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Comparative Study of Water Quality Assessment for Wastewater Discharge from Industrial Plants: A Case Study of Surface Water in Ismailia Canal (Nile River)

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Abstract

Management of water quality is very vital in the industry and agriculture; limiting concentration of contaminants leads to control on the distribution of wastewater between the plants and agriculture areas. The main objective of our research is to manage the water quality along thirty kilometer of Ismailia canal in which six industrial plants discharged their wastewater and seven agriculture areas are taken their water. Ismailia canal is one of the longest canals that taken their water from Nile River. Firstly, the data were collected from the studied area for one year; the physical and chemical characteristics are studied for each two weeks. The data collected are refer to acceptable readings, except the readings of chemical oxygen demand (COD), biological oxygen demand (BOD) and total dissolved solid (TDS); the industrial plants and agriculture areas are solved this problem by using a huge amount of freshwater to reduce the concentration of contaminants. Secondly, a mathematical model (LINGO Program) is applied to reduce the freshwater consumption and optimize the distribution of wastewater between six industrial plants and seven agriculture areas. The most effective distribution of wastewater network and minimization of freshwater are obtained in our case study.

Keywords: *Water quality; Ismailia canal; Freshwater; Wastewater; Mathematical model.*

1. Introduction

Water sources are very important for agriculture, industrial processes, refineries and human life, so the management of water quality was presented in our research with solving the problem of high consumption of freshwater in the adaptation process of contaminants. Determination the physical and chemical characteristics are studied in a river in India; Grode et al are tested the pH, turbidity, nitrates, chemical oxygen demand and biological oxygen demand [1]. Kelani river is one of the major rivers in Sri Lanka, so Mahagamage *et al.* are tested the water quality (dissolved solids, dissolved oxygen, hardness, pH value) for one year [2]. A twenty-eight sampling sites are determined to manage the water quality of Hindon River for eleven physiochemical parameters [3]. Water quality of Terengganu River are tested monthly; Suratman *et al.* are studied six parameters (pH, dissolved oxygen COD, BOD, total dissolved solid and ammonical nitrogen) at ten sampling areas [4]. Ammonia-nitrogen was presented as a major contaminant of pollution in Skudai River; Naubi *et al.* selected eight sections for samples [5]. Al-Gharraf River is a branch of the largest rivers in Iraq so Ewaid studied the water quality of thirteen physical and chemical parameters for one year [6]. The water quality of bond in Athiyannoor district in India is studied at different sampling stations for one year; Sajitha *et al.* are studied physical and chemical parameters including pH, TDS, temperature and dissolved oxygen [7]. A mathematical model of predicting the missing reading is presented to observe the maximum and minimum reading of several parameters; Abdelmalik applied their mathematical technique on a Qaroun lake [8]. Two steps of stagnation experiments are presented to minimize the pollution load in drinking water; Zlatanovic *et al.* are studied the water residence time and temperature as critical parameters in the distribution of water network [9]. Arithmetic water quality index method is applied on Vijayawada River in district of Pradesh to control the physical and chemical parameters (pH, TDS, Cl, K and Mg) [10]. The effect of microbial-contaminated water was studied to decrease the bad effect of that polluted water on the population of Limpopo province [11]. Cluster analysis and principal component analysis are applied on Nag River; Dutta *et al.* are studied twenty-five biological and physio-chemical parameters including pH, TDS, nitrate, COD, BOD and total coliform [12]. The water quality of Coruh River was studied in different sites for four years; the monitoring sites are divided by Bilgin in two groups by cluster analysis [13]. The role of water quality is presented as an agent of sustainable development goals (SDGs); Alcamo observed the direct or indirect effect of water quality on SDGs in four case studies [14]. Relationship between the water quality and land use is studied to control on the pollution in Malaysia; Camara *et al.* are studied the effect of water pollution on agriculture [15]. A stational techniques are presented to management the water quality in Iraq River; Ewaid et al used the modified of Delphi method to analyze the water quality [16]. Different systems are proposed for water quality monitoring; Ighalo et al observed that artificial neural networks and adaptive neuro fuzzy inference system are the most effective monitoring of water quality [17]. The study of water quality is done for two pond water, one stream water, one rainwater, one hand pump water and one motorized borehole water to determine the limiting readings of parameters alkalinity, TDS, pH and the concentrations of Ca, Mg, K, Na and Cl in the water resources [18].

In this paper, the management of physical and chemical characteristics of water quality were studied for six industrial plants (sources) and seven agriculture areas (demands) in the Ismailia Canal. For one year, the data of temperature, pH, COD, BOD and TDS were collected each two weeks; the obtained results showed the normal reading of pH and temperature but the reading of COD, TDS and BOD is unacceptable so these sinks used a mixing process of large amount of freshwater with the wastewater from sources. A mathematical model is proposed to reduce the freshwater consumption by optimize the distribution of wastewater between sources and demands.

2. Research methodology

Six sources (refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant) discharged their wastewater in Ismailia canal. Seven agriculture areas supplied their water from the six sources; the wastewater samples of sources and demands were collected from April 2022 to March 2023 along thirty kilometers in Ismailia canal. The wastewater quality analyzed the physical and chemical properties that includes the temperature of waste water, pH, BOD, COD and TDS. As shown in Figure 1, the wastewater flowrates of a refinery plant and ceramic plant are near to two sinks agriculture area 1 and agriculture area 2.

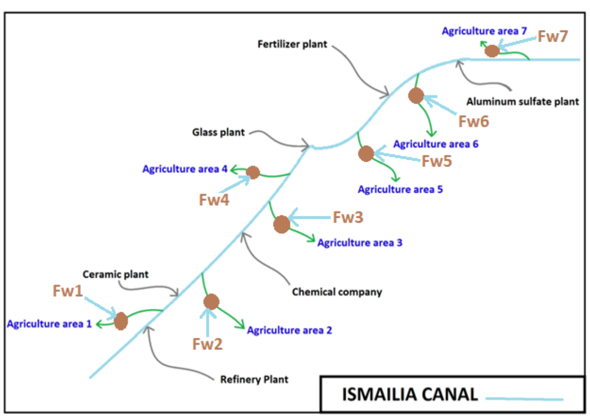

Figure 1. Location map of ISMAILIA CANAL.

The chemical company and glass plant have the third and fourth agriculture area between them. Fifth and sixth agriculture area found in the right side of the canal while the fertilizer plant in the left side. The final source in the studied area is the aluminum sulfate plant; beside him the seventh agriculture area but in the other side of Ismailia canal.

There are seven mixing points; each agriculture area has the ability to decrease the concentrations of the contaminants by adding freshwater to the wastewater in the mixing point.

3. Model formulation

In our research, the physical and chemical parameters of each sink and source were collected and studied; the data included pH, temperature, COD, BOD and TDS. All wastewater flowrates of six sources and seven sinks are studied along one year; the freshwater flowrate that consumed in each sink is studied to show the effectiveness of our mathematical model.

A mathematical approach (LINGO Program) is applied to minimize the freshwater consumption in each sink by optimizing the distribution of wastewater between sources and sinks.

As shown in Figure 2, the allocation of six sources refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant to seven agriculture areas; the freshwater distributed to seven demands according to limiting mass load of sinks.

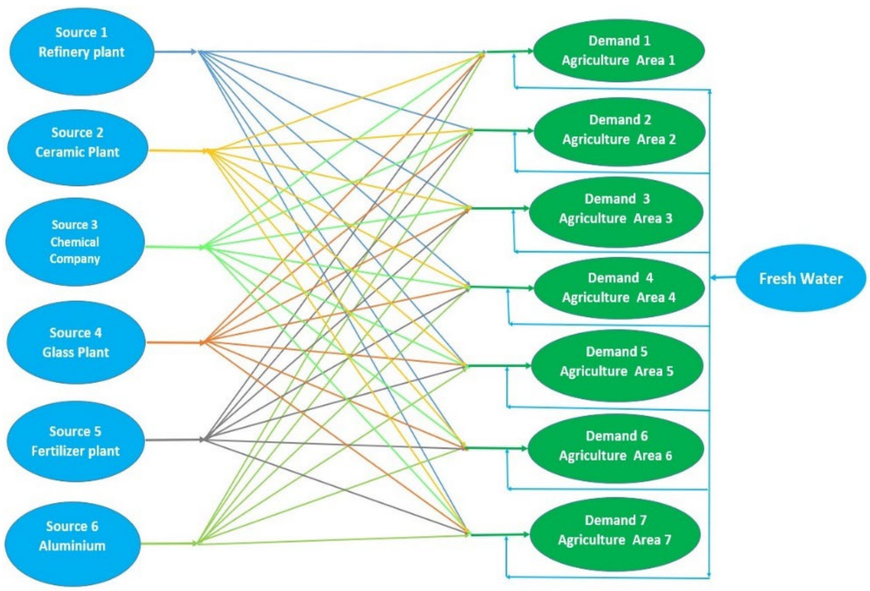

Figure 2. Allocation of sources to demands.

3.1 Mass balance of freshwater

Overall mass balance is applied on all freshwater usage (F_w) in seven sinks; as shown in Equation 1, the total freshwater flowrate (F_w) is equal to the sum of freshwater in each sink, where F_{w1}, F_{w2}, F_{w3}, F_{w4}, F_{w5}, F_{w6} and F_{w7} are the freshwater consumption in mixing point 1,2,3,4,5,6 and 7 respectively.

3.2 Mass balance of each source

Each source has a wastewater flowrate (F_n) that has the ability to distribute to each sink and waste; the distribution of sources to sinks is done according to the limiting mass load of sources and sinks. As shown in Equation 2, wastewater flowrate for source n is F_n and it is equal to the sum of the flowrates from a source n to each sink K and the over load of contaminant send to waste by flowrate G_{nwaste}, where F_{sn_k} is flowrate of source n to sink k.

3.3. Mass balance of each sink

With applying overall mass balance rule on each sink; the wastewater flowrate of sink1 collected the wastewater from all sources and it feeds by freshwater flowrate as shown in Equation 3; the wastewater flowrate of each sink (F_m) is equal to the sum of flowrate of source n to sink k (F_{n_m}) and freshwater flowrate in each sink (F_{wk})

3.4. Component mass balance of each sink

The component mass balance equations are applied for three contaminants COD, BOD and TDS as shown in Equations 4, 5 and 6. The flowrate of source Fm is multiple to concentration of COD in the sink X_{CODm} and the obtained result is equal to the multiple of summation of flowrates of sources to sinks ($\sum F_{n\_m}$) by the concentration of COD in source (X_{CODn}) that shown in Equation 4. With applying a component mass balance on BOD and TDS as shown in Equations 5 and 6, the flowrate of source Fm is multiple by the concentration of BOD and COD respectively and the obtained results are equal to the wastewater flowrate multiple by the concentration of BOD and TDS in the sink respectively.

$$Fw = Fw1 + Fw2 + Fw3 + Fw4 + Fw5 + Fw6 + Fw7 \quad (1)$$

$$Fn = \sum \mathrm{Fsn_k} + \sum \mathrm{Fn_{waste}} \quad (2)$$

$$Fm = \sum \mathrm{Fn\_m} + \mathrm{Fwk} \quad (3)$$

$$Fm * XCODm = \sum \mathrm{Fn\_m} * XCODn \quad (4)$$

$$Fm * XBODm = \sum \mathrm{Fn\_m} * XBODn \quad (5)$$

$$Fm * XTDSm = \sum \mathrm{Fn\_m} * XTDSn \quad (6)$$

4. Results and discussion

A large amount of freshwater was required to decrease the concentration of the contaminants that discharged from the industrial plants; our case study presented the study of water quality along thirty kilometer of Ismailia canal, six sources of industrial plants discharged a wastewater into Ismailia canal while there are seven demands taken their water from Ismailia canal.

Effect of temperature on the water quality is very vital, so our study tests the degree of temperature of the wastewater discharged from the six industrial plants and the wastewater which inlet to the seven agriculture areas; as shown in Table 1, Figure 3 and Figure 4, the degree of temperature of the wastewater discharge from the refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant is between 18℃ to 42℃ while the degree of temperature of the wastewater that entered to the agriculture areas is between 16℃ to 48℃; the reading of temperature of sources and demands is normal reading.

The reading of pH was studied for the wastewater that discharged from the industrial plants to show the acidity or alkalinity of them; the reading of pH value of sources showed the alkalinity of the wastewater as shown in Table 2 and Figure 5. The reading of pH value for seven agriculture areas refer to the alkalinity of the wastewater which entered to the agriculture areas as shown in Table 2 and Figure 6 and that means the wastewater of sources and demands is not acidic and is safe to use.

The COD values in the refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant ranges from 36 mg/L to 45 mg/L, 34 mg/L to 46 mg/L, 32 mg/L to 46 mg/L, 28 mg/L to 45 mg/L, 35 mg/L to 48 mg/L and 32 mg/L to 48 mg/L respectively as shown in Table 3 and Figure 7. As presented in Figure 8 and Table 3, the COD values of agriculture area 1, agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 are varied from 40 mg/L to 48 mg/L, 32 mg/L to 48 mg/L, 30 mg/L to 46 mg/L, 28 mg/L to 45 mg/L, 27 mg/L to 46 mg/L, 26 mg/L to 46 mg/L and 26 mg/L to 46 mg/L respectively.

The BOD values in the refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant ranges from 22 mg/L to 28 mg/L, 20 mg/L to 27 mg/L, 20 mg/L to 28 mg/L, 20 mg/L to 27 mg/L, 20 mg/L to 26 mg/L and 18 mg/L to 28 mg/L respectively as shown in Table 4 and Figure 9. The reading of BOD values of agriculture area 1 and agriculture area 2 are varied from 24 mg/L to 28 mg/L, 25 mg/L to 29 mg/L while the agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 have the same range of BOD values 726 mg/L to 29 mg/L as shown in Table 4 and Figure 10.

As presented in Table 5 and figure 11, the TDS values in the refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant ranges from 750 mg/L to 980 mg/L, 750 mg/L to 950 mg/L, 750 mg/L to 1000 mg/L, 750 mg/L to 1050 mg/L, 750 mg/L to 1000 mg/L and 850 mg/L to 1050 mg/L respectively. The TDS values of agriculture area 1, agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 are varied from 420 mg/L to 580 mg/L, 420 mg/L to 600 mg/L, 440 mg/L to 580 mg/L, 470 mg/L to 600 mg/L, 460 mg/L to 600 mg/L, 420 mg/L to 600 mg/L and 450 mg/L to 690 mg/L respectively as shown in Table 5 and Figure 12.

Table1. Temperature reading of sources and sinks. $Al_2(SO_4)_3$

Time (week)	Temperature of sources, (℃)						Temperature of sinks (℃), (agriculture areas)						
	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Started	28	26	29	27	26	28	26	24	30	26	28	25	29
2	29	27	31	28	27	29	28	25	29	29	26	27	26
4	31	32	33	31	30	32	30	29	34	32	29	30	28
6	32	32	31	34	30	31	30	31	36	35	31	34	31
8	36	35	34	36	33	35	34	34	34	38	34	36	34
10	38	37	37	35	37	38	37	38	35	42	38	40	36
12	38	36	35	37	36	38	39	40	38	43	40	42	39
14	42	39	39	37	40	42	42	42	43	46	44	45	43
16	36	37	36	35	41	40	40	40	40	44	47	48	46
18	33	35	33	34	37	38	36	36	37	40	45	44	48
20	33	35	33	30	35	36	34	34	35	38	43	41	45
22	30	32	30	27	30	35	32	30	32	35	38	37	42
24	28	30	28	27	30	33	27	30	30	29	34	34	36
26	26	27	26	28	27	29	24	29	30	26	28	29	31
28	24	23	24	26	23	26	22	25	25	23	24	26	26
30	21	20	21	24	22	22	20	22	22	20	21	23	24
32	21	20	21	22	19	18	19	18	18	18	18	20	20
34	18	19	18	22	19	20	19	20	20	20	18	18	18
36	18	18	18	19	18	19	18	20	19	21	20	16	20
38	19	20	19	20	20	18	20	19	18	18	22	18	18
40	20	21	20	22	22	20	18	22	22	20	18	16	18
42	21	22	21	24	20	19	17	18	20	18	16	18	20
44	24	23	24	25	23	22	19	20	18	19	18	20	19
46	25	26	25	26	24	24	24	22	20	22	22	20	20

Table 2. pH reading of sources and sinks.

Time (week)	pH of sources						pH of sinks, (agriculture areas)						
	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Started	7.5	8	7.6	8	8.7	7.8	8.6	8.2	7.9	8.7	8.4	8.6	8
2	7.8	8.5	8.3	8.5	8.5	7.6	8.2	7.8	7.8	8.5	8.2	7.9	7.5
4	8.2	8	8.2	8.5	8.8	8.2	8.8	7.6	7.4	8.8	8.5	8.5	7.8
6	7.9	8.2	8	8.2	7.9	8.5	8.2	7.8	8.2	8.7	8.7	8.3	7.6
8	8	8	7.5	8.6	8.5	8	8	7.9	8.1	8.2	8.2	8.5	8
10	8.5	7.8	7.5	7.8	8.2	8.4	8.6	7.5	8.3	8	8.4	8.1	7.8
12	8	7.5	7.5	7.5	7.8	8.5	8.1	7.4	8.4	8.5	8.5	8.6	8.2
14	9	8.5	8	7.9	7.6	8.2	8.9	7.8	8.6	8.7	8.2	8.4	8.4
16	8.5	9	8.2	8.5	7.8	8.5	8.5	7.9	8.4	8.9	8	7.8	8.5
18	7.5	7.8	8.3	8.3	7.8	8.7	8.7	8.2	8	8.5	7.6	7.5	7.9
20	7.5	7.5	7.9	8.5	8	8.5	8.1	8.7	7.7	8.8	7.5	7.9	8.2
22	8.2	8.4	7.6	7.8	8.5	8.2	8.4	8.8	7.9	7.9	7.5	8.2	8.6
24	8.5	8.5	8	7.6	8.8	8.3	8.6	8.2	7.4	7.7	8.2	8.5	8.4
26	7.5	8.2	8.5	7.9	8.5	7.8	8.8	8.7	7.8	8.1	8.6	7.8	8.2
28	7.9	8.4	8.5	8.5	8.6	7.5	8.4	8.5	7.8	8.4	8.8	8.2	8
30	7.5	7.9	7.8	8.4	8.4	7.9	8.6	8.6	7.5	8	8.2	8.6	8.2
32	7.6	7.5	7.9	8.6	8.5	7.4	7.9	8.2	8	7.8	8.6	8.4	7.5
34	7.9	7.9	8	8.2	8.2	7.8	7.5	8	8.2	8.2	8	7.9	7.8
36	8.3	8.6	8.3	8.6	7.8	8.1	7.8	8.4	8.8	8	7.5	8.5	8
38	8.5	8.6	8.2	8.4	7.5	8.3	8.2	8.5	7.9	8.5	7.8	7.8	8.2
40	7.6	7.9	8	8.2	7.9	8.5	8.4	8.1	7.5	8.2	8.2	8	8.4
42	7.8	7.6	8.2	7.9	8.5	8.7	8.8	8.7	8.5	8.6	8.4	8.4	8.6
44	8	7.9	8.5	7.7	8.4	8.5	8.5	8.9	8.4	8.2	8.8	8.2	7.8
46	8.5	8.2	8	8.4	8.2	7.8	7.9	8.5	8.6	8.5	8.4	8	7.5

Table 3. COD reading of sources and sinks.

Time (week)	COD of sources, (mg/L)						COD of sinks (mg/L), (agriculture areas)						
	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Started	44	42	46	44	45	42	45	42	30	32	44	40	45
2	42	44	42	40	48	46	48	35	34	35	46	43	42
4	38	40	45	45	42	38	40	38	32	36	42	45	46
6	40	38	40	42	46	42	46	33	36	30	45	48	38
8	43	34	38	38	42	40	45	34	38	28	48	46	34
10	45	38	42	45	44	36	43	36	34	34	46	40	28
12	42	42	44	43	38	40	47	38	30	32	38	42	26
14	38	46	46	46	38	44	42	42	36	35	39	49	32
16	36	42	42	38	40	38	40	45	40	29	34	46	34
18	38	46	44	35	45	42	45	41	35	36	35	44	37
20	40	40	41	28	43	38	47	38	31	38	33	47	29
22	43	46	43	36	46	35	41	34	36	39	42	28	40
24	40	44	40	40	48	39	43	36	38	42	40	26	42
26	46	42	38	43	42	32	45	40	32	45	38	34	45
28	40	38	32	40	40	36	44	44	30	38	36	38	38
30	38	40	35	35	38	40	46	46	35	32	35	32	34
32	42	45	37	31	35	42	42	32	38	35	30	36	36
34	45	42	39	36	38	46	45	35	44	40	29	38	38
36	42	44	34	40	42	44	44	34	34	43	27	34	42
38	44	40	40	38	46	42	46	38	40	38	40	36	40
40	42	42	36	35	40	48	47	40	36	42	44	40	42
42	40	38	38	32	42	46	42	46	38	45	35	44	40
44	38	40	32	36	46	44	40	48	42	42	40	40	45
46	42	42	40	33	42	40	42	40	46	44	42	43	43

Table 4. BOD reading of sources and sinks.

Time (week)	BOD of sources, (mg/L)						BOD of sinks (mg/L), (agriculture areas)						
	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Started	24	26	24	24	26	25	26	28	27	29	28	28	29
2	26	26	25	25	24	28	28	28	28	28	28	29	29
4	24	24	24	25	24	24	24	26	28	28	29	29	27
6	26	25	26	22	25	26	28	25	27	29	27	28	28
8	28	24	22	23	22	25	25	27	26	29	28	28	27
10	27	22	23	26	24	28	26	26	29	27	26	27	29
12	28	20	28	25	26	25	27	28	29	28	28	26	26
14	24	27	25	25	25	20	28	28	28	26	27	28	27
16	25	26	27	22	22	18	28	27	28	28	28	29	28
18	27	24	24	25	20	22	25	27	26	27	29	27	29
20	26	24	22	24	24	25	26	29	28	29	28	28	28
22	27	26	20	24	24	22	27	28	29	28	27	26	28
24	25	25	20	26	20	26	28	25	27	29	28	26	29
26	28	24	24	27	25	20	26	26	28	29	29	28	27
28	25	26	28	25	26	20	27	28	28	27	28	28	28
30	27	24	26	26	24	25	28	27	29	28	28	27	29
32	27	25	23	24	24	28	26	28	29	27	27	28	27
34	25	25	21	24	20	24	27	26	26	27	29	29	28
36	26	22	20	27	20	28	28	27	28	26	28	28	28
38	22	24	20	27	22	26	26	28	27	28	28	27	29
40	24	25	27	25	25	28	27	26	28	27	29	27	28
42	25	25	28	22	24	24	25	28	26	28	27	28	28
44	26	26	24	20	26	25	27	27	28	27	28	29	29
46	24	24	22	24	20	25	27	27	27	28	29	27	27

Table 5. TDS reading of sources and sinks.

Time (week)	TDS of sources, (mg/L)						TDS of sinks (mg/L), (agriculture areas)						
	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Started	750	780	850	960	950	900	420	480	520	580	580	520	450
2	800	850	800	1050	880	850	440	520	490	550	550	560	550
4	780	800	900	850	920	940	425	460	440	470	470	420	580
6	850	850	850	750	1000	960	450	420	550	520	520	590	620
8	950	890	750	800	850	1000	470	460	520	500	500	490	650
10	760	860	800	890	800	980	450	520	500	460	460	450	640
12	850	900	850	780	750	1050	510	550	540	480	480	430	680
14	790	950	900	950	800	920	500	480	500	520	520	500	620
16	950	850	950	900	760	880	530	500	520	450	450	480	580
18	900	900	850	850	820	820	480	550	550	480	480	450	630
20	790	880	900	900	860	860	550	600	580	510	510	550	650
22	850	850	950	920	920	950	510	550	540	550	550	580	680
24	890	870	1000	880	960	1000	540	580	560	580	580	540	650
26	850	900	950	940	890	920	480	550	520	600	600	580	620
28	880	950	900	980	920	850	420	500	480	560	560	450	680
30	800	750	850	890	850	950	450	520	550	520	520	510	640
32	860	800	950	850	880	860	490	470	530	550	550	560	580
34	840	850	920	900	950	890	520	510	500	580	580	480	620
36	900	780	880	920	980	960	560	530	520	520	520	500	660
38	950	750	960	960	950	910	480	490	480	540	540	520	690
40	960	800	940	940	920	820	420	500	440	560	560	550	640
42	980	850	980	880	980	960	580	540	460	580	580	600	680
44	950	900	890	950	920	920	540	560	520	560	560	520	590
46	800	950	940	920	850	850	560	600	550	590	590	560	620

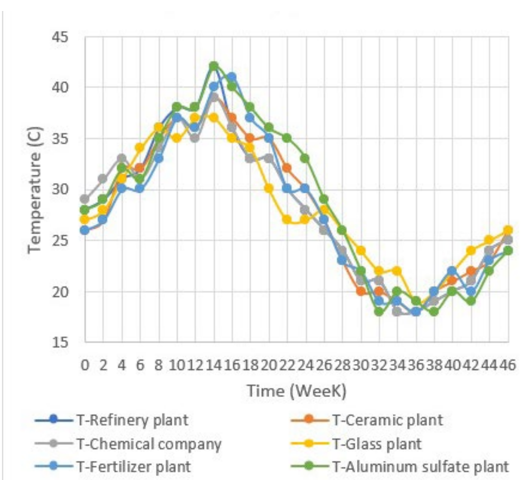

Figure 3. Temperature reading of sources.

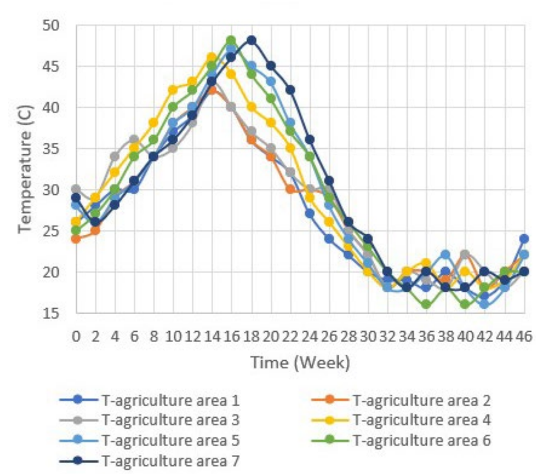

Figure 4. Temperature reading of demands.

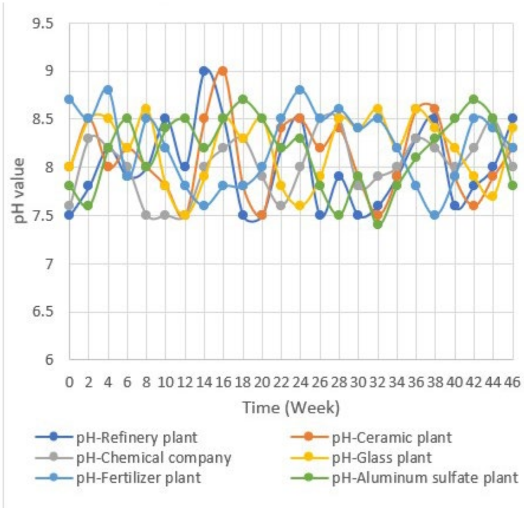

Figure 5. pH reading of sources.

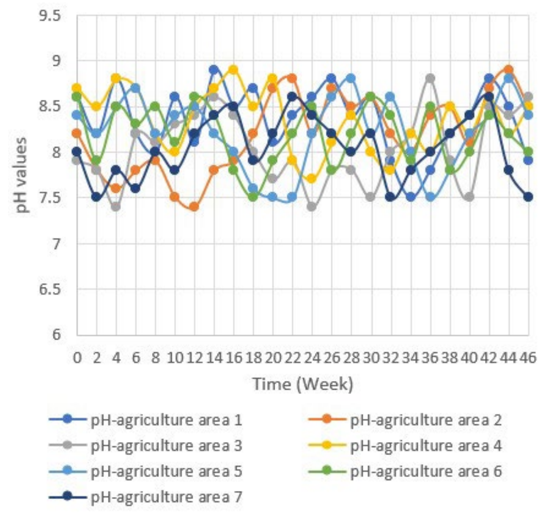

Figure 6. pH reading of demands.

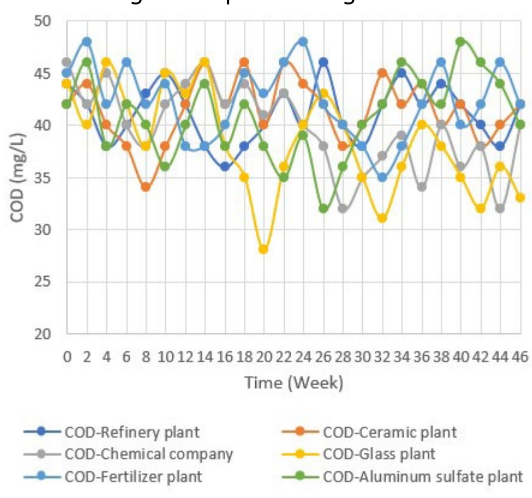

Figure 7. COD reading of sources.

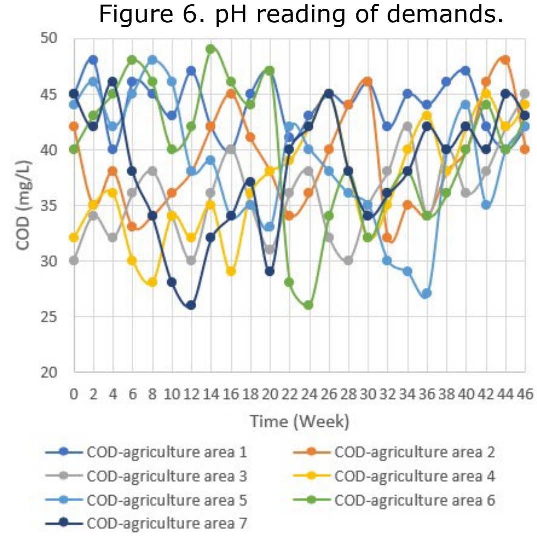

Figure 8. COD reading of demands.

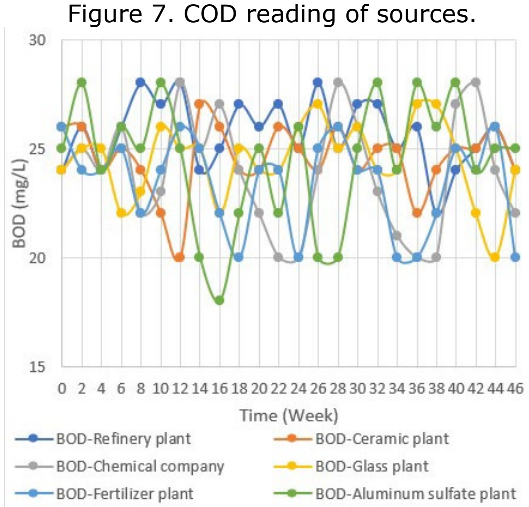

Figure 9. BOD reading of sources.

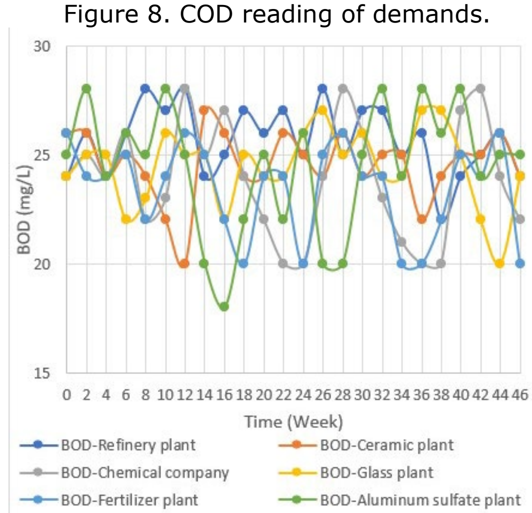

Figure 10. BOD reading of demands

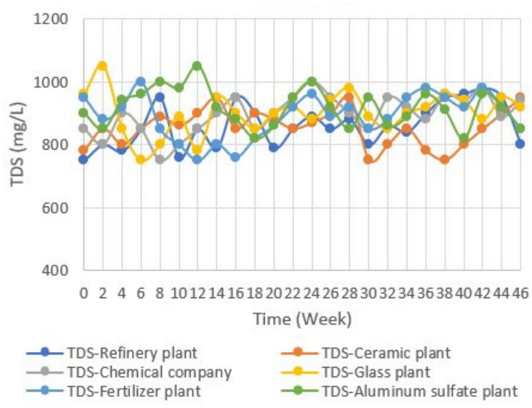

Figure 11. TDS reading of sources.

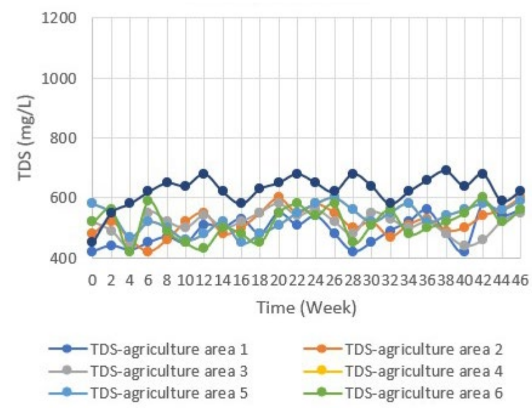

Figure 12. TDS reading of demands.

The flowrates and concentration of COD, BOD and TDS of six industrial plants and seven agriculture areas are listed in Table 6 and Table 7 respectively. The limiting concentrations of our case study was taken as the maximum concentrations of TDS, COD and BOD.

Table 6. Limiting flowrates and concentrations of contaminants in sources.

Flowrates & concentrations	Refinery plant	Ceramic plant	Chemical company	Glass plant	Fertilizer plant	$Al_2(SO_4)_3$ plant
Flowrate (m^3/hr)	50	40	70	35	80	30
COD (mg/L)	45	46	46	45	48	48
BOD (mg/L)	28	27	28	27	26	28
TDS (mg/L)	980	950	1000	1050	1000	1050

Table 7. Limiting flowrates and concentrations of contaminants in demands.

Flowrates & concentrations	Agriculture area 1	Agriculture area 2	Agriculture area 3	Agriculture area 4	Agriculture area 5	Agriculture area 6	Agriculture area 7
Flowrate (m^3/hr)	60	90	50	60	50	80	80
COD (mg/L)	48	48	46	45	46	46	46
BOD (mg/L)	28	29	29	29	29	29	29
TDS (mg/L)	580	600	580	600	600	600	690

After applying the data given into the mathematical model (LINGO program) for the Ismailia canal case study, the obtained results of streams flow rates from sources to demands listed in Table 8.

Table 8. Flow rate of sources to sinks and waste for Ismailia Canal case study.

Stream	Flowrate (m^3/hr)	Stream	Flowrate (m^3/hr)
$F_{\text{Refinery plant - Agriculture Area 6}}$	19.1	$F_{\text{Glass plant- Agriculture Area 5}}$	6.8
$F_{\text{Refinery plant - Agriculture Area 7}}$	30.9	$F_{\text{Glass plant- Agriculture Area 7}}$	0.5
$F_{\text{Ceramic plant- Agriculture Area 2}}$	32.6	$F_{\text{Glass plant- waste}}$	7.5
$F_{\text{Ceramic plant- Agriculture Area 3}}$	0.8	$F_{\text{Fertilizer plant- Agriculture Area 1}}$	2.3
$F_{\text{Ceramic plant- Agriculture Area 4}}$	0.2	$F_{\text{Fertilizer plant- Agriculture Area 2}}$	23.1
$F_{\text{Ceramic plant- Agriculture Area 5}}$	0.8	$F_{\text{Fertilizer plant- Agriculture Area 3}}$	3
$F_{\text{Ceramic plant- Agriculture Area 6}}$	2.8	$F_{\text{Fertilizer plant- Agriculture Area 4}}$	27.7
$F_{\text{Ceramic plant- Agriculture Area 7}}$	2.8	$F_{\text{Fertilizer plant- Agriculture Area 5}}$	2.9
$F_{\text{Chemical company- Agriculture Area 1}}$	32.5	$F_{\text{Fertilizer plant- Agriculture Area 6}}$	10.5
$F_{\text{Chemical company- Agriculture Area 3}}$	3	$F_{\text{Fertilizer plant- Agriculture Area 7}}$	10.6
$F_{\text{Chemical company- Agriculture Area 4}}$	8.1	$F_{\text{Aluminum sulfate plant- Agriculture Area 3}}$	1
$F_{\text{Chemical company- Agriculture Area 5}}$	2.9	$F_{\text{Aluminum sulfate plant- Agriculture Area 5}}$	15.5
$F_{\text{Chemical company- Agriculture Area 6}}$	13	$F_{\text{Aluminum sulfate plant- Agriculture Area 6}}$	3
$F_{\text{Chemical company- Agriculture Area 7}}$	10.6	$F_{\text{Aluminum sulfate plant- Agriculture Area 7}}$	0.6
$F_{\text{Glass plant- Agriculture Area 3}}$	20.3	$F_{\text{Aluminum sulfate plant- waste}}$	9.9

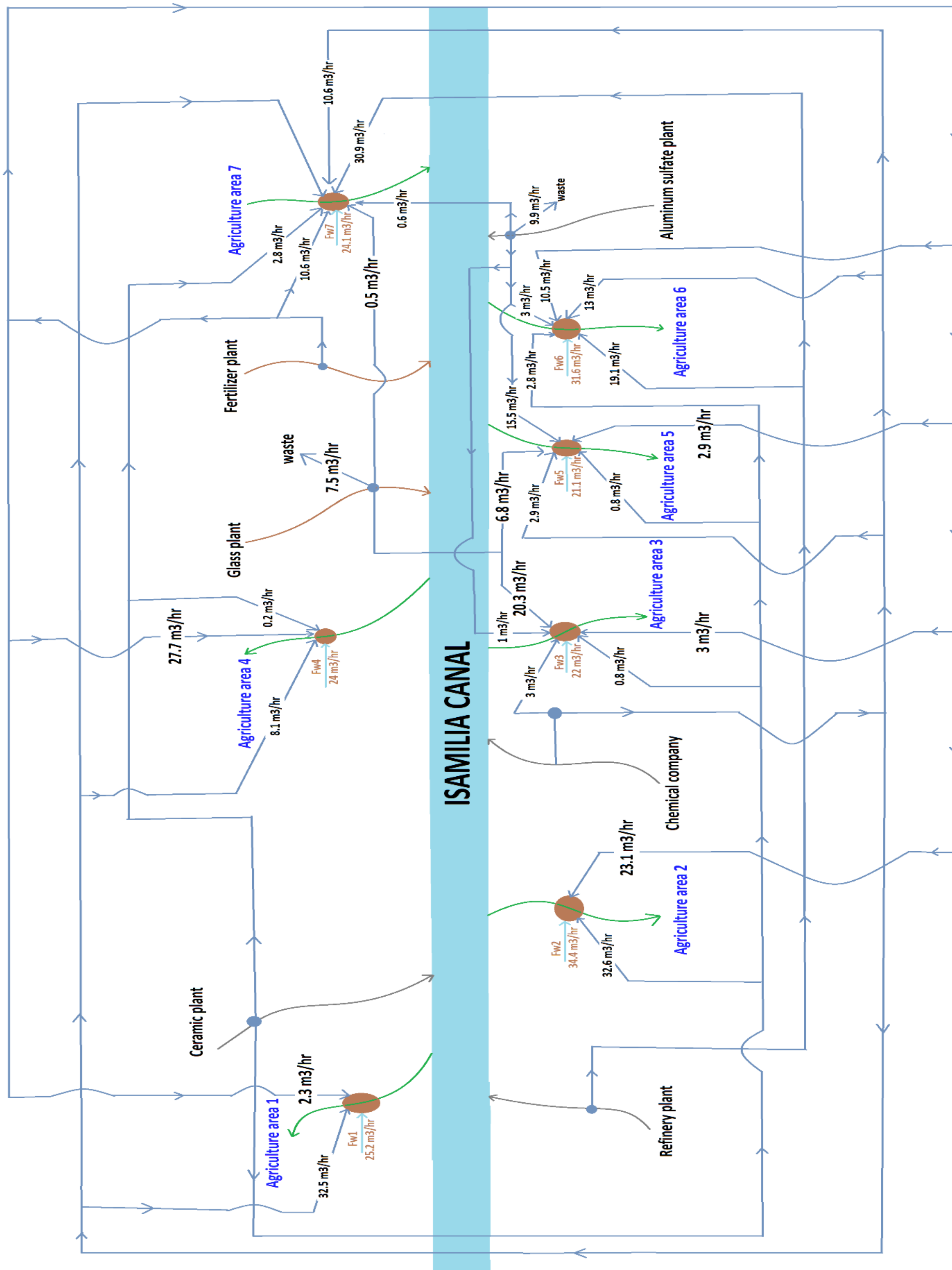

Figure 13. Optimization wastewater network of Ismailia Canal.

As shown in Figure 13 and Table 8, the wastewater discharged from the refinery plant feeds the agriculture area 6 and agriculture area 7 by 19.1, 30.9 m^3/hr respectively while the ceramic plant supplied their wastewater to agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 by flowrates 32.6, 0.8, 0.2, 0.8, 2.8, 2.8 m^3/hr respectively.

The chemical company feeds six agriculture areas (agriculture area 1, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7) by flowrates 32.5, 3, 8.1, 2.9, 13 and 10.6 m^3/hr respectively.

The glass plant was supplied its wastewater to agriculture area 3, agriculture area 5 and agriculture area 7 by 20.3, 6.8 and 0.5 m^3/hr respectively while the remains wastewater 7.5 m^3/hr send to waste. The fertilizer plant supplied the all seven agriculture areas agriculture area 1, agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 by 2.3, 23.1, 3, 27.7, 2.9, 10.5 and 10.6 m^3/hr respectively.
The Aluminum sulfate plant feeds the agriculture area 3, agriculture area 5, agriculture area 6 and agriculture area 7 by flowrates 1, 15.5, 3 and 0.6 m^3/hr respectively while the remain wastewater 9.9 m^3/hr send to waste.

The freshwater feeds the agriculture areas in the mixing units to adapt the concentration of COD, BOD and TDS before entering the wastewater to them; the freshwater consumption is reduced from 320 m^3/hr to 182.4 m^3/hr by a saving percentage 57% as shown in Figure 13; the flowrate of freshwater is distributed to agriculture area 1, agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7 by 25.2, 34.4, 22, 24, 21.1, 31.6 and 24.1 m^3/hr respectively.

5. Conclusion

Adaptation the water quality in the Ismailia canal is very important because a lot of agriculture areas taken their water from it. Two aims are presented in our research, Firstly is to study and analyze the physical and chemical properties of six sources (refinery plant, ceramic plant, chemical company, glass plant, fertilizer plant and aluminum sulfate plant) and seven demands (agriculture area 1, agriculture area 2, agriculture area 3, agriculture area 4, agriculture area 5, agriculture area 6 and agriculture area 7) along sixty kilometers in Ismailia canal for one year; secondly is to solve the huge consumption of freshwater in the agriculture areas by applying a simple mathematical model (LINGO program). Distribution of wastewater from six industrial plants to the agriculture areas is optimized to minimize the consumption of freshwater. The obtained results showed the freshwater consumption is reduced from 320 m^3/hr to 182.4 m^3/hr by a saving percentage 57%.

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