Paper Title

Integerated Management For Water Resources And Enviroment Both Local & Regional Case Study: “Reprocess Agriculture Run Off Water (Subsurface Drainage Water) For Potash Production"

Prepared By:

Eng. Ala’a Omari
Solar Pond Superindendent/ Technical Directorate
The Arab Potash Company

P.O. Box 1470 Amman 11118 Jordan
Tel: 962 77 548 23 99
E-mail: alaa.o@arabpotash.com

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ABSTRACT

Water is a major and essential element in potash production. To produce one ton of potash a five cubic meters of water is required. Potash factories consume about 12 million m^3/year. Process water is used mainly for decomposition of carnallite, 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.

Since Water is also limited source in the area, a special attention has been given by The Arab Potash Company for water securing, even though the company has its own resources there is a gap between the water needs and the current available water resources, this gap is expected to be increased with the future potash planed expansion in addition to expansion in the farming fields in the surrounding area.

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.

To bridge this gap, decrease good quality water consumption and protect the surrounding area from pollution (this water are not suitable for domestic or agriculture reuse), the agricultural run-off water are targeted resources for potash production.

This paper will highlight further details on reuse of agriculture runoff water in potash industry at the Arab Potash Company particularly quantity, quality and suitability of this water for Potash Production and project implementation works including the engineering design stage.

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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-chemical fertilizer) and other minerals from the Dead Sea, with minimum impact on the Environment.

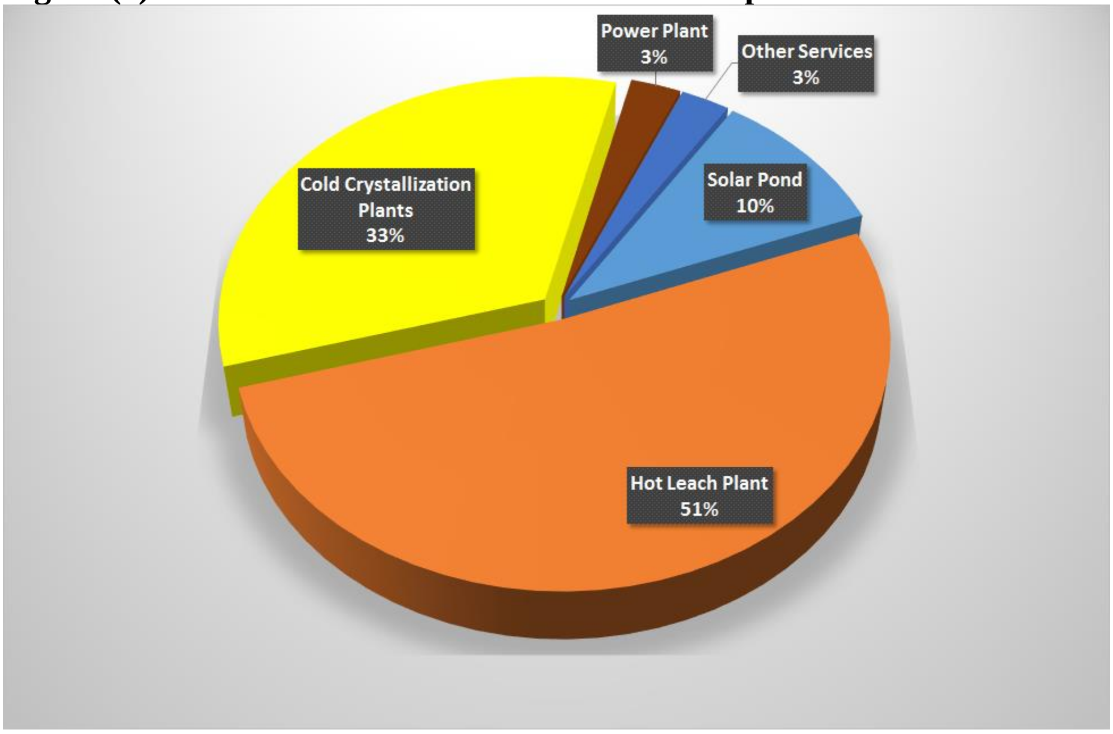
The location of APC is 110 km south of Amman, the capital of Jordan. The area adjacent to the project area is an intensive farming area. The Company utilizes two of Jordan's most abundant natural resources; Solar Energy and the Minerals of which the Dead Sea is rich.

The Arab Potash Company operates one of the largest man made Solar Pond system which was built on the land which was part of the Dead Sea, to prepare the raw material known as carnallite ($KCl.MgCl_2.6H_2O$), to feed three refineries to produce potash at the annual capacity of 2.45 MMTPY. Different processes are applied in order to produce high quality potash and these are: (Hot Leach and Cold Leach). See Figure (1) below.

Water is a major and essential element in potash production. To produce one ton of potash a five cubic meters of water is required. Potash Refineries consume about 12 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. See Figure (2) below.

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 on the farm owners, the people living in the neighborhood, as well as the mass media. These reactions can easily harm the company image on the long run.

Series of dry years has 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 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 sacristy 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 requires the country to invest billions in constructing facilities to close the growing gap between supply and demand.

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

To bridge this gap, secure water for expansion and to decrease good quality water consumption and to protect the surrounding area from pollution, The Arab Potash Company executed a planned program summarizes as following: -

- Recharging the existing wells.
- Drilling more wells.
- Collection water by traditional methods such as harvesting of water from surface water.
- 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).
- Financing construction of dams for the water authority.

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.

The Arab Potash Company Environmental Policy

Evolving from Arab Potash Company's commitment to sustainable development, which the environment protection is one of its main elements; Arab Potash Company, 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 it's 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 reuse of Subsurface Drainage Water in potash industry at the Arab Potash Company.

Methodology

Jordan Valley Authority originates the agriculture run off water from the return flow of the irrigated land project in Safi area that 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. See Attach Figure (3).

The two main sources are: -

- **Sammar Source**

It is about fifteen- (15) kilometer South of APC Plant Site.

- **Ain Abatta Source**

It consists of four streams, these streams flow in open channels towards the boarders' line. The streams are located North of Safi City and faraway four to five (4 - 5) kilometer from Plant Site.

Photo (1): Combination Of Channels At Ain Abatta

The main objectives of usage Subsurface Drainage Water for potash industry is 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 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 Quantity to Domestic Usage.
- Low cost with relative to other sources.

Waters from these sources are not suitable for domestic uses and/ or agriculture reuse, and so The Arab Potash Company has express intrest in using this water as process water in its plants to augment its existing resources. Upon this, the Arab Potash Company has singed 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 Plants'.

Since the use of low quality water may result in an inferior quality of potash, diminished production and lower equipment life (increase maintenance cost), 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 conveying it.

1. **Measuring Quantity of Targeted Water**

   Measuring water quantities' for Al- Sammar & Ain Abbata streams depended on the following procedures: -

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

2. **Quality and Suitability For Potash Production**

   Study the quality and suitability for potash production for Al- Sammar & Ain Abatta streams was carried out depending on the following approach to assess the usage of such water in potash production: -

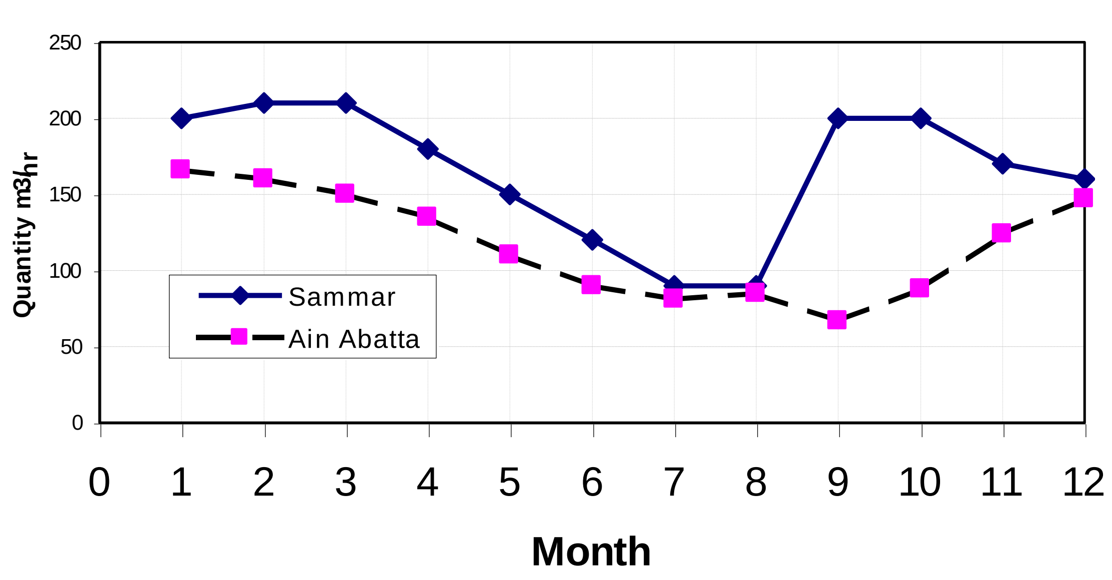
- Analysis of available data concerning the water quality parameters for both water sources. Physical, chemical and biological parameters were considered during that. See Attach Table (1)
- Taking another representative samples of the water from Sammar source and the discharge of the four channels of Ain Abatta source and analyzing these samples in an internationally approved reputative laboratory specialized in water analysis. See Attach Table (2)
- A 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 it self (Pilot Test).
- Monitoring the quality of subsurface water drainage and collecting all the data required to set the design parameters for selected period. A new data were continually obtained during monitoring program to study water quality variation versus the irrigation water application in Safi Area.
- Study and analysis results of the water and study it's suitability for potash production with it's impact on potash quality and quantity produced and suggests any treatment required for the water.
- Study the effect of water in increasing the potential for corrosion on APC plants and system.
- Study the feasibility of transferring the water through pumping from the source of Al-Sammar & Ain Abatta to APC plants.
- International and local consultants reviewed the results to be sure that the water is suitable for potash industry.

3. <u>Technical Staff Evaluation of Drainage Water</u>

- **<u>Quantity</u>**

- The overall 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 noted from September to April in which agriculture farming is taking place.

Figure(4): The Monthly Average Quantitie



4. Water Quality of the Targeted Sources

The evaluation of the Sub surface drainage water was consisted of three main tasks as follows:

- Chemical modeling of the thermodynamics equilibrium relationships between the water and the various minerals 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 a saline because it contains 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 agriculture runoff water, so it contains solids; the analysis shows that these solids were divided into inorganic or organic materials and/or live organisms.

Because existing 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 its known, water is called the universal solvent, and the chemical parameters 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. Regarding to thermodynamics equilibrium, excess potassium chloride must be discharge as purge as a result of increasing magnesium and calcium chloride added in the agriculture 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 get 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.

$$KCl.MgCl_2.6H2O(s)+NaCl(s)+H_2O$$

$$\downarrow\uparrow$$

$$KCl(s) + KCl(l) + NaCl(s) + NaCl(l) + MgCl_2(l) + KCl.MgCl_2.6H2O(s) + H_2O$$

Where as water is added in 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 chanlle 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 number I water in potash industry is questionable because it contained high concentration of sodium, calcium and magnesium chloride. Also use channel number V water in potash industry is questionable because it contained high sulfate.
- Channels number II through V could be used for carnallite decomposition in hot leach refinery.

Biological Water- Quality Parameters

Aquatic organisms range in size complexity from the smallest single – cell microorganism to largest fish may live in water, thus all members of the biological community are, to some extent, 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-coil that is higher than the allowable limits, while streams I, III, IV and V contained E-coil population below the standard limits.

Consequently, effective disinfections are required as a result of presence of E-coil 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 three) 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 month) is predicted 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.

- **WORK PROGRESS**
  - All Hydraulic, Strength, Elongation & Water Hammer Calculations were prepared and reviewed by an International Engineering Company.
  - The Specification of Pumps, Pipes, and Valves & Accessories were prepared and reviewed by an International Engineering Company.
  - The Quality Study was prepared by APC's technical staff and a local consultant and reviewed by an International Engineering Company.
  - Pipeline routs survey, pumping station survey and Soil investigation has been carried out by APC.
  - Civil works, water pumps supporting system, excavations for the concrete ponds and steel structure had been done by local contractor.
  - Electomechnical works had been carried out by local contractor.
  - The project has operated and commissioned by APC.

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 (See table 3 below) of the project would be 2,5 million JD, 2.0 million JD for Sammar and the rest for Ain Abatta).

Conclusion and Recommendations

The achieved results after implementation this project are: -

- Reducing 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 ground water by chemical pollutants.

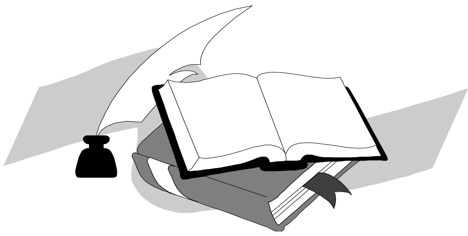
Reference: -

- 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 (APC).

APPENDIX



The Arab Potash Company

Table (1) Comparison Between The Average Analysis of Summer .vs. Winter Seasons

For Agriculture Runoff Water

		Average Concentrations Results			
Parameter	**Unit**	**Summer ***	**Winter ****	**Difference**	**Control**
Con.	*MS*/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 Sammer Season For Agriculture Runoff Water

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
1	10670	7.22	6307	3168	191.9	89.7	1405	3401.97	3	541.2	440	-	-	1579.17	-
2	13180	7.72	7776	4207.5	247.5	27.65	1734	3908	111	844.8	508	-	-	2121	-
3	11650	7.82	6874	3861	209.8	44.4	1643	3620	1	593	516	157.6	0.46	1983	251.51
4	10930	7.54	6449	3671.25	172.5	25.3	1350	3282.5	20	561	550	148.6	0.11	2091	210.24
5	9430	7.38	5564	2417.11	-	25.85	1004	2133.78	6	389.1	347.7	122.1	0.066	1819	-
6	16000	7.31	9440	5533.1	-	2953	2005	4201	3.5	745.4	875.8	175.2	-	2527	-
7	7510	7.88	4421	2021.25	-	42.6	867.9	2029	1.5	343.2	282	101.6	-	736	-
8	14090	7.62	8313	4283	193	76	1770	3930	-	607	672	186	-	2500	235
9	13350	7.21	7877	4280	219	47	1683	3305	-	706	612	213	-	3000	267
10	8320	7.83	4909	2685	188	75	888	2223	-	462	372	116	4.4	1400	229
11	14030	7.3	8278	4447	198	92	1702	3934	-	627	700	194	4	2500	242
12	13210	7.66	7793	4001	229	72	1629	3451	-	561	630	184	17	2550	280
13	14050	7.63	8289	4414	191	94	1725	3533	-	527	696	192	-	3150	233
14	13180	7.71	7775	4166	192	91	1639	3374	-	594	650	195	2.6	2920	234
15	13670	7.36	8065	4349	216	77	1608	3805	-	693	636	222	8	2441	264
16	14180	7.36	8366	4283	230	79	1795	4100	-	746	588	209	-	2300	280
17	14800	7.66	8730	4530	225	98	1850	3800	-	627	720	220	-	3150	274
18	15900	7.5	9450	4579	249	89	2278	4500	-	653	716	228	-	3000	304
19	15300	7.46	9027	4779	215	97	1971	4212	-	710	700	233	-	3020	262
20	16400	7.77	9676	5024	137	85	2050	4505	-	693	800	227	6	3133	167
21	16300	7.75	9617	4942	204	112	2042	4771	-	640	812	255	13	3400	249
22	13060	7.84	7836	3660	240	100	1800	3538	-	520	610	169	--	2500	293
23	14150	8	8348	3795	195	78	1710	3650	-	561	580	185	16	2358	238
24	15700	7.34	9263	4694	167	87	2000	4360	-	838	632	229	7	2320	204
25	-	8.19	12188	-	-	83.9	2410	5645	70	598	855	212	4.9	2210	212
26	-	7.42	15244	-	-	51.3	2995	6956	36	749	1033	240	7.4	2542	247
27	-	8.07	14846	-	-	48.1	2700	6760	43	719	1002	274	6.4	2474	250
28	15900	8.02	9540	-	207.8	101.25	1910	4406	-	701.25	712.5	180	15.6	2625	253.3
29	16180	7.79	9708	-	245.81	55	1951.25	5038.8	-	679.8	648	161.25	30	1900	299.88
30	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 Agriculture Runoff Water

Test / Sample	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
1.	15490	7.73	9103.7	4702.5	359.1	41.5	1757.5	4559.4	5.1	627	760	-	-	2100	-
2.	8000	7.97	4720	2095.5	164.6	42.61	863	2112.92	3	478.6	224	-	-	-	-
3.	7490	7.99	4655.1	2095.5	209.7	19.6	826	2195.9	3	528	188	-	-	-	-
4.	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
5.	10900	7.67	6431	3324.75	190.1	38.6	1374.5	3081	2	521.4	480	134	0.25	1642	231.69
6.	9810	7.45	5788	2821.5	205.1	35.72	1185	2590.72	0.92	528	364	142	0.41	1754	250.7
7.	14510	7.78	8561	4207.5	174.1	24.4	1918	4158	10	619.91	644.3	178	0.079	2119	212.19
8.	13690	7.43	8077	3601.53	-	22.2	1949	3711.97	4	414.9	612	152.5	-	1850	-
9.	16400	7.47	9676	4552.18	-	27.28	2174	906.3	1.8	676.5	682.8	196.6	-	3924	-
10.	13640	7.33	8048	3795	-	30.6	1737.9	3680.8	6.8	693	500	163.1	-	1943	-
11.	13040	7.61	7693	4009	214	91.4	1540	3784	-	600	572	168	-	2200	261
12.	12430	4.6	7334	3953	199	106	1491	3764	-	587	604	207	4.9	2200	243
13.	14740	7.63	8697	4180	203	98.6	1584	3692	-	561	660	167	2.5	2900	248
14.	11310	7.63	6673	3547	187	97.5	1350	3121	-	502	556	154.5	-	2000	228
15.	10870	7.63	6413	3399	180	55	1400	3185	-	548	492	155.7	3	1865	220
16.	10420	7.65	6148	3597	175	103	1150	2876	-	560	560	145	1.5	1900	214
17.	9890	7.64	5835	3464	177	48	1200	2897	-	528	520	146	-	1850	216
18.	10320	7.62	6088	3410	180	42	1212	2897	-	520	500	146	2	1800	220
19.	13600	7.36	8024	4184	169	96	1662	3950	-	627	636	174	-	2200	206
20.	11450	7.56	6755	3854	139	102	1250	3180	-	568	592	164	-	2039	170
21.	11740	7.3	6927	3739	152	108	1437	3162	-	640	520	150	-	2300	185
22.	12930	7.25	7629	4198	165	57	1630	3325	-	713	588	179	-	3000	201
23.	12140	7.27	7163	3953	166	97	1514	3264	-	627	580	185	-	2600	203
24.	11310	7.35	6673	3588	146	109	1340	3723	-	624	488	149	-	2500	178
25.	12410	7.15	7322	3986	157	104	1529	3266	-	555	632	162	-	2600	192
26.	12810	7.46	7558	4250	152	104	1595	3672	-	726	592	166	-	2500	186
27.	12760	7.2	7528	4052	149	95	1553	3590	-	587	628	162	-	2300	182
28.	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