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Forum & Technical Field Visit

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USING AGRICULTURAL RUN-OFF "SUBSURFACE DRAINAGE WATER" FOR POTASH PRODUCTION

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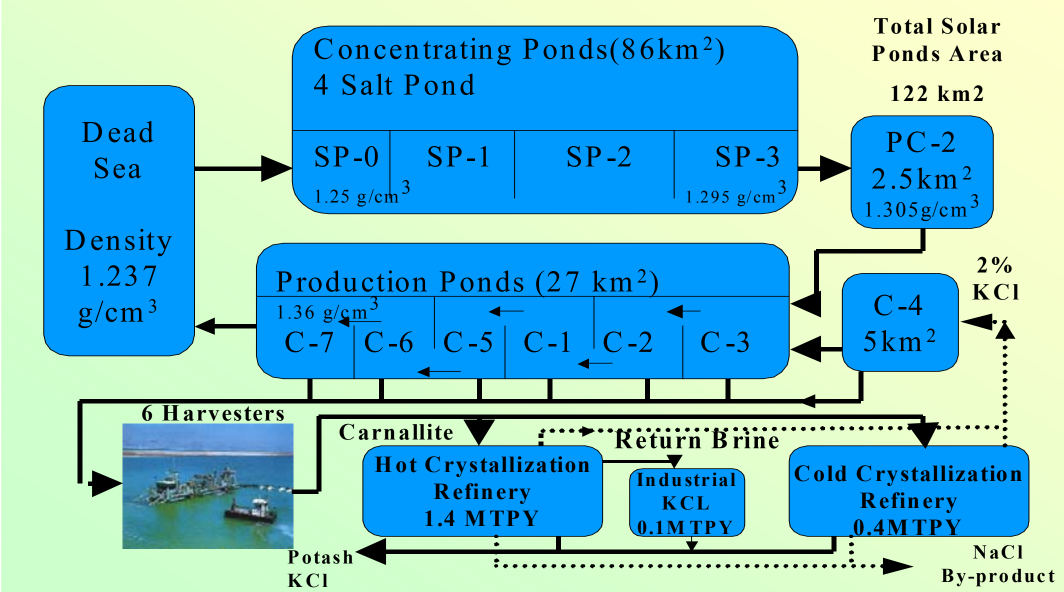
Introduction

The Arab Potash Company (APC) was founded in 1956, by the Jordanian Government to execute the project for the production of potash (KCl) and other minerals from the Dead Sea, with minimum impact on the environment.

The location of APC is 110 km south of Amman, the capital of Jordan. The adjacent project area is farming intensive. The Company utilizes two of Jordan's most abundant natural resources: solar energy and the minerals of which the Dead Sea is rich.

The Arab Potash Company operates one of the largest man-made solar pond system built on the land and is part of the Dead Sea, to prepare the raw material known as carnallite ($KCl.MgCl_2.6H_2O$), to feed two refineries to produce potash at the annual capacity of 2.0 MMTPY. Different processes are applied in order to produce high quality potash and these are: Hot leach and Cold leach (Figure 1).

Figure 1: Production Scheme



Water is a major and essential element in potash production. To produce one ton of potash about five cubic meters of water is required. Potash refineries consume about 9-10 million m^3/year. Process water is used mainly in decomposition of carnallite (Process nature requirements according to brine chemistry), dissolution of sodium chloride in crystallization unit, washing of the sylvinite cake, cooling of pump seal and general purposes such as cleaning. This high consumption uses up mainly the good quality water on the account of farming and local community domestics uses (Figure 2).

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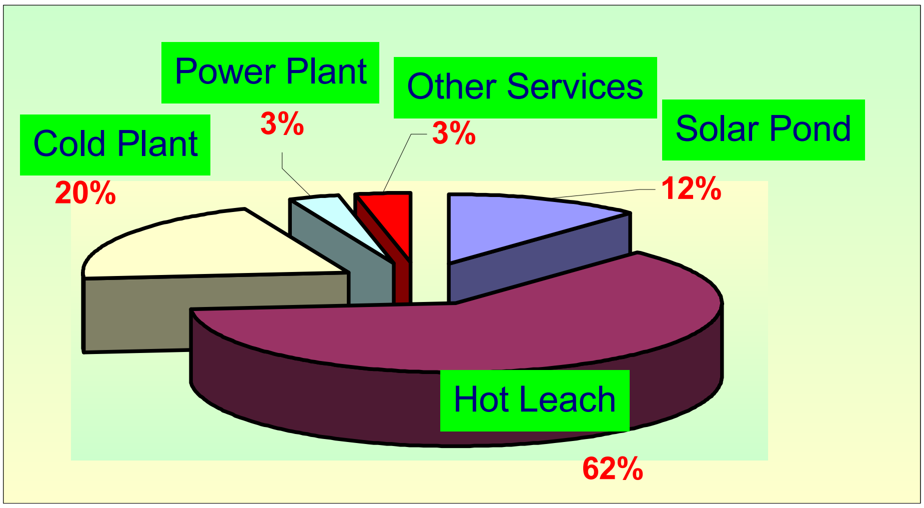
Figure 2: Distribution of Process Water Consumption in APC Facilities



And due to the climatic conditions prevailing in the south of the plants and the neighboring agricultural area within the proximity of the complex, damage to the vegetation in the surroundings of the plants may raise strong reactions by the farm owners, the people living in the neighborhood, as well as the mass media. These reactions can easily harm the company's image on the long run.

Series of dry years have become a common phenomenon in Jordan. The fact that the water supply system in Jordan is designed to suit average rainfall conditions, series of dry years (drought condition) may result in a collapse of the water supply system, inability to meet the minimal water demand for maintaining reasonable hygienic life, water quality degradation, food stuff shortages, health detriments, unemployment and eventual social unrest.

The population pressure on the water resources of Jordan today has never been as intense. Since the 1980s, water consumption has exceeded the renewable resources, leading to groundwater depletion; Jordan's available water resources are, on a per capita basis, among the lowest in the world.

Water supply deficiency is constraining Jordan's economic development and is therefore limiting the achievement of a higher standard of living. The lack of renewable water resources is seriously hindering economic and social development as well as the quality of life for residents. Water scarcity will result in a national crisis unless significant measures are taken to use all water resources to satisfy growing demands. Jordan's water development strategy through 2010 requires the country to invest approximately $5 billion in constructing facilities to close the growing gap between supply and demand. Investment in the water sector is projected to account for one third of all expenditure in the country's 5-year economic strategy.

Since water is also a limited resource in the area, a special attention has been given from The Arab Potash Company to water securing. Even though the Company has its own resources there is a gap between its water needs and the current available water resources, and this gap is expected to be increased with the potash planned expansion.

To bridge this gap, secure water for expansion, prevent the decrease of good quality water consumption and to protect the surrounding area from pollution, The Arab Potash Company has executed a planned program which is summarized as follows:

- Recharging existing wells.
- Drilling more wells.
- Collection of water by traditional methods such as harvesting of water from the surface.
- Brackish water is targeted water even from underground wells such as Haditha or from subsurface drainage water for potash production. (This water is not suitable for domestic use).

The principal goal of The Arab Potash Company has been to attain the best performance consistent with environmental compatibility at APC sites in both Safi and Aqaba and reduce environmental impact as far as possible in accordance with highest international standards.

Arab Potash Company's Environmental Policy

Evolving from The Arab Potash Company's commitment to sustainable development, of which the environment protection is one of its main elements, APC, at all its management and executive levels, commits to comply with local environmental laws and regulations related to its extraction and production operations of various types of potash, and does its utmost to reduce pollution through the following methodologies:

- Minimizing the adverse environmental impacts through the efficient management of solid, liquid wastes and gaseous emissions.
- Conservation and rationalizing the consumption of energy, water, and natural resources.

This paper will highlight further details on the reuse of subsurface drainage water in potash industry at The Arab Potash Company.

Methodology

The Jordan Valley Authority originates the agricultural run-off water from the return flow of the irrigated land project in the Safi area that was commissioned in 1986. The irrigated land has served mainly from the base flow of Wadi Hasa at Safi. This water is collected by subsurface drainage system and conveyed via open collective channels towards two main sites at Sammar and Ain Abatta (Figure 3).

The two main sources are:

Sammar Source

It is about fifteen 15 kilometers south of the APC Plant site.

Ain Abatta Source

It consists of four streams that flow in open channels towards the border line. The streams are located north of Safi city and four to five (4-5) kilometers away from the plant site.

Figure 3: Project Components Water Channels & Pipelines Layout

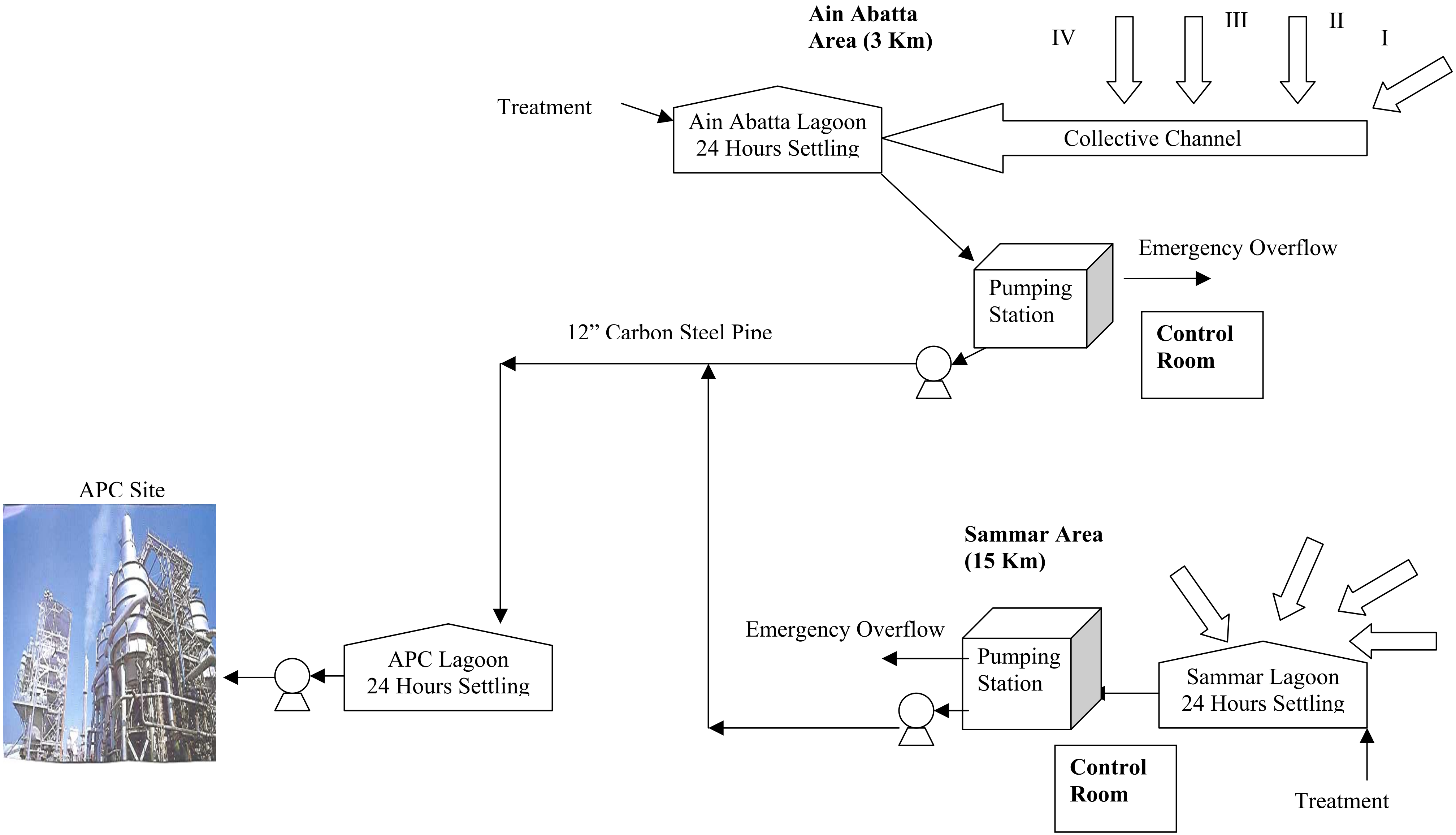


Photo 1: Combination of channels at Ain Abatta

The main objectives of using subsurface drainage water for potash industry are divided into two main categories: -

Environmental objectives

- ✓ Protecting ground water from contamination by bad quality agricultural runoff water. Project area is an intensive farming area resulting in high usage quantity of chemical and biological fertilizers.
- ✓ Preventing the formation of local swamps resulting from unused agricultural runoff surface water accumulation, which help to transfer many diseases among citizens, by flies and insects.

Economic objectives

- ✓ Reuse of drainage water in potash production.
- ✓ Reducing of fresh water consumption in potash production, and increasing availability of fresh water to domestic usage.
- ✓ Low cost relative to other sources.

Water from these sources are not suitable for domestic uses and/ or agricultural reuse, and so The Arab Potash Company has expressed interest in using this water as process water in its plants to augment its existing resources. Upon this, The Arab Potash Company has signed an agreement with Ministry of Water and Irrigation / Jordan Valley Authority to pump these free of charges waters from its sources to The Arab Potash Company plants.

It is probable that the use of low quality water may result in an inferior quality of potash, diminished production and lower equipment life (increase maintenance cost), therefore, The Arab Potash Company decided to study the potential hazards, its impacts and how these might be reduced.

Water Suitability for Potash Industry

Scientific approach was the core elements for The Arab Potash Company technical staff to decide if this water is suitable for potash industry before endorsing its usage.

Measuring quantity of targeted water

Measurement of water quantities for Al-Sammar and Ain Abbata streams depended on the following procedures:

- Available data and information were collected and reviewed.
- New data was obtained from monitoring program for different seasons.
- Study and analysis of the results of the water statistically.

Quality and suitability for potash production

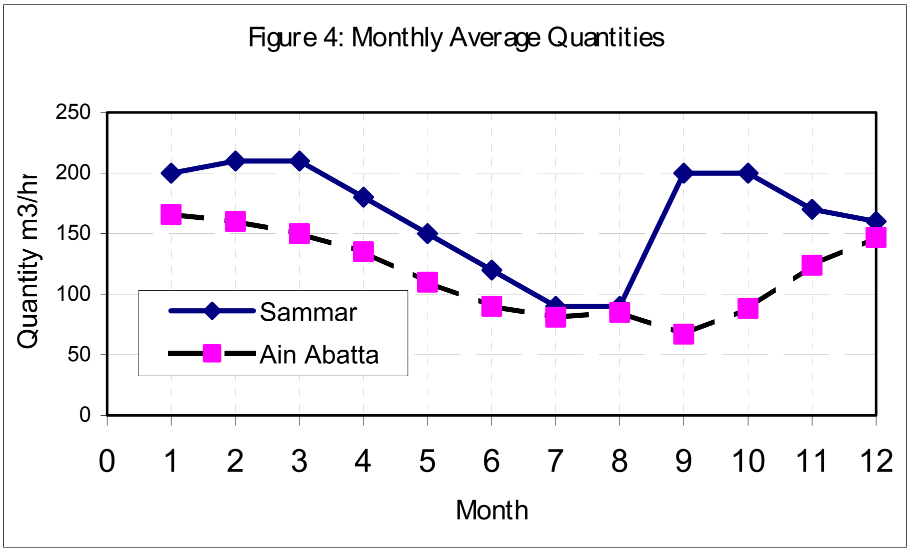
The study of the quality and suitability for potash production from Al-Sammar and Ain Abatta streams was carried out with the following approach to assess the usage of such water in potash production:

- Analysis of available data concerning the water quality parameters for both water sources. Physical, chemical and biological parameters were considered during that analysis (Table 1).
- Taking representative samples of the water from Sammar source and the discharge of the four channels of Ain Abatta source and analyzing these samples in an internationally approved reputative laboratory specialized in water analysis (Table 2).
- Laboratory tests were carried out on decomposition of carnallite and dissolution of sodium chloride, after that this water was transferred to The Arab Potash Company plants, and was added to decomposition unit itself (Pilot Test).
- Monitoring the quality of subsurface water drainage and collecting all the data required to set the design parameters for a selected period. New data were continually obtained during the monitoring program to study water quality variation versus the irrigation water application in the Safi area.
- Study and analyze the results of the water quality its suitability for potash production with its impact on potash quality and quantity produced and suggests any treatment necessary for the water.
- Study the effect of water in increasing the potential for corrosion on APC plant system.
- Study the feasibility of transferring the water through pumping from the source of Al-Sammar and Ain Abatta to the APC plants.
- International and local consultants review the results to ensure that the water is suitable for potash industry.

Technical Staff Evaluation of Drainage Water

Quantity

- The total water quantities at Ain Abatta and Sammar are 2 4 million cubic meters per year.
- The daily quantities vary between 100 to 250 m^3/hr for Sammar source and 60 to 200 m^3/hr for Ain Abatta throughout the year.
- The monthly average quantity varies according to irrigation season; the peak value is remarkably higher from September to April in which farming is taking place.



Water quality of the targeted sources

The evaluation of the sub-surface drainage water consisted of three main tasks as follows:

- Chemical modeling of the thermodynamics equilibrium relationships between the water and the various mineral phases to potash production.
- An evaluation of the corrosion potential of the water in question on the pipes and equipment of APC's plants.
- An evaluation of the biological contamination of the water.

Water quality itself

The analysis of water shows that the water is saline because it contains a high percentage of salts, chemical elements and compounds, and some biological matters.

Physical water- quality parameters

The main physical parameters that have been studied in this category were suspended solids, turbidity, color, odor and temperature. Because this water is agricultural runoff water, so it contains solids; the analysis shows that these solids were divided into inorganic or organic materials and/or live organisms.

The existence of these solids causes, sometimes, odor as a result degradation of organic solids. So filtration and sedimentation were a must, the pathway of water involves self-purification since its open channels and two big lagoons were built in order to surge water, the settling pond shall preferably hold at least one day's usage.

Chemical water- quality parameters

As it is known, water is an universal solvent, and the chemical parameters are related to the solvent capabilities of water. The main chemical parameters that have been studied in this category were total dissolved solids, alkalinity, hardness, fluorides, metals, organics and nutrients.

Chemical modeling of the thermodynamics equilibrium relationships between the water and the various minerals phases to potash production was the base to calculate potassium chloride loss. With regards to the thermodynamics equilibrium, excess potassium chloride must be discharged as a purge due to increasing magnesium and calcium chloride added in the agricultural runoff water, plus the increase of insoluble (sodium chloride and calcium carbonate) in the tailings cake.

Extraction of sylvite from carnallite is achieved by two main steps; the dissolution of carnallite and the precipitation of sylvite. It is required to obtain complete carnallite decomposition with minimum water usage, carnallite decomposition discharges magnesium chloride, potassium chloride and water. Magnesium chloride solubility is higher than potassium chloride solubility. Magnesium chloride entering the brine causes potassium chloride to precipitate from the brine.

$$KCl.MgCl_2.6H_2O(s)+NaCl(s)+H_2O$$

$$\downarrow\uparrow$$

$$KCl(s) +KCl(l)+ NaCl(s)+ NaCl(l)+ MgCl_2(l)+ KCl.MgCl_2.6H_2O(s) + H_2O$$

Here water is added in the crystallization process to prevent the precipitation of sodium chloride and to dissolve the entrained fine crystals.

Loss of potassium chloride product was estimated to be 0.00057 ton KCl per m^3 drainage water, so Channel I is eliminated, this gives just 0.00014 ton KCl per m^3 drainage water as losses in hot leach refinery and 0.0043 ton KCl per m^3 drainage water in cold crystallization plant.

Based on the above product losses: -

- Drainage water use in cold crystallization plant was not recommended due to product loss and / or product contamination. All channels could be used for carnallite decomposition.
- Use Channel I water in potash industry is questionable because it contained high concentration of sodium, calcium and magnesium chloride. Also the use of Channel V water in potash industry is questionable because it contained high sulfate.
- Channels II through V could be used for carnallite decomposition in hot leach refinery.

Biological water- quality parameters

Aquatic organisms range in size and complexity from the smallest single–cell microorganisms to the largest fish that may live in water, thus all members of the biological community are, to some extent, dependent on water quality parameters.

In view of the fact that the water source in question is intended to be used as process water only, the potential health hazards that are associated with handling and processing were considered.

The biological analysis of water shows that Stream II contained 740 MPN/100 ml E.coli that is higher than the allowable limits, while Streams I, III, IV and V contained E.coli population below the standard limits.

Consequently, effective disinfections are required as a result of presence of E.coli and pathogens.

Corrosion Study

The electrochemical behavior of steel in the target water had been studied; using the potential current technique by applying anodic potential. As a result of that small amount of densities was measured and the current density increases as potential increases in the same solution, upon comparison the effect of the chloride ions percentage a shift toward the active direction (less anodic) was observed as the concentration of chloride ions increase.

Accordingly, stainless steel or non-metallic or lined carbon steel is recommended as material of construction for pumping system.

Project Component and Implementation Works

Project components (Fig 3) consist of the following:

- Collecting lagoons.
- Pumping station consists of three (3) pumps.
- Pipelines with a diameter of 12″ and a length of 15 km and its accessories such as valves, joints, and pipeline.
- Electrical transformer combined with electrical cables and control room in the project area.

Work Plan

Project time schedule (fourteen months) is envisaged to be of four (4) phases: -

- Preparing engineering design.
- Implementation of civil works such as (Collecting pond, control room building, pipeline path preparation, pipes, joints, valves, pumps, motors, transformer cables.
- Procurement of mechanical and electrical equipments and pipes.
- Construction and installation of equipments and commissioning at start-up.

<u>Work progress</u>

- All hydraulic, strength, elongation and water hammer calculations were prepared and reviewed by an international engineering company.
- The specification of pumps, pipes, valves and accessories were prepared and reviewed according by an international engineering company.
- The quality study was prepared by APC's technical staff and a local consultant and reviewed by the international engineering company.
- Pipeline route survey, pumping station survey and soil investigation has been completed.
- Civil works, water pumps supporting system, excavations for the concrete ponds and steel structure had been completed

Photo 2: Collection Lagoon For Drainage Water At Sammar Site

Photo 3: Refinery Collection Pond For Sub-Surface Drainage Water

Photo 4: Refinery Collection Pond For Sub-Surface Drainage Water (side view)

Project Cost

The feasibility study showed that the total capital investment (Table 3) of the project would be 2.5 million JD (USD 3.5 million), 2.0 million JD for Sammar and the rest for Ain Abatta.

Conclusion and Recommendations

The expected results after implementation of this project would be the reduction of fresh water consumption in potash production; utilizing the recovered water from agricultural runoff water in potash production, improving local environment, and make the local farmers more aware to environmental issues, and contamination of ground water by chemical pollutants.

References

George T. Austin: " Shreve's Chemical Process Industries" New York 1976. Fifth edition. P. 833

Gilbert M. Masters:" Introduction to Environmental Engineering and Science", New Jersey 1991. P. 451

Papers, Memos, and Reports of Technical staff at The Arab Potash Company.

Appendix

The Arab Potash Company

Table 1 Comparison Between The Average Analysis of Summer vs Winter Seasons for Agricultural Runoff Water between Year 1993 until 2002

		Average Concentrations Results			
Parameter	Unit	Summer *	Winter **	Difference	Control
Con.	*M*S/cm	13740	12300	1439	-
PH	SU	7.63	7.40	0.23	7.72
T.D.S	ppm	8729	7264	1465	1330
T.H (ppm)	$CaCO_3$	4141	3768	373	-
ALK.	ppm	208	188	19	-
SiO_2	ppm	170	70	100	NIL
Na^+	ppm	1822	1504	318	188
Cl^-	ppm	4065	3333	733	652
TUR	NTU	30	4	26	-
Ca^{++}	ppm	635	594	40	135
Mg^{++}	ppm	660	552	108	80
K^+	ppm	188.81	164	25	23
NH_3	ppm	8.90	1.65	7.25	<0.03
SO_4^{--}	ppm	2422	2255	167	168
HCO_3^-	ppm	250	220	30	206

* Summer Season from March through September
** Winter Season from October through February

Table 2 Analysis of Summer Season for Agricultural Runoff Water in the Year 1995 through 2002

Test / Sam. Date	Con. /cm	PH	T.D.S	T.H (ppm) $CaCO_3$	ALK. ppm	SiO_2 ppm	Na^+ ppm	Cl^- ppm	TUR NTU	Ca^{++} ppm	Mg^{++} ppm	K^+ ppm	NH_3 ppm	SO_4^{--} ppm	HCO_3^- ppm
11/6/1995	10670	7.22	6307	3168	191.9	89.7	1405	3401.97	3	541.2	440	-	-	1579.17	-
3/5/1996	13180	7.72	7776	4207.5	247.5	27.65	1734	3908	111	844.8	508	-	-	2121	-
13/4/1997	11650	7.82	6874	3861	209.8	44.4	1643	3620	1	593	516	157.6	0.46	1983	251.51
6/4/1997	10930	7.54	6449	3671.25	172.5	25.3	1350	3282.5	20	561	550	148.6	0.11	2091	210.24
12/9/1997	9430	7.38	5564	2417.11	-	25.85	1004	2133.78	6	389.1	347.7	122.1	0.066	1819	-
3/9/1998	16000	7.31	9440	5533.1	-	2953	2005	4201	3.5	745.4	875.8	175.2	-	2527	-
17/7/1998	7510	7.88	4421	2021.25	-	42.6	867.9	2029	1.5	343.2	282	101.6	-	736	-
21/3/2000	14090	7.62	8313	4283	193	76	1770	3930	-	607	672	186	-	2500	235
4/4/2000	13350	7.21	7877	4280	219	47	1683	3305	-	706	612	213	-	3000	267
9/4/2000	8320	7.83	4909	2685	188	75	888	2223	-	462	372	116	4.4	1400	229
11/4/2000	14030	7.3	8278	4447	198	92	1702	3934	-	627	700	194	4	2500	242
16/4/2000	13210	7.66	7793	4001	229	72	1629	3451	-	561	630	184	17	2550	280
23/4/2000	14050	7.63	8289	4414	191	94	1725	3533	-	527	696	192	-	3150	233
26/4/2000	13180	7.71	7775	4166	192	91	1639	3374	-	594	650	195	2.6	2920	234
30/4/2000	13670	7.36	8065	4349	216	77	1608	3805	-	693	636	222	8	2441	264
4/5/2000	14180	7.36	8366	4283	230	79	1795	4100	-	746	588	209	-	2300	280
8/5/2000	14800	7.66	8730	4530	225	98	1850	3800	-	627	720	220	-	3150	274
13/5/2000	15900	7.5	9450	4579	249	89	2278	4500	-	653	716	228	-	3000	304
17/5/2000	15300	7.46	9027	4779	215	97	1971	4212	-	710	700	233	-	3020	262
27/5/2000	16400	7.77	9676	5024	137	85	2050	4505	-	693	800	227	6	3133	167
4/6/2000	16300	7.75	9617	4942	204	112	2042	4771	-	640	812	255	13	3400	249
10/6/2000	13060	7.84	7836	3660	240	100	1800	3538	-	520	610	169	--	2500	293
17/6/2000	14150	8	8348	3795	195	78	1710	3650	-	561	580	185	16	2358	238
28/6/2000	15700	7.34	9263	4694	167	87	2000	4360	-	838	632	229	7	2320	204
27/6/2001	-	8.19	12188	-	-	83.9	2410	5645	70	598	855	212	4.9	2210	212
2/7/2001	-	7.42	15244	-	-	51.3	2995	6956	36	749	1033	240	7.4	2542	247
8/7/2001	-	8.07	14846	-	-	48.1	2700	6760	43	719	1002	274	6.4	2474	250
10/4/2002	15900	8.02	9540	-	207.8	101.25	1910	4406	-	701.25	712.5	180	15.6	2625	253.3
25/4/2002	16180	7.79	9708	-	245.81	55	1951.25	5038.8	-	679.8	648	161.25	30	1900	299.88
16/6/2002	19830	7.6	11898	5735.45	218.97	112.4	2558.51	5590	-	807.6	902.49	57.28	17.24	-	266.92
Average	13740	7.63	8729	4141	208	170	1822	4065	30	635	660	189	8.90	2422	250
Maximum	19830	8.19	15244	5735	249	2953	2995	6956	111	845	1033	274	30.00	3400	304
Minimum	7510	7.21	4421	2021	137	25	868	2029	1	343	282	57	0.07	736	167

Table 3 Analysis of Winter Season for Agricultural Runoff Water in the Year 1993 through 2002

Test / Sam. Date	Con. /cm	PH	T.D.S	T.H (ppm) $CaCO_3$	ALK. ppm	SiO_2 ppm	Na^+ ppm	Cl^- ppm	TUR NTU	Ca^{++} ppm	Mg^{++} ppm	K^+ ppm	NH_3 ppm	SO_4^{--} ppm	HCO_3^- ppm
29/2/1993	15490	7.73	9103.7	4702.5	359.1	41.5	1757.5	4559.4	5.1	627	760	-	-	2100	-
9/12/1994	8000	7.97	4720	2095.5	164.6	42.61	863	2112.92	3	478.6	224	-	-	-	-
18/10/1994	7490	7.99	4655.1	2095.5	209.7	19.6	826	2195.9	3	528	188	-	-	-	-
9/10/1996	17600	7.21	10384	4834.5	306.9	56.78	2239.38	5306.13	1.55	805.2	684	192.5	0.22	2147	374.04
10/10/1996	10900	7.67	6431	3324.75	190.1	38.6	1374.5	3081	2	521.4	480	134	0.25	1642	231.69
1/11/1997	9810	7.45	5788	2821.5	205.1	35.72	1185	2590.72	0.92	528	364	142	0.41	1754	250.7
10/10/1997	14510	7.78	8561	4207.5	174.1	24.4	1918	4158	10	619.91	644.3	178	0.079	2119	212.19
10/10/1998	13690	7.43	8077	3601.53	-	22.2	1949	3711.97	4	414.9	612	152.5	-	1850	-
5/11/1998	16400	7.47	9676	4552.18	-	27.28	2174	906.3	1.8	676.5	682.8	196.6	-	3924	-
8/12/1998	13640	7.33	8048	3795	-	30.6	1737.9	3680.8	6.8	693	500	163.1	-	1943	-
13/11/1999	13040	7.61	7693	4009	214	91.4	1540	3784	-	600	572	168	-	2200	261
15/11/1999	12430	4.6	7334	3953	199	106	1491	3764	-	587	604	207	4.9	2200	243
22/11/1999	14740	7.63	8697	4180	203	98.6	1584	3692	-	561	660	167	2.5	2900	248
27/11/1999	11310	7.63	6673	3547	187	97.5	1350	3121	-	502	556	154.5	-	2000	228
29/11/1999	10870	7.63	6413	3399	180	55	1400	3185	-	548	492	155.7	3	1865	220
4/12/1999	10420	7.65	6148	3597	175	103	1150	2876	-	560	560	145	1.5	1900	214
7/12/1999	9890	7.64	5835	3464	177	48	1200	2897	-	528	520	146	-	1850	216
11/12/1999	10320	7.62	6088	3410	180	42	1212	2897	-	520	500	146	2	1800	220
25/12/1999	13600	7.36	8024	4184	169	96	1662	3950	-	627	636	174	-	2200	206
28/12/1999	11450	7.56	6755	3854	139	102	1250	3180	-	568	592	164	-	2039	170
2/1/2000	11740	7.3	6927	3739	152	108	1437	3162	-	640	520	150	-	2300	185
5/1/2000	12930	7.25	7629	4198	165	57	1630	3325	-	713	588	179	-	3000	201
11/1/2000	12140	7.27	7163	3953	166	97	1514	3264	-	627	580	185	-	2600	203
15/1/2000	11310	7.35	6673	3588	146	109	1340	3723	-	624	488	149	-	2500	178
18/1/2000	12410	7.15	7322	3986	157	104	1529	3266	-	555	632	162	-	2600	192
22/1/2000	12810	7.46	7558	4250	152	104	1595	3672	-	726	592	166	-	2500	186
25/1/2000	12760	7.2	7528	4052	149	95	1553	3590	-	587	628	162	-	2300	182
30/1/2000	12710	7.2	7499	4102	183	104	1654	3671	-	680	584	167	-	2409	223
Average	12300	7.40	7264	3768	188	70	1504	3333	3.82	594	552	164	1.65	2255	220
Maximum	17600	7.99	10384	4835	359	109	2239	5306	10.00	805	760	207	4.90	3924	374
Minimum	7490	4.6	4655	2096	139	20	826	906	0.92	415	188	134	0.08	1642	170