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Pollution Indices and Ecological Evaluation for Wastewater in Industrial Areas

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Abstract

Wastewaters from Tenth Ramadan and El-Obour cities and El-Khadrwia drain verify their environmental effects. The research focused to study Wastewater Quality Index (WQI) and their suitability for irrigation and aquatic life during 2018-2019. The data showed almost of chemical parameters were unacceptable for water irrigation suitability that used to derive criteria and guidelines of hazards ions interactions, FAO for irrigation and Canadian Water Quality Guidelines for aquatic organism. The results indicate that there is no effect of metals in the case of wastewater use for agricultural purposes, whereas for aquatic life, all measured metals except Fe^{+3}, Mn^{+2}, Pb^{+2}, Zn^{+2} and Cu^{+2} show different degrees of contamination in wastewaters of investigated areas. The obtained results indicated organic pollution values of examined variables were higher than the recommended standards and they were major waste impacts. They supported by Organic Pollution Index (OPI) evaluation that ranged from 15 to 822 while the maximum Comprehensive Pollution Index (CPI) and OPI values were (16.1 and 822) for cheese whey wastewater at El-Obour City affects aquatic environmental live in this area and producing healthy harms. The study concluded primary treatment removed 50-60% of pollution. So, study recommended use nanoparticles with low cost to acquire positive ecological impacts and increase national goals.

Key Words: Ecological Evaluation, Industrial Wastewater, Aquatic Environment, Organic Pollution Index; Water irrigation suitability, Comprehensive Pollution Index

1. Introduction

Water is a fundamental force in ecological life-support systems on which sustainable social and economic development depends. Despite its importance, water is the most poorly managed resource in the world. The increasing demand on water arising from anthropogenic activities including fast growth of industries, rapid urbanization and increased agricultural runoff has put pressure on limited water resources that led to ground and surface waters contamination by several sources **[1]**. In developing country like Egypt which is naturally has limited fresh water resources facing valuable water challenges to achieve national goals and water management requirements. Recent studies evaluated water value, categorize the pollutants, strategize the corrective measures to conform different proposes of water use, maintain ecological health and restore the carrying capacity of the water resources **[1-4]**. Deterioration of industrial wastewater quality had a strong ecological impact for aquatic ecosystems **[5]** that physico-chemical variables, heavy metals changed remarkably wastewater quality and accumulated in sediment, fish and plants **[5-8]**. Many of these pollutants break down relatively quickly in the environment; many others are highly resistant to degradation **[9]**. Moreover, bacteria including total coliform, fecal coliform and Escherichia coli groups are useful indicators for wastewater and soil quality **[8, 10]** because of their species diversity and their rapid response for changing environmental conditions **[11-12]**. Water quality assessment is mainly based on its physicochemical components, biological quality and heavy metals concentrations **[13]**. Therefore, prevention of pollution for natural resources by non-treated industrial wastewater and adequate

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preparation or renovation of the wastewater before reuse, are further important considerations in formulating and designing appropriate wastewater disposal arrangements **[14]**. New communities (Tenth Ramadan and El-Obour city) had risk of pollution from industrial wastewater and require more studies and monitoring programs **[15]** for different uses. The degradation and significant variations reported 10-50% of industries wastewater value according to their application standard. The trail clarified food factory in Quesna and the industrial wastewater discharged from the Textile Factory in Quesna had high concentrations range of organic **[16].** The environmental negative impacts of organic matter on aquatic organisms and their pollutants at traditional area (Mubarak Industrial Zone, Quesna – Monufia governorate) considered as primary source of metal poisoning to fish and other aquatic animals in Egypt **[3-16].** Recently studies reported the physical, chemical method and biological growth will remove particles, colloidal matter **[14]** and dissolved molecules using nano-particles **[17]**. Therefore, the use of technology for resourceful precise production in new communities (Tenth Ramadan and El-Obour Cities) and conventional area (Mubarak Industrial Zone, Quesna - El-Khadrwia drain) need controlling several offending industries.

The present study aims to evaluate and matched the results with the standard values established by **FAO, 1985 [18]** for irrigation and Canadian Council of Ministers of the Environment **CCME, 2007 [19]** for aquatic life as well as calculate Organic Pollution Index (OPI) and Comprehensive Pollution Index (CPI).

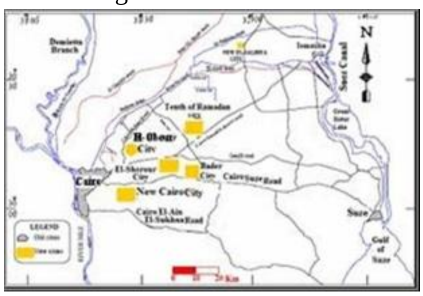
2. Research Methodology

Quantitative analysis of wastewater was carried out and some of qualitative data associated with wastewater was studied through direct observational method, and through both structured and unstructured questionnaires.

2.1 Description of Study Area

Pollution load in the River Nile system (main body, branches, canals, and drains) has increased dramatically through recent industrial activities **[20]**. Traditional and newly constructed industrial cities as shown in Fig.1 (a, b) that are Mubarak Industrial Zone, Quesna - Monufia governorate, Tenth Ramadan – Cairo governorate and El-Obour Cities – Qalubia governorate reprehensive to investigated as following:

- El-Obour City covers almost 64.8 km^2, Qalyubia Governorate, that located between latitudes 30° 09' 00" and 30° 17' 00"N and longitudes 31° 25' 00" and 31° 31' 30" E as shown in Fig.(1a). It is designated to include variations of activities; great residential, industrial and agricultural areas that play an important role in drainage of sewage and irrigation water **[3, 21]**.
- Industrial wastewater of Tenth of Ramadan disposed in three oxidation ponds: P_1- domestic wastewater, P_2- domestic and industrial wastewater and P_3- heavy industries wastewater) that overflow from oxidation ponds is discharged into Wadi El-Watan about 15 km northeast city. The environmental decision related to migrate pollutants to aquifer, soil and consequent serious pollution risk.
- El-Khadrawia drain, Menoufiya governorate receives different industrial Quesna activities which dumped as raw sewage into left El-Khadrawia agricultural drain.Fig.(1b). Morever, Mubarak industrial zone is located on the left El-Khadrawia drain at km 19,600 until at km 29 of El-Khadrawia drain at the intersection of the drain with the Cairo-Alexandria agricultural road **[16]** as shown in Fig.1b.



a

b

Fig. 1 (a, b): General View of New Communities (Tenth of Ramadan and El-Obour City) and Quesna plus Mubarak Industrial Zones Outfuls at El-Khadrawia Drain ,Monufia Governorate

2.2 Water Sampling

Water sampling processes for environmental measurements included physical, chemical (inorganic and organic) and bacteriological parameters were adequate considerations to assess negative impacts of toxic pollutants on aquatic environment in three industrial zones during 2018-2019. Sampling, preservation and experimental procedure of the water samples were carried out according to the standard methods for examination of water and waste water; American Public Health Association **APHA 2017 [8]**.

2.3 Monitoring locations and Parameters

A total of eight sites along three examining areas were selected for sampling that summarized in Table 1.

2.3.1 In Situ-Field Measurements

Analytical chemical grade and free organic and de-ionized water were utilized for preparing standards and instrument calibration solutions under satisfying a clean laboratory environment. Indicators of water quality degradation included filed measurements such as pH, Electrical Conductivity (EC), Dissolved Oxygen (D.O), turbidity, and Total Dissolved Solids (TDS) for water samples were measured in situ using the multi-probe system, model Hydralab-Surveyor and recorded in the same time of sample's collection.

2.3.2 Laboratory Measurements and Analytical Procedures

In addition to the determinations of the field samples, several of physico-chemical measurements were determined such as ammonia (NH_3), Total Suspended Solids (TSS). Major anions (chloride (Cl^-), sulfate (SO_4^{-2}), nitrate (NO_3^-) and phosphate (PO_4^{-3})) are measured in wastewater samples using ion chromatography (IC - model DX-600, USA) as approved methods 4110 & 4500 **[8]**. In addition, carbonate (CO_3^{--}) and bicarbonate (HCO_3^-) are measured by applying a titration method (0.02N H_2SO_4 with phenol phethalein and methyl orange as indicators) as described in Titration Method 2310B Acidity & 2320B Alkalinity **[8]**. Total hardness calculated using 2340B, C - hardness **[10]**. Moreover, clean plastic bottles washed with were10% HNO_3 solution furthermore flushing aliquots of the sampled waters, prior to collection. Single standard for trace elements solutions including Aluminum (Al), Barium (Ba), Boron (B), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb), Zinc (Zn) to prepare calibration standards (Merck, Germany, 1000 mg/l) and major cations (Calcium–Ca^{+2}, Magnesium–Mg^{+2}, Sodium–Na^+, Potassium–K^+) are measured with using the Inductively Coupled Plasma- Emission spectrometry (ICP-ES) Ultra Sonic Nebulizer (USN) model Perkin Elmer optima 3000, USA. The samples were filtered through filtration system via membrane filter of pore size 0.45 um before analyses **[8]**. The percentage of Recovery for the previously mentioned elements varied between 90%and 106%.

Organic content in terms of Chemical Oxygen Demand (COD) using Huch spectrometric DR-3900 and Biological Oxygen Demand (BOD) using incubator WTW 606/4-I are analyzed according international methods **[8]**. The wastewater quality was compared with water quality standards. Finally, Total coliform (TC) and Fecal coliform (FC) using membrane filter technique described according to the Standard Methods for Examination of Water and Wastewater **[8]**. The mean count was calculated for each sample as total coliforms bacteria. Results were recorded in CFU/100 ml using the following equation:

$$\text{Colonies/100 ml} = \frac{\text{counted colonies}}{\text{ml of sample filtered}} \times 100$$

Table (1): Descriptive of Sampling location in Different Industrial Zones

No.	Area	Code	location
1	Tenth of Ramadan	P_1	Oxidation pond (1)
2		P_2	Oxidation pond (2)
3		P_3	Oxidation pond (3)
4	El-Obour City	OP	Pump station 7
5		OF	Cheese whey
6	El-Khadraweia Drain	K1	outlet Mubark industrial city
7		K2	Upstream outlet Mubark industrial city
8		K3	Downstream outlet Mubark industrial city

2.4 Water Pollution Indices

Wastewater index developed to assess water resource quality for various applications but Vietnam Environmental Agency recommended there is not widely international standard water quality assessment **[22-23]**. Organic pollution indexes (OPI) and comprehensive pollution index (CPI) **[24]** assess wastewater quality based on water monitoring parameters.

Comprehensive Pollution Index (CPI)

Physiochemical parameters are necessary tool to evaluate the water resources value **[25]**. Laboratory testing data reported CPI is mathematical process and expressed in three steps as following:

1) Calculation of Pollution index (PI) for monitoring parameters during water samples collections as following equation:

$$\text{Pollution index (PI)} = \frac{\text{Concentration of individual measured parameter}}{\text{Standard acceptable concentration}} \quad \textbf{Equation (1)}$$

2) Sumiton of Pollution index (PI) of each individual measured parameter

Calculation of Comprehensive Pollution Index (CPI) as following equation:

$$\text{Comprehensive Pollution Index (CPI)} = \frac{1}{n}\sum_{i=1}^{n} PI \quad \textbf{Equation (2)}$$

Where, n is the total number of parameters and standards acceptable concentration of water quality parameters in wastewater prescribed by Egyptian Governorate Law Decision 92/2013 **[26]** has been considered in the present study to check the suitability of industrial wastewater for irrigation purpose. Comprehensive Pollution Index (CPI) classified water quality as tabulated in Table (2).

Organic Pollution Index (OPI)

Organic pollution index (OPI) is main tool to assess pollution status and evaluate chemical quality of wastewater that impacted by organic quality along investigated areas based on BOD_5, ammonia, COD and dissolved oxygen. OPI distribute the values of the pollutants in five classes corresponding for each parameter.

The average data of measured concentration of water quality parameters have been used to calculate OPI of the selected parameters **[24]** according to the following equation:

$$OPI = [(\Sigma \frac{Ci}{Cmi})/n]\,X10$$

Where: Ci: are measured concentrations of water quality parameters in monitored pollution areas

Cmi: are maximum acceptable standard concentrations for pollutant **[26]**. N: is the number of variable.

2.5 Primary Treatment

The work investigates primary treatment effect to remove pollutants for succeeding treatment processes as clarified by **Oakley, 2018 [27]**.

3. RESULTS AND DISCUSSION

Wastewater reuse (direct and indirect) is considered as an alternative water resource. Direct wastewater reuse refers to control quality of wastewater treatment plant (WWTP) discharge for irrigation water quality. While indirect wastewater reuse that untreated wastewater collected downstream is dependent on various factors such as quality of treated wastewater discharge and the hydrological conditions of the stream **[27]**. Therefore, the study presents suitability of chemistry wastewater quality for irrigation and effect of primary treatment.

3.1 Laboratory Measurements

Physicochemical Factors and Indexes Values

pH of aquatic environment affects the biological and chemical reactions that it is one of the most traditional measuring parameters for most water. pH values of the sample wastewaters ranged from 6.6 to 7.76, 6.06 to 7.92 and 7.58 to 7.96 at Tenth Ramadan, El-Obour Cities and El-Khadraweia drain, respectively as shown in Table (4).

The pH value of Cheese whey - food industry was slightly acidic (6.06) which were situated near a shipyard and food processing industry. The study recorded the highest pH values (7.92 and 7.96) in industrial and sewage wastewaters from Pump station 7 and El-Khadraweia drainage water downstream outlet Mubark industrial city sampling sites, respectively. While the lowest pH values (6.6 and 7.58) in industrial wastewater from oxidation pond P_2 and El-Khadraweia drainage water near outlet Mubark industrial city sampling sites. Table 4 recorded the individual physico-chemical parameters for wastewater quality and irrigation purpose.

Table (2): Compréhensive Pollution Index (CPI) Values

Class Group	Range	Class Group	Range
Clean	0-0.20	slightly polluted	0.41-1.00
Sub clean	0.21-0.4	moderately polluted	1.01-2
		severely polluted	≥2.01

Table (3): OPI Classes

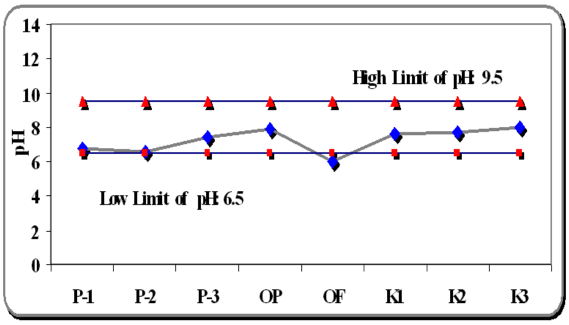
Average of Classes	Level of Organic Pollution
0.0-4	Excellent
0.0-1.0	Good
1.0-4.0	Polluted
4.0-5.0	Heavily polluted

Table 4: Physical Analysis for Wastewater at New Communities (Tenth Ramadan, El-Obour Cities) and El-Khadraweia Drain

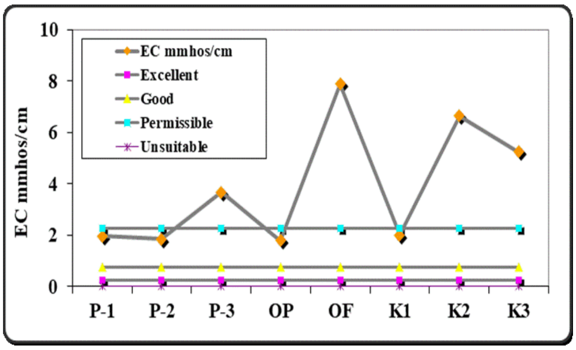
	P-1	P-2	P-3	OP	OF	K-1	K-2	K-3	FAO/EEL	Aquatic live (CCME,2007)
pH value	6.76	6.6	7.4	7.92	6.06	7.58	7.66	7.96	6.5-8.5	6.5-9
E.C	1.975	1.849	3.670	1.800	7.876	2.01	6.64	5.25	0.7–3	----
TDS	1400	1513	3889	1115	9400	1286	4554	3801	450–2000	500
D.O	1.51	3.7	3.89	2.65	1.03	3.96	1.60	2.80	≤5	5.5
TSS	630	591	423	489	2100	618	1378	1031	500	+25
Turbidity	100	105	81	128	235	37	362	203	30	
Ammonia NH_3	3.36	10.29	20.09	4.43	6.96	1.7	7.8	6.5	1	1.37
Carbonates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	
Bi-carbonate	34.4	31.5	38.0	270	200.2	576	874	1513	---	
Nitrates, NO^-_3	140.0	160.0	76.0	115	154.8	2.32	7.75	6.61		2.93
Chloride, Cl^-	236.2	261.7	591.0	271	2400	221.32	1077.57	704.39	---	120
Calcium	175.14	164.19	25.26	120	79.3	66	298	224	0 – 400	
Magnesium	16.13	13.1	9.87	20	45.2	90	68	40	0 – 60	
Sodium	485.0	453.0	875.0	240	1100	284	1125	905	0 – 900	
SAR	9.4	9.2	38.2	5.3	24.5	5.3	15.3	14.6	---	
TH	503.7	463.5	103.7	382	384.00	534	574.3	724	----	
COD	857.0	672.0	462.0	880	6500	80	1500	1200	30	9
BOD	90.00	75.00	50.00	112	3150	35	100	410	----	5
WWQI Value	30	31	35	31	26	37	31	30		
Rating	Poor Quality and CCME-WWQI served poor for aquatic Life									

Note: all values in mg/l except E.C (mmhos/cm), Turbidity (NTU) and pH, SAR (unit-less)

All samples result that provided in Table (4) met Egyptian Governmental Law Decision 92/2013 **[29]** and the Food and Agriculture Organization of the United Nations **[30]** standards (6.5 to 8.4) for the agricultural reuse of treated water and the optimal range of water pH for most of the aquatic species (6.5 to 8.5) except Cheese whey - food industry wastewater (OF: 6.06); pH values outside of this range indicate that the water is of poor quality **[30]**. The data of study showed that irrigation water pH less than 6.5 supports discharge of exchangeable cations while pH more than 11 causes soil microorganism's death and immobile movement of ions. Generally, wastewater pH values outside EEL, 2013 and FAO, 2017 **[29-30]** standard range cause a nutritional imbalance and plant growth restriction **[31]**. Figure (2a) indicated prior to discharge, the wastewater under proper observation and its pH less than limit, necessary treatment is needed.



(a)



(b)

Fig.2(a, b): pH and EC Values along New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain

Electrical conductivity (E.C) shows the scale of water mineralization and classified as tasteless, fresh, brackish, saline and brine. EC classified salinity **[32]** as excellent (low salinity- <0.25 mmho/cm), good (medium salinity 250–750 µmho/cm), permissible (high salinity 0.75–2.25 mmho/cm) and unsuitable (very high salinity 2.25–5 mmho/cm) while FAO criteria for irrigation reported EC <1 dS/m is considered to be low (very good), 1-2 dS/m is medium (good), 2-4 dS/m is high (marginal), 4-6 dS/m is very high (harmful) and >6 dS/m is severe (very harmful). Similarly, EC values showed significant variation with maximum value occurred in cheese whey - food industry wastewater (OF: 7.876 mmhos/cm) which might be due to the presence of mineral ions. This is value outfalls FAO standard limits >6 dS/m which is severe (very harmful) **[18, 30]**. Figure (2b) presented the relative status of the character physico-chemical parameter EC for irrigation purpose that considered all values of EC mmho/cm within permissible range except pond-3 (3.67 mmhos/cm), cheese whey - food industry wastewater (7.876 mmhos/cm), El-Khadraweia drain (K2 (6.64 mmhos/cm) – K3 (5.25 mmhos/cm)) at New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia drain, respectively as described in Fig.(2b). These values clarified wastewaters outside quality principles of FAO guidelines which consider a "potential issue" approach with their levels of restriction on uses: none (EC<0.7dS.m^{-1}), mild to moderate (0.7<EC<3 dS m^{-1}), and severe (>3 dS m^{-1}). Additionally, higher irrigation water EC may cause soil structure mass and reduce the absorptive of irrigated soil **[33]** and may also result in soil and plant toxicity; depending on the irrigation period and soil nature **[34]**.

TSS Values and Optical Quality of Water (Turbidity)

Suspended matter such as clay, silt and organic matter, as well as plankton and other microscopic organisms interfere with the passage of light through the water and can be expressed by turbidity or total suspended solids (TSS) content. FAO, 2017 **[29-30]** limits of <50 mg/l (no restriction on use) and >100 mg/l (Severe restrictions on use for TSS) when irrigating with drip lines. In study case, the determination of TSS for the industrial wastewater (Table 1) ranged from 423 to 630 mg/l, 489 to 2100 and 618 to 1378 at New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia drain, respectively as described in Fig.(3a). These values were critical to higher limit of Egyptian Environmental Law decision 92/2013 and FAO, 2017 **[29-30]**

On other hand, turbidity describes the degree of particles which water contains, because cloudiness or muddiness resulting in the disturbance of sunlight that turbidity measurement was used as a surrogate. Figure (3b) showed all turbidity values for five wastewaters that ranged from 81 to 105, 128 to 235mg/l and 37 to 262 at New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia drain, respectively. These values were critical to higher limit of USEPA, 2012 **[32]** especially for secondary whey cheese wastewater as described in Fig. (3b).

3.2 Water Irrigation Suitability

The irrigation water suitability is mainly assessed according to the presence of not needed dissolved salts or essentials **[35]**. Irrigation water quality and its classes are described using absolute ions concentrations as presented in Equations (1-6).

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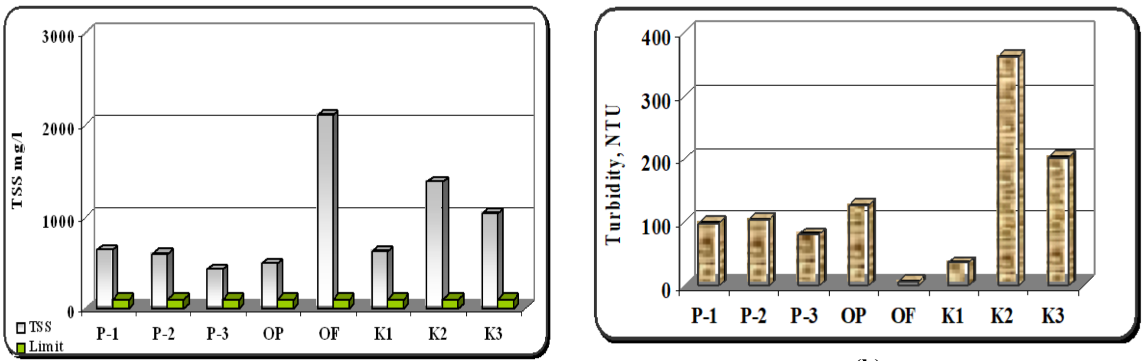


(a) (b)

Fig.3(a, b): TSS and Turbidity Values long New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain

3.2.1 Water Quality Using Absolute Ions Concentrations

The physico-chemical quality parameters including conductivity (EC) and total dissolved salts (TDS) play major roles in classifying and evaluation water quality using different approaches and methodologies. Moreover, absolute concentration of ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and HCO_3^{-}in meq/l) by itself is not enough for assessing suitability of ions for irrigation usage. Thus, the effects of relations among the ions should be considered that Residual Sodium Carbonate (RSC), total hardness (TH), Magnesium Adsorption Ratio (MAR), sodium adsorption index (SAR) and Permeability Index (PI) use to derive the criteria and guidelines of the hazards ions interactions **[36]** as described in the following equations and Figs. (4 a, b, c, d, e, f).

$$SAR = Na^+ \Big/ \sqrt{0.5(Ca^{2+} + Mg^{2+})} \qquad \textbf{Equation 1}$$

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100 \qquad \textbf{Equation 2}$$

$$\mathbf{KR} = \frac{\mathbf{Na^+}}{\mathbf{Ca^{2+} + Mg^{2+}}} \qquad \textbf{Equation 3}$$

$$RSC = (CO_3^- + HCO_3^-) - (Ca^{+2} + Mg^{+2}) \qquad \textbf{Equation 4}$$

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Na + Ca^{2+} + Mg^{2+}} * 100 \qquad \textbf{Equation 5}$$

$$TH = (Ca^{2+} + Mg^{2+}) * 50 \qquad \textbf{Equation 6}$$

Figure (3a) reported the quality rating of TDS values for each wastewater type. These values indicated that all TDS within the desirable range (below 2000 mg/l) as standardized by Egyptian Environmental Law decision 92/2013 except pond-3 (3889 mg/l) and secondary whey cheese (9400mg/l) wastewater samples at Tenth Ramadan and Obour Cities, respectively which are above the recommended threshold level for irrigation (high to severe condition). Clearly, they exceed national and international standard permissible limits that are used for agriculture, irrigation of green space, discharge into surface water and injection in wells for recharge.

Sodium Adsorption Ratio (SAR) Index

SAR index consider sodium hazard and its suitability for irrigation. Significance SAR content decreases soil permeability, increase soil hardness that making soil saline and alkaline **[37]**. Table (4) presented SAR index values that express the rate of sodium adsorption in wastewater and increase the exchange potential of soil. Figure (4) described United States SAR classification that showed oxidations ponds (1-2) at Tenth Ramadan city, Industrial and sewage wastewater from Pump station 7 at Obour City and outfall Mubark industrial city at within the range (0-10 of low sodium rate). While drainage water of El-Khadraweia drain (upstream and downstream outlet Mubark industrial city) are within the range (10-18 of moderate sodium rate and not suitable for long-term irrigation). Oxidation pond-3 at Tenth Ramadan city is within the range (18–26 sodium rate is intensive and not suitable for irrigation) and secondary whey cheese (26–30 sodium rate is very intensive and is very dangerous and illegal for irrigation) wastewater samples and Obour Cities, respectively.

Magnesium Adsorption Ratio (MAR).

MAR calculated by Equation 2 is close to ≥50 values at oxidation pond-3 wastewater (99.9) at Tenth Ramadan city, secondary whey cheese wastewater sample (48.7) at Obour city and outlet Mubark industrial city site on drainage water of El-Khadraweia drain (69.4) that considered as risk index above 50 **[38]** while the others are lower than risk index and suitable for irrigation as described in Fig.(4C).

Similarly, Kelly's Index (KR) which has been calculated based on sodium, magnesium and calcium contents and is expressed as Equation 3 **[39-40]** to assess hazardous effect of sodium on water quality for irrigation usage**.** Figure (4d) presented KR index classification for water as suitable (KR<1), marginal (1<KR<2) and unsuitable (KR>2) for irrigation purposes **[39-41].** The data showed all wastewaters samples were unsuitable for irrigation purposes. KR index values range in order pond-3 wastewater (154.64) at Tenth Ramadan city> secondary whey cheese wastewater sample (12.37) at Obour city> drainage water of El-Khadraweia drain downstream outlet Mubark industrial city (5.41)> ponds (1-2) wastewater (4.17, 4.23) at Tenth Ramadan city and drainage water of El-Khadraweia drain upstream outlet Mubark industrial city (4.75)> Pump station 7 wastewater at Obour city (2.72)> outlet Mubark industrial city wastewater on El-Khadraweia drain (2.28).

Total Alkalinity (Carbonate and Bicarbonates) Hazard

Recently, some studies **[35, 42]** have efforts to present Equations (4-5) that show the effects of Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-} and CO_3^{2-} interactions for irrigation water quality purposes. Concentrations of carbonate and bicarbonate play a significant role of determination water irrigation suitability that carbonate concentration more than total concentrations of calcium and magnesium with high excess carbonate residual. These excess carbonate ions react with cations ions (calcium and magnesium ions) to form solid material which settles out of the water and the relative abundance of sodium increases creating deteriorating consequences on the plants.

Table (4) recorded potential bicarbonate hazard that ponds (1-3) wastewaters were slight hazard (34.4, 31.5, 38.0 mg/l) at tenth Ramadan industrial city (0-120 mg/l). While Pump station 7 and secondary whey cheese wastewaters at Obour industrial city were severe hazard (180-600 mg/l) and outfall Mubark industrial city (270, 200.2, 576 mg/l). Moreover, drainage water of El-Khadraweia drain (874 and 1513 mg/l) upstream and downstream outlet Mubark industrial city were very severe (<600 mg/l) according to irrigation water quality.

Figure (4e) clarified a negative values of RSC index ponds (1-2) and secondary whey cheese wastewaters (-5.41, -4.133, -0.584 meg/l) indicated little risk of sodium accumulation due to equalize levels of calcium and magnesium while a positive values (0.246, 0.593, 4.042, 4.044, 17.537) of pond 3, Pump station 7, drainage water of El-Khadraweia drain at outlet Mubark industrial city, drainage water of El-Khadraweia drain upstream and downstream outlet Mubark industrial city wastewaters indicated that the bicarbonate and carbonate will rescue free calcium and magnesium in the soil, thereby creating room for sodium to accumulate. These values indicated the alkalinity hazard for soil and the suitability of the water for irrigation in clay soils which have a high cation exchange capacity **[43]**.

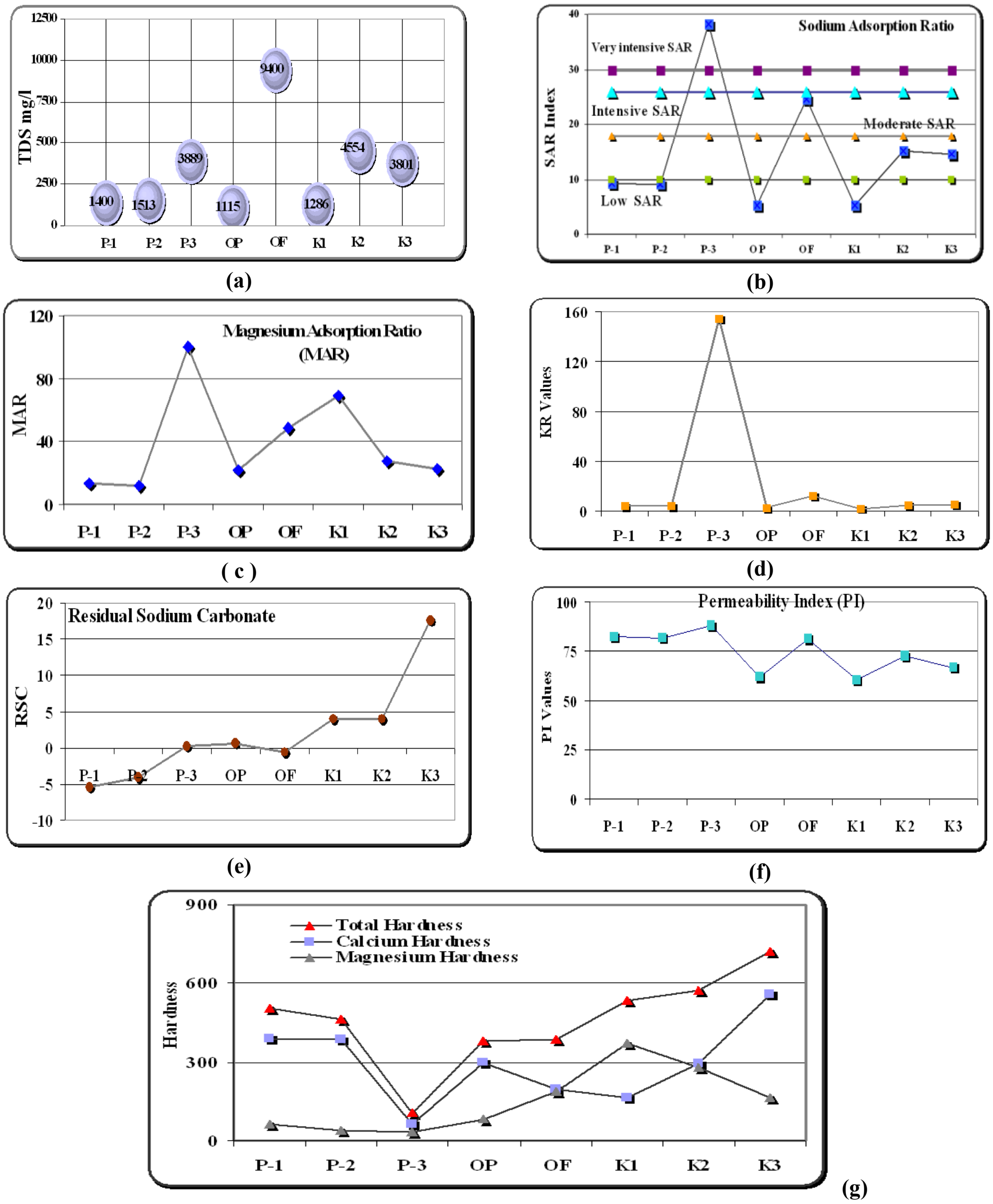


Fig. 4(a, b, c , d, e, f): TDS, Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Residual Sodium Carbonate (RSC), Permeability Index (PI) and Total Hardness (TH) long New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain

US Salinity Laboratory, stated RSC<1.25 meq/l are safe for irrigation, 1.25>RSC<2.5 meq/l are marginal and RSC values>2.5 meq/l are unsuitable for land irrigation that high pH lead to statement of sodium carbonate **[36]**.

Permeability index (PI) classified water as Class I and Class II (good for irrigation with ≥75 % of maximum permeability) while Class III unsuitable irrigation (≤25 % of maximum permeability) **[41]** Figure (4f) demarcated that the PI values fluctuated from 60.2 to 82.1 with an average of 66.05. Nearly all wastewater samples fall into the Class I and II as good for irrigation except drainage water of El-Khadraweia drain at outlet Mubark industrial city (60.2) and Pump station 7 (62.0) were moderate for irrigation.

Hard water is water that has high content of calcium and magnesium ions which calcium usually enters the water as calcium carbonate ($CaCO_3$), in the form of limestone and chalk or calcium sulfate (CaSO4) in the form of other mineral deposits. The predominant source of magnesium is dolomite ($CaMg(CO_3)_2$). In the present study, area hardness of water samples varied from 103.7 to 724 with a mean value of 458.65 mg/l as $CaCO_3$. Thus, the result suggests that most of the water samples can be problematic for plumbing of irrigation systems. Figure (4g) It was found that total hardness of all of samples (Table 4) were moderate to very hard permissible limit (60-120, 120-180 mg/l) but were higher than highest desirable limit for discharge (100 mg/l) according to WHO standard. Calcium hardness was responsible than magnesium hardness which these high levels of hardness can cause some problems. Elimination of the hardness is essential for wastewater to be reused. The research analytical data that included the previous indexes calculations for RSC, PI and SAR suggest that there is tendency for calcium and magnesium to precipitate with carbonate and bicarbonate as calcite and mangesite in the soils irrigated by the water, resulting in an increased sodium hazard and its related problems in the area.

3.3 Heavy Metals Assessment

The concentrations of Aluminum (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Zinc (Zn), Selenium (Se), Stranshium (Sr), Tin (Sn), Vanadium (V) and total heavy metals (THMs) in wastewaters samples collected along New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain are listed in Table 5.

The concentrations of the measured metal in wastewaters were under detection Limits (<MDL): Antimony-Sb, Arsenic-As, Beryllium-Be, Cadmium-Cd, Cobalt-Co, Molybdenum-Mo, Nickel-Ni, Zinc-Zn, Selenium- Se, Stranshium-Sr, Tin-Sn as presented in Table 5. While the others trace elements, total heavy metals (THMs) and demonstrated in Figs. (5a, b, c, d, e, f, g): Al, B, Cr, Fe, Mn and THMs) and the distribution of them found to be in the following order in wastewaters of investigated studied areas (mg/l): Al (10.79), Fe (6.855), Sr (3.897), Cr (3.082), Mn (1.192), B (0.457), Ba (0.413), Zn (0.216), Cu (0.176), V (0.152), Pb (0.092), Ni (0.016). Commonly, most of the metals had higher concentration at oxidation ponds (1-3) of tenth Ramadan industrial city were Al (1.73 mg/l), Sr (1.43 mg/l), Fe (0.421 mg/l), B (0.36 mg/l), Cu (0.111 mg/l) as result of huge different industrial wastewaters and total heavy metals recorded 1.171 mg/l, 1.501 mg/l, 1.652 mg/l for Pond-3< pnd-2< pond-1, respectively. While higher metals concentration recorded at Pump station 7 and cheese whey from food industry wastewaters of El-Obour City was Al (5.85 mg/l), Fe (4.56 mg/l), Sr (0.73 mg/l), Mn (0.43 mg/l) and total heavy metals recorded 4.889 mg/l and 7.023 mg/l, respectively as results of sewage and industrial discharges.

Table (5): Toxic Measurements for Wastewater at New Communities (Tenth Ramadan, El-Obour Cities) and El-Khadraweia Drain

Parameters				Tenth of Ramadan Area			El-Obour City		El-Khadraweia Drain		
	MDL	FAO[35]	(CCME,2007)	P-1	P-2	P-3	OP	OF	K1	K2	K3
Al	<0.005	5.0		0.42	0.81	0.5	2.1	3.75	<MDL	2.96	0.250
Ba	<0.005	--		0.04	0.03	0.015	0.01	0.02	0.073	0.142	0.083
B	<0.2	0.7		0.19	0.11	0.06	0.051	0.046	<0.2	<0.2	<0.2
Cr	<0.002	0.1		0.002	0.001	0.001	0.003	0.003	<MDL	2.81	0.262
Sr	<0.006	----		0.54	0.46	0.43	0.61	0.12	0.673	0.493	0.571
Fe	<0.006	5.0	0.3	0.256	0.058	0.107	1.73	2.83	0.052	1.59	0.232
Mn	<0.004	0.2	0.05	0.066	<MDL	<MDL	0.31	0.12	0.09	0.435	0.171
Pb	<0.007	5.0	0.007	0.028	0.003	<MDL	0.029	0.032	<MDL	<MDL	<MDL
Ni	<0.004	0.2	0.025	<MDL	<MDL	<MDL	0.004	0.012	<MDL	<MDL	<MDL
Zn	<0.005	0.2	0.05	<MDL	<MDL	0.004	0.012	<MDL	<MDL	<MDL	0.2
Cu	<0.003	0.2	0.004	0.05	0.029	0.032	0.02	0.03	<MDL	0.015	<MDL
V	<0.001	0.2		0.06	<MDL	0.022	0.01	0.06	<MDL	<MDL	<MDL
TH		----	1	1.652	1.501	1.171	4.889	7.023	0.888	8.445	1.769
	Note: All parameters in mg/l										

Drainage water of El-Khadraweia drain at outlet Mubark industrial city and upstream and downstream outlet Mubark industrial city was Al (3.21), Cr (3.072), Fe (1.876), Sr (1.737), Mn (0.696) and total heavy metals recorded 0.888< 1.769< 8.445 mg/l for outlet Mubark industrial city, upstream outlet Mubark industrial city, downstream outlet Mubark industrial city, respectively. El-Khadraweia drain receives large amounts of agricultural drainage and sewage as well as industrial wastewater of Mubark and Quesna industrial city rendering it unfit for human use that and anthropogenic activities cause a rise in heavy metal levels in eco-systems, increasing contamination and putting human health at risk. The obtained data showed the elimination of un-acceptable concentrations of toxic elements must be done which precipitation or adsorption process was taken in biological treatment or chemical treatment **[44-45]** as described in Fig. (5f).

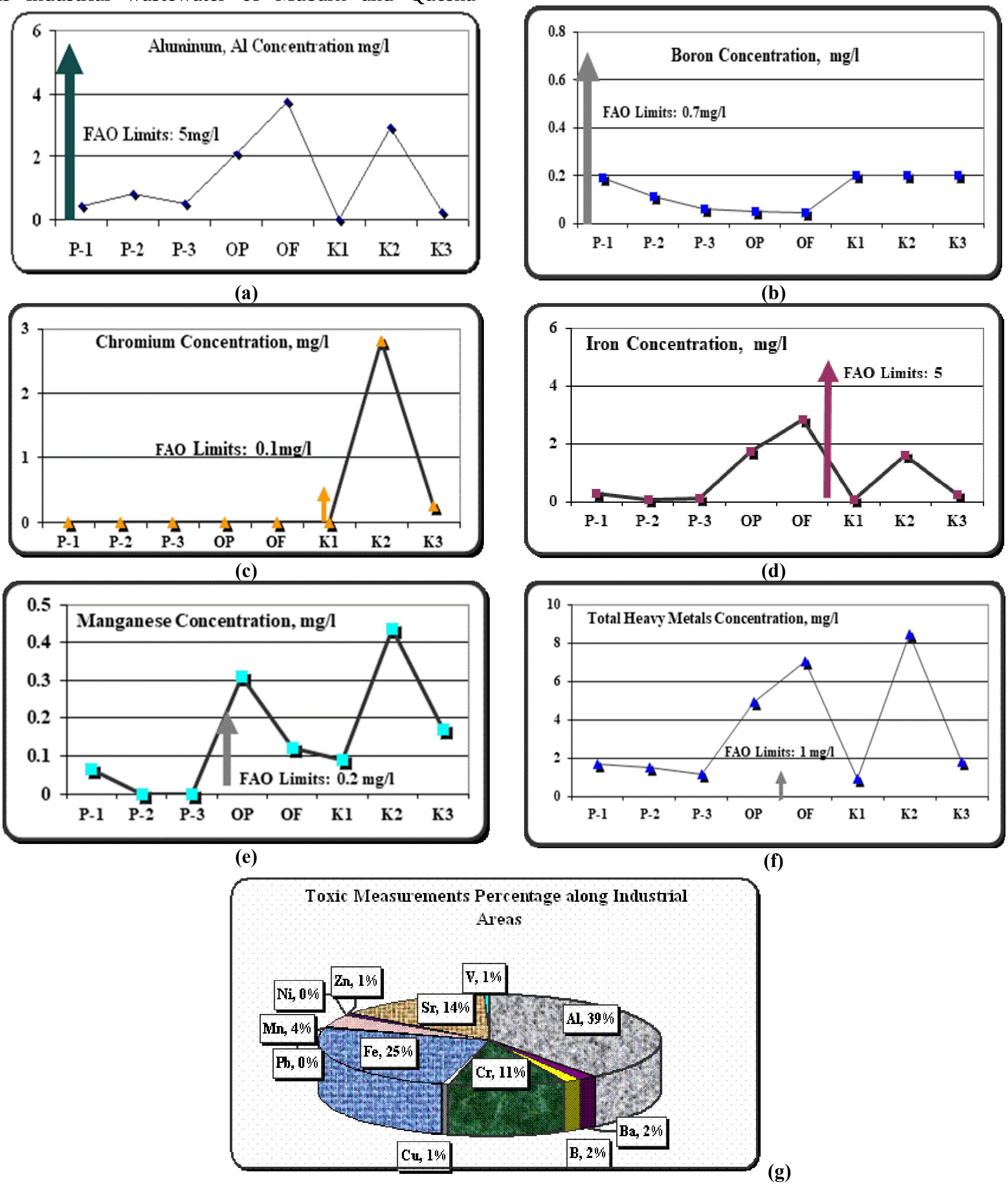


Fig. 5(a, b, c , d, e, f):Al, B, Cr, Fe, Mn and Total Heavy Metals along New Communities (Tenth Ramadan and El-Obour Cities (and El-Khadraweia Drain

3.4 Wastewater Indices

The results of Comprehensive Pollution Index (CPI) and Organic Pollution Index (OPI) of Tenth Ramadan and El-Obour Cities as new communities and conventional area (Mubarak City Industrial - El-Khadrwia drain) 2018-2019 are shown in Table 6.

From the Figure 6a, it can be clearly practical variation that the considered CPI was found to be more in cheese whey wastewater from food industry at El-Obour City (16.1)> upstream outlet Mubark industrial city on El-Khadraweia drain (7.5)> downstream outlet Mubark industrial city on El-Khadraweia drain (4.5)> oxidation Pond-3 at Tenth Ramadan City (3.1)> pump station 7 at El-Obour City (2.9)> oxidation Pond-2 at Tenth Ramadan City (2.7)> oxidation Pond-1 at Tenth Ramadan City (2.6)> outlet Mubark industrial city on El-Khadraweia drain (0.768), respectively.

From the Figure 6a, it can be clearly practical variation that the considered CPI was found to be more in cheese whey wastewater from food industry at El-Obour City (16.1)> upstream outlet Mubark industrial city on El-Khadraweia drain (7.5)> downstream outlet Mubark industrial city on El-Khadraweia drain (4.5)> oxidation Pond-3 at Tenth Ramadan City (3.1)> pump station 7 at El-Obour City (2.9)> oxidation Pond-2 at Tenth Ramadan City (2.7)> oxidation Pond-1 at Tenth Ramadan City (2.6)> outlet Mubark industrial city on El-Khadraweia drain (0.768), respectively.

Comprehensive Pollution Index (CPI) values ranged from 0.768 to 16.1 during study work which could be classified from qualified or slightly polluted to seriously contamination for investigated sites in industrial areas. While CPI index showed drainage water and industrial wastewaters is considered severely polluted (≥2.01) that COD is the most dominant factor representing 65% of total pollutants values followed by Ammonia (8%), Turbidity (7%), E.C (7%), TDS (2%), pH (2%) and others ranged 0-1% where the least dominate.

Organic pollution by wastewater discharge from human activities (cities, farming, and industry) affects humans and ecosystems. Accumulation of organic pollutants in water resources stimulates microbial growth, leading to oxygen depletion (Fig.6d) and disturbance of the entire river ecosystem **[46-48]**.

Table 6: Variation of Pollution Indices in Tenth Ramadan and El-Obour Cities and Mubarak City Industrial at El-Khadrwia Drain

Sites	**P_1**	**P_2**	**P-3**	**OP**	**OF**	**K1**	**K2**	**K3**
CPI	2.6	2.7	3.1	2.9	16.1	0.76	7.5	4.5
Status	Severely polluted							
OPI	88	89	94	95	822	15	153	151
Status	Heavily polluted							

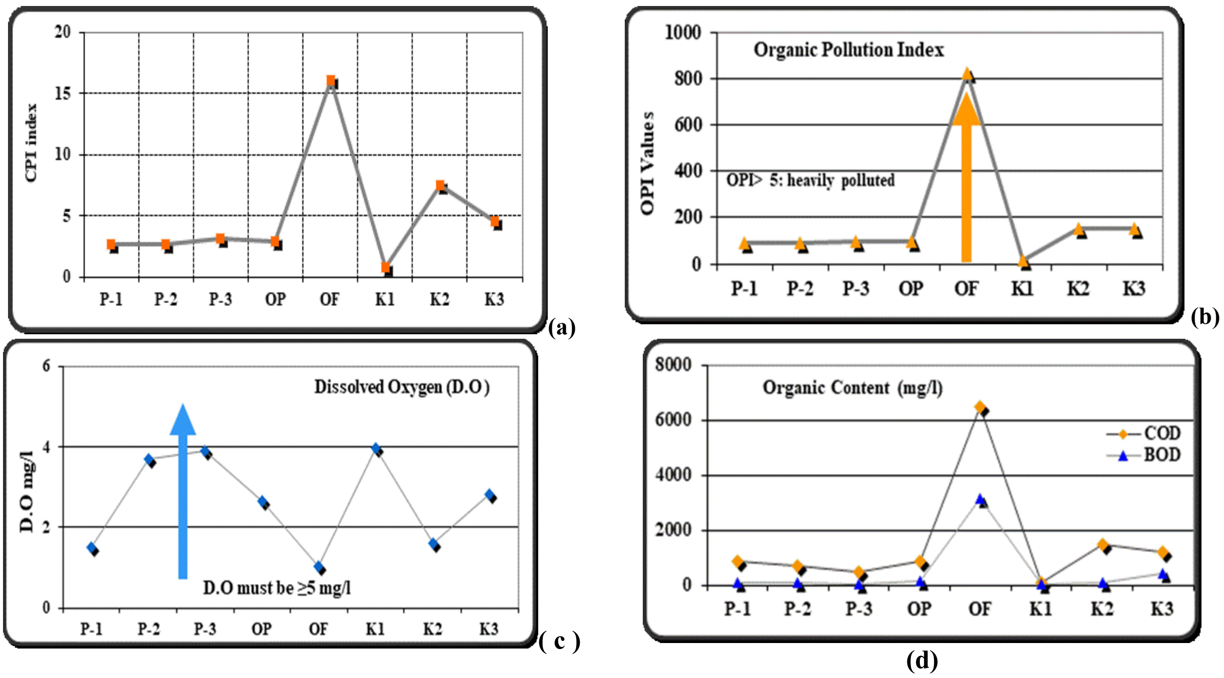


Fig.(6a, b, c, d, e) CPI Index, Dissolved Oxygen, Organic Content and Organic Index Values along New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain

Small concentrations of certain organic solutes can render water unsuitable for use by humans or toxic to aquatic or other life forms **[49]**. The levels of organic pollution commonly expressed by BOD and COD that quantitative assessment of human and industry effects on increasing in-stream organic pollution at scales as shown in (Fig.6 c, d). The study showed wastewater has not chemical treatment facilities or biological or biological/chemical treatment as tabulated in Table 3 and (Fig.6 c, d).

Figure (Fig.6 d) demonstrated the interpretation for organic measurements values (BOD and COD) that clarified organic content exceeded their national standards limits (BOD :< 20 and COD: < 30). Moreover, this comparison showed that require high degree of treatment. Advanced treatment technologies might be used to treat the wastewater from these industries to a quality that could allow reuse of wastewater. Comprehensive Pollution Index (CPI) and Organic Pollution Index (OPI) showed higher BOD values at meant that there were greater quantities of degradable wastes proba bly which had BOD levels corresponded with COD levels. It is supported by OPI evaluation that ranged from 15 to 822 while the maximum CPI and OPI value at cheese whey wastewater from food industry at El-Obour City. The statuses of all monitoring locations were heavily polluted wastewater quality of industrial areas in order Tenth of Ramadan< El-Obour City > El-Khadraweia Drain as shown in Table (6) and Fig.(6a, b, d).

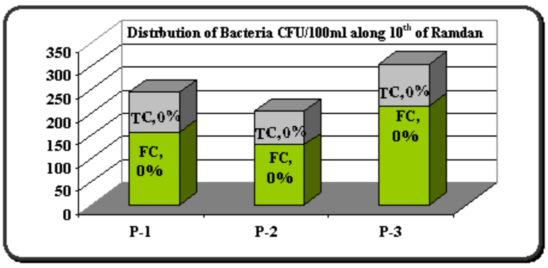
3.5 Bacteria Measurements Assessment

Data in Table (7) and Fig.(7a, b, c) indicated that wastewater samples from El-Khadraweia Drain was very contaminated and thus appeared with the resulted bacteriological parameters. Fecal coliform were $18x10^5$, $11x10^5$ and $320x10^4$ CFU/100ml for K-1, K-2 and K-3 respectively. El- Khadrawia drain is non-safe from contamination with pathogenic bacteria **[16]** that several studies stated microbiological investigation of water samples along El-Khadraweia revealed their highly contamination with Fecal coliforms and pathogenic bacteria **[16]**.

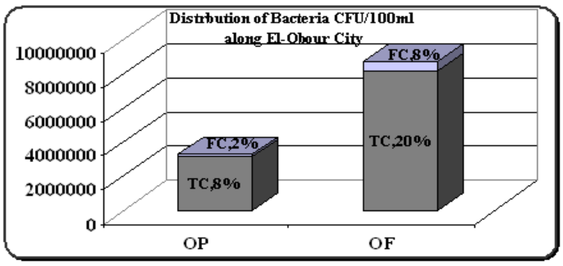
Table (7) presented Total Coliforms (TC) in order: OF > K_3> OP > K_2> K_1> P_3> P_1> P_2 while Fecal Coliforms (FC) recorded in order: OF> K_3> OP> K_1> K_2> P_3> P_1> P_2. Figures 7a, b, c showed El-Khadraweia drainage water recorded the highest bacteriology contamination followed cheese whey wastewater and Pump station 7 while all oxidation ponds in Tenth of Ramadan city reported the lowest bacteriological measurements as described in Figs.(7a, b, c).

Table (7): Bacteria Measurements along non-Convention Wastewater and New Communities (Tenth Ramadan and El-Obour Cities)

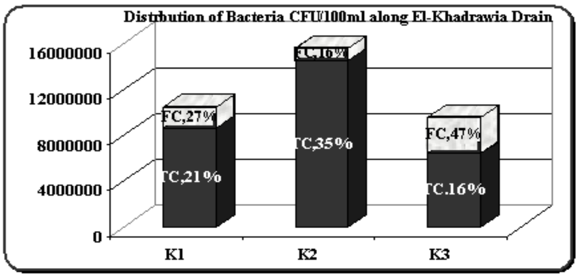
Parameters	Tenth of Ramadan Area			El-Obour City		El-Khadraweia Drain		
	P_1	P_2	P_3	OP	OF	K_1	K_2	K_3
TC	159	129	215	$320x10^4$	$820x10^4$	$87x10^5$	$145x10^5$	$640x10^4$
FC	85	74	89	$102x10^3$	$567x10^3$	$18x10^5$	$11x10^5$	$320x10^4$



(a)



(b)



(c)

Figs.(7a, b, c): Bacteria Measurements along New Communities (Tenth Ramadan and El-Obour Cities) and El-Khadraweia Drain

3.6 Suitability of Wastewater for Ecological life

Table 8 illustrates protection of aquatic life according guidelines of Canadian Council of Ministers of the Environment **CCME, 2001 and CCME, 2007 [50, 19]**. The classifications of WWQI are represented in Tables 4 and 5. The selected parameters for both surface water and aquatic life included pH, TDS, DO, TS, BOD, FC, COD, Cl^-, TP, NH_3-N, and NO_3-N and turbidity. Quality of wastewater (WWQI) is: Excellent 95-100, Good 80-94.9, Fair 65.9-79.9, Marginal 45.0-64.9, Poor 0-44.9 that clarified WWQI rating was poor for all investigated areas and aquatic life which Poor: (CWQI value 0-44.9), water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels. The data confirmed with **Ebrahimi, 2018 [51]** who studied performance data variables, interconnectedness of the variables, provide an effective means for environmental systems evaluation.

3.7 Primary Treatment

Wastewater treatment process aimed to eliminate or decrease pollutants in water system that force threats to human and environment **[52]** The work showed primary treatment effect to remove suspended solids, settle-able and floating organic material that reduce the suspended solids load for succeeding treatment processes **[53]** but removal of pathogens during primary treatment is not high **[54]** as shown in Fig.8. The data clarified the removal of total suspended solids (TSS) and biochemical oxygen demand (BOD_5) in primary sedimentation process were 79% and 50% as shown in Fig.9 a, b that agreed with **Mohammed etal., 2014; Marín etal., 2015; Nuralhuda, 2020 [52-54]**. The data agreed with **Ronan et al., 2019 [55]** who reported specific safety and safety requirements of wastewater treatment processes that reduce suspended solids and biodegradable organic matter concentrations in water of rivers and impede the movement of water in the channels and pipes after deposition. Recent studies reported an excellent wastewater purification effect for industrial-level discharge by micro-algae that increase reduction percentage (97%) of water conservation by **Kim et al., 2019 [56].** Advanced treatment process of supernatant gravity thickener, and underflow mechanical thickener might be used by side-stream elimination on a full-scale anaerobic/anoxic/oxic system reached to 93-98% for BOD, COD and TSS as reported by **Faris et al., 2022 [57].**

4. Conclusion

Certain pollutants in industrial wastewater are more important for pollution prevention than others. Total suspended solids, ammonia and organic content levels are high concentrations in industrial wastewater that assessed according to Egyptian Environmental Law 92/2013 limits. Indexes of RSC, TH, MAR, SAR, KR and PI showed almost of chemical parameters were unacceptable for water irrigation suitability that used to derive the criteria and guidelines of the hazards ions interactions. While the maximum CPI and OPI indexes values recorded 16.1 and 822 for cheese whey wastewater at El-Obour City. The ecological monitoring clarified that heavily industrial wastewater were in order Tenth of Ramadan< El-Obour City > El-Khadraweia Drain. The experimental data clarified the removal of total suspended solids (TSS) and biochemical oxygen demands (BOD_5) in primary sedimentation process were 79% and 50% and the study recommended advanced treatment by nano- particles can control pollution and increase national goals.

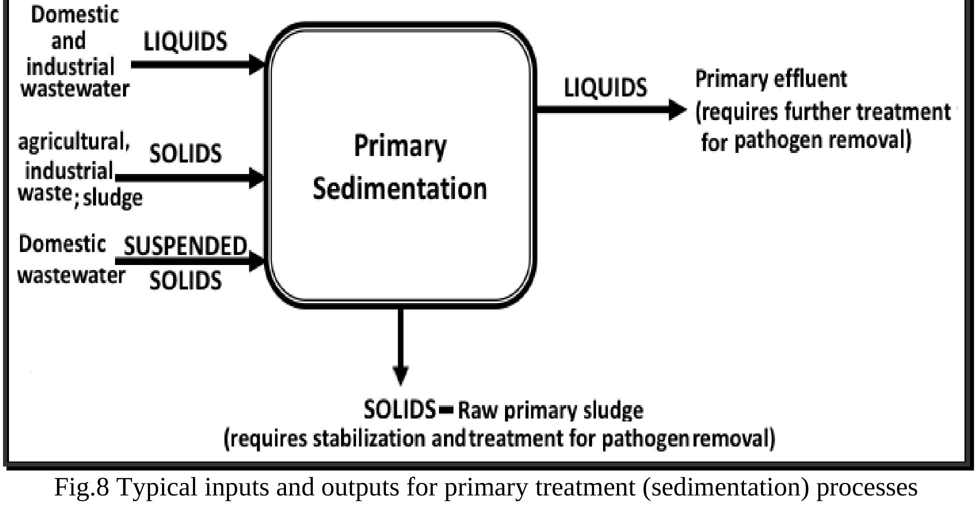


Fig.8 Typical inputs and outputs for primary treatment (sedimentation) processes

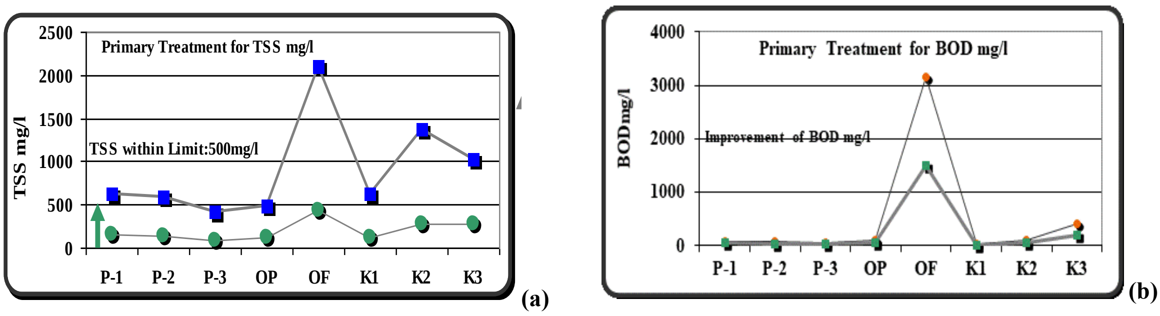


Fig.9 (a,b): Improvement of TSS and BOD mg/l Using primary treatment Processes

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