TENTATIVE REPORT ON
FEASIBILITY STUDY OF
RO BRINE REJECT TREATMENT IN
THE KINGDOM OF SAUDI ARABIA

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1. Outline

This feasibility study is carried out to meet the request of the Government of the Kingdom of Saudi Arabia to evaluate the method of disposal of brine reject from the reverse osmosis (RO) plant which was installed to treat ground water pumped up from deep well in Riyadh City.

In order to cope with demands for fresh water by increasing population of Riyadh City, the Government of the Kingdom of Saudi Arabia have decided to supply potable water from aquifer of 1,200 meters to 1,500 meters below the surface. This ground water has high values of hardness, sulfuric acid radical and total disolved solids (TDS), and is supplied as potable water after the treatment by lime soda process which is mainly aimed to softening water quality in the existing Malez, Shemessy and Manfouha Water Treatment Plants.

As a result of studies by the Ministry of Agriculture and Water, the Government of the Kingdom of Saudi Arabia, a new method including RO process was adopted in order to improve the quality of potable water of which sources is ground water from deep well.

Improvement of quality of supply water would be attained by the RO plant. However, on the contrary, there arise a new problem of the treatment of concentrated brine that are rejected from the RO plant.

It is said that Malez, Shemessy and Manfouha Plants are not able to start formal operation of the RO plant because of brine reject disposal problem.

A solusion for this problem is to dispose the brine reject to the existing municipal sewage pipeline. However, the capacity of sewage treatment system and the influence to the water re-use program which is currently promoted at the part of sewage treatment plants must be fully considered.

A counter measure must also be decided if the disposal of the RO brine reject into the municipal sewage system is not allowed.

In this report, feasibilities of the following cases are studied:

Case 1: Evaporation Pond in the Suburbs

Case 2: Deep Well Injection

Case 3: Concentration by Electrodialysis Process

- Case 3-1: Electrodialysis process followed by evaporation pond in the suburbs
- Case 3-2: Electrodialysis process followed by evaporation pond at the RO plant site
- Case 3-3: Electrodialysis process followed by evaporator/crystallizer
- Case 3-4: Electrodialysis process followed by deep well injection

Case 4: Concentration by Reverse Osmosis Process

Case 5: Disposal into Municipal Sewage Pipeline

Case 6: Recovery of Valuables

Details of the above case studies will be described in Chapter 3.

This tentative report was prepared on the bais of limited data which were offered by the Ministry of Agriculture and Water, the Government of the Kingdom of Saudi Arabia and those publicly known. But, we found discordance in these data.

Therefore, a series of discussions must be carried out in order to make the contents of this feasibility study identical to the actual condition.

Time schedule of this feasibility study is shown in Fig. 1.1.

We would like to clarify uncertain data and conditions through the discussions and site investigations, and hope to submit you better study report. We would sincerely appreciate your rendering us assistance and cooperation.

Fig. 1.1: Time Schedule

Items \ Year & Month	1980				1981		
	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1. Preparation							
1) Planning	—						
2) Tentative Report	—						
2. Site Meeting & Investigation	(26th)—	—(13th)					
1) Mtg. with MAW	(28th)						
2) Mtg. with WSA	(29th)						
3) Mtg. on Interim Report		(8th)					
4) Visits to Plants	—	—					
3. Assessment Studies							
1) Sewage Pipeline		—					
2) Sewage Treatment Plant		—					
3) Water Re-use		—					
4. Conceptual Design		—	—	—			
5. Final Report							
1) Drafting				—	—	—	
2) Draft check by MAW						(7-11)	
3) Presentation to MAW							

Note: MAW = Ministry of Agriculture and Water
WSA = Water and Sewage Authority

2. Tentative Conclusion and Proposal

2.1 Tentative Conclusion

1) On an assumption that capacity of sewage treatment system in Riyadh City is increased to 80,000 m^3/day in 1981 and that disposal of brine reject would not offer any problem to operation and maintenance of municipal sewage system, a total of 1,232 m^3/day brine reject from the RO plant can be disposed into municipal sewage pipeline.

2) We cannot recommend the disposal of total brine reject, that is discharged from RO plants installed in the water treatment plants in Riyadh City, to the existing municipal sewage system because the capacity of sewage treatment system is not sufficient at present time.

3) We have tentatively concluded that concentration by the electrodialysis (ED) process followed by evaporation pond is most suitable in both technological and operational points of view.

We anticipate that a total of 5,323 m^3/day of fresh water is produced by the ED process additionally and that there will be no effect to the municipal sewage system.

4) We do not think that recovery of chemicals from the concentrated brine is economically feasible, because the plant capacity is too small.

2.2 Tantative Proposal

1) We strongly recommend to complete the expansion program of sewage treatment plant as soon as possible.

2) On completion of the above-mentioned expansion

program, the brine reject from Malez RO Plant can be disposed into the municipal sewage pipeline.

3) As for the brine reject from Shemessy and Manfouha, we recommend to treat by the ED process followed by evaporation pond to be constructed in each plant, if necessary space would be available.

4) Schedules of the above recommended methods are as shown in the table below, in case brine reject of Malez RO Plant is disposed into the municipal sewage pipeline:

Method \ Year	1980	1981	1982	1983	1984	1985
Expansion of Sewage Treatment Plant			80,000	m^3/d	200,000	m^3/d
Brine Disposal from Malez RO Plant			1,232	m^3/d	Full	
ED Plant in Shemessy		(P)		(C)		(O)
ED Plant in Manfouha		(P)		(C)		(O)

Note: (P) = Preparation

(C) = Construction

(O) = Operation

3. Detail Description

The applicable methods for disposing brine reject are briefly summarized in previous section. In this section, those methods are described in some detail.

The methods to be discussed are as follows:

Case 1 Evaporation Pond in the Suburbs

Case 2 Deep Well Injection

Case 3 Concentration by Electrodialysis Process

Case 3-1 Electrodialysis process followed by evaporation pond in the suburbs

Case 3-2 Electrodialysis process followed by evaporation pond at the RO plant site

Case 3-3 Electrodialysis process followed by evaporator/crystallizer

Case 3-4 Electrodialysis process followed by deep well injection

Case 4 Concentration by Reverse Osmosis Process

Case 5 Disposal into Municipal Sewage Pipeline

Case 6 Recovery of Valuables

The plant construction costs for each method are estimated here. However, these costs only show the extent of the magnitude for evaluating the methods, because of lack of information to make an exact estimation. Operation costs are not shown in this tentative report because prices of utilities and chemicals are not known at this time. Consumption of utilities and chemicals are shown in each section, and operation cost will easily be calculated when the prices become clear.

The general conditions which are applied for this feasibility study are shown below, and specific conditions for each method are described in each section of said method.

General Conditions

1) Quantity of Brine Reject: 6,800 m^3/d

The feasibility study is made only for the Manfouha plant. The feasibility for other two plants will easily be supposed from the results of the study for the Manfouha plant.

2) Quality of Brine Reject

Sodium	3,520 mg/l
Calcium	160 mg/l
Magnesium	470 mg/l
Chloride	3,120 mg/l
Fluoride	0 mg/l
Bicarbonate	0 mg/l
Sulfate	5,350 mg/l
Silica	85 mg/l
Phosphate	20 mg/l
TDS	12,725 mg/l
pH	5 ∿ 6
Temperature	30°C

3) Climatological Data

Temperature and Humidity:

			Relative Humidity
Minimum	-4°C (winter)	----	100% ∿ 16%
Maximum	52°C (summer)	----	51% ∿ 5%

Highest Total Daily Rainfall:	Maximum 57 mm/d
Annual Rainfall (Erratic):	Minimum 15 mm
	Maximum 230 mm
Wind Velocity:	Maximum 128 km/h (carrying sand & dust)

Wettest Months: March - April

Driest Months: June - October

3.1 Case 1 -- Evaporation Pond in the Suburbs

1) General

The evaporation pond is a conventional method of waste water treatment in dry tropical areas. However, it is said that the evaporation pond system is not applicable, because the RO plants are located inside Riyadh City, and it is difficult to find a space for evaporation ponds around the RO plants as well as to construct pipelines through the town to evaporation ponds in the suburbs.

The evaporation pond method is studied here as a base case in comparison with other methods.

2) Design Basis

a) Capacity: 6,800 m^3/day

b) Source of brine reject: RO Plant

c) Climate conditions

Temperature (average):	24.7°C
Humidity (average):	43%
Rainfall (average):	81 mm/year
Sand storms (average):	75 times/year
Evaporation rate:	3,000 mm/year

d) Site condition of the evaporation pond

Location:	20 km from the RO plant
Terrain:	Flat desert field (no need of surface preparation)

3) Process Description

The method consists of a pump station at the RO plant site, a pipeline and a evaporation pond in the suburbs. The brine reject from the RO plant is pressurized by pumps and sent through a pipeline to the evaporation pond in the suburbs.

In the evaporation pond, water is evaporated into the atomosphere and the salt is deposited on the bottom of the evaporation pond.

The salt deposited is to be removed from the pond once every four years after the first operation of several years.

The evaporation rate is an important factor for designing an evaporation pond. The evaporation rate of 3,000 mm/year is assumed from the figures in Mexican and Australian salt field and may be too conservative for the Riyadh area. The evaporation pond is constructed in a desert field outside of the city. It is a type of earth diked pond having an area of 850,000 m^2.

The bottom of the pond is lined with plastic film to prevent infiltration of brine reject into the earth.

The pipeline having a nominal diameter of 350 mm is layed underground along roads.

The inner surface is lined with cement for corrosion protection.

4) Utilities and Chemical Consumption

The evaporation pond method consumes approximate 0.6×10^6 KWH/year of electric power for normal operation.

No other utility or chemicals are necessary except for handling the salt deposited.

5) Construction Cost

The construction cost of this method is approximate 19 million dollars.

The construction cost will vary greatly with the evaporation rate, topological conditions of the evaporation pond site, difficulties in the construction of the pipeline and the length of said pipeline.

6) Required Area

This method requires a space of about 200 m^2 for a pump station near the RO plant and a space of about 850,000 m^2 for the evaporation pond in the suburbs.

7) Discussion

The evaporation pond method will provide the easiest operation and lowest operation costs where land space for the evaporation pond and pipeline is available.

However, the salt deposited must be periodically removed from the pond and transferred to another place for permanent storage. It will be a troublesome work because of the large amount of the salt deposited: more than 30,000 ton/year.

If there are some suitable places to build a kind of dam utilizing natural valley, the evaporation pond can be constructed with less expense, and after the evaporation pond becomes full of the salt deposited, a new one can be built in a place near the old one in which the salt deposited remains for permanent storage. It seems to be a good solution to the problem of handling the salt deposited.

The following information is required for further studies on the evaporation pond method.

a) Climate in Riyadh

(1) Evaporation data

(i) Evaporation rate in each month

(ii) Method of measurement

(2) Sand storms

(i) Frequency in each month or in a year

(ii) Depth of sand deposited by a sand storm

(3) Temperature of surface water and brine reject from the RO plant

b) Configuration of the ground at the site considered

(1) Allowed area for the evaporation pond

(2) The topography of the land

(3) Geology and permeability coefficient with respect to water

c) Method of carrying out the accumulated salt

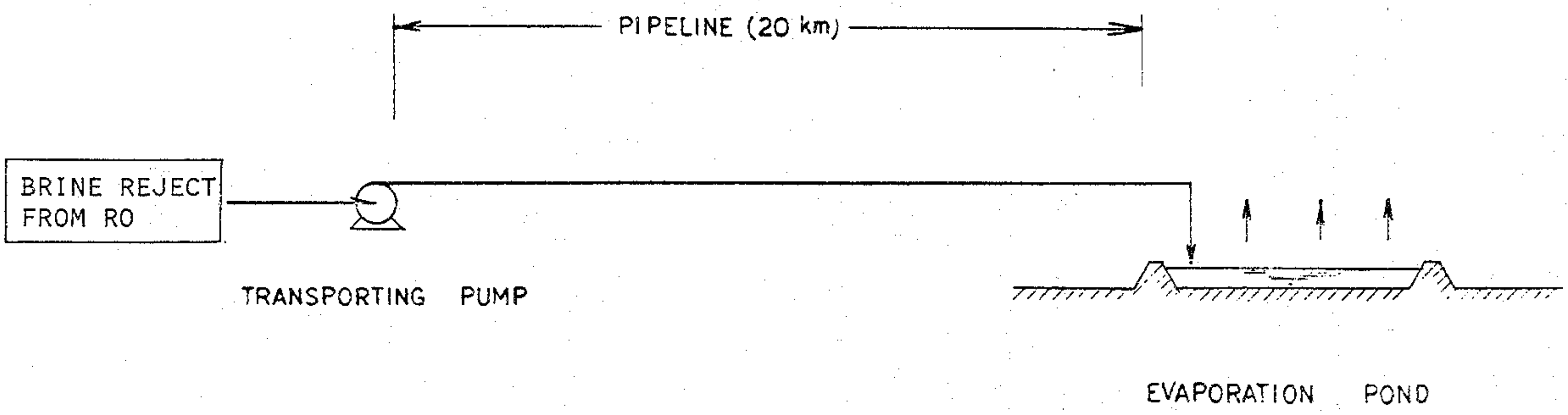
(1) Method of scraping (manual or mechanical)

(2) Method of transportation (truck, train or pipeline)

d) Pipeline

(1) Pipeline route

(2) Geological and topological conditions of the pipeline route



Case 1: Evaporation Pond in the Suburbs

3.2 Case 2 -- Deep Well Injection

1) General

The deep well injection method has been used in oil refineries, oil fields, steel mills and chemical industries to inject waste water into underground aquifers and formations.

Deep well injections are considered feasible in areas where potable ground water or surface water supplies do not reach great depths and hence cannot be contaminated by the waste water injected.

2) Design Basis

a)	Capacity:	6,800 m^3/day
b)	Source of Brine Reject:	RO Plant
c)	Injection Rate per Well:	2,400 m^3/day
d)	Depth of Well:	3,000 m
e)	Injection Pressure:	200 kg/cm^2G
f)	Well Location:	Near the RO Plant

3) Process Description

The deep well injection method consists of filters, deaerators, a high pressure pump station and three deep wells.

The brine reject from the RO plant is filtered to remove suspended solids. Suspended solids contained in brine reject would plug the aquifer pores.

Then, the filtered brine reject flows into the deaerators to reduce dissolved oxygen.

Dissolved oxygen in the brine reject will cause for plugging of the aquifer pores with microbe growth and chemical deposits, and also corrosion problems.

An oxygen scavenger and biocide are fed into the deaerated brine reject. The brine reject is then pressurized by high pressure pumps and injected into the deep well.

Injection rate and injection pressure will vary according to the conditions of underground aquifers and formations.

The injection pressure of 200 kg/cm^2G, as a design basis, is assumed from data of water flooding operation in oil fields.

The depth of the injection well will also vary with the conditions of underground aquifers and formations. For this study, an injection well having a depth of twice the depth of potable water well in the Riyadh area is assumed not to become a cause for pollution of potable well water by brine reject.

4) Utility and Chemical Consumption

The deep well injection method requires approximately 24×10^6 KWH/year electric power.

Chemical consumption is listed below:

Filter aid:	5 ton/year
Oxygen Scavenger:	3 ton/year
Biocide:	12 ton/year

5) Construction Cost

It is difficult to estimate the cost of deep well drilling because lack of cost information on well drilling in the Riyadh area. An estimate of 15 million dollars is assumed from cost data of a water flooding project in an oil field.

A more exact estimate could be obtained from local drilling contractors in your country.

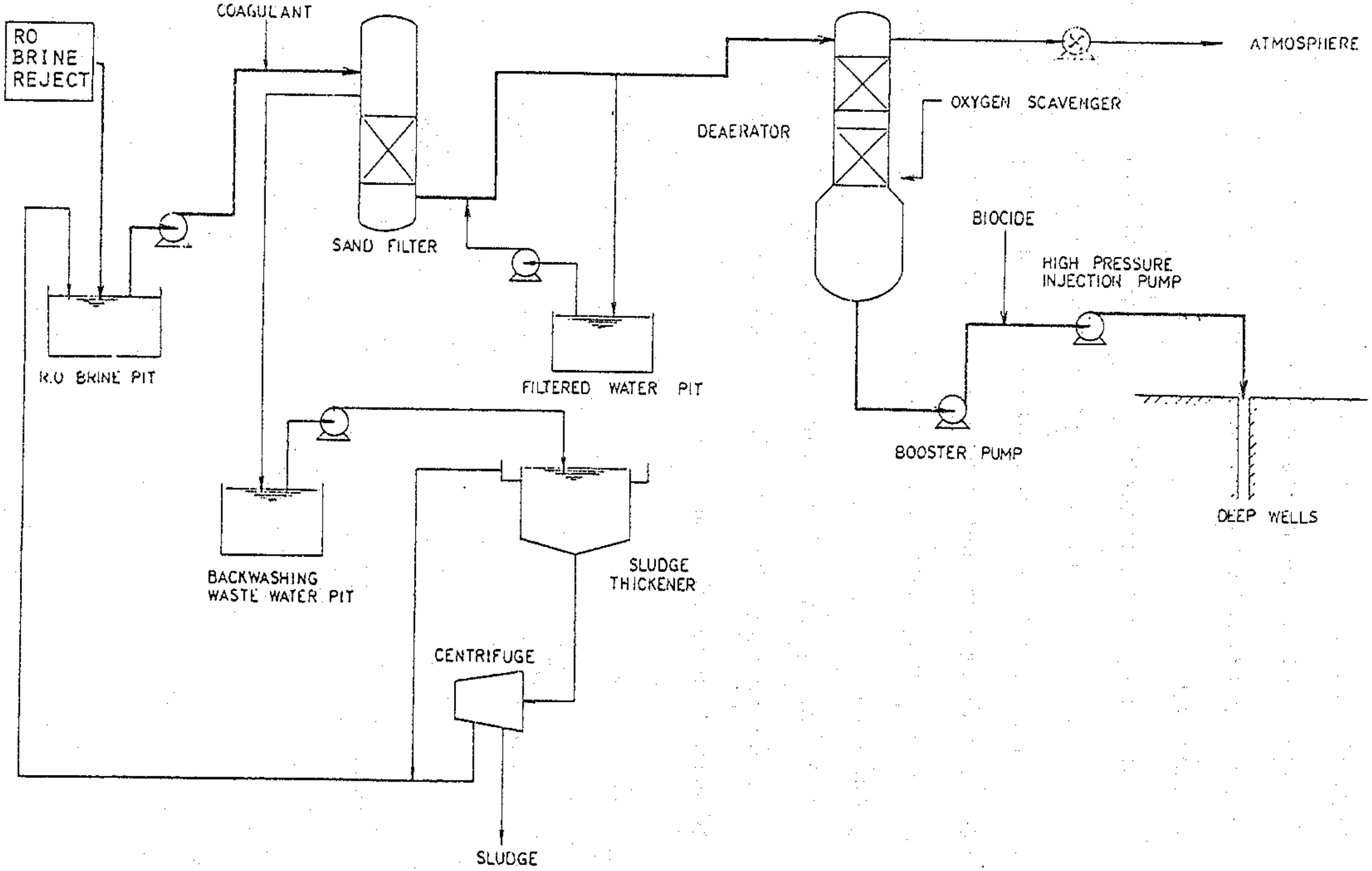
6) Required Area

This method requires a space of approximate 2400 m^2 including pretreatment facilities.

7) Discussion

The deep well injection of brine reject will be a useful method in areas where the conditions of underground aquifers and formations are suitable for injecting brine reject underground by means of a deep well without any effects caused by brine reject on potable ground water.

A survey on underground aquifers and formations, and test boring should be made for further studying the feasibility of the method.



Case 2: Deep Well Injection

3.3 Concentration by Electrodialysis Process

1) General

The electrodialysis (ED) process is an applicable method for concentrating brine reject discharged from the RO plant.

The ED process has been applied for concentrating sea water in the salt manufacturing industry. The ED process produces concentrated brine and the desalinated water which can be recycled to the RO plant.

The concentrated brine discharged from the ED process must be treated in combination with other processes. Combination processes are described in sections 3.3.1 - 3.3.4.

The ED process requires pretreatment for reducing calcium hardness and silica contained in the brine reject in order to prevent ED membranes from scaling.

2) Design Basis

a) Capacity: 6,800 m^3/day

b) Source of Brine Reject: RO plant

3) Process Description

a) Pretreatment Process

The pretreatment process is composed of a cold lime-soda softener, and filters and a cation exchanger.

Before flowing into the softener, chemicals such as sodium carbonate, caustic soda and coagulatns are fed into the brine reject. In the softener, the calcium component in the brine reject is precipitated as calcium carbonate, and the brine reject is softened.

The softened brine reject is fed to the filter where residual suspended solids are removed. The filtered brine reject is sent to the cation exchanger to remove residual calcium hardness and is then supplied to the ED process. The ion exchanger is regenerated by using concentrated brine discharged from the ED process and fresh sodium chloride.

b) Electrodialysis Process

There are 2 units of Model DS-V electrodialysis units in the ED section, and each ED unit comprises four blocks of electrodialyzers. Each block comprises one pair of electrodes, 400 pairs of ion-excahge membranes and 400 pairs of cells of dilute and concentrate water chambers.

The ED section operates continuously, and approximately 220 m^3/h of the softened brine is fed to the dilute tank and remainder part of the softened brine is fed to the concentrate tank. Diluted and concentrated liquors are recycled between tanks and two ED units while DC electricity at a constant voltage is applied to the units.

Desalinated water continuously overflows from the dilute tank, and is recycled to the RO plant. Concentrated brine from the concentrate water tank is fed to a posttreatment section and is recycled afterwards as electrode rinse liquid.

For neutralization of feed brine and for the prevention of scale formation in the cathode chamber, a small amount of acid is added to the liquid.

4) Utility and Chemical Consumption

a) Pretreatment Process

The pretreatment process requires approximately 0.95×10^6 KWH/year of electric power.

Chemical consumption is listed below:

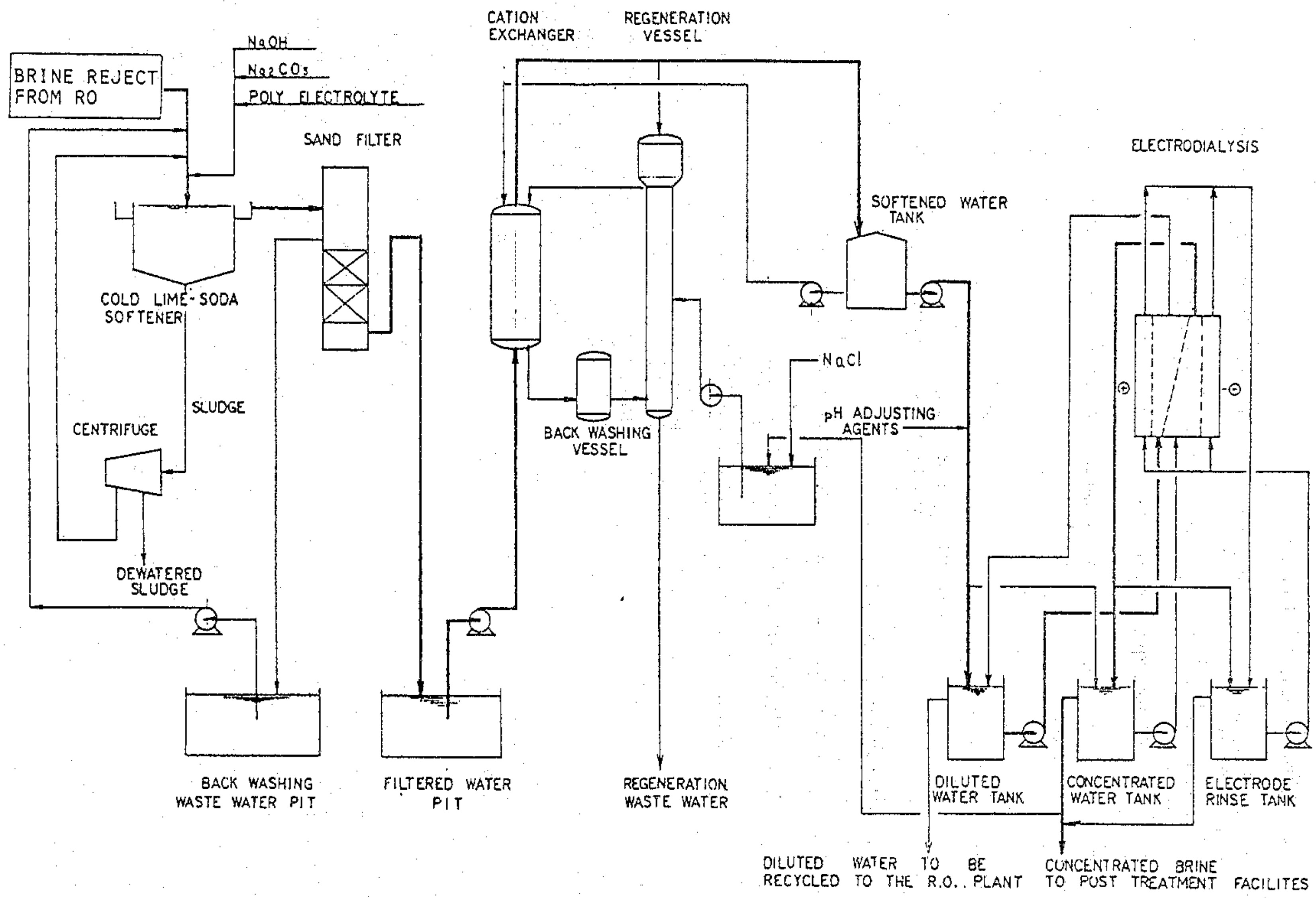
For coagulator:	Na_2CO_3	867 ton/year
	NaOH	5,067 ton/year
	Coag. Aid	6 ton/year
For regeneration of cation exchanger:	NaCl	3,000 ton/year

b) Electrodialysis

Electrodialysis requires approximately 12.2×10^6 KWH/year of electric power.

Chemical consumption is listed below:

H_2SO_4	1,100 ton/year
Na_2SO_3	64 ton/year



Case 3: Concentration by Electrodialysis

3.3.1 Case 3-1 -- Electrodialysis Process Followed by Evaporation Pond in the Suburbs

1) General

The volume of brine reject is reduced by ED process to one fifth of the volume of brine reject from the RO plant. This will reduce construction costs of the evaporation pond and the pipeline.

2) Design Basis

Capacity of the evaporation pond: 1,450 m^3/day

Other design basis are same as described in sections 3.1 and 3.3.

3) Process Description

This method consists of the ED process and a pump station at the RO plant site, a pipeline and an evaporation pond in the suburbs. Regarding the ED process and the evaporation pond, please refer to section 3.3 and 3.1 respectively.

An evaporation pond having an area of 185,000 m^2 is constructed in the suburbs.

4) Utilities and Chemical Consumption

This method requires approximately 14.6 x 10^6 KWH/year of electric power. Chemical consumption is same as described in section 3.3.

5) Construction Cost

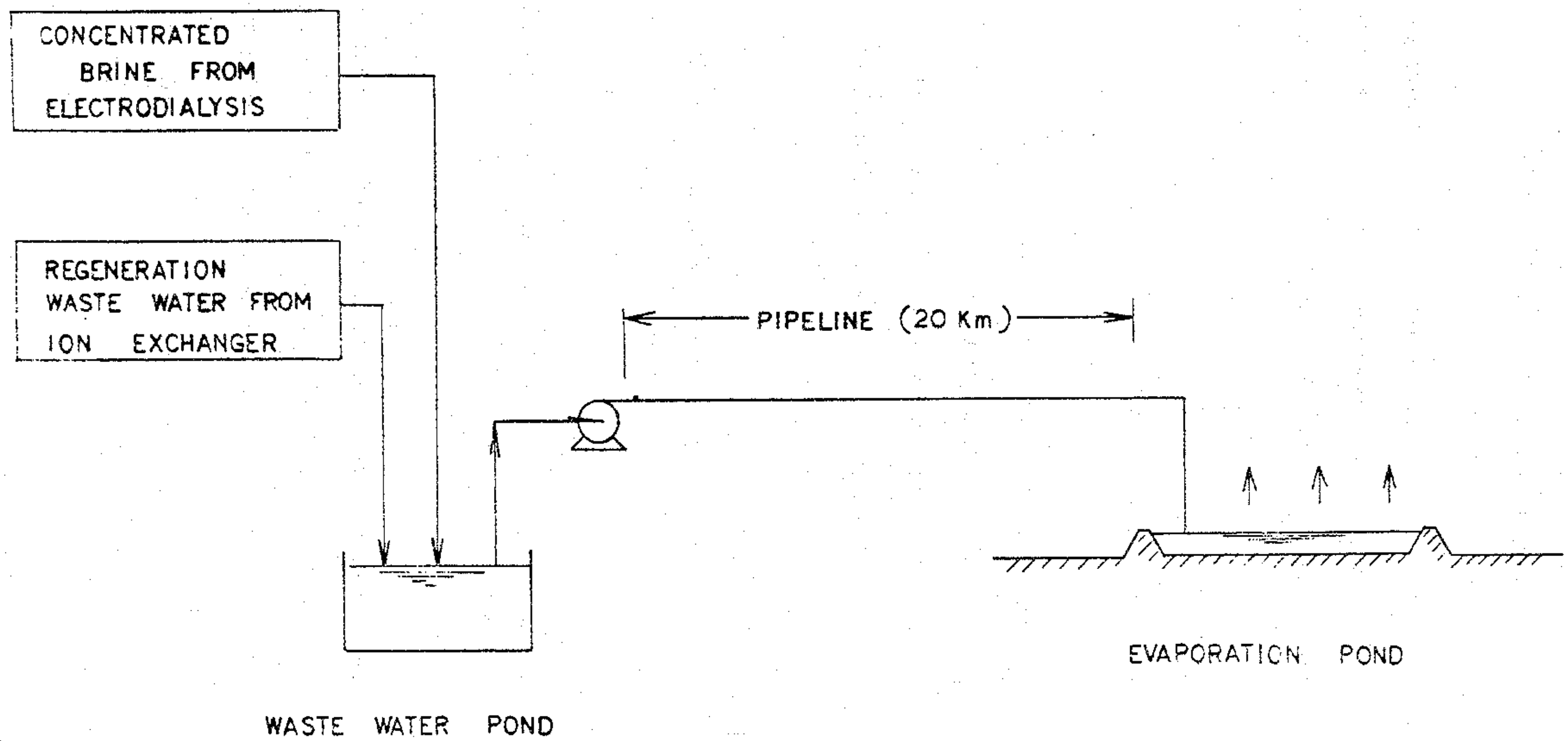
The construction cost is approximate 12 million dollars.

6) Required Area

This method requires a space of approximate 3,200 m^2 for the ED process at the RO plant site, and a space of approximate 185,000 m^2 for the evaporation pond in the suburbs.

7) Discussion

The construction cost of this method is much less in comparison with Case 1 in section 3.1. However, operation costs greatly increases. Further discussion of this is made in sections 3.1 and 3.3.



Case 3-1: Electrodialysis Process Followed by Evaporation Pond in the Suburbs

3.3.2 Case 3-2 -- Electrodialysis Process Followed by Evaporation Pond at the RO Plant Site

1) General

In this case, the evaporation pond is constructed at the RO plant site, if possible. Thus, investment costs for the pipeline and the pump station can be saved.

2) Design Basis

Same as described in section 3.3.1.

3) Process Description

Same as described in section 3.3.1.

4) Utilities and Chemical Consumption

This method requires approximate 13.2 x 10^6 KWH/year of electric power. Chemical consumption is same as described in section 3.3.

5) Construction Cost

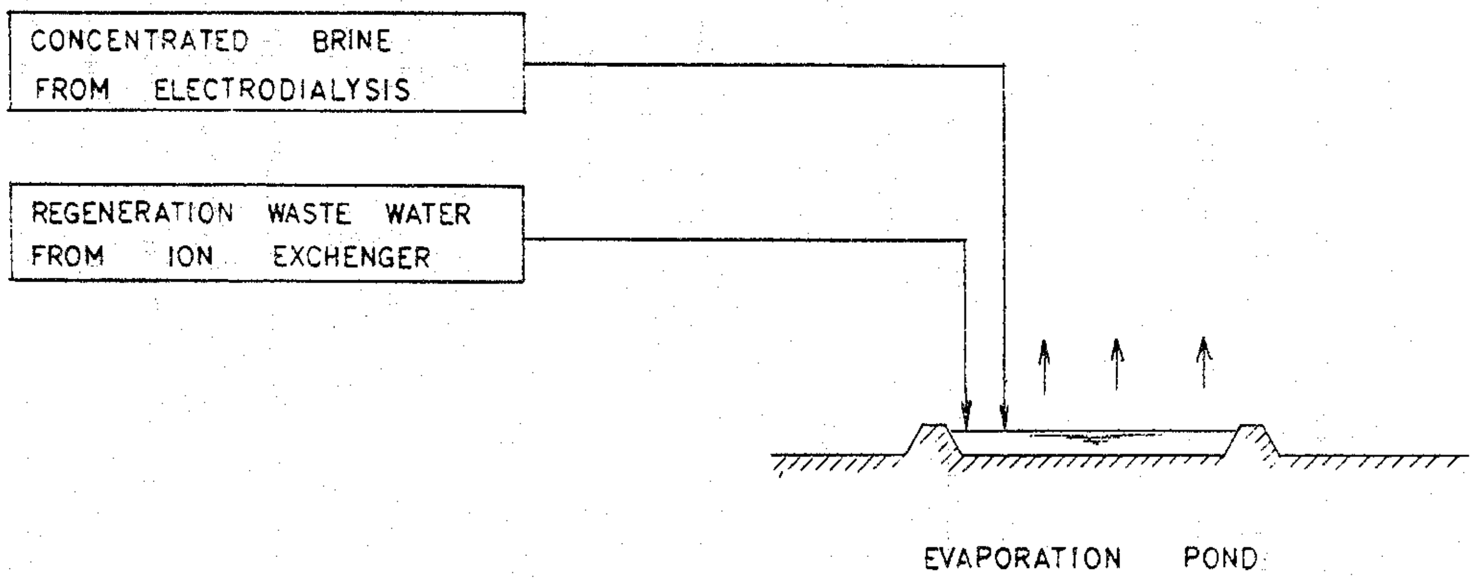
The construction cost of this method is approximate 10 million dollars.

6) Required Area

This method requires a space of approximate 188,200 m^2 near the RO plant site.

7) Discussion

The construction costs of this method is less in comparison with Case 3-1 and the operation costs nearly same as Case 3-1. Further discussion of this is made in sections 3.1 and 3.3.



Case 3-2: Electrodialysis Process Followed by
Evaporation Pond at RO Plant Site

3.3.3 Case 3-3 -- Electrodialysis Process Followed by Evaporator/Crystallizer

1) General

This method intends to treat the brine reject without any liquid waste discharge. The concentrated brine from the ED process is evaporated and salts dissolved in the concentrated brine are crystallized.

Approximately 75 ton/day (dry base) of solid salts are produced.

2) Design Basis

Capacity of the Evaporator/Crystallizer:	1,450 m^3/d
Salt Contents:	Approx. 5.5 wt%
Temperature of Brine Reject:	30°C

3) Process Description

This method consists of the ED process, an evaporator/crystallizer, centrifuge, a boiler, a power generator and a cooling tower. Regarding the ED process, please refer to section 3.3.

The concentrated brine from the ED process is fed to the triple effect evaporators. Exhaust steam from the power generator is used as heat source for the evaporator/crystallizer. The steam condensate from the first heater is recycled to the boiler and that from the second and the third heater is used as makeup water for the cooling tower after it is cooled with feed brine. The vapor from the third evaporator is cooled in a surface condenser with circulating cooling water.

The non-condensable gas from the evaporators is discharged by means of vacuum equipment.

The evaporators are of the forced circulation type to avoid scale formation on the surface of the heating tubes.

The salts are crystallized only in the third evaporator. For this reason, the third evaporator is designed as the crystallizer.

Many kinds of salts dissolved in brine reject are crystallized into mixed salt in the third evaporator. The mixed salt slurry is sent to the centrifuge feed tank by a slurry pump. After being thickened in the centrifuge feed tank, the slurry is fed to a continuous push type centrifuge. The wet salt from the centrifuge is rejected as solid waste.

The power generator produces the electric power required not only for the evaporator/crystallizer but also for the ED process.

Steam generated by the boiler is supplied to the power generator, and exhaust steam from the power generator is used for the first heater of evaporator.

4) Utilities and Chemical Consumption

This method self-produces water, steam and electric power. Fuel is the only utility required for this method and fuel consumption is about 24×10^3 kl/year. Chemical consumption is same as described in section 3.3.

5) Construction Cost

Construction cost is approximate 17 million dollars.

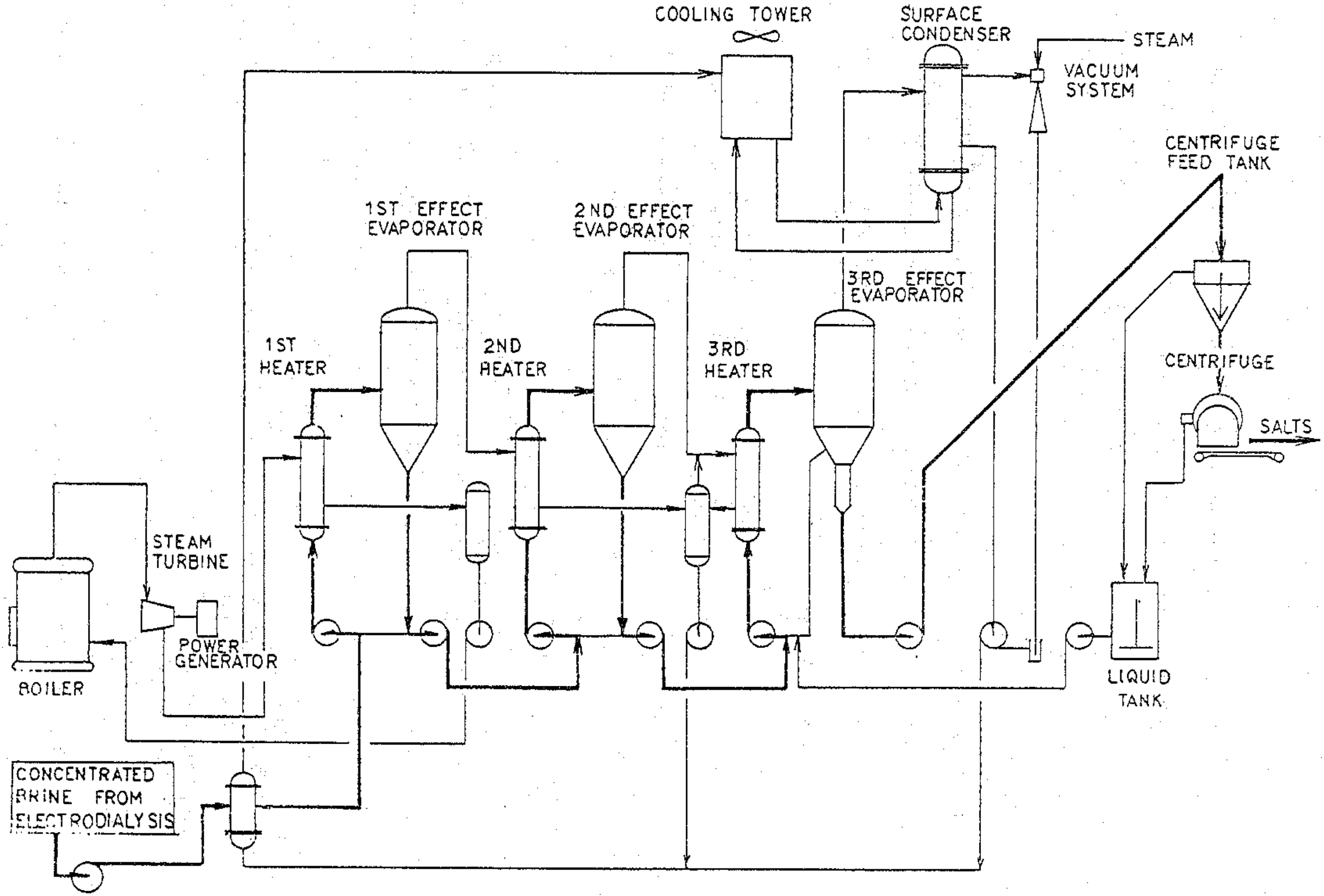
In this study, the power generator is facilitated. However, when electric power is supplied from public sources at a low price, and self-production of electric power is not necessary, construction cost can be reduced.

6) Required Area

This system requires a space of about 4,000 m^2 near the RO plant. Space for a solid waste stock yard is not included in above figure.

7) Discussion

This method does not discharge any liquid waste, and on the other hand, produces over 30,000 ton/year of solid salt waste. The solid waste must be transported to another place for permanent storage. Seven to eight trucks will be needed every day for such transportation.



Case 3-3: Electrodialysis Process Followed by Evaporator/Crystallizer

3.3.4 Case 3-4 -- Electrodialysis Process Followed by Deep Well Injection

1) General

In this case, the concentrated brine reject from the ED process is injected into a deep well. Water volume to be injected is about one fifth of Case 1 and power consumption will be reduced.

2) Design Basis

a) Capacity of Concentrated Brine: 1,450 m^3/day

b) Source of Concentrated Brine: ED process

Other design basis are same as described in parasections 3.2 and 3.3.

3) Process Description

This method consists of the ED process, a filter, a deaerator, a high pressure pump station and a deep well. Regarding detail description, please refer to sections 3.2 and 3.3.

4) Utilities and Chemical Consumption

This method requires approximate 19.6 x 10^6 KWH/year of electric power. In addition to the chemical consumption described in section 3.3 of the ED process, the following chemicals are required:

Coagulant:	7 ton/year
Hydrazin:	1 ton/year
Biocide	3 ton/year

5) Construction Cost

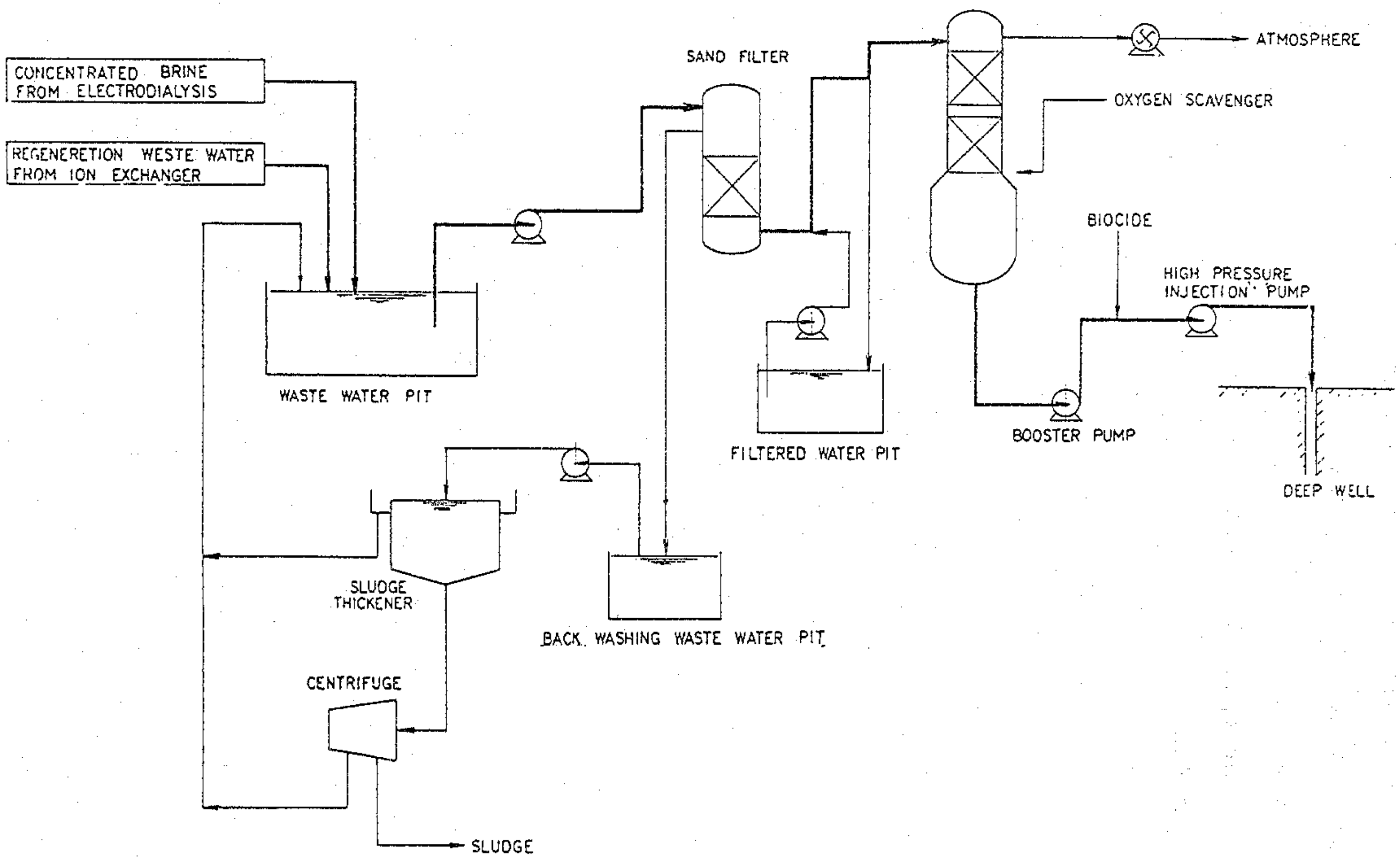
The construction cost of this method is approximate 12 million dollars.

6) Required Area

This method requires a space of approximate 3,600 m^2 near the RO plant site.

7) Discussion

The operation costs increase greatly in comparison with Case 2.



Case 3-4: Electrodialysis Process Followed by Deep Well Injection

3.4 Case 4 -- Concentration by Reverse Osmois Process

1) General

The reverse osmosis (RO) process is applied widely both for desalination and concentration of chemicals, attributed to the recent development of membranes with superior performances.

An application of the RO process necessitates an suitable pretreatment in order to prevent pollution of membrane by contamination and scale-generating substances of feed water, and deterioration of membrane caused by pollution. The most suitable pretreatment is cold lime-soda process that is capable of removing silica and calcium.

The brine reject discharged from the main RO plant which produces potable water from ground water, is treated by the auxiliary RO plant after the pretreatment described in the aforegoing paragraph.

Desalinated water produced by the auxiliary RO plant is mixed with that by the main RO plant and is supplied as a potable water.

2) Design Basis

a) Capacity: 6,800 m^3/day

b) Source of Brine Reject: RO Plant (Main)

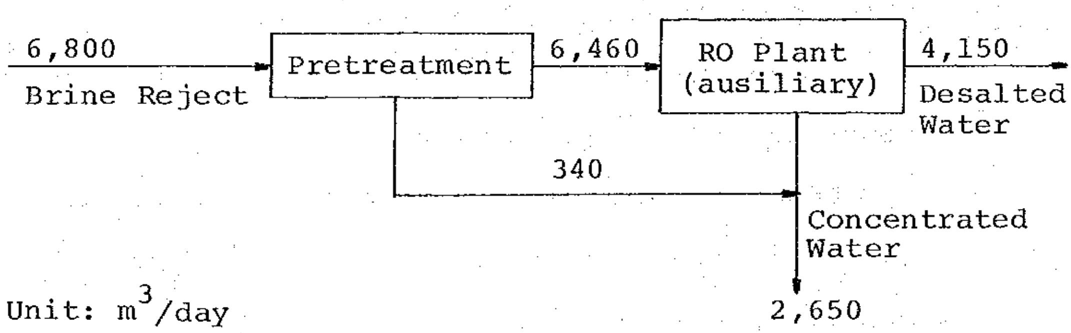
c) Quality of Brine Reject: Same as section 3.2)

3) Process Description

Calcium and silica are apt to educed by concentration of the RO plant. In case that solubilities of calcium and silica are 3,000 ppm as $CaSO_4$ and 120 ppm as SiO_2 respectively, the maximum concentration ratio is approximate 1.4 because the concentration of SiO_2 in the feed water is 85 ppm. Therefore, concentration of SiO_2 in the feed water must be lowered in order to raise the concentration ratio.

A cold lime-soda method is generally applied to remove silica in normal temperature by educing silica together with calcium. Removal ratio of silica is different in accordance with properties of silica and to existing substances. The value is usually decided by removal test.

The concentration ratio would be approximate 2.8 on an assumption that 50% of silica is removed by the pretreatment, and the water balance would be as the diagram shown below:



The osmotic pressure in this case is calculated to be approximate 13 atm. Thus, approximate 3.5% TDS of concentrated water is obtained by using RO membrane for sea water with high rejection ratio under the operating pressure of 55 kg/cm^2G. In this case, concentration ratio of concentrated water from the auxiliary RO plant and cencentrated brine reject from the main RO plant is 2.8.

The concentrated water from the auxiliary RO plant is treated by the posttreatment. Desalted water is mixed with the product water of the main RO plant. supplied as potable water.

4) Discussion

In concentration of brine reject by the RO process, one cannot raise concentration ratio because of eduction of silica. Upraise of concentration ratio by improving removal ratio of silica through pretreatment results in an increase of cost.

Brine reject discharged from the RO process, of which concentration ratio is approximate 2.8, is much in volume in comparison with that from the ED process. Therefore, total construction costs of this process, including posttreatment, increase relatively.

Confirmation of removal ratio of silica in pretreatment is absolutely necessary prior to applying this method. Therefore, experiments by at least jar test must be carried out to promote this study.

3.5 Case 5 -- Disposal into Municipal Sewage Pipeline

1) General

On an assumption that the capacity of sewage treatment plant in the Riyadh area is increased to 80,000 m^3/day in 1981, 1,232 m^3/day of brine reject from the RO plant can be disposed into the municipal sewage pipeline.

This is based on a calculation that TDS vaule of effluent would not exceed a design criteria of 2,500 mg/l for re-use program.

2) Design Basis

	1981	1983
TDS of brine reject:	12,725 mg/l	12,725 mg/l
TDS of treated sewage:	2,340 mg/l	2,340 mg/l
TDS for re-use program:	2,500 mg/l	2,500 mg/l
Total capacity of sewage treatment plant:	80,000 m^3/d	200,000 m^3/d

Based on the above figures, quantities of brine reject and municipal sewage to be treated at the sewage treatment plant are calculated as follows:

	1981	1983
Quantity of brine reject:	1,232 m^3/d	3,090 m^3/d
Quantity of municipal sewage:	78,768 m^3/d	196,910 m^3/d

These quantities must be readjusted if disposal of brine reject into the municipal sewage pipeline would offer problem to operation and maintenace of the above mentioned pipeline.

3) Construction Cost

Cost for adopting this method is only for that of pipeline installation. Therefore, detailed estimation should be done after the pipeline route is decided.

It is recommended to use pipes which have strong resistance to corrosion.

4) Discussion

(1) The concentrated brine of the RO plant is assumed not to contain pollutant such as heavy metal. However, items listed below may affect the sewage treatment facility when the brine is disposed into the municipal sewage pipeline. Therefore, it is necessary to prove that quality is within the allowable limit by making sure of the quality.

a) Temperature
b) pH
c) BOD
d) SS
e) n-Hexan Extract Substances
f) Iodine concumed
g) Phenols
h) Cyanide
i) Alkyl Hg
j) Organic P
k) Cd
l) Pb
m) Cr (6 valence)
n) As
o) Total Hg
p) Cr
q) Cu
r) Zn
s) Fe (soluble)
t) Mn (soluble)
u) F

(2) Affects by soluble material such as SO_4^{2-} should also be investigated.

3.6 Case 6 -- Recovery of Valuables

1) General

The brine reject from the RO plant contains some valuable components as solutes. Typical examples of the chemical composition of the brine and potential resources in the brine are shown in Table 3.6.1.

In these components, sodium and chlorine are useful substances for the production of alkali and hydrochloric acid. On the other hand, magnesium is a starting substance for the production of magnesium hydroxide, which is a raw material for fertilizers or fire bricks.

But, in this case, the brine is too dilute to utilize it as the raw material for the efficient recovery of such valuable chemicals, and the concentration of the brine reject by means of the ED process, evaporation or other means are necessary for the recovery of said valuable components.

2) Process Description

a) Electrodialytic Concentration of Brine Reject

As mentioned above, the ED technique is able to concentrate the brine over five times.

The chemical composition and the annual amount of main components in the concentrated brine are shown in Table 3.6.2. This concentrated brine contains over 80% of soluble components in the brine reject from the RO plant.

b) Recovery Process of Valuable Chemicals

A rough idea for the recovery of valuable chemicals from the concentrated brine is shown in Fig. 3.6.1.

The concentrated brine is first evaporated and concentrated by suitable evaporation equipment to remove less soluble calcium salts. As the amounts of these salts are small, there is no interest in considering the utilization of these calcium salts.

Next, caustic soda is added and magnesium hydroxide is removed for the purification of the brine. Although a small amount of silica is absorbed in the precipitate, magnesium hydroxide can be utilized as raw material of inorganic chemical processes. If there is no need for the utilization of magnesium hydroxide, it is disposable on the ground after dehydration.

After the purification, residual main components are separated and crystallized into sodium chloride and sodium sulfate separately. For the separation of these salts, the brine is evaporated and cooled to crystallize the sodium sulfate.

After removal of the sodium sulfate, sodium chloride is decomposed by the electrolysis technique to produce caustic soda and chlorine gas. A part of the caustic soda is used for the precipitation of magnesium hydroxide and the remainder part is obtained as a final product.

Caustic soda is easily carbonated by CO_2 gas to produce sodium carbonate, and on the other hand, chlorine gas can be converted into hydrochloric acid by a reaction with hydrogen gas exhausted from the cathode chamber of electrolytic cell.

3) Utilization of Recovered Chemicals

The materials balance of Fig. 3.6.1 is based on an RO plant discharging 6,800 m^3/day brine reject. It is assumed that about 24 ton/day of sodium carbonate and 2.3 ton/year of hydrochloric acid are consumed in the water pretreatment section of the RO plant.

As shown in Fig. 3.6.1, 17 ton/day of sodium carbonate is recovered from the brine reject treatment plant, and in other words, approximately 70% of the necessary amount of sodium carbonate can be supplied from the brine reject treatment plant.

A part of chlorine gas exhausted from the brine reject treatment plant can be utilized as hydrochloric acid for the pH adjustment of feed water, and the remainder part of chlorine gas is used for disinfection of product water.

4) Discussion

Production capacity of the brine reject treatment plant in this study is too small compared to that of a usual commercial plant, and, as a result, the production cost of chlorine and caustic soda may be higher than their market prices in Europe or Japan. But, it may be feasible to construct such a plant in the Riyadh area if prices of chlorine, hydrochloric acid, caustic soda or soda ash are extraordinary high and/or supply conditions of these chemicals are very tight.

To make a further study of this process, the following information is needed:

a) Supply condition and prices of chemicals

b) Demand of chemicals

c) Supply condition and cost of electric power

d) Ideas for the utilization of maganesium compound and other chemicals

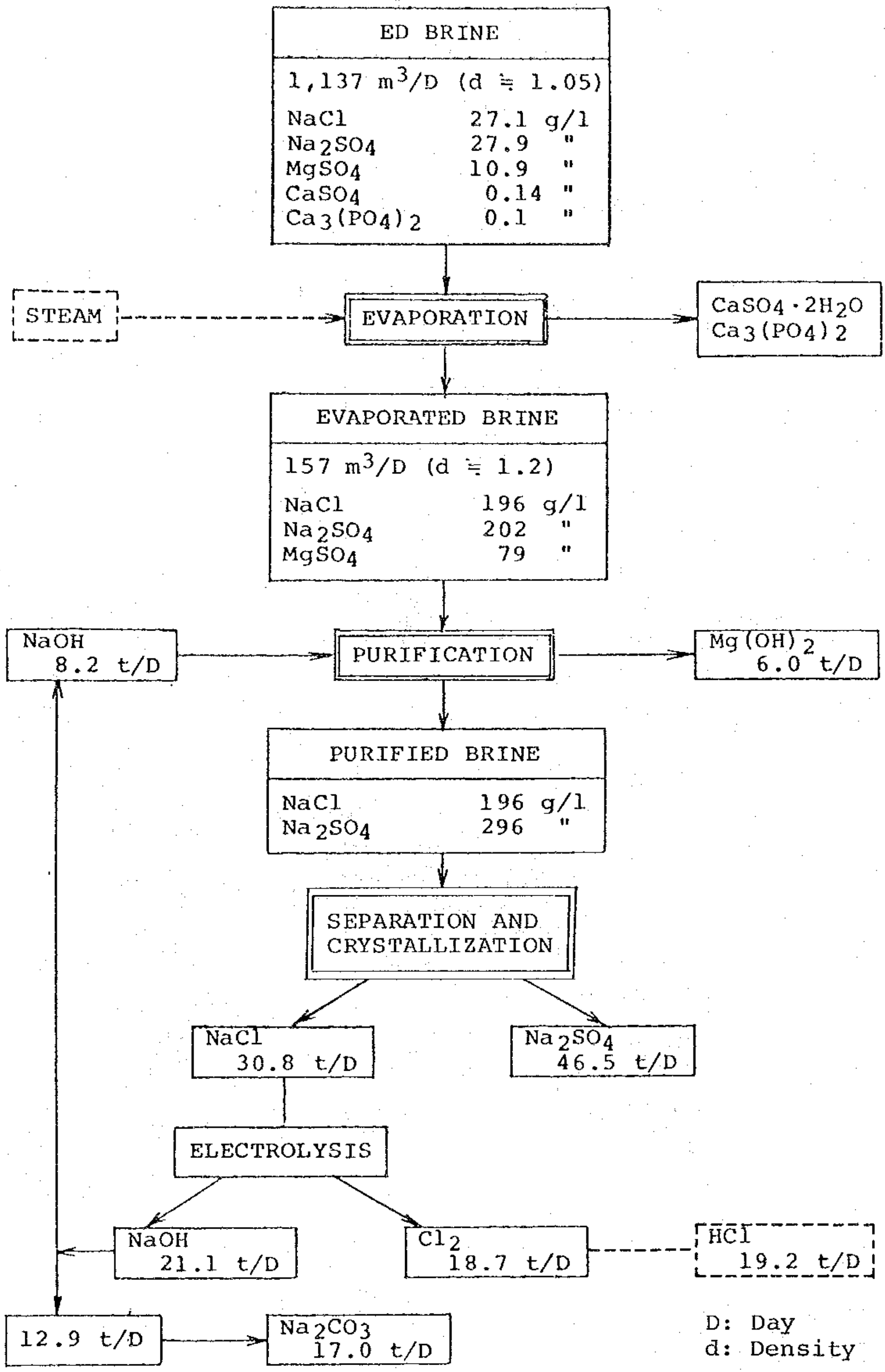
Table 3.6.1: Chemical Composition of Brine Reject from the RO Plant

Component	Concentration (mg/l)	Potential Resources (ton/year)
Na	3,520	8,737
Ca	160	397
Mg	470	1,167
Cl	3,120	7,744
F	0	
HCO_3	0	
SO_4	5,350	13,279
PO_4	20	
SiO_2	85	

Table 3.6.2: Main Components of Concentrated Brine from the ED Process ($1,137\ m^3$/day)

Component	Concentration (g/l)	Annual Amount (ton/year)
NaCl	27.1	11,247
Na_2SO_4	27.9	11,579
$MgSO_4$	10.9	4,524
$CaSO_4$	0.14	58
$Ca_3(PO_4)_2$	0.1	42
SiO_2		

Fig. 3.6.1: Recovery of Valuable Componets from Brine Reject



INTERIM REPORT ON
FEASIBILITY STUDY OF
RO BRINE REJECT TREATMENT IN
THE KINGDOM OF SAUDI ARABIA

(DOCUMENT NO. SAJ/RO-102)

OCTOBER 1980

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

Interim Report on Feasibility Study of RO Brine Reject Treatment in the Kingdom of Saudi Arabia

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# # #

1. Outline

This interim report is made to give a frame work of the feasibility study of RO brine reject treatment in the Kingdom of Saudi Arabia. It is also made to report the result of on-the-spot survey of feasibility study.

The one-the-spot survey is carried out to meet the Minutes of Meeting which were signed in September 28th, 1980 in Riyadh between H.E. Abdullah Al Gholaikah, Deputy Minister for Water Affairs of the Ministry of Agriculture and Water on behalf of the Government of the Kingdom of Saudi Arabia and Mr. Masaru Ikai, the leader of Japanese delegation on behalf of the Japan International Cooperation Agency.

The Japanese delegation has proposed several methods of RO brine reject treatment in the Kingdom of Saudi Arabia in their tentative report on feasibility study (Document No. SAJ/RO-101). This interim report is also a proposed amendment of Document No. SAJ/RO-101.

Time scheudle of feasibility study is shown in Fig. 1.

Fig. 1: Time Schedule of Feasibility Study

Items \ Year & Month	1980				1981		
	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1. Preparation							
1) Planning	—						
2) Tentative Report	—						
2. Site Meeting & Investigation	—	*1) —					
3. Assessment Studies							
1) Sewage Pepeline		—					
2) Sewage Treat-ment Plant		—					
3) Water Re-Use		—					
4. Conceptual Design		—	—	—			
5. Final Report							
1) Drafting				—	—	—	
2) Explanation of Draft to MOAW						*2) —	
3) Presentation to MOAW							

Note: MOAW = Ministry of Agriculture and Water, The Government of the Kingdom of Saudi Arabia

*1): From September 26th to October 13th, 1980

*2): From February 7th to 11th, 1981 (tentative)

2. Summary

During the on-the-spot survey, we come across the followings:

- First, the procurement of new land for the RO brine treatment plant is very difficult.

- Second, the disposal of RO brine reject to the sewage pipeline causes basically the increase of TDS values of sewage effluent to some extent.

From the view point of re-use, the increase of TDS value of sewage effluent is undesirable at all, but the problems of RO brine reject disposal is urgent that the following planning may be introduced:

2.1 Disposal Method for each RO Plant

2.1.1 Manfouha

This plant has vacant spaces in the present yard. Consequently, disposal methods are proposed interimly as follows:

(1) Concentration by electrodialysis (ED) followed by evaporator/crystallizer

Construction cost: 17 million US$

Required area: 4,000 m^2

(2) Concentration by ED followed by evaporation pond

Construction cost: 10 million US$

Required area: 188,000 m^2

2.1.2 Shemessy

This plant has vacant spaces in the present yard and close to the plant. Consequently, disposal methods are proposed interimly as follows:

(1) Concentration by ED followed by evaporator/-crystallizer

Construction cost: 11 million US$

Required area: 1,200 m^2

(2) Evaporation pond in the suburbs

Construction cost: 8 million US$

Required area: 150 m^2 (in plant)

420,000 m^2 (present lagoon)

2.1.3 Malez

This plant has no vacant spaces in the present yard. Therefore, the disposal to the municipal sewage pipeline is proposed interimly.

2.2 Assessment to Sewage Pipeline and Re-Use

Sewage pipeline gives no harm to sewer pipe or sewage treatment, because anticorrosive pipe is used and is thought that RO brine reject contains few organic substances and heavy metal ions.

However, it is necessary to investigate the influence to re-use sewage effluent by increase of TDS concentration.

2.3 Other Studies

(1) We cannot comment on the deep well injection because of the lack of related data.

(2) The structure of evaporation pond should be followed to the one existing in the area of the municipality of City of Riyadh.

(3) For a reference, summary of case study on RO brine reject treatment is shown in Table 1.

Table 1: Summary of Case Study on RO Brine Reject Treatment *1)

Plant Names	Items \ Methods	Case 1 Evaporation Pond in Suburbs	Case 2 Deep Well Injection	Case 3-1 Concentration by Electrodialysis (ED) followed by Evaporation Pond in Suburbs	Case 3-2 Evaporation Pond at Plant Site	Case 3-3 Evaporator/-Crystallizer	Case 3-4 Deep Well Injection	Case 4 Concentration by Revers Ocmosis (RO)	Case 5 Disposal into Sewage	Case 6 Recovery of Valuables
Manfouha Plant	Initial Cost (Million $)	19	15	12	10 *4) (9)	17	12	-	-	-
	Direct Operation Cost (Mil. $)	0.014	0.59	3.73	3.70 (2.74)*4)	3.95 (3.0)*4)	3.85	-	Negligible	-
	Required Area in Plant/ in Suburbs (m^2)	200/ 850,000	2,400/ 0	3,200/ 185,000	188,000/ (187,000) 0 *4)	4,000/ (2,450) 0 *4)	3,600/ 0	-/ -	nill/ 0	-/ -
	Comment	not recommendable	no comment	not recommendable	recommendable (2)	recommendable (1)	no comment	not recommendable	not recommendable	not recommendable
	Remarks	no space	no information	no space	if existing lagoon is available	most practical	no information	not suitable technically	effect on sewage plant	not economical
Shemessy Plant	Initial Cost (million $)	(8 *1)) *4)	-	-	-	(11) *4)	-	-	-	-
	Direct Operation Cost (Mil. $)	(0.01) *4)	-	-	-	(1.262) *4)	-	-	Negligible	-
	Required Area in Plant/ in Suburbs (m^2)	(150/ *4) 420,000)	-/ 0	-/ 0	-/ -	(1,200 *3) *4) (2 stories)/0	-/ 0	-/ -	nill/ 0	-
	Comment	recommendable (2)	no comment	not recommendable	not recommendable	recommendable (1)	no comment	not recommendable	not recommendable	not recommendable
	Remarks	if existing lagoon is available	no information	no space	no space	most practical	no information	not suitable technically	effect on sewage plant	not economical
Malez Plant	Initial Cost (million $)	(7 *2)) *4)	-	-	-	(9) *4)	-	-	-	-
	Direct Operation Cost (Mil. $)	(0.007)*4)	-	-	-	(0.848)*4)	-	-	Negligible	-
	Required Area in Plant/ in Suburbs (m^2)	150/ *4) (280,000)	-/ 0	-/ 0	-/ 0	(2,000/ 0) *4)	-/ 0	-/ -	nill/ 0	-
	Comment	not recommendable	no comment	not recommendable	not recommendable	not recommendable	no comment	not recommendable	recommendable	not recommendable
	Remarks	no space	no information	no space	no space	no space	no information	not suitable technically	most practical	not economical

Note: *1) This summary table is prepared based on the design basis in the tentative report.
*2) Existing sludge lagoon located within 3 km from the water treatment plant.
*3) Because of shortage of space, the ED plant will be integrated into a 2-story construction.
*4) Figures in parentheses are roughly estimated and will be revised in the final feasibility study.

3. Manfouha Water Treatment Plant

3.1 Recommended Method

An ED concentration process followed by evaporator/-crystallizer is recommended for disposing the RO brine reject in the Manfouha Water Treatment Plant.

The Manfouha Plant is the largest among the three water treatment plants inside the City of Riyadh. When the brine reject from the Manfouha Plant is disposed into the sewage, the brine reject flow will account for 8.5% of the hydraulic load of Manfouha Sewage Treatment Plant having a capacity of 80,000 m^3/d.

Disposing the brine reject to the sewage plant means the decrease of receiving capacity of the domestic sewage to the sewage treatment plant.

On the other hand, TDS value (total dissolved solids) in sewage water will also increase to around 3,400 mg/l by the brine reject.

It will cause some effects vis a vis re-use of the treated sewage water for irrigation and industrial usage.

The Manfouha Water Treatment Plant has a space which is now used as chemical storage area, and a sludge lagoon of millions of square meters just outside the plant.

An ED concentration process plant followed by evaporator/crystallizer can be built in those areas mentioned above and produces no liquid waste but recoverable water containing 1,500 mg/l of TDS, and solid waste, that is, an ultimate solution of the brine reject problem.

(1) Utility and chemical consumption with operation cost

Fuel Oil: 2.4×10^4 kl/y

Soda Ash: 7.0×10^3 ton/y

Lime: 3.7×10^3 ton/y

Polyelectrolite: 14 ton/y

Sodium Sulfite: 63 ton/y

Sulfuric Acid: 1.1×10^3 ton/y

Total Operation Cost: 3.o million US$

(2) Construction Cost

17 million US$

(3) Required Area

2,450 m^2

Refer to the plot plan of Fig. 3.

3.2 Alternate Recommended Method

An ED concentration process followed by evaporation pond at the plant site is recommended alternatively.

In this case, the brine reject is concentrated by ED process and the volume of the liquid waste becomes one-fifth of the brine reject, and the diluted water produced by ED process can be recycled as feed to RO process.

The ED plant can be built at a space which is now used as storage area and evaporation pond can be built in a portion of the space which is now used as sludge lagoon.

An additional facilities or modification of existing sludge treating facilities should be required to decrease the sludge volume to be dumped from the precipitators to the sludge lagoon and then to decrease the required space for sludge lagoon.

The ED concentration method followed by evaporation pond at the plant site will be less expensive both in operation and initial cost than that of the ED concentration method followed by evaporator/crystallizer, if the evaporation pond can be build in a portion of the existing sludge lagoon, though the exact area of the sludge lagoon was not known during the site survey.

(1) Utility and chemical consumption with operation cost

Electric Power:	13.2×10^6	KWH/y
Soda Ash:	7.0×10^3	ton/y
Lime:	3.7×10^3	ton/y
Polyelectrolite:	14	ton/y
Sodium Sulfite:	63	ton/y
Sulfuric Acid:	1.3×10^3	ton/y

Total Direct Operation Cost: 2.74 million US$

(2) Construction Cost

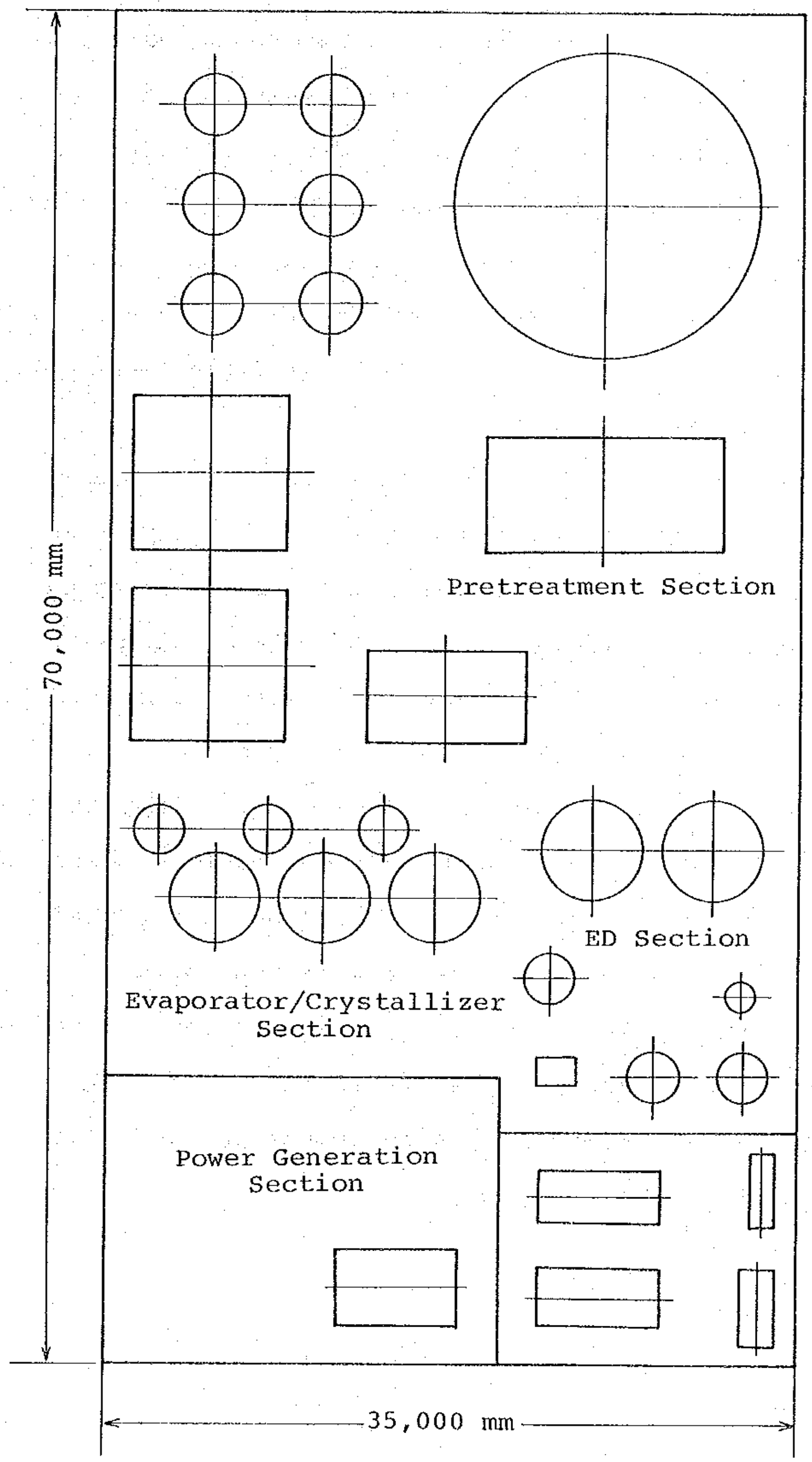
9 million US$

(3) Required Area

for ED plant: 2,000 m^2

for Evaporation pond: 185,000 m^2

Fig. 3: Plot Plan of Brine Reject Treatment Plant for Manfouha Water Treatment Plant



4. Shemessy Water Treatment Plant

4.1 Recommendation

After visits to water and sewage treatment plants, it is interimly concluded that RO brine reject of the Shemessy Water Treatment Plant should not be disposed to the sewage pipeline for the avoidance of further increase of either treating amount of sewage treatment or salt content in the effluent from the sewage treatment plant, because estimated amount of RO brine reject in Shemessy Water Treatment Plant is not so small.

This plant is located in the City area, and existing facilities and buildings are constructed closed to each other, and only narrow space is availble for future use. But, at present stage, it is interimly considered that such space is enough to construct the concentration facilities for the post-treatment of RO brine reject.

And, it is recommended at this stage that the concentration facilities, including brine treatment, electrodialysis and crystallization section, should be constructed at the vacant land space in the water treatment plant.

By the application of this process, dissolved solid in the RO brine reject is solidified and dilute liquid exhausted from the electrodialysis equipment can be reclycled to the RO process.

(1) Utility and chemical consumption with operation cost

Fuel: 1.2×10^4 kl/y

Soda Ash 2.8×10^3 ton/y

Lime: 1.8×10^3 ton/y

Polyelectrolite: 5.5 ton/y

Sodium Sulfite: 31 ton/y

Sulfuric Acid: 5.3×10^2 ton/y

Total Direct Operation Cost: 1.262 million US$

(2) Consturction Cost

11 million US$

(3) Required Area

1,200 m^2

Because of shortage of space, the ED plant will be integrated into two-story construction. Refer to the plot plan of Fig. 4

4.2 Alternate Recommendation

If it is impossible to apply the above mentioned idea, the following alternative idea will be recommendable.

That is, RO brine reject is transported to the sludge lagoon by means of newly installed pipeline and is evaporated by solar energy. To realize this alternative idea, it is necessary to construct the evaporation pond at the site of existing sludge lagoon by the rearrangement of the area.

(1) Utility and chemical consumption with operation cost

Electric Power: 5.0×10^4 KWH/y

Total Direct Operation Cost: 0.01 million US$

(2) Construction Cost: 8 million US$

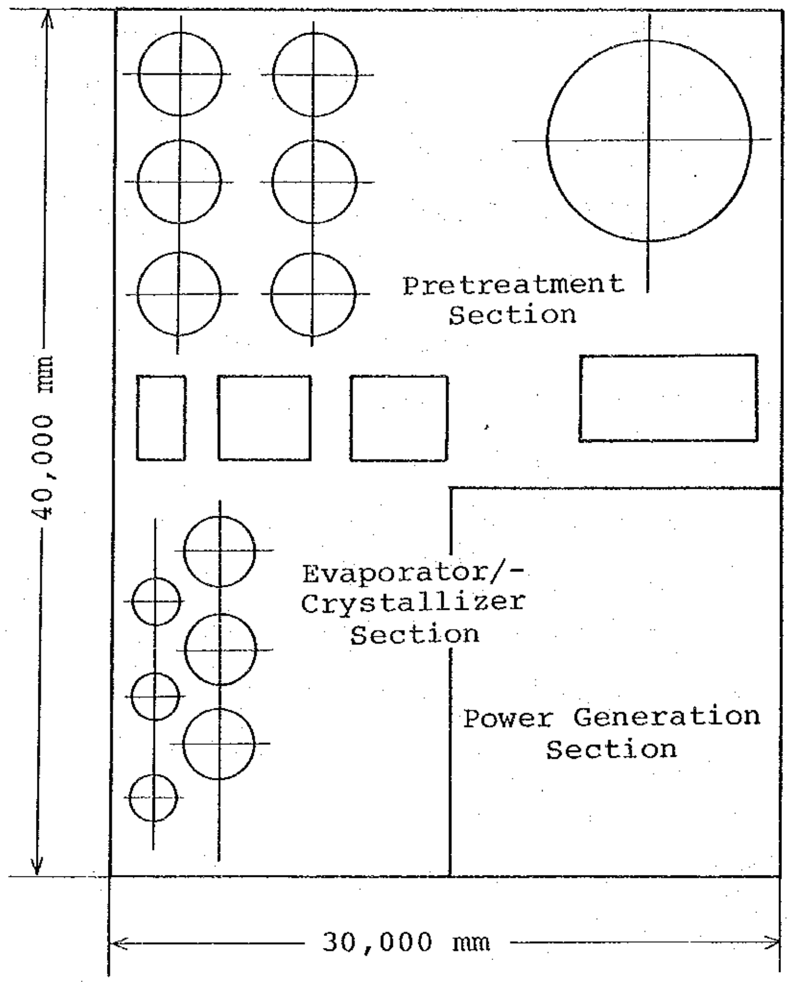
(3) Required Area

in the Plant: 150 m^2

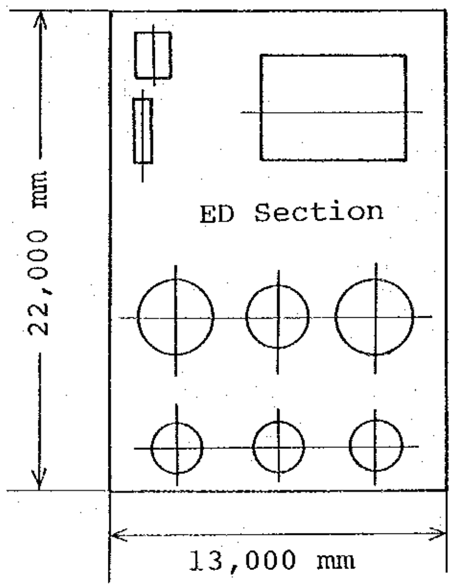
in the Suburbs: 420,000 m^2

Fig. 4: Plot Plan of Brine Reject Treatment Plant for Shemessy Water Treatment Plant

1st Floor



2nd Floor



5. Malez Water Treatment Plant

5.1 Recommended Method

Disposing the brine reject into the municipal sewage is recommended for the Malez Water Treatment Plant.

The Malez Plant is the smallest among these three water treatment plants inside the City of Riyadh.

When the brine reject from the Malez Plant is disposed into the sewage, the brine reject flow will account for only 2.8% of the hydraulic load of the Manfouha Sewage Treatment Plant having a capacity of 80,000 m^3/d.

The actual influent wanter flow rate to the sewage plant fluctuates from 30,000 m^3/d to 50,000 m^3/d or more, while the design capacity of the plant is only 40,000 m^3/d at present.

TDS value of sewage water will also be increased to nearly 2,800 mg/l by the brine reject from the Malez Plant, while the actual TDS value of sewage water ranges from 2,000 to 3,000 mg/l and average figure is 2,500 mg/l.

The increase both in the hydraulic load and TDS with disposing the brine reject into th sewage from the Malez Plant might be left within the daily fluctuation in the hydraulic load to the sewage treatment plant and TDS value of the sewage water.

Therefore, it is supposed that the operational efficiency of the sewage treatment plant may be little effected by disposing the brine reject into the sewage from the Malez Plant.

However, biological treatment process is a sensible process and a rapid fluetuation in the hydraulic load and influent water quality will cause damaging of microorganism.

Thus, special care shall be given when introducing the brine reject into the sewage.

At the beginning, one-fourth or one-fifth of the brine reject flow should be introduced into the sewage, giving carefull attention to the operation of the biological treatment for a few weeks and then brine reject flow rate should be gradually increased to the maximum.

There is no recommendable method other than the disposal of brine reject into the sewage as mentioned above, because the plant is so tight in space that a new brine reject treatment plant could not be built within the space of the plant.

A sludge lagoon having an area of 60,000 m^2 is located in front of the head office of Riyadh Water Division which is located about one km to the east from the plant, and a portion of it could be available for building a new brine treatment plant.

However, a new brine treatment plant to be built at a distance from the main water treatment plant may cause some operational and administrative problems.

Note: pH value of the brine reject should be checked periodically and if the measured value is usually lower than 5, a pH adjusting equipment should be provided at the outlet of the brine reject to prevent the sewage facilities from corrosion and to avoid effect on the sewage treatment.

6. Assessment and Investigation on RO Brine Reject Disposal

6.1 Disposal into the Municipal Sewage Pipeline

The pH value of RO brine reject is 5 to 6 and is somewhat lower than that of common sewage.

However, anti-corrosive pipe, for example PVC pipe and clay pipe etc., is used as sewer pipe, and no trouble is expected vis a vis corrosivity of RO brine reject

6.2 Influence on Sewage Treatment Plant

The Fluctuation of quantity of sewage which flows into the sewage treatment plant is 42,000 to 57,000 m^3/d, and the average of the quantity is 45,000 m^3/d at present time.

It is well-known that a fluctuation of this kind is common.

At the time when the capacity of the sewage treatment plant enlarges to 80,000 m^3/d, quantity of the RO brine reject of the Malez Water Treatment Plant, 2,230 m^3/d forms a little proportion. Therefore, we believe there is no problem vis a vis quantity.

If the RO brine reject of the Malez Water Treatment Plant will be discharged into the sewage, the increase of TDS value is 280 mg/l (from 2,490 to 2,770 mg/l).

It is not so important that the TDS value increase of 280 mg/l, because the TDS value is fluctuating at present in the range from 1,910 to 3,130 mg/l.

There is no regulations neither in Japan nor in the Kingdom of Saudi Arabia concerning TDS value vis a vis the standard of influent into sewage.

But, the quality of discharge into sewage is regulated vis a vis organism, heavy metals and so on.

It is thought that the RO brine reject contains some unknown materials, so it is important that the RO brine reject will increase to discharge into sewage little by little under consideration of influence to the microbe.

6.3 Water Re-Use Program

The sewage treatment influent contains 2,492 mg/l TDS (average), and its TDS increases to 2,770 mg/l by adding RO brine reject.

On the other hand, the sewage treatment effluent contains 1,956 mg/l TDS (average) and varies 1,350 to 2,340 mg/l, and its TDS increases to 2,174 mg/l (average) by adding RO brine reject.

Therefore, it is necessary to investigate sewage treatment and quality whith regard to influence for re-use by increase of TDS concentration.

7. Integrated Plant

7.1 General

It is advised by the MOAW that the RO brine rejects from the three water treatment plants in the City of Riyadh--Manfouha, Shemessy and Malez--are gathered to a place by means of a conveying system, and an integrated ED process plant followed by evaporator/crystallizer is built at the place which may be located near the Manfouha Water Treatment Plant.

Thus, the intergrated ED plant might be more conomical than separate three plants, if the brine reject gathering ana and conveying system could be built without difficulties in construction.

The scope of this study does not cover the gathering and conveying system, and is limited to within the battery limit shown in the Plot Plan, Fig. 7.

Since this integrated plant is independent of the existing water treatment plants, supporting facilities such as building, utility facilities and others should be required.

We could not carry out the study on these supporting facilities, because of lack of data at present. After returning to Japan, we could do it on your request.

The scope of work is shown in the section 7.2.

7.2 Scope of Work

(1) Included

1) Pretreatment facilities with chemical feeding equipment

2) Electrodialyzer

3) Evaporator/crystallizer

4) Sludge dewatering facilities

5) Boiler, steam turbine and generator

6) Inter-connecting piping for items 1)-5)

7) Instrumentation for items 1)-5)

8) Electrical work for items 1)-5) and 7)

9) Painting work for items 1)-8)

10) Foundation and concrete work for items 1)-5)

11) Installation work for items 1)-8)

Note: Work to be done is limited within the battery limit shown in the Plot Plan, Fig. 7.

(2) Excluded

1) Brine reject gathering and conveying facilities

2) All buildings for control, administration, laboratory etc.

3) Utility facilities such as public power receiving facility, lighting and communication facilities, air conditioners, canteen, furniture, utility and drinking water supply facilities, oil storage, etc.

4) Civil work such as site preparation, road, pavement, fence and gates, etc.

5) Stand by train for items 1)-5) of (1)

6) Recovered water storage and transfer facilities

7.3 Design Basis

(1) Flow Rate of Brine Reject

$12,340\ m^3/d$

From Manfouha:	$6,800\ m^3/d$
Shemessy:	$3,310\ m^3/d$
Malez:	$2,230\ m^3/d$

(2) Water Quality

1) Brine Reject

Sodium:	3,250 mg/ l
Calcium:	160 mg/ l
Magnesium:	470 mg/ l
Chloride:	3,120 mg/ l
Fluoride:	0 mg/ l
Bicarbonate:	0 mg/ l
Sulfate:	5,350 mg/ l
Silica:	85 mg/ l
Phosphate:	20 mg/ l
TDS	12,725 mg/ l
pH:	5 ∿ 6
Temperature:	30°C

2) Recovered Water

TDS: 1,500 mg/l or less

pH: 6 ∿ 8

(3) Electric Power

For plant use: Self-produced

For utility use: Supplied by public power system

7.4 Process Description

The process flow of the integrated plant is basically the same as Case 3-3, electrodialysis (ED) process followed by evaporator/crystallizer in the Tentative Report (Document No. SAJ/RO-101 of September 1980). Refer to sections 3.3 3) and 3.3.3 of this document.

However, the integrated plant is not provided with cation exchanger, because the field tests during the site survey showed that calcium in the brine reject could be decreased to a limit only by cold lime-soda softener.

The results of the field test and the necessity of cation exchanger will be re-examined after returning to Japan.

The recovered water from ED plant is good in quality. The expected quality is as follows:

TDS:	1,389	mg/l
Na:	379	mg/l
Ca:	1.6	mg/l
Mg:	42	mg/l
Cl:	277	mg/l
SO_4:	594	mg/l

It seems that the recovered water is better in quality than the deep well water in the Riyadh area and could be used for irrigation as well as for the feed to the RO plant to produce potable water.

On the other hand, when TDS of recovered water higher than the one of design basis is allowed, the plant construction cost could be reduced with the increase of TDS of recovered water.

The recovered water volume will be about 10,000 m^3/d.

7.5 Utility and Chemical Consumption with Operation Cost

Fuel oil:	40.8×10^3	kl/y
Soda ash:	11.1×10^3	ton/y
Lime:	6.6×10^3	ton/y
Polyelectrolite:	21	ton/y
Sodium Sulfite	120	ton/y
Sulfuric acid:	2×10^3	ton/y

Total direct operation cost: 4.89 million US$

7.6 Construction Cost

26 million US$

7.7 Required Area

6,000 m^2

Refer to the Plot Plan of Fig. 7.

Fig. 7: Plot Plan of Brine Reject Integrated Treatment Plant