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Environmental Management of the Stone Cutting Industry in Hebron, Palestine

إدارة بيئية لصناعة قطع الحجر في مدينة الخليل، فلسطين

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ABSTRACT: Environmental Management of the stone cutting industry in Hebron, Palestine, is required to reduce the industry's adverse impacts on the downstream agricultural land and on the drinking water aquifers. This situation required the implementation of an industrial wastewater management strategic approach and technology within the environmental need and available technical and financial resources. Ten pilot projects at different locations were built at Hebron to reduce or eliminate the incompatible discharge of the liquid and solid waste to the environment and improve the stone cutting industry's effluent quality. A review of existing practices and jar test experiments were used to optimize the water recycling and treatment facilities. The factors reviewed included influent pumping rates and cycles, selection of the optimal coagulant type and addition methods, control of sludge recycling process, control over flow rates, control locations of influent and effluent, and sludge depth. Based on the optimized doses and Turbidity results, it was determined that the use of Fokland polymer with an optimal dose of 1.5 mg/L could achieve the target turbidity levels. The completion of the pilot projects resulted in the elimination of 18% of the total stone cutting waste discharges in Hebron. The results included an improvement in the recycled effluent quality by 44-99%. This in turn reduced the long term operating costs for each participating firm. A full-scale project that will include all the stone cutting firms in Hebron industrial area is required.
Keywords: *stone cutting industry, slurry disposal, environmental management, Hebron, Palestine.*

المستخلص: إن صناعة قطع الأحجار في مدينة الخليل، فلسطين، لها آثار سلبية على الأراضي الزراعية وعلى المياه الجوفية المستخدمة للشرب. ويتطلب هذا الوضع تنفيذ ادارة بيئية ونظام ذو نهج إستراتيجي لإدارة المياه المستخدمة والمخلفات الصلبة الناتجة عن هذه الصناعة ضمن الموارد التقنية والمالية المتاحة. لقد تم إنشاء عشرة مشاريع نموذجية تجريبية في عشرة مواقع في الخليل للحدّ من او القضاء على ظاهرة طرح النفايات السائلة والصلبة ذات التأثير السلبي على البيئة ولتحسين جودة المياه الناتجة عن صناعة قطع الاحجار. تم استعراض الممارسات القائمة وعمل تجارب مخبرية (Jar Test) لإختيار مرافق المعالجة والطريقة المثلى لإعادة تدوير المياه. وتم مراجعة عدة عوامل شملت معدلات الضخ المتدفق والدورات، والإختيار الامثل لنوع المجلط وطرق الإضافة، بالإضافة إلى مراقبة عملية إعادة تدوير الحماة، والتحكم في معدلات التدفق، ومراقبة مواقع تدفق المياه والنفايات السائلة وعمق الحماة. وبناءا على نتائج فحص التعكر لتحقيق مستوى التعكر المطلوب تبين ان الجرعة الامثل تحققت باستخدام بوليمر الفوكلاند بمقدار 1.5 ملغ/لتر. ولقد ادى إنجاز هذه المشاريع إلى الغاء 18% من إجمالي تصريف فضلات صناعة قطع الحجر في الخليل والارتقاء بالمرافق القائمة في معالجة النفايات السائلة. وبينت النتائج تحسنا في نوعية المياه المعاد تدويرها (44 % -99 %). وهذا بدوره ادى إلى خفض تكاليف التشغيل طويل الاجل لكل من الجهات المشاركة. ويوصى بإقامة مشروع متكامل يشمل جميع شركات صناعة قطع الحجر في منطقة الخليل الصناعية للحد من تدفق نفايات صناعة قطع الحجر للبيئة.
كلمات مدخلية: *صناعة قطع الاحجار، إدارة بيئية، معالجة النفايات السائلة، الخليل، فلسطين.*

INTRODUCTION

Most of the Middle-Eastern countries, including Palestine, are characterized by arid to semi-arid climatic conditions and have very limited water resources. The majority of fresh water supplies in these countries come from scarce groundwater resources. Future population growth in these countries and its associated water demands is expected to place severe pressures on the limited groundwater reserves. It is anticipated that Palestine will experience serious water deficits, where the water shortage is projected to reach about 271 million cubic meters (Mm3) in the year 2020 (Mimi and Smith, 2000). There are numerous studies and plans for expanding water resources supplies through various schemes including water transfers from other basins and desalination. However, most of these schemes are expensive and also face daunting logistical and political barriers.

In recognition of the scarcity of water and the inevitable population growth in the region, conservation and efficient use of existing water sources is becoming imperative. Saving water and protection of water supply, rather than development of new water resources and supply projects may prove to be in many cases the appropriate and optimal policy. Moreover, from an environmental perspective, it is advisable to minimize leakage, to prevent pollution, and address specific wastewater discharges (Mimi, *et al.* 2003).

In the West Bank (Figure 1), the industry of stone cutting is one of the largest industrial sectors; its contribution to GDP is about 10% and it is one of the largest water consuming industries, currently at about 0.5 Mm3 per year. During the stone cutting process, water is used for the purpose of cooling and for collecting stone dust. The resulting wastewater is a suspension of limestone powder. The annual amounts of wastes generated by this process include 700,000 tones of slurry waste in addition to one million tone of solid waste. The dumping of this waste in open areas has created several environmental problems, and negatively impacts agriculture, humans, and groundwater (Al-Jabari and Sawalha, 2002).

The problems related to water consumption and random wastewater dumping from this industry has been classified as one of the major environmental problems in the West Bank. Improper management of the stone cutting industry wastes is the main reason for the increasing of the Total Suspended Solids (TSS) levels in Hebron groundwater (Al-Jabari and Sawalha, 2002).

The high cost of water and the environmental problems associated with slurry disposal has motivated the implementation of water saving technology to reduce economic losses as well as environmental impacts. Currently, wastewater is being treated in order to recycle the water for reuse, while the produced slurry is being dumped to open areas. The resulting solid waste consists mainly of limestone powder which can be recycled in different forms of useful products like those related to construction materials (CH2MHILL, 2002).

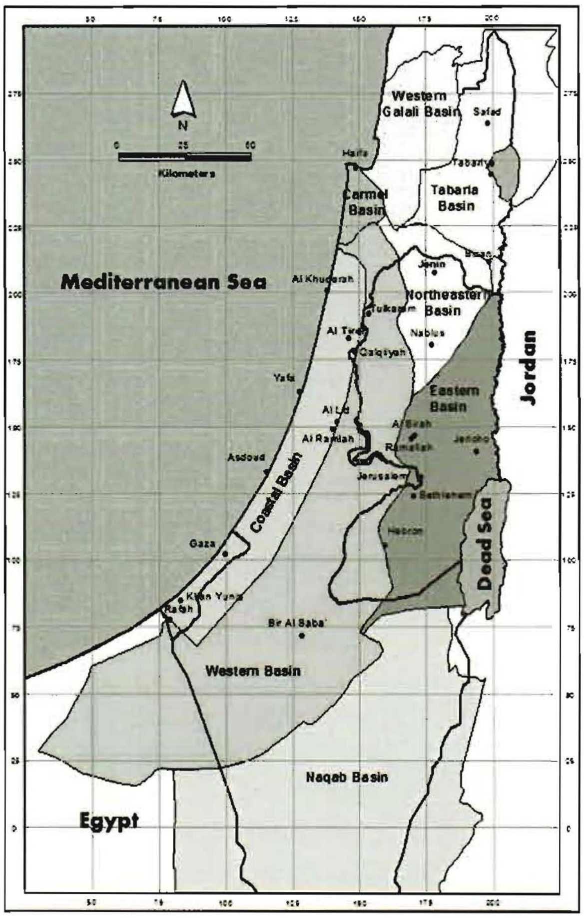

Fig. 1. West Bank location map and major hydrologic basins.

Implementing change to this historical industry is difficult due to the heavily fragmented membership consisting of approximately 400 independent stone cutters firms in the West Bank. The liquid wastes of the stone cutting industry include fine solids that are generated in the production process by diamond saws. For example, in Hebron city of the West Bank, the stone cutting firms typically discharge waters with TSS concentration of about 120,000 mg/L (CH2MHILL, 2002). Historically, this discharge has caused high maintenance costs on existing sewer pipes and open channels for several kilometres downstream. During wet weather events, large volumes of fine stone solids are re-suspended and deposited on the downstream agricultural lands, causing soil contamination and reducing soil quality. Furthermore, the discharge areas of these liquid stone wastes are located in the recharge areas of the principle aquifers used for drinking water supply, the Eastern and Western Aquifers (Figure 1).

Therefore, the environmental management of the stone cutting industry in the West Bank and mitigating and reducing its adverse impacts on the downstream agricultural lands as well as its potential adverse impacts on the drinking water aquifers is becoming very crucial. These adverse impacts of the stone cutting industry on the environment can be reduced when the industry become less polluting, using the resources in a more sustainable manner, recycle more of its wastes, and handles its residual wastes in an environmentally more acceptable manner.

In this study, the Hebron Industrial area was chosen for the implementation of an industrial wastewater strategy and its supporting pilot projects. This is due to the concentration of over 70 stone cutting firms within a limited geographic area. Moreover, a planned investment in municipal wastewater treatment infrastructure for the Hebron area mandated that the practice of discharging stone cutting wastes into the municipal wastewater conveyance systems would need to be terminated to ensure sustainable operation of the planned municipal wastewater treatment facilities (CH2MHILL 2003).

The objectives of the pilot projects were: 1) reduce or eliminate the incompatible discharge of the liquid and solid waste to the environment; 2) improve the stone cutting industry's effluent to a quality that would allow an increase in the industry's internal recycle rate a minimum of 25%, a decrease in water consumption a minimum of 25% and a decrease in a firm's waste discharges by 25%; and 3) provide a local mean for dewatering the stone slurry such that the waste is dewatered to more than 40% solids and being easily disposed as a solid by-product rather than being discharged to the public sewer.

This study demonstrates the implementation of sustainable technology to reduce the discharges of the liquid and solid wastes of the stone cutting industry to the environment, and illustrates an effective and innovative approach for encouraging efficient water use in the industry of stone cutting, which can be effectively implemented in similar areas worldwide.

METHODOLOGY AND APPROACH

The study was carried out in two phases; the first phase consisted of the identification of the stone cutting industry needs, while the second phase consisted of the actual implementation of the environmental management system. The first phase included conducting a bench-scale treatment process on samples collected from the stone cutting processes, initializing a database on the existing water consumption, wastewater generation, recycled effluent quality, and providing descriptions, plans, estimated capital costs, estimated operating costs savings, and estimated improved effluent quality of optimized facilities.

The second phase included installing of ten Palestinian-made plate and frame filter presses at ten stone cutting firms, optimizing the water recycling process through installing ten wastewater submersible pumps, installing a wastewater piping system and chemical metering pumps to inject a polymer solution to the main sedimentation tank.

Most Palestinian stone cutting firms currently practice some degree of water recycling. Generally small firms use simple sedimentation tanks without chemical addition that are manually emptied monthly. However, most medium and large firms use vertical clarifiers either with or without polymer addition. A few larger firms have also started to use plate and frame filter presses to treat the resulting slurry from the vertical clarifiers.

The stone cutting industry located in the project area is comprised of medium to large manufacturers of cut stone. Each of the ten selected firms had water recycling facilities including raw wastewater pumping, a vertical clarifier, and some form of polymer addition facilities (Figure 2). Two firms also had plate and frame filter presses to treat the slurry generated by the vertical clarifier.

A review of existing practices and jar test experiments were used to optimize the selected water recycling and treatment facilities. Factors reviewed included influent pumping rates and cycles, selection of the optimal coagulant type and addition methods, control of sludge recycling process, control over flow rates, control locations of influent and effluent, and sludge depth.

The preferred coagulant (polymer) and optimal dose was chosen by conducting Jar Tests on wastewater samples collected from the stone cutting process. Only one brand of polymer, Fokland, was available through local suppliers. This polymer was tested against a cationic polymer, and an anionic polymer as shown in Table 1. Turbidity (measured as NTU, Nephlon Turbidity Unit) was used to compare and select the most efficient coagulant and the optimal doses. Based on the optimized doses and NTU results, it was determined that the use of Fokland polymer with an optimal dose of 1.5 mg/L could achieve the target turbidity levels. For the three polymers negligible changes between initial and final pH were observed (CH2MHILL, 2004).

The additions of micro-sand and recycled sludge were tested as potential modifications to the process. The addition of micro-sand and recycled sludge resulted in marginal improvements to the final effluent quality.

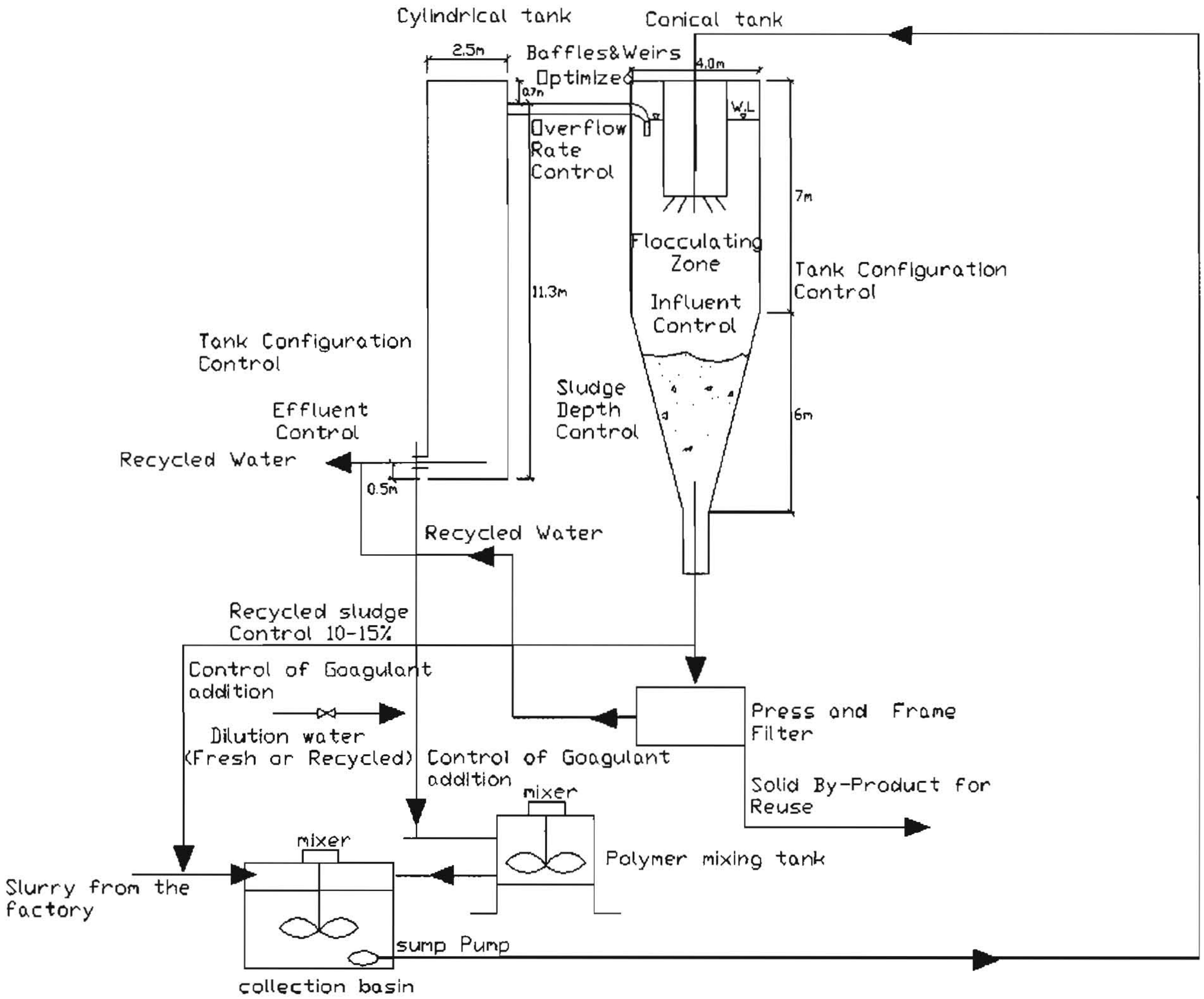

Fig. 2. Schematic flow diagram of the solid and liquid wastes treatment pilot projects

Table 1. Minimum and optimum Polymer dosages.

Polymer Type	Minimum dosage (mg/L)	Optimal dosage (mg/L)	Weight of MS[1] or RS[2]	Initial NTU	Final NTU	% Removal	Initial pH	Final pH
Anionic	4	6		6,400	58.4	99.08	8.05	8.08
Cationic	4	6		6,400	55.4	99.13	8.05	8.07
Fokland	2	1.5		6,400	26.1	99.60	8.05	8.09
Anionic + Micro-sand	4	6	5	6,400	54.8	99.14		8.1
Cationic + Micro-Sand	4	6	5	6,400	32.9	99.49		8.1
Anionic + Recycled Sludge	4	6	15	6,400	31.1	99.51		8.1
Cationic + Recycled Sludge	4	6	5	6,400	31.8	99.50		8.09
Fokland + Recycled Sludge	2	1.5	15	6,400	24.9	99.61		8.09

(1) MS: Micro Sand (gm) in 800 ml Sample (2) RS: Recycled Sludge (ml) in 800 ml Sample

RESULTS AND DISCUSSION

Analyses of the pilot projects results have indicated that all of the ten participating firms achieved 100% elimination of discharges to the environment. i.e., an annual discharge of 3300 metric tons of solids from the ten stone cutting firms was eliminated. Furthermore, the daily water use was consistently reduced by 30% through dewatering the stone slurry to more than 75% solids, while optimization of the water recycling processes further reduced daily water use by an additional 15%. In addition, the improvement in the effluent quality (turbidity) ranged between 44% to 99%.

Table 2 shows the improvement in the recycled effluent quality due to the optimization of the water recycling process. The pilot projects showed that sustainable industrial wastewater treatment facilities in the stone cutting sector can be achieved both technically and economically.

The technical achievements included reducing water consumption. This reduction improves sustainability by reducing the risk for a firm to have its production curtailed during periods of low or no municipal water supply. The second technical achievement was the reduction of the equipment replacement costs. Based on interviews with each of the participating firms, the common experience is that diamond saws last 3 to 6 months depending on stone type and production schedule. Moreover, the diamond saw blade is extended by about 30% since clean recycle water is used in production.

Analysis of the cost saving is summarized in Table 3, which included change in water consumption, electricity, sludge disposal, labour, and equipment replacement costs. The average annual cost saving was calculated at about $7,000 for small firms, about $11,000 for medium size firms, and about $16,000 for large firms (Table 3; Figure 3). Based on the capital investment (approximately $57,000) invested at each of the stone cutting firms, the simple payback period is 3 years for large firms, 5 years for medium size firms, and 8 years for small firms.

Table 2. Improvements achieved in recycled effluent.

Stone cutting firms	Raw wastewater quality NTU	Effluent quality before optimization NTU	Effluent quality after optimizationNTU	% Improvement
Khalil El- Rahman	15288	16503	5505	67
Al-Isra'	16640	206	8	99
Al-Bara'	5376	2423	22	99
Alpha	34304	21035	9699	54
AL-Aqsa	10416	39655	22021	44
Abedel Hafiz	30464	36568	384	99
Al-Mamal	70758	1984	134	94
Al-Anwar	32960	343	21	93
Al-Worood	20544	11504	3304	71
Abu Jihad	59776	27051	12144	55

Table 3. Estimated cost savings achieved in the stone cutting liquid and solid waste treatment facility.

Name of the firm	Base line			After optimization			Annual cost savings $ (Net of energy cost)
	Annual water cost, $(1)	Annual solids disposal(2)	Annual equipment replacement cost, $(3)	Annual water cost, $(4)	Annual solids disposal Cost, $(5)	Annual equipment replacement cost, $(6)	
Khalil El-Rahman	5318	5318	28500	4520	3723	19095	11798
Al-Isra'	5318	5318	28500	4520	3723	19095	11798
Al-Bara'	10636	10636	45500	9041	7445	30485	19801
Alpha	11660	11660	45500	9910	8161	30485	20262
AL-Aqsa	4254	4254	13500	3616	2978	9045	6370
Abedel Hafiz	6381	6381	13500	5425	4467	9045	7327
Al-Mamal	5318	5318	13500	4520	3723	9045	6848
Al-Anwar	3273.	3273.	45500	2782	2291	30485	16488
Al-Worood	5318	5318	13500	4520	3723	9045	6848
Abu Jihad	4254	4254	13500	3616	2978	9045	11798
Total, $	**61730**	**61730**	**261000**	**52472**	**43212**	**174870**	**107540**

1. Actual quoted trucked water costs paid by Hebron industries.
2. Actual quoted trucking costs paid by Hebron industries.
3. Actual replacement costs for diamond saw blades and industry's estimate of extended blade life.
4. Based on estimated 15% reduction in water purchases achieved through the liquid wastewater treatment optimization.
5. Based on a 70% reduction in volume resulting from the solid waste treatment.
6. Based on the 30% extended life of the saw equipment resulting from the liquid wastewater treatment optimization.

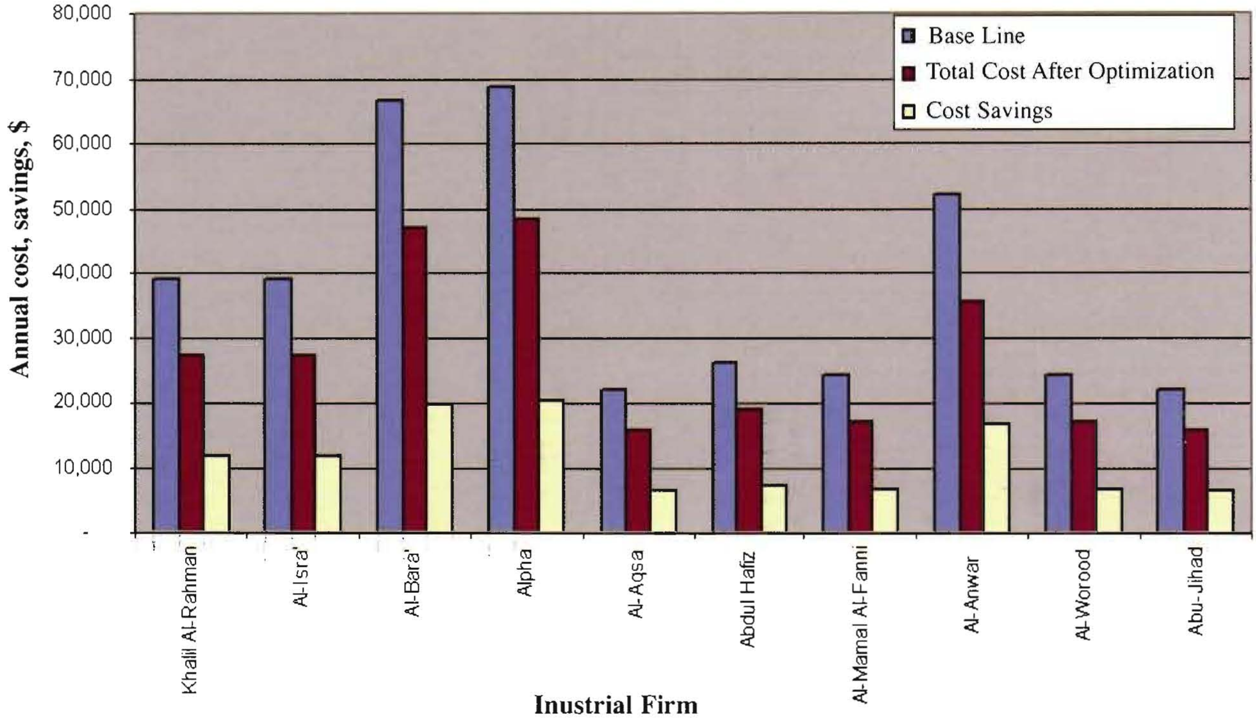

Fig 3. Reduction in Operating Costs Achieved in stone cutting Liquid and Solid Waste Treatment Facilities.

CONCLUSIONS

The implementation of the pilot projects in the 10 selected stone cutting firms in Hebron Industrial area has reduced the effluent discharges of the stone cutting industry that have adverse impact on the downstream agriculture and the groundwater. The Pilot projects eliminated 18% of the total stone cutting waste flow discharges in the Hebron industrial area. i.e., approximately 3300 metric tons/year of solids and 5400 m^3/ year of water. Improvements in effluent quality ranged between 44% and 99% compared to the original conditions.

The majority of environmental savings were generated from the solid waste treatment project. A range of 18 - 42% of the water content in the slurry was recovered and recycled within the stone cutting facilities by using the frame and plate filter presses.

The majority of cost savings were generated from the liquid waste optimization facilities. Approximately 70% of the operational cost savings were achieved in having less frequent cutting saws replacement. Higher effluent quality improvements resulted in longer operation time of the equipment. The pay back periods of investment costs was found to be 3 years for large sized firms, 5.0 years for medium sized firms, and 8 years for small stone cutting firms.

A full-scale project that will include all the stone cutting firms in Hebron industrial area is required to eliminate the stone cutting waste flow discharges to the environment.

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