EXECUTIVE SUMMARY

Eshidiya Slimes Disposal and Water Recovery Systems Feasibility Study
July 2000

U.S. Firm: Behre Dolbear, Inc.
Main Contact Name: Mr. Don Cooper, President
Current Phone: 212-684-4150
Fax: 212-684-4438
E-Mail: newyork@dolbear.com

Project Sponsor: Jordan Phosphate Mines Company
Main Contact Name: Mr. Khalib Sheyyab, General Manager
Current Phone: 962-6-5607141
Fax: 962-6-5691290

TDA Activity Number: 1999-10005A
NTIS Number: PB2001-102060

Region: Africa/Middle East
Country: Jordan

Sector: Water & Environment

Executive Summary

Pursuant to a contract dated 15-June-1999, Jordan Phosphate Mines Company, Ltd. (-JPMC-) engaged Behre Dolbear & Company, Inc. ("Behre Dolbear") to evaluate various technologies and to determine the best approach to reduce process water losses at JPMC's Eshidiya Mine (the "Feasibility Study"). The Feasibility Study is part of JPMC's program to lessen its demands on Jordan's water resources and to reduce the costs associated with phosphate processing at Eshidiya. The United States Trade and Development Agency ("TDA") funded the Feasibility Study under TDA Grant Number GH910503 1.

The Eshidiya operations have a current (Phase I) design capacity of 3.25 million tonnes of phosphate rock concentrates per year. JPMC's proposed development includes two facility expansions at Eshidiya. Phase 11, to be undertaken before 2003, will increase annual capacity to 7.50 million tonnes and Phase III will increase production to a total of 10.0 million tonnes. Phase III construction is projected to begin within five years after Phase II is operational.

Eshidiya's Phase I beneficiation plant (or "the mill") upgrades raw phosphate ores in a water-based processing system. The mill re-circulates approximately 2,020 cubic meters of water per hour to carry the ore through its processing circuits. Re-circulating water is clarified and made ready for re-use by two 75-meter-diameter settling tanks (or "thickeners") in which ultra-fine phosphate waste solids ("slimes") are settled into a sludge (or "thickener underflow"). The mill is designed to discard thickener underflow containing 17 percent solids and 83 percent water, by weight. This material is constantly bled from the mill's re-circulating water systems and pumped to disposal sites. At design capacity, the mill loses approximately 465 cubic meters of its re-circulating water each hour. To replace these losses and maintain the plant's re-circulating water requirement, fresh water is drawn from deep wells drilled into the regional Amman-Wadi Sir aquifer. Given the magnitude of these water losses, the mill would pose a severe threat to the longevity of that aquifer if it were expanded in its current configuration.

The current cost of fresh water delivered to the mill is approximately US$1.00 per cubic meter. National levies and increased expenditures for fresh water pumping will create substantial upward cost pressure in the future. More importantly, the long-term availability of fresh water cannot be assured at any cost.

The objectives of the Feasibility Study were to:

- Survey a wide range of mechanical and chemical dewatering technologies by which Eshidiya slimes could be treated to extract recyclable process water.
-

* Review the operational, environmental and financial aspects of each option.

* Identify the most promising and cost-effective water recovery technology.

* Conduct a treatability testing program to quantify technical and financial aspects of the chosen option.

* Quantify potential water recovery, capital costs and operating costs associated with the most appropriate technology.

* Provide a bid package that would allow JPMC to procure a system that can cost-effectively recover process water from the Eshidiya waste slimes prior to discharge.

In July 1999, Behre Dolbear collected indicative samples of Eshidiya thickener underflow slurries and subjected them to physical and chemical characterization studies. During August 1999, under Behre Dolbear's instructions, JPMC technicians secured representative bulk samples of thickener underflows. Approximately 11.5 cubic meters of slurry were shipped in drums to the USA. Representative increments of the bulk samples were extracted and subjected to physical and chemical characterization studies by Behre Dolbear and by a number of testing laboratories in the USA. The remainder of the bulk samples were ultimately sent to testing laboratories for bench scale and pilot plant treatability tests.

Concurrently, Behre Dolbear conducted broad-ranging literature and mineral process operation surveys to investigate the full range of technologies with potential to achieve the slimes dewatering and water recovery goals of the Feasibility Study. Behre Dolbear used data from the physical and chemical characterization studies to evaluate the applicability -of various technologies highlighted by the surveys. Three Options were deemed appropriate for further investigation:

* Option A: Existing Thickener Underflows Report to Specially Designed Settling Ponds for Water Recovery and Slimes Disposal
* Option B: Existing Thickener Underflows Report to Densifiers for Secondary Water Recovery and Slimes Densification. Prior to Disposal in Settling Ponds
* Option C: Existing Thickener Underflows Report to Densifiers for Secondary Water Recovery and Slimes Densification with Tertiary Water Recovery by Slimes Centrifugation and/or Filtration Prior to Disposal

Option A contemplated the use of incised ponds or earthen impoundments to receive the dilute thickener underflow, settle the slimes in place and decant a recyclable supernatant that would be pumped back to the plant's water circuits. These were postulated as having deep and narrow configurations to minimize surface area and reduce evaporation potential. Previous studies by JPMC showed that ambient temperatures and humidity levels at Eshidiya would cause extraordinarily high evaporation rates. JPMC's recent unfavorable experience using rudimentary impoundments for water recovery led Behre Dolbear to conclude that while Option A was a simple, low-cost approach, it did not offer the water recovery efficiencies sought by JPMC. Option A was not studied in further detail.

Option B contemplated the use of secondary densifiers to receive and further 6oncentrate thickener underflow - to levels as high as 35 or 40 percent solids by weight prior to disposal. Behre Dolbear's survey showed that these densifiers had potential to recover 50 to 60 percent of the process water being lost in the existing thickener underflow, while sponsoring immediate recycling of that recovered water to the mill. Two types of densifiers (Enviro-Clear High Rate Units and EIMCO Deep Cone Units) were considered.

Option C contemplated the use of high-energy mechanical devices to further dewater the existing thickener underflow or the Option B densifier underflow. This Option contemplated the following five equipment alternatives:

* Stacked disk centrifuges;
* Decanter centrifuges;
* Drum and/or disk vacuum filters;
* Pressure filters, and
* VSEP screens.

A detailed operations and literature search of Option C equipment alternatives showed that vacuum filters were not technically or operationally capable of dewatering the ultra-fine clay particles which are predominant in the Eshidiya slimes. Investigation of the VSEP technology indicated that dewatering might be technically feasible, but a lack of operational acceptance and a lack of documented success in production situations caused Behre Dolbear to rule out further study of this technology.

Behre Dolbear conducted intensive interviews with manufacturers and users of densifiers, stacked disk centrifuges, decanter centrifuges and pressure filters. It became clear that, absent further physical studies, none of these technologies could be clearly set apart as the single most promising approach to water recovery at Eshidiya. Until they had conducted their own testing programs on the Eshidiya thickener underflows, none of the Option B or Option C equipment manufacturers were willing to speculate on the technical performance of their units or the capital and operating costs associated with their potential use.

To be sure that technical and financial feasibility were accurately assessed for each technology option, Behre Dolbear contracted for three separate treatability testing programs. Alfa Laval Separations, Inc., performed tests on stacked disk and decanter centrifuges. Larox, Inc. performed tests on pressure filters and EIMCO-Baker Hughes performed tests on its densifier (also called the "Deep Cone Paste Thickener"). The scheduling and conduct of multiple test programs caused the Feasibility Study timetable to extend beyond the contract deadline for final report submission. JPMC acknowledged the value of this more comprehensive program and agreed to a delay in final report submission.

Using its own laboratory test results, each manufacturer developed equipment recommendations, materia balances for its dewatering process and typical capital costs for its technology. To rank the treatabilit options, Behre Dolbear calculated the percentage of lost process water that might be recovered by eacl technology, the capital cost of installation plus ten-year capital replacement costs associated with eacl option and the capital cost per unit of water recovered during the ten-year period. Table 1. 1 summarizes th results, indicating a clear choice for Eshidiya's water recovery technology.

Table 1.1

Estimated Recovery of Lost Process Water and Capital Cost per Unit Recovered

"Option"/Alternative	**Percent of Water Recovered from Al and A3 Underflows**	**10-Year Capital Cost $ per M3 of Water Recovered)**
"B" / Deep Cone Densifier	62.2%	$0.30
"C" / Decanter Centrifuge	80.0%	$2.16
"C" / Pressure Filter *	92.7%	$2.31
"C" / Stacked Disk Centrifuge	31.3%	$4.30
*Processing Densifier Underflow		

Option B, EIMCO Deep Cone Densifiers, proved the most technically and financially attractive based on the capital cost per unit of recovered process water. Among the Option C alternatives, stacked disk centrifuges were shown to be neither technically nor economically feasible. Decanter centrifuges demonstrated excellent water recovery, but their indicated costs were quite high and their dewatered products were not amenable to handling for disposal. Pressure filters offered the most complete water recovery, but absent a socio-political mandate to conserve water in the national interests, it is unlikely that JPMC can financially justify this approach at any time in the near future.

EIMCO Deep Cone technology can reduce water losses from the current range of 460 to 470 cubic meters per hour to approximately 170 to 180 cubic meters per hour, saving approximately two-thirds of the water currently being lost in existing thickener underflows.

Using generally accepted estimating techniques for feasibility studies of this nature, Behre Dolbear determined that the installed capital cost of the EIMCO Deep Cone system will be approximately US$5.8 million. The 10-year total cost is estimated at US$0.63 per cubic meter of water recovered.

Assuming a capital investment of US$5.8 million and annual operating costs of US$628,450, the EIMC Deep Cone Densifiers provide water savings of 1,907,400 cubic meters per year. Utilization of the densifiers to dewater Phase I slimes results in a 10-year project internal rate of return of 17.7 percent. Th project payback of investment is 5.5 years, based upon a fresh water cost of US$1.00 per cubic meter.

It should be noted that this technology is also applicable to the Phase II and Phase III expansions. Howeve for each expansion, a new capital investment will be required for Deep Cone units.

During Option C testing, Larox concentrated a portion of its bulk sample to approximately 30% solids th subjected that material to pressure filter testing. This was done to approximate pressure filter performan when dewatering underflow from the Option B densifiers. These tests were extremely successful and showe potential for very high levels of water recovery. Behre Dolbear cannot recommend such a system at this tim because the capital expenditures are quite large. However, JPMC is advised to consider the addition pressure filters to receive and dewater Deep Cone densifier underflow when the future cost of make-up wat reaches $1.75 to $2.00 per cubic meter.

Behre Dolbear was not required to perform an environmental impact statement, but it did generally assess tl significant environmental aspects of the proposed new technology. The most significant impact on t environment will be reduced demand on the regional aquifer. In comparison with current operating practice Eshidiya, the proposed technology will not degrade the existing environment.

Behre Dolbear recommends a field test of the EIMCO Deep Cone Densifier at Eshidiya prior to detail design. Given a successful field test, the Deep Cone units could be installed and operational within fourte months from the date of contractual commitment by JPMC.