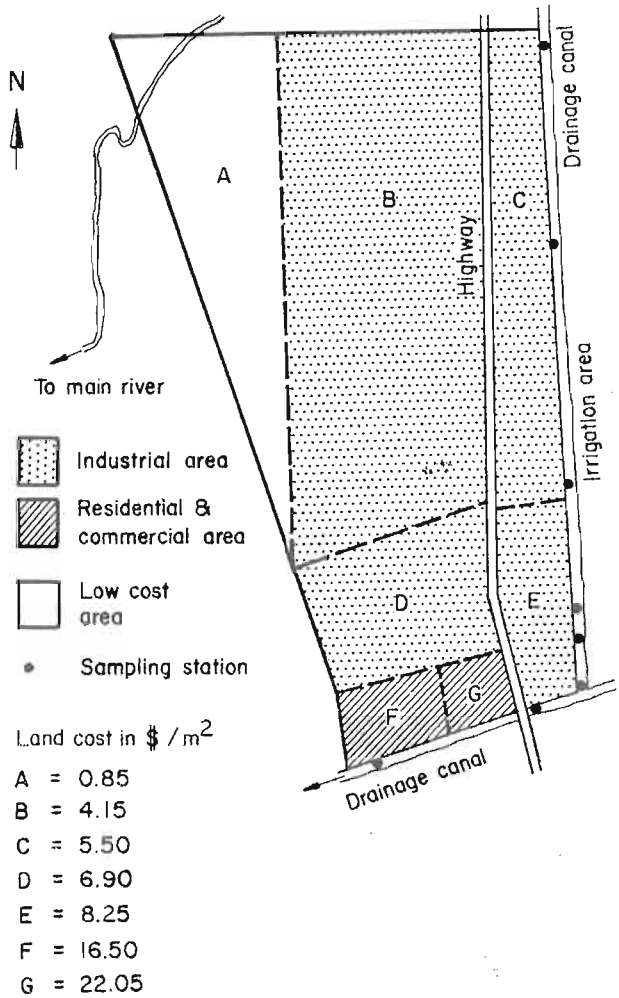

Fig. 1: Overview of the project area

structures, even septic tanks, are to be based on piles.

Because of its vicinity to a metropolis, the project area is influenced by the rapid industrial and economic development of the metropolis. The estimated annual growth rate is 8% for the population and 21 ha for the industrial area. Main types of industry are textile, food processing, and ceramic industry. For the planning period a population of 31,650 inhabitants and an industrial builtup area of 774 ha are expected. The total project area comprises about 1,900 ha.

The commercial and residential area is supplied by a public water supply scheme, whereas the water source of factories are about 80 deepwells. The total draw-off from the underground is estimated to be 21,000 m^3/d. The sanitary wastewater of the residential and commercial area is treated by on-site facilities, in most cases cesspools. The wastewater of the industrial areas is mainly process water, whereas domestic wastewater counts for less than 18%. The total wastewater flow of about 21,000 m^3/d carries a BOD_5 load of about 10,000 kg/d. The most frequent treatment processes in the industrial area are trickling filter, activating sludge, chemical coagulation, and air floatation.

After treatment the wastewater is discharged to some small ponds outside of the builtup area. The overflow of the ponds is discharged to canals which partly discharge to a river and partly are connected to the irrigation scheme. The fact that most cesspools and industrial treatment plants cannot maintain the effluent standards have resulted already in pollution of irrigation water. With respect to irrigation, the water samples taken from 6 locations at the east side of the planning area are of particular interest. They show a dissolved oxygen content between 0.2 and 1.5 mg/ℓ indicating considerable organic pollution. The maximum electrical conductivity was found to be 1500 $\mu S/cm^{-1}$, the maximum residual sodium carbonate 5.01 mg/ℓ. The values exceed by far the standards of 750 $\mu S/cm^{-1}$ and 1.25 mg/ℓ respectively.

ALTERNATIVE WASTEWATER MANAGEMENT STRATEGIES

The present on-site wastewater treatment was compared to 6 alternative systems with central treatment plants. For the centralized systems two types of collection systems were compared, a) a piped system and b) a partly open channel system. Open channels are only considered for the industrial area, whereas closed sewers are proposed for the commercial and residential area.

The wastewater from the commercial and residential area is discharged to a main sewer or open channel. For the sewer options, the main sewer is located along the highway in the industrial area. The wastewater from the factories reaches the main sewer by gravity. The open channels are located at the back of the factories for aesthetic as well as for economical reasons. The wastewater is to pumped to the open channels. Since the treatment plants of the factories are located at the back of the factories, an open sewer in front of the factories would increase the pumping cost.

Figs. 2 and 3 show the sewer and the open channel option for a centralized solution with one treatment plant.

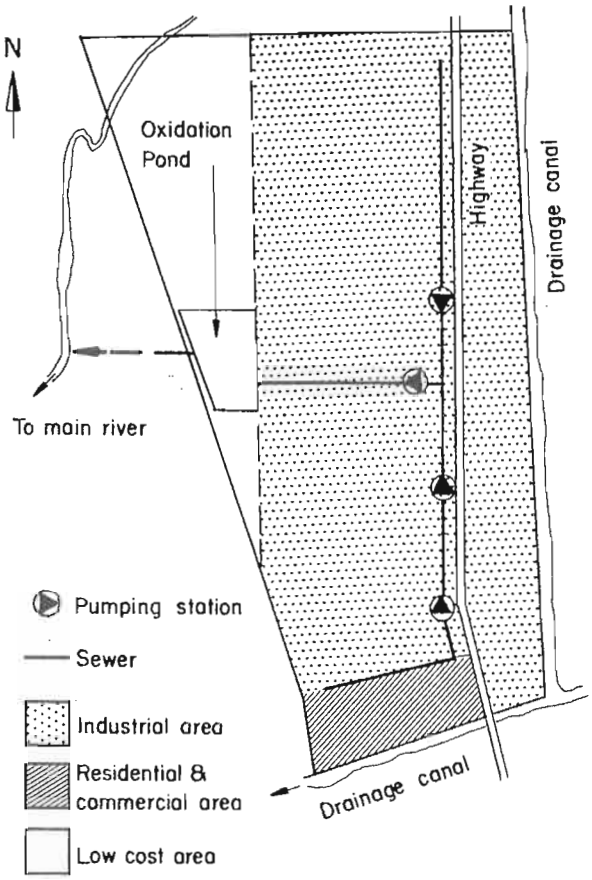

Fig. 2: Layout of the centralized wastewater treatment and collection scheme (sewer option)

The cost for a piped system is only slightly higher than for an open channel system. This is mainly due to the fact that open channels are to be built above the flood level with accordingly high cost. The further comparison between on-site wastewater treatment and a centralized solution is based on the open channel system. However, the choice between a piped system and an open channel system affects the comparison between on-site wastewater treatment and centralized treatment only to a very limited extent.

Fig. 3 shows the layout of the most economical solution. The treatment unit is a stabilization pond. The wastewater is transported to the treatment plant by two main sewers. Since the area is flat, 9 pumping stations are required. They are equipped with submersible pumps. The five other alternatives for centralized

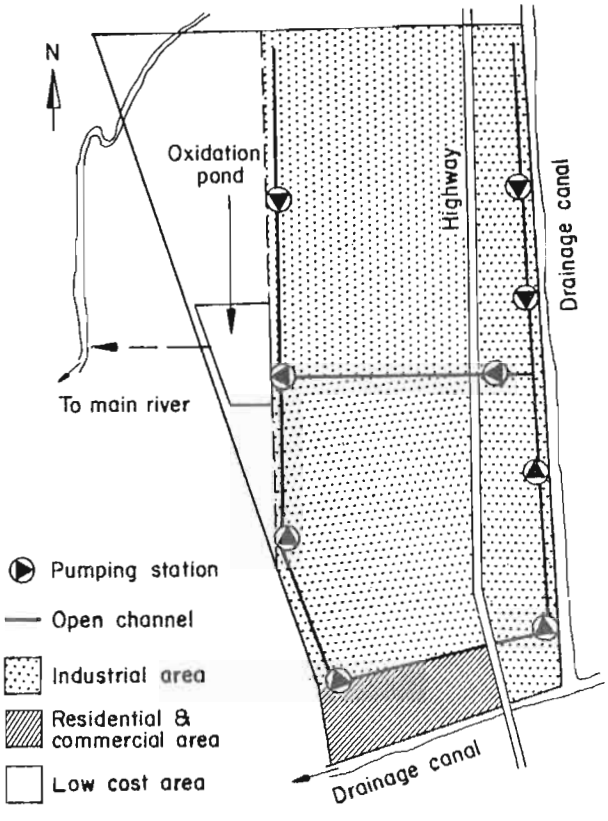

Fig. 3: Layout of the centralized wastewater treatment and collection scheme (open channel option)

treatment show similar layouts. The main difference is that instead of 1 treatment plant, 2 and 3 either aerated or unaerated plants are used.

TECHNICAL AND ECONOMICAL DESIGN CRITERIA

Preliminary designs were developed for all alternatives which were based on common design standards. Some specific design criteria are given in Table 1. The cost of all facilities is developed from the preliminary designs and local unit cost rates. The economic comparison is based on the present value. The main criteria for the economic comparison are also given in Table 1. For interest and for energy cost inflation two different rates were used. The interest rate of 14% represents the rate for public loans, the rate of 18% the commercial rate. The increase of energy cost of 25% was chosen in view of the high increase of the last 5 years, which was about 29% as annual average in the project area. The lower rate of 7% results from the consideration that the high increase of the past years was a single event rather than a long term development. The other rates are based on official statistics.

Table 1: Basic design criteria for the planning period

	Industrial area	Residential and commercial area
Builtup area	774 ha	92 ha
Pop. density	-	344 c/ha
Flowrate	1 /(s·ha)	201 /(c·d)
BOD_5	44 kg/(d·ha)	52 g/(c·d)
Infiltration	0.9 /(s·ha)	0.9 /(s·ha)

Planning period	25 a
Interest rate	14 and 18%
Inflation rate for	
construction	6%
equipment	7%
energy, operation	7 and 25%

A difficulty arose in the estimation of the future cost for on-site wastewater treatment, since it is not known which type of treatment plant the future factories will build. To cope with this problem, the present cost of on-site treatment was extrapolated on the basis of the present and the expected future BOD load.

RESULTS OF THE COMPARISON

The most significant result is that on-site treatment is about 4 to 5 times more expensive than the various centralized treatment alternatives. The explanation is that the ponds for centralized treatment are located in an area with very low land cost (see Fig. 1). On the contrary, on-site treatment which is done on valuable industrial land employs rather expensive processes such as activated sludge, coagulation and air floatation. This general result is also not altered by the different rates of interest and the extremely different increase of energy cost. These variations change only to some extent the ranking order among the centralized treatment alternatives.

The cost relationships become apparent from Table 2 which shows the present value for the main cost items of centralized and of on-site wastewater treatment options. The cost for treatment plants is very high for the on-site solution compared to the centralized solution. For the variants with the high increase of energy cost, the operation costs are the main cost factor, which result from operating the treatment plants in the on-site option and operating the pumping stations in the centralized option. They count in these cases for about 70-80%

Table 2: Present value of on-site and centralized wastewater treatment strategies

Item	Present value in monetary units			
	Interest rate 14%		Interest rate 18%	
	Operation cost increase		Operation cost increase	
	7%	25%	7%	25%
A) On-site treatment				
Treatment plant construction	560	560	532	532
Treatment plant operation	316	2659	231	1496
Total	876	3219	763	2028
B) Centralized treatment				
Treatment plant construction	77	77	77	77
Treatment plant operation	8	67	6	38
Pumping stations construction	18	18	17	17
Pumping stations operation	53	448	39	252
Open channel construction	36	36	37	37
Open channel operation	1	11	1	6
Total	193	657	177	427

and 60-70% respectively of the total present value.

Besides the lower cost the technology employed for centralized treatment is also much simpler. Treatment is done in an oxidation pond. The most complicated elements of the centralized system are submersible pumps. This simple technology is be compared to the rather complicated processes employed for on-site treatment. This difference in technology is particularly important for operation and maintenance. Professional staff for the many individual plants cannot be expected. Another disadvantage of on-site treatment is that the plants are rather small. It is a well known experience that processes such as the activated sludge process are more difficult to operate in small units.

The centralized treatment is also advantageous in respect to the receiving water conditions. The effluent of the oxidation ponds is discharged to a small water course on the west side of the area, which directly leads to the main river. The wastewater discharge therefore is separated from the irrigation area on the east side of the industrial area. In contrast to the centralized schemes, a part of the effluent of on-site treatment plants discharges to drainage canals which at some points are connected with irrigation canals.

CONCLUSIONS

In the presented case study, centralized wastewater treatment is advantageous compared to on-site wastewater treatment. It involves lower cost as well as a simpler technology and a better protection of the receiving water. However, the study represents an individual case and should not be generalized. It simply shows that there is no general solution. Each planning problem demands an individual solution based on specific conditions. The main reason which makes centralized treatment favourable in the presented case is, that inexpensive land is available for the construction of oxidation ponds.

REFERENCE

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