A COMPARATIVE STUDY OF TWO LABORATORY PILOT-PLANT SLUDGE DEWATERING UNITS

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الخلاصة :

تقع محطة تقنية الجهراء لمياه الصرف الصحي على بعد ١٥ كيلو متراً غرب مدينة الكويت وتخدم المحطة مدينتين هما مدينة الصليبية ومدينة الجهراء. وتم تشغيل المحطة منذ عام ١٩٨١م كمعالجة ثلاثية وصُممت المحطة لتستقبل حوالي ٦٦٠٠٠م٣/ يومياً من مياه المجاري ويصل معدل التدفق اليومي حوالي ٤٥٠٠٠م٣/ يومياً. كما يتم ضخ الحمأة الناتجة من عمليات المعالجة إلى أحواض التجفيف الرملية ويوجد في المحطة ٣٠ حوضَ تجفيف تتمكن من تجفيف حوالي ١٠٠م٣ يومياً. تشير الدراسات بأنَّ أحواض التجفيف الرملية الحالية لا تستطيع مستقبلاً أنْ تستقبل كميات الحمأة الناتجة عن عمليات التنقية لقلة عددها ومحدودية الأراضي في المحطة مما يستدعي إلى إيجاد طرق وخطط بديلة لمعالجة الحمأة الناتجة لتواكب الخطط المستقبلية للتوسعة في المحطة.

لذا تم التفكير في إنشاءَ وحدة أبحاث الحمأة تهدف إلى إجراء تجارب مقارنة ما بين وحدتين ميكانيكيتين (مرشح ضاغط السير، ومرشح الطرد المركزي) وتقدير أفضل نوعية من البوليمرات مع تقييم كفاءة كلٍّ وحدة تحت الظروف المحلية.

المصطلحات: مرشح ضاغط السير، الطرد المركزي، ترشيح، مجاري، محطات المعالجة، بوليمر، الكويت .

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ABSTRACT

The Jahra sewage treatment plant is located 15 km west of Kuwait City and serves two cities, Sulaibiya and Jahra. The plant has been in operation since 1981 as a tertiary treatment plant. It was designed to receive daily 66 000 m^3/d of sewage. Currently, daily inflow to the plant is about 45 000 m^3/d of sewage.

The sludge produced at the Jahra plant is stable as a result of extended aeration. At present, there are 30 drying beds, with a drying capacity of about 100 m^3/d of sludge. However, the present dewatering system will be inadequate to handle the projected sludge production. Therefore, the problem of insufficient area for the present drying beds and the lack of additional land around the plants demands an assessment of alternative dewatering technologies to cope with the plant's present and projected physical constraints.

A pilot-plant study was conducted to evaluate two mechanical filtration systems, belt filter and centrifuge units, for dewatering sludge at the Jahra treatment plant. The study included determination of optimum dosages of coagulants for thickening the sludge for both the belt filter and the centrifuge units. The feasibility and effectiveness of the two systems were evaluated under local conditions.

Keywords: Belt filter, centrifuge, filter, sewage, treatment plant, polymer, Kuwait.

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INTRODUCTION

The Jahra treatment plant is located 15 km west of Kuwait City and serves two cities, Sulaibiya and Jahra. The design and construction of the Jahra plant took place in the late 1970s, and the plant was operated in 1981 as a secondary treatment plant. The plant was improved by construction of additional units to reach the performance level of a tertiary plant. It was designed to receive daily 66 000 m^3/d of sewage [1].

The plant includes primary, secondary, and tertiary treatment. The treated effluent is used in afforestation practices or is discharged through sea outfalls [2]. The sludge produced at the Jahra plant can be classified as excess activated sludge, which combines primary and secondary solids. The excess sludge produced in the Jahra plant is directed to pre-thickeners prior to final dewatering in drying beds. There are two thickeners, each 15m in diameter and 3.7m in mean depth, accommodating a volume of $730m^3$.

The sludge produced at the Jahra plant is stable as a result of extended aeration. At present, there are 30 drying beds that are able to dry about 100 m^3/d of sludge. The dried sludge is mechanically removed from the dry beds and transported to a dumping area within the plant. As the number of drying beds is not sufficient for drying the total produced sludge, part of it is hauled out of the plant directly after thickening by tankers for specified disposal at a location. Figure 1 shows both liquid and sludge trains at the Jahra treatment plant.

An effective mechanical filtration system needs to be thoroughly investigated. As a result, a pilot study was conducted to determine the most cost-effective processes to be used in a testing program, whereby a single dewatering unit would be selected for processing excess activated sludge produced at the Jahra sewage treatment plant. As a result of this study, two units were chosen for pilot-plant testing: a belt filter unit and a centrifuge unit.

Studies have shown that mechanical dewatering units, such as the belt filter and centrifuge, can be used to remove liquids and increase solid concentrations [4–6]. Research by Novak and Hangan [7] found that mechanical dewatering processes are an effective method for dewatering solids and use of a polymer was important in such units. Preliminary work [8] indicates that the nature of the sludge, its original solids content, and whether or not a conditioner is added, are important factors in the performance of mechanical dewatering units, and the overall performance of dewatering units, both belt filter and centrifuge, could be improved radically, if fluctuations in feed sludge characteristics are minimized [9]. Several sludge technologies were reviewed [10, 11]. It was found that the quality of sludge and its dryness are important in determining the most cost-effective dewatering process.

Therefore, a pilot mechanical dewatering facility was established at the Jahra plant. It provided necessary information about the mechanical dewatering system, and the capacities of, and necessary operating conditions for, sludge dewatering systems (*i.e.* belt filter and centrifuge) were determined.

DESCRIPTION OF PROCESSES

Belt Filter Press

The unit consists of two belts forming a closed loop around a series of metal rollers. These rollers can be adjusted in a manner that brings the belts closer and closer. The belts are driven by a variable-speed motor that allows the belt speed to be adjusted. Both of the belts and rollers are fixed on a stainless-steel frame. The sludge enters the unit and flows between the belts, which forces the liquid out of the sludge by compression. The dried sludge is discharged, and the belts pass through a series of sprays for cleaning. In addition, a polymer-mixing tank is mounted on a stainless-steel frame. The system was provided with sludge feed pumps and necessary piping. Polymer No. 7633-1 was used in this system. A diagram of the belt filter is shown in Figure 2 (PE Trading, SDN, and BHP, Malaysia). The technical specifications of the belt filter model PEBP 180B- is presented in Table 1.

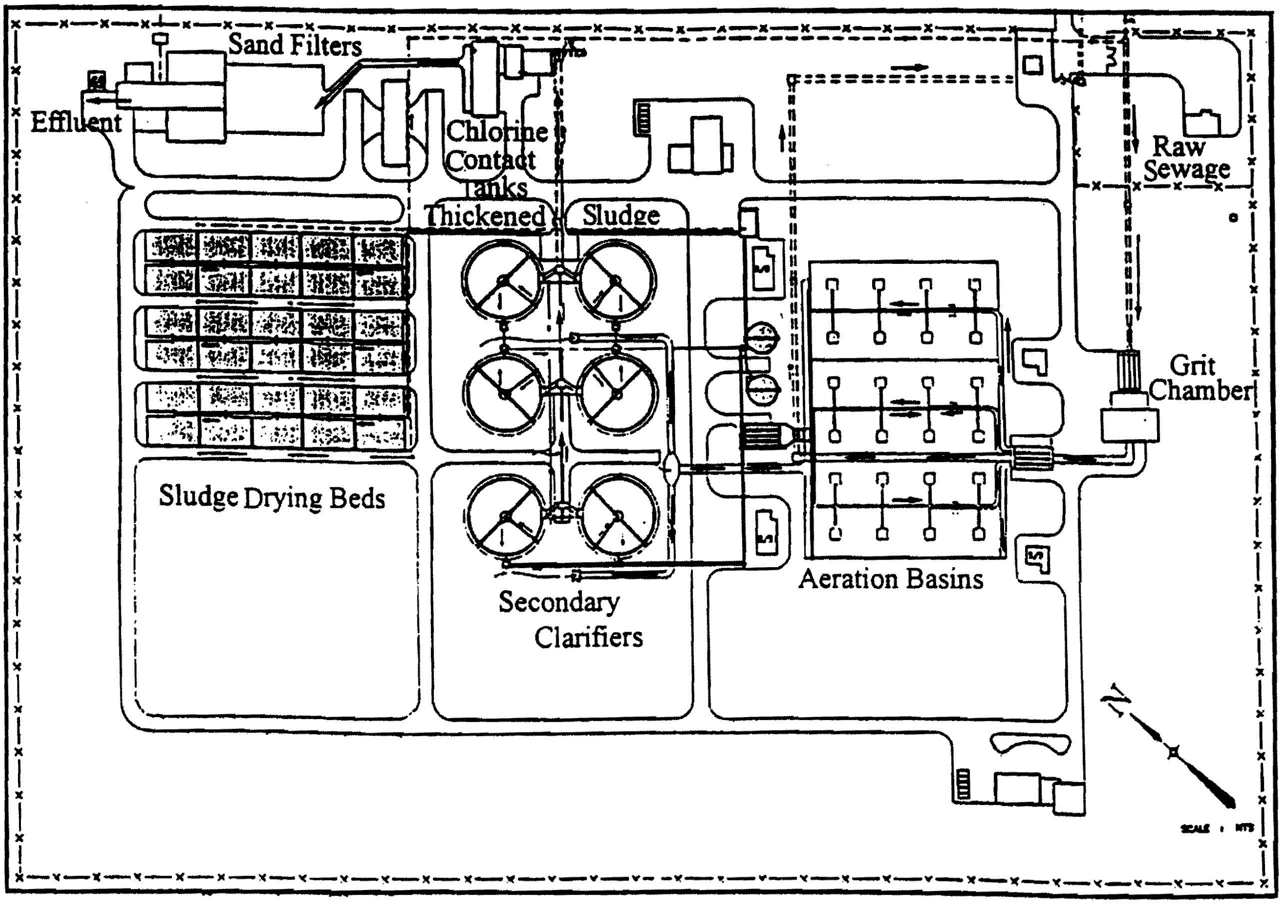

Figure 1. Schematic representation of the liquid and sludge trains at the Jahra treatment plant.

Table 1. Technical Specifications of a Belt Filter.
(Model PEBP 180B)

A. Specifications	
Parameter	Specifications
Model	PEBP-180B
Capacity	8–13 m^3/h (ss: 2%)
Belt Width	1800 mm
Washing Water	8.3 m^3/h
Dimensions (L x W x H)	3.3 × 2.3 m × 2.4 m
Belt Tension Adjustment	Air
Sludge Pump	8–13 m^3/h
Washing Pump	Hp
Chemical Dosing Pump	1–1.3 m^3/h
Weight	2280 kg

B. Power Consumption	
Power Consumption	Amount (kW)
Air Compressor	¼
Drive Motor	1
Stirrer	¼
Rotary Dewatering Motor	¼

Centrifuge Unit

The most widely used centrifuge for wastewater sludge treatment is the solid-bowl or decanter type with an electric motor drive. The machine consists of a cylindroconical rotor that rotates between two bearing blocks supported by a base frame, and includes a decantation bowl, screw conveyor, and speed reducer. The unit is driven by horizontal double-electric motors. The screw conveyor is driven by the speed reducer that turns at a slightly higher speed than the bowl.

Polymer 7633-1 was added to the sludge and mixed thoroughly before treatment. In general, mixed sludge and polymer is fed into a rotating mechanism that separates it into a dense cake containing the most solid discharge stream and a dilute central stream containing the remaining fine-density solids. Figure 3 presents a diagram of the centrifuge unit (Scientific Supply House Company, Germany). The specifications of the centrifuge model (LWZ # 20 x 770) are presented in Table 2.

Experimental Program

The purpose of the experimental program was to determine the performance of dewatering units in terms of the yield of solids on a dry weight basis (kg/m^2/h). In this experiment, the unit was operated at its highest performance level so that it could produce a cake with a high solids content that could be separated easily from the filter.

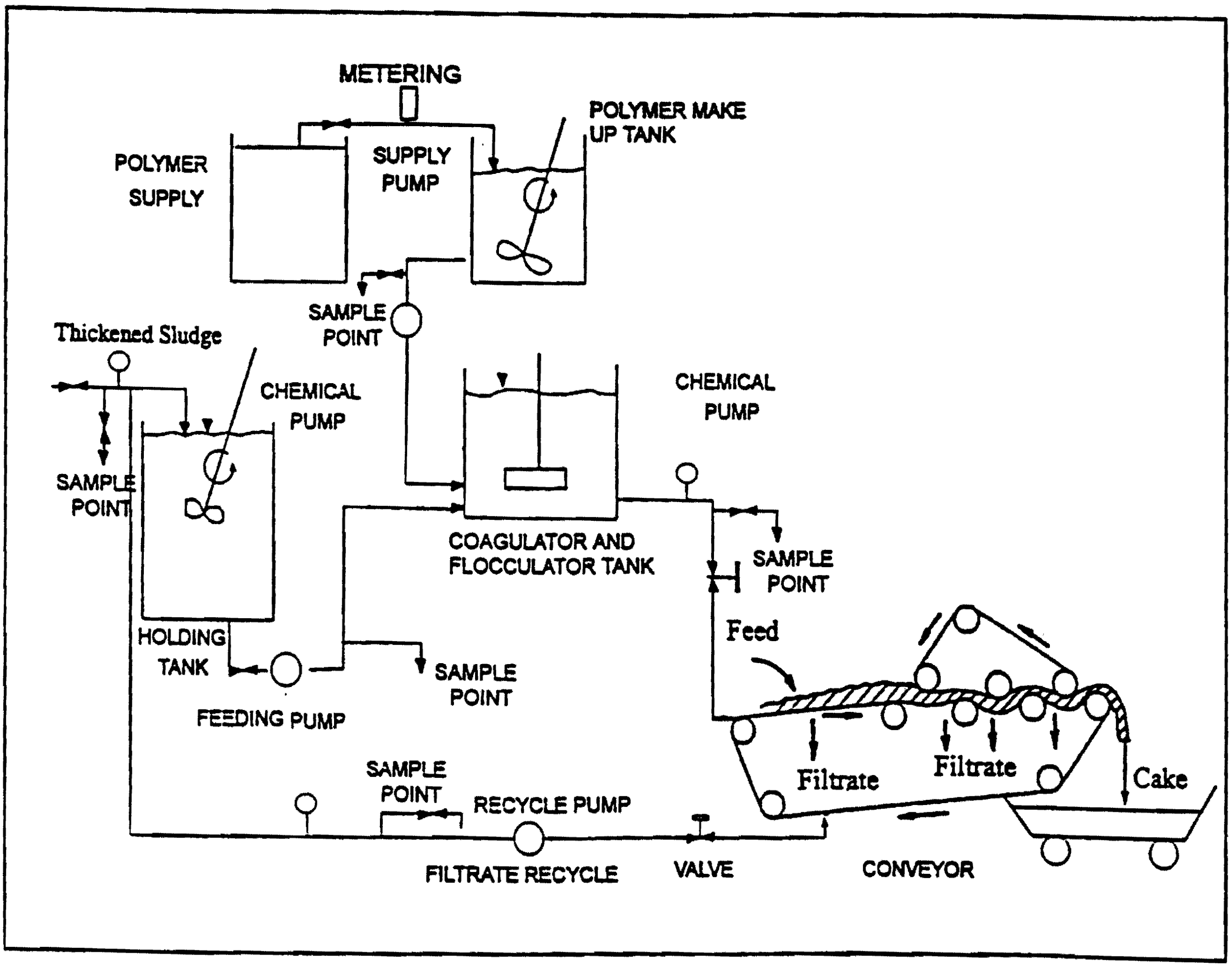

Figure 2. Process Flow Diagram for a Belt Filter Press.

MATERIALS AND METHODS

Coagulant Selection

After studying a large number of polymers and inorganic chemicals available for coagulating wastewater sludge (Table 3), the laboratory results indicated that Polymer 7633-1 has the ability to achieve efficiencies greater than 97% at 3.5 mg/l concentration, in increasing in the solids content in the cake. This is a cationic polyelectrolyte polymer obtained from Allied Colloids Limited, Kuwait, and was used for this study. Table 3 lists the optimum coagulant times and dosages.

Belt-Filter and Centrifuge Unit Testing

Each of the mechanical dewatering units was tested and operated at various operating settings to optimize the performance of each unit as well as to assess the effect of the varying parameters on the outputs of each unit.

Sampling and Analyses

Grab samples of cake were collected at the end of each test run. Grab samples of sludge feed to the unit were taken according to the operating conditions. All feed and cake samples were analyzed for total suspended solids (TSS) and total volatile solids (TVS). All analyses were done in accordance with standard methods [12].

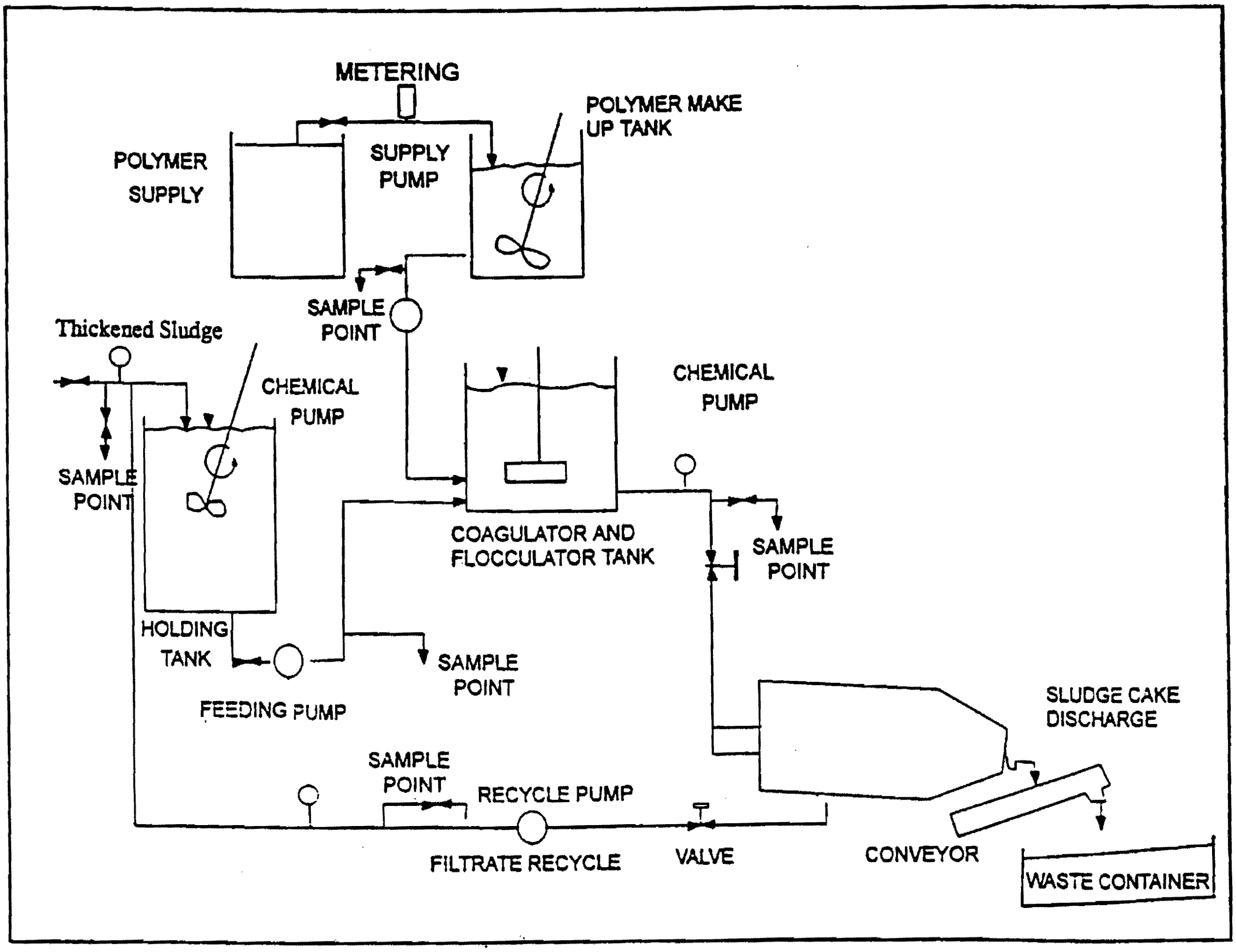

Figure 3. Process Flow Diagram for a Centrifuge Unit.

Table 2. Technical Specifications of a Centrifuge Unit (LWZ# 20 x 770).

Parameter	Specifications
Diameter	380 mm
Rotational Speed	3000 rpm
Centrifuge Force	1915 × G
Operating Temperature	15–50°C
Dryness (Solid Cake)	30–40%
All Fittings & Piping	Stainless steel

Table 3. Optimum Coagulant, Time, and Dosage.

Coagulant	Dosage Range Min – Max (mg/l)	Optimum Coagulant Concentration (mg/l)	Time (min)
Mud	10–15	12	20
Lime	4–6	5	40
Klinker-1	4–6	5	40
Alum	8–14	10.5	30
$FeCl_3$	6–11	9	30
Klinker-2	7–12.5	10	30
Polymer 53-1	4–8	6.5	30
Polymer 53-2	8–12	11	20
Polymer 57-1	8–12	10	60
Polymer 57-2	9–13	12	30
Polymer 63-1	10–12	11	20
Polymer 63-2	8–14	10	30
Polymer 78-1	10–12	11	10
Polymer 78-2	8–14	10	10
Polymer 7633-1	3–4	3.5	10
Polymer 7633-2	4–6	5	30

RESULTS

Characteristics of Sludge Produced at the Jahra Plant

The sludge feed to each of the dewatering units was aerobically digested sludge. To raise the digested sludge total solids content, the feed sludge was conditioned with Polymer 7633-1 at a concentration of 3.5 mg/l. Then, the sludge was dewatered using belt-filter and centrifuge units, which resulted in a dry cake to the desired level. Since these dewatering units were operated over a variety of periods, the composition of the sludge feed to the dewatering units varied.

Performance of the Belt-Filter Unit

Conditioning of wet sludge was necessary to achieve satisfactory yield from the belt-filter unit. Conditioning of the sludge allowed the water to drain freely. In addition, the belt speed and roller pressures were adjusted to obtain the desired cake solids content. For a small plant, such as, the Jahra plant, the dewatering unit was run for three weeks in one month.

The performance of the belt filter can be measured in terms of the yield of solid on a dry weight basis expressed as a percent. The quality of the produced cake is measured by its moisture content on a wet weight basis expressed as a percent. In this experiment, the unit was operated at its highest performance level so that it could produce a cake with a high solid content that could be separated easily from the filter. Table 4 presents the performance testing program for the belt filter. A design rate of 13.10 content of solid $kg/m^2/h$ is estimated for this type of filter, based on experimental output.

Table 4. Performance of the Belt Filter.

Experiment No.	TSS Raw sludge Before Dewatering (mg/l)	TSS Filtrate After Dewatering (mg/l)	TVS (mg/l)	Dewatered Sludge (% Solids)	Yield ($kg/m^2/h$)
1	0.004	10 000	6000	19–23	12.98
2	0.005	10 850	6200	19–24	13.70
3	0.006	12 000	6400	20–25	13.10
4	0.005	11 000	7200	18–25	13.25

Note: TSS – total suspended solids; **TVS** – total volatile solids

Performance of the Centrifuge Unit

During the testing program, the operating parameters of the centrifuge units were varied systematically to achieve the driest percentage of dry cake. Table 5 presents data on centrifuge performance. The unit ran satisfactorily during the test period and it produced approximately 19–20% solids.

Table 5. Centrifuge Performance.

ɜscription	alue	Unit
ɔading	·.97	:g/min
ɜwatering Sludge	)–20	) solids
ɔncentrate Solids	000	mg/l
ılymer Dosage	I–3	mg/l

Overall Performance and Technical Evaluation of the Two Systems

Comparative pilot-plant testing of dewatered sludge was conducted to select the best dewatering unit for dewatering sludge in Kuwait. Mechanical dewatering units were suggested, such as the belt filter and centrifuge. The main objective of the testing program was to select a technically applicable, economically feasible, and environmentally sound mechanical sludge dewatering technique for use in Kuwait. Summaries of the performance and technical assessment of the systems are presented in Tables 6 and 7 respectively. Each unit produced different products based on the solids content achieved in the dewatering process. The belt filter produced a fairly dry cake with only slight dampness, but that which centrifuge produced was quite dry. The polymer requirement and capital cost for both the centrifuge and belt filter were identical (Table 6). The technical assessment of the selected dewatering system was in terms of parameters such as performance, reliability, flexibility, ease of operation, and ease of maintenance. This assessment was made for the candidate dewatering systems, using scoring that denoted the advantage, indifference, and disadvantage of the dewatering systems in relation to each factor. The results of the assessment are shown in Table 7. The centrifuge is more flexible than the belt filter. However, the number and complexity of operating variables are greater for the belt filter than for the centrifuge. These are variables which require periodic maintenance and follow up when in operation.

Table 6. Performance Summary.

Parameter	Unit	
	Belt filter	Centrifuge
Loading	13.10 kg/m^2/h	4.97 kg/min
Cake Solid	18–25	19–20
Polymer Dosage	3.5 mg/l	3.5 mg/l
Capital Cost	KD 30 000	KD 30 000

Note: 1 KD = US $3.30

Table 7. Technical Assessment scores for the Belt Filter and Centrifuge.

Factor	Belt Filter	Centrifuge
Performance	0	0
Reliability	1	1
Flexibility	–1	1
Ease of Operation		
No. and Complexity of parameters	–1	0
Level of Automation	1	1
Operating Mode	1	1
Ease of Maintenance		
No of Moving Parts	–1	–1
Level of Sophistication	–1	–1
Accessibility	–1	–1
Total Score	**–2**	**+1**

Note: 1 = advantage, 0 = indifference, –1 = disadvantage.

CONCLUSION

From the data collected during the testing program and the discussion of the technical analysis, it was determined that the centrifuge would be the mechanical dewatering unit that would meet the Jahra treatment plant's requirements for sludge dewatering. Furthermore, the results of this small testing program can be used to establish design criteria for the unit needed. This will lead to the preparation of an engineering design, operational requirements, and economic analysis for the Jahra treatment plant.

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