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Environmental assessment of aquatic weeds, water and sediments related to rehabilitation and manual maintenance (Case study: Desonas Canal, Egypt)

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Abstract: The massive spread of aquatic weeds leads to cause many problems including water losses, retardation of flow, health hazards and alteration in the physic-chemical characteristics of both water and hydro soil. The aquatic environment in this case is a fertile source of diseases affecting Farmers health who are dealing directly with the aquatic environment through the use of canal water to irrigate their lands. The objective of this research to ascertain the improvement of the aquatic environment in Desonas Canal after rehabilitation and manual maintenance. The study included the aquatic weed, water and sediments condition before and after rehabilitation and manual maintenance. The result of the study showed that the periodic manual weed maintenance on Desonas Canal decreasing the aquatic weed infestation with a percentage ranged from 38 % up to 64 %, and, the implemented rehabilitation of low efficient reaches on the canal leads to increasing flow velocities. Also, the physico-chemical properties of both canal water, and bed sediments were improved with varying rates. This may be attributed to removal of surface layer of canal bed while rehabilitation process, this layer are controls the exchange of elements between sediments and water. This layer containing some decaying aquatic weeds, organic sediment and the residues of agricultural fertilizers accumulated over time. Also, the removal of aquatic weed and increasing flow velocities has improved the physico-chemical properties.
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Keywords: Aquatic weeds; water quality; sediments; rehabilitation; manual maintenance.

1. Introduction

The impacts of aquatic weeds spread causes the reduction in quality and quantity of water, clogging of irrigation canals and pumps, alteration in the physic-chemical characteristics of both water and hydro soil. Therefore, there is a necessity to improve monitoring of aquatic weeds to avoid problems that may change water and sediments characteristics in the waterways. Identifying a management strategy as well as preparing a good maintenance plan is important to reduce the problem of weed growth in irrigation and drainage canals in Egypt and reduce maintenance costs (**Damian and Donna 2007, and Ali and Khedr, 2018**).

Hill, (2003) reported that the most important feature for worldwide weed control are the reduction of nutrients entering aquatic ecosystems. The presence of nutrient rich waters have contributed to the weed invasiveness such as Water hyacinth *"Eichhornia crassipes"*, water lettuce "*Pistia Startiotes*", salvinia "*salvinia molesta"* and red water fern "*Azolla filiculoides"* to aquatic ecosystems.

In Egypt, the aquatic weeds infestation has started shortly after the construction of the High Dam due to reduced sedimentation and lower turbidity downstream irrigation canals. This could enhance weed growth through increased light penetration. Also, the increased use of organic fertilizers leads to eutrophication in canals and drains which in turn excessive weed growth. These factors have encouraged fast growth of aquatic weeds such as Water hyacinth "*Eichhornia crassipes*" in the Egyptian Nile River during of the growing season (from March to October) **(Van Zon, 1984 and El-Shinnawy, *et al.*, 2000)**. More than 80% of Egyptian canals and drains are heavily infested with all types of aquatic weeds (especially, submerged weeds). Field monitoring showed that more than 40% of earthen Egyptian Canals are infested with submerged weeds **(Bakry 1992, El-Samman, *et al.,* 2003)**.

Gore, (1985) indicated that river and waterway rehabilitation should be viewed as a “process of recovery enhancement” in which management strive to help the waterway regulate naturally. When this success of rehabilitation works is achieved, sustainable physical and ecological functioning can occur **(Fryirs and Brierley 1998). Tarek *et al.,* (2017)** explained that partial rehabilitation of the less efficient reaches of open channel result in satisfactory hydraulic performance enhancement. **Brown et al., (1999)** showed that there have pointed out the need for long-term maintenance if the rehabilitation systems are to be effective and sustainable. Practical manual maintenance for a number of years is necessary for improve performance **(Morris and Moses 1999).**

The hand-held implements currently in use for controlling weeds in irrigation and drainage systems in Egypt are mostly modified forms of traditional tools used for agricultural purposes. Using developed manual tools is one of the main advantages to clean the small Egyptian canals (bed width less than 2 m) without any damage on the cross section **(El-Samman and Abou El Ella, 2006). Wade, (1990)** stated that, in programmers for *SaIvinia* clearance it was essential to have follow-up treatment in order to achieve lasting control, up to three manual cuts being reported for some channels. Without this, complete re-infestation can occur. Examples of successful or partially successful (65 to 90%) treatments have been reported for lotus "*Nelumbo nucifera"*, water lettuce "*Pistia stratiotes"*, water lily "*Nymphaea stelllata"*, and Water thyme "*Hydrilla verticillata"***.** In a study of the Fayoum Water Management Project, Egypt, for an average sized canal with normal weed infestation. It was estimated that two periods of maintenance are necessary per year to guarantee a proper water flow in the canal **(Smout *et al.,* 1997).**

Water quality monitoring of the water resources is necessary to assess the water quality for ecosystem health, hygiene and industrial, agricultural and domestic uses **(Poonam *et al.,* 2013).** In the Egyptian irrigation system, elements resulting from daily domestic and industrial activities may induce considerable changes in the physical and chemical properties of the Nile River and its canals **(Mason, 2002 and El-Sayed, 2011)**. Major source of Desonas canal water is Mahmoudia canal. The assessment of environmental quality with respect to heavy elements in aquatic systems includes the measurement of a group of these elements in water, sediments and living organisms **(Samecka-Cymerman and Kempers, 2001, Sanchez Lopez, *et al.,* 2004)**. Heavy elements are partitioned among various environmental components (water, suspended solids, sediments and biota) **(Iken *et al.,* 2003, Shakweer and Abbas, 2005, and Khalil *et al.,* 2007)**. The most important heavy elements from the point of view of water pollution are Zn, Cu, Pb, Cd, Hg, Ni and Cr. Some of these elements (e.g. Cu, Ni, Cr and Zn) are essential heavy elements to living organisms, but become toxic at higher concentrations **(Dudka and Adriano, 1997)**. The concentration of such elements in the water column can be relatively low, if it is compared with their concentrations in the sediment. Low-level discharges of a contaminant may meet the water quality criteria, but long-term partitioning to the sediment could result in the accumulation of high loads of pollutants **(Binning and Baird, 2001)**. **(Galal, 1983)** reported that the heavy metals (Cu, Pb, Zn, Mn and Fe) were found in Mahmoudia canal at levels less than the maximum permissible limits.

The high content of organic matter within the sediment was mainly produced from the inputs of field residues, domestic organic waste and wastewater which is throwing to the canal in addition to decaying aquatic weeds. Such organic matter acts as a metal carrier and plays an important role in the metal distribution patterns within the sediment **(Lin and Chen, 1998). Natural Resources Conservation Service, United States Department of Agriculture (2014)** proved that soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (Ksat) and aeration, and a general degradation of soil structure. This research was focused on verifying the improvement of the aquatic environment of aquatic weeds, water and sediments after rehabilitation and manual maintenance in Desonas Canal, Egypt.

2. Materials and Methods

Study area

The length of the Desonas Canal is 4.900 km., the average width of the water surface is ranged between 4 - 7 meters, the area of the water surface is 27511 m^2 and canal serves about 2640 feddan passing through eight villages. Dessons canal water is mainly supplied from El- Mahmoudia canal at kilometer 29,750 (as shown in Figure 1) at intersection of latitude 31° 06′ 20.4″ North with longitude 30° 16′ 57.4″ East.

Inventory and Determination of the infestation percentages for aquatic weeds

Desonas Canal was divided into six reaches to facilitate the inventory and determination of the infestation percentages, first reach from Km 0.000 to Km 1.100, second reach from Km 1.100 to Km 1.800, third reach from Km 1.800 to Km 2.590, fourth reach from Km 2.590 to Km 2.920, fifth reach from Km 2.920 to Km 4.100 and sixth reach from Km 4.100 to Km 4.900, as shown in Figure (1).

Site investigation and visual observations were preformed through field visits to detect the percentage infestations for floating, ditch-bank and emergent weeds; moreover, survey on the cross sections was conducted using Echo Sounder to detect the percentage of the submerged weeds infestation in the studied reaches.

Determination of the infestation percentages was attributed to total water surface area on three time periods during April, July and November 2015 before rehabilitation and manual maintenance. In 2016, such activates were repeated during the same months after canal rehabilitation and manual maintenance.

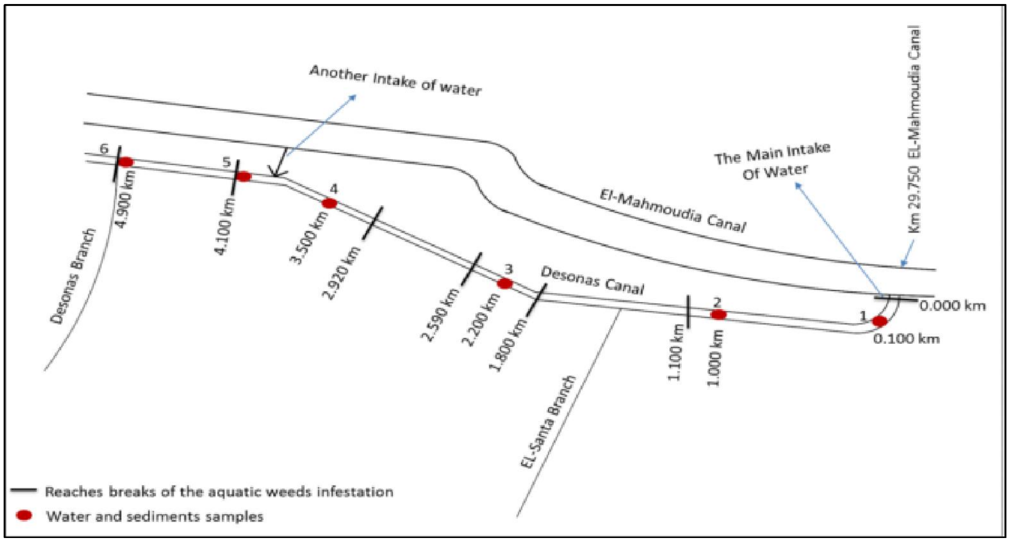

Figure 1: Map shows Desonas Canal site (study area).

Sampling procedure of water and sediment

Six samples were collected from Desonas Canal for water and sediments, sample (1) at 0.100 Km, sample (2) at 1.000 Km., sample (3) at 2.200 Km., sample (4) at 3.500 Km., sample (5) at 4.100 Km. and sample (6) at 4.900 Km. Samples were collected on three time periods during April, July and November 2015 before rehabilitation and manual maintenance and three others after rehabilitation and manual maintenance during April, July and November 2016. Water samples were collected from midstream water about 30 cm beneath water surface by water sampler and saved in cleaned polyethylene bottles. All water samples were filtered using whatman No. 42 filter paper. Preliminary treatment and preservation methods for various water parameters were applied according to (**APHA, 2012(.** Surface sediments were collected, randomly, using sediment sampler, as this layer controls the exchange of metals between sediments and water **(El-Nemr *et al.,* 2006)**. Water and sediments samples were analyzed in the laboratories of the National Water Research Center (NWRC).

Laboratory analysis of water

pH samples were measured using a combined electrode connected to a pH meter, DO (Dissolved oxygen) was measured using a combined electrode connected to a (DO) meter and EC was determined by digital electrical conductivity meter. Water samples were analyzed for soluble cations according to standard methods described by **(APHA, 2012)**. Sodium and potassium were determined using the flame photometer model, corning 410. Calcium and Magnesium were determined by the titration against sodium versinate (0.01 N Na_2 EDTA). Ammonium (NH_4^+), Nitrate (NO_3^-), Nitrite (NO_2^-) and Phosphate (PO_4^{3-}) were determined spectrophotometrically using the spectrophotometric as described by **(APHA, 2012)**. Determinations of heavy metals (Fe, Mn, Cu, Zn, Pb and Ni) were determined using **Inductively Coupled Plasma-Emission Spectrometry (ICP-OES).** Egypt law No. 48/1982 for Water Quality of the Nile River and Main Branches and Canals was used as reference for water quality limits.

Laboratory analysis of sediments

The sediment samples were collected air-dried, crushed, passed through a 2-mm mesh screen and stored in polyethylene bags for analysis. The chemical properties, pH were measured at 1:2.5 sediments to water ratio suspension, while electrical conductivity, cations and anions were measured at 1:5 sediments to water ratio extracts as soon as the samples reached the laboratory. Soluble cations were determined according to the standard methods **(APHA, 2012)**. For the determination of total heavy elements, 2 g of each sediments sample was digested with 15 ml of aqua-regain (1: 3 HCl: HNO_3) in a Teflon bomb for 2 h at 120 C^o. After cooling, the samples were filtered and kept in plastic bottles. Heavy elements (copper, iron, manganese, nickel, lead, and zinc) have been measured using Inductively Coupled Plasma-Emission Spectrometry (ICP-OES). Ammonium (NH_4^+), Nitrate (NO_3^-), Nitrite (NO_2^-) and available phosphorus (P) was determined spectrophotometric ally using the spectrophotometric as described by **(APHA, 2012)**. Organic matter was determined by Walkley-Black method as described by the **Recommended Chemical Soil Test Procedures (1998).**

Statistical Analysis

The relationships for the aquatic weeds infestation, the chemical properties of water and sediments were evaluated before and after rehabilitation and manual maintenance by using SPSS 16 statistical program, the significant difference - t-test (two tailed, p=0.05) to verify the improvement of the aquatic environment of aquatic weeds, water and sediments.

3. Results and Discussion

Intensive spreading of aquatic weeds into waterways causes degradation in channel efficiency and hydraulic performance, alteration in the physic-chemical characteristics of both water and hydro soil. Moreover, reduction of water flows to agricultural lands at the end of irrigation networks. The irrigation networks maintenance through various means including, rehabilitation and manual maintenance are important to manage efficient water distribution (especially, branch canals). Rehabilitation for some reaches and manual maintenance was carried out at the Desonas canal through irrigation administration and Stakeholders Participation.

Rehabilitation in Desonas canal

Primary field measurements were applied on actual cross section of Desonas Canal. The canal water course was surveyed and the actual hydraulic parameters were measured. All the results of primary field measurements were compared with the design ones. The less efficient reaches were from inlet to Km (0.250), Km (0.800) to Km (1.600), Km (2.620) to Km (2.925) and from Km (3.275) to Km (3.650). The canal cross section was redesigned using Regime theory and the less efficient reaches were rehabilitated. The effect of rehabilitation process was evaluated. There was a remarkable increase in the canal water velocities and discharge as shown in Figure (2). The discharges at the intake before and after rehabilitation are 0.48 and 1.0 m3/s respectively. Also at the downstream reach of the canal; the discharge is improved by 16% of its actual discharge before rehabilitation.

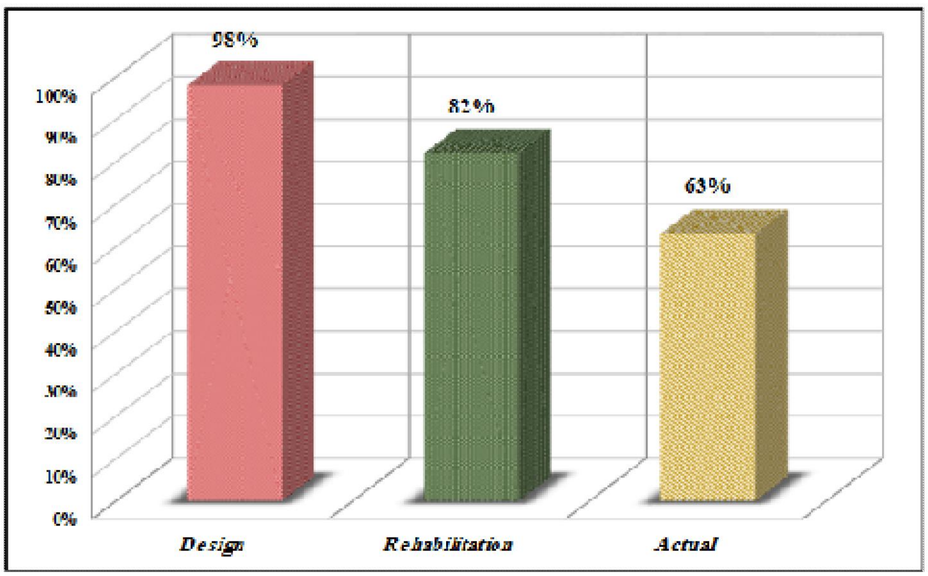

Figure (2) Comparison between velocities actual, design cases and after rehabilitation of Desonas Canal

Manual weed maintenance in Desonas Canal

The farmers participating in local water board association take the charge of applying manual weed maintenance to the entire canal length. CMRI offer ten sets of the modified hand tools to stakeholders along the canal. The tools were distributed on the ten maintenance groups (five farmers per each group) to apply manual maintenance process regularly. Each group takes charge of a distance of 500 m long. Also, The CMRI introduces the required training courses for farmers. The farmers used the modified hand tools (Long Handled Spit Knife, Long Handled Reed Sickle, Long Handled Fork, and Long Handled Digging Hoe) to remove all types of aquatic weed. The maintenance activities were applied periodically to insure high efficiency of the canal especially after rehabilitating the less efficient reaches. Regular monitoring and evaluating to the applied maintenance activities and canal efficiency were implemented through Inventory and the infestation percentages of aquatic weeds.

Inventory and the infestation percentages of aquatic weeds

Table (1) show the results of the inventory of aquatic weeds types and determination of the mean infestation percentages during April, July and November 2015 before rehabilitation and manual maintenance compared to after rehabilitation and manual maintenance during April, July and November 2016. The aquatic weed was monitored to four main types which related to the plants position of Desonas Canal. These four types are floating weeds represented in water hyacinth "*Eichornia crassipes*", ditchbank weeds represented in Common reed "*Phragmites australis*" and horseweed or butterweed *"Conyza dioscoridis*" emergent weeds represented in hippo grass "*Echinochloa stagninum*", submerged weeds represented in Coontail "*Ceratophyllum demersum*" and sago pond weed "*Potamogeton nodosus*". It is very clear from the summary that floating weeds was the most common types in the six reaches, followed by ditchbank weeds and emergent weeds, while, submerged weeds are the least common and monitored from the first reach to the third reach only.

The results in Table (1) show the mean of total infestation percentage of all aquatic weeds before rehabilitation and manual maintenance ranged between 20 - 55 %, while, after rehabilitation and manual maintenance were decreased to reach 10 - 25 %. Infestation percentage of floating weeds, ditch-bank weeds, emergent weeds and submerged weeds before rehabilitation and manual maintenance ranged between 10 - 25 %, 6 - 15%, 4 – 10 % and 0 -7 %, respectively, while, after rehabilitation and manual maintenance were decreased to reach 4 - 10 %, 4 – 6 %, 2 – 5 % and 0 – 5 %, respectively. The rate of infestation decreased of all types aquatic weed ranged between 38 – 64 % in six reaches, due to the manual maintenance applying for a full year. In addition to, rehabilitation of the less efficient reaches, resulting in an increase in water velocities, and therefore, low weed growth. These results agree with **(Wade, 1990)** which showed examples successful or partially successful as a result of manual maintenance ranged between 65 to 90%, and agree with **(John and Patrick, 1993)** which reported low water velocities were associated with density of weeds while faster flowing water was found in open water free of weeds.

To verify the improvement of the aquatic environment of aquatic weeds in Desonas canal as a result of rehabilitation and manual maintenance, the aquatic weed infestation of water were evaluated during April, July and November 2015 before rehabilitation and manual maintenance compare to after rehabilitation and manual maintenance during April, July and November 2016 by using the statistical analysis (t test). The results presented in Table (2) show significance was achieved for all aquatic weed (floating weeds, ditch-bank, emergent weeds and submerged weeds), the rehabilitation and manual maintenance had a tendency to decrease infestation percentage for aquatic weeds.

Physico-chemical properties in Desonas Canal water

The results of the physico-chemical properties in Desonas Canal water (Table 3) showed that the Dissolved oxygen concentration decreased in water with the direction of water flow from Km 0.000 to Km 3.500, then, the oxygen concentration returned to altitude at Km 4.100, such change in Dissolved oxygen concentration, may be attributed to the water supply from El- Mahmoudia canal to Desonas canal at Km 4.000 as shown in Figure (1). Dissolved oxygen concentrations in water of Desonas canal before rehabilitation and manual maintenance ranged between 2.90 mg/l - 5.10 mg/l, decreased to reach between 3.20 mg/l - 7.00 mg/l after rehabilitation and manual maintenance. Dissolved oxygen improved slightly after rehabilitation and manual maintenance due to increase in flow velocity and removed aquatic weed, these results agree with **(Ali and Hussona, 2014)** reported that the dissolved oxygen concentrations of Mahmoudia canal ranged from 4.9 mg O_2/l to 5.9 mg O_2/l.

The values of electrical conductivity (EC) was slightly decreased in the water after rehabilitation and manual maintenance (0.481 – 0.564 dSm^{-1}) compared to before rehabilitation and manual maintenance (0.463 – 0.538 dSm^{-1}) as shown in Table (3). These decrease after rehabilitation and manual maintenance as a result of the removal of part from the surface sediments accumulated over time on the canal bed, this surface sediments are controls the exchange of elements between sediments and water **(El-Nemr *et al.,* 2006).**

Nutrients concentrations in water of Desonas Canal before rehabilitation and manual maintenance for NH_4^+, NO_2^-, NO_3^- and PO_4^{3-} ranged between 0.65 – 0.85, 0.059 – 0.073, 0.44 – 0.74 and 0.31 – 0.52 mg/l, respectively. These values decreased to reach between 0.22 - 0.35, 0.014 – 0.023, 0.34 – 0.57 and 0.23 – 0.42 mg/l, respectively, after rehabilitation and manual maintenance. The results fall within Egypt law No. 48/1982, except for the concentration of ammonia before rehabilitation and manual maintenance as shown in Table (3), these results agree with **(Ali and Hussona, 2014)** reported that the nutrient concentrations of Mahmoudia Canal are consistent with permissible limits except ammonia, were exceeding of Egypt standard. The high concentration of ammonia in Desonas Canal water before rehabilitation and manual maintenance is caused likely from the main source (Mahmoudia Canal) which receives the discharge from Zarcon Drain which is feeding the canal at Km 6 **(Ali and Hussona 2014)**.

Table 1: Aquatic weeds types, mean of infestation percentages of each type, and mean of total infestation of all types before and after rehabilitation and manual maintenance in Desonas Canal

Reach distance (Km.) From (Km)	To (Km)	Aquatic weeds types	Scientific name of weeds	Mean of infestation of each type % (b)	Mean of total infestation of all types % (b)	Mean of infestation of each type % (a)	Mean of total infestation of all types % (a)	Rate of infestation decrease of each type %	Decrease in infestation %
0.000	1.100	floating weeds	*Eichornia crassipes*	15	40	10	25	34	38
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	10		6		40	
		emergent weeds	*Echinochloa stagninum*	8		5		38	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	7		4		43	
1.100	1.800	floating weeds	*Eichornia crassipes*	18	40	10	25	44	38
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	7		5		29	
		emergent weeds	*Echinochloa stagninum*	8		5		38	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	7		5		29	
1.800	2.590	floating weeds	*Eichornia crassipes*	25	55	7	20	72	64
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	15		6		60	
		emergent weeds	*Echinochloa stagninum*	10		5		50	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	5		2		60	
2.590	2.920	floating weeds	*Eichornia crassipes*	15	35	9	20	40	43
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	12		6		50	
		emergent weeds	*Echinochloa stagninum*	8		5		38	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	0		0		-	
2.920	4.100	floating weeds	*Eichornia crassipes*	15	35	7	15	43	57
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	13		5		62	
		emergent weeds	*Echinochloa stagninum*	7		3		57	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	0		0		-	
4.100	4.900	floating weeds	*Eichornia crassipes*	10	20	4	10	60	50
		ditch-bank weeds	*Phragmites australis Conyza dioscoridis*	6		4		34	
		emergent weeds	*Echinochloa stagninum*	4		2		50	
		submerged weeds	*Ceratophyllum demersum Potamogeton nodosus Poir*	0		0		-	

(b) Before rehabilitation and manual maintenance **(a) after rehabilitation and manual maintenance**

Table 2: Mean values, std. error and significant variations of different types of aquatic weed infestation in Desonas Canal before and after rehabilitation and manual maintenance.

aquatic weed infestation	Df	Mean (b)	Mean (a)	Std. Error (b)	Std. Error (a)	P-value (2-tailed) (b – a)
Floating weeds	17	16.333	8.167	1.567	0.638	*0.011*
Ditch-bank weeds	17	11.000	6.000	0.993	0.621	*0.026*
Emergent weeds	17	7.500	3.667	0.724	0.577	*0.000*
Submerged weeds	17	3.167	1.500	0.841	0.459	*0.001*

- **df** = degree of freedom, Std. Error = standard error of the mean, P-value =attained level of significance
- **Bold Value** (P) >0.05 - *Italic Value* (P) <0.05.
- **(b):** Before rehabilitation and manual maintenance
- **(a):** After rehabilitation and manual maintenance.

In general, nutrients concentrations decreased after rehabilitation and manual maintenance as a result of the removal on decaying aquatic weeds and part from the organic sediment accumulated over time of the canal bed during rehabilitation and manual maintenance. This could explain the low concentration of the nutrients especially ammonia, phosphate which are closely related to the increase of organic matter.

The concentrations of cations in Desonas Canal water of Na^+, K^+, Ca^{2+} and Mg^{2+} before rehabilitation and manual maintenance ranged between 75 – 83, 33 – 36, 31 – 41 and 16 – 23 mg/l, respectively. While, after rehabilitation and manual maintenance decreased to reach between 62 - 67, 27 – 30, 30 – 37 and 16 – 20 mg/l, respectively, as shown in Table (3). This decrease may be attributed to decrease of electrical conductivity (EC) in the water, which is an indicator to the content of dissolved inorganic salts of water.

Heavy elements concentrations in Desonas Canal water for Cu, Fe, Mn, Ni, Pb and Zn before rehabilitation and manual maintenance ranged between 0.047 – 0.079, 0.271 – 0.888, 0.142 – 0.405, 0.020 – 0.045, 0.039 – 0.048 and 0.041 – 0.162 mg/l, respectively. After rehabilitation and manual maintenance these concentration slightly decreased to reach between 0.021 – 0.064, 0.241 – 0.836, 0.136 –

0.257, 0.016 – 0.028, 0.021 – 0.038 and 0.030 – 0.141 mg/l, respectively, as shown in Table (3). The results of heavy metals (Cu, Pb, Zn, Mn and Fe) were found in the canal at levels less than the maximum permissible limits for **Egypt law No. 48/1982**, except the concentration of Ni. These results agree with **(Galal, 1983)** for each (Cu, Pb, Zn, Mn and Fe). The nickel source is likely to be seepage from agricultural land adjacent to the canal, containing the residues of fertilizers and organic manures, these interpretation agree with **(Gopal *et al.*, 2014)** reported that Nickel is released into the environment from various anthropogenic activities, such as using fertilizer and organic manures.

To verify the improvement of the aquatic environment of water quality in Desonas canal as a result of rehabilitation and manual maintenance, the Physico-chemical properties of water were evaluated during April, July and November 2015 before rehabilitation and manual maintenance compared with after rehabilitation and manual maintenance during April, July and November 2016 by using the statistical analysis (t test). The results presented in Table (4) showed significance was achieved for nutrients and heavy elements. The rehabilitation and manual maintenance had a tendency to decrease concentrations of some nutrients and some heavy elements.

Chemical properties in sediments of Desonas Canal

The results presented (Table 5) of sediments in Desonas Canal showed that the values of electrical conductivity (EC) was slightly decreased after rehabilitation and manual maintenance (0.514 – 0.615 dSm^{-1}) compared to before rehabilitation and manual maintenance (0.526 – 0.646 dSm^{-1}). Such the results indicate that the content of dissolved inorganic salts in the sediments was low after rehabilitation and manual maintenance. The concentrations of nutrients in Desonas Canal sediments for NH_4^+, NO_2^-, NO_3^- and P before rehabilitation and manual maintenance ranged between 5.97 – 8.75, 0.39 – 0.52, 9.21 – 11.32 and 5.32 – 8.32 mg/kg, respectively, then decreased to reach between 5.46 - 8.01, 0.33 – 0.42, 6.98 – 9.85 and 4.96 – 7.45 mg/kg, respectively, after rehabilitation and manual maintenance as shown in Table (5). The high values of NH_4^+, NO_2^-, and NO_3^- before rehabilitation and manual maintenance may be related to decomposition of plants and organic matter and agricultural fertilizer tailings from the adjacent lands. While, lower those elements after rehabilitation and manual maintenance may be related to the denitrification and deammonification by denitrifying bacteria due to removing of decaying plants and organic matter from the canal bed, this interpretation agree with the findings of **Mostafa and Toufeek (2015).**

Table 4: Mean values of chemical properties of Desonas Canal water before and after rehabilitation and manual maintenance and their Std. error and the significant variation among them.

property	df	Mean (b)	Mean (a)	Std. Error (b)	Std. Error (a)	P-value (2-tailed) (b – a)
DO	17	4.100	4.825	0.225	0.303	*0.000*
PH	17	7.29	7.78	0.338	0.316	*0.005*
EC	17	0.521	0.503	0.007	0.005	*0.000*
NH_4^+	17	0.923	0.285	0.008	0.012	*0.008*
NO_2^-	17	0.069	0.018	0.002	0.001	*0.000*
NO_3^-	17	0.504	0.428	0.029	0.018	*0.001*
PO_4^{3-}	17	0.416	0.316	0.024	0.014	*0.003*
Na^+	17	76.17	65.33	0.793	0.511	*0.005*
K^+	17	33.28	29.61	0.463	0.325	*0.003*
Ca^{2+}	17	35.94	32.61	0.782	0.561	*0.001*
Mg^{2+}	17	19.28	17.50	0.666	0.445	*0.009*
Cu	17	0.063	0.034	0.003	0.004	*0.002*
Fe	17	0.605	0.546	0.206	0.185	*0.005*
Mn	17	0.361	0.309	0.246	0.197	*0.004*
Ni	17	0.032	0.022	0.002	0.001	*0.000*
Pb	17	0.063	0.039	0.005	0.002	*0.000*
Zn	17	0.094	0.076	0.012	0.010	*0.000*

- **df** = degree of freedom, Std. Error = standard error of the mean, P-value =attained level of significance
- **Bold Value** (P) >0.05 - *Italic Value* (P) <0.05.
- **(b):** Before rehabilitation and manual maintenance
- **(a):** After rehabilitation and manual maintenance.

Table 3: Mean values (± SD) of physico-chemical properties of Desonas Canal water before and after rehabilitation and manual maintenance

Parameters	Conc.	Location Km. 0.100 (b)	(a)	Km. 1.000 (b)	(a)	Km. 2.200 (b)	(a)	Km. 3.500 (b)	(a)	Km. 4.100 (b)	(a)	Km. 4.900 (b)	(a)	Law 48/1982
DO	mg /l	5.00±0.15	5.50±0.05	4.10±0.06	4.77±0.06	3.03±0.06	3.60±0.07	2.90±0.05	3.20±0.05	5.10±0.06	7.00±0.10	3.50±0.11	4.88±0.06	≥ 5
PH	-	7.40±0.02	7.40±0.03	7.24±0.06	7.38±0.03	7.02±0.03	7.70±0.05	7.35±0.03	7.40±0.02	7.43±0.05	7.40±0.07	7.30±0.07	7.62±0.08	7- 8.5
EC	dSm^{-1}	0.481±0.02	0.463±0.03	0.516±0.01	0.500±0.02	0.538±0.02	0.505±0.03	0.564±0.01	0.538±0.02	0.510±0.02	0.500±0.01	0.539±0.03	0.500±0.02	-
NH_4^-	mg /l	0.65±0.09	0.22±0.03	0.85±0.07	0.35±0.03	0.74±0.09	0.23±0.03	0.77±0.15	0.31±0.03	0.84±0.05	0.26±0.06	0.76±0.08	0.26±0.09	≤ 0.5
NO_2^-	mg /l	0.064±0.01	0.018±0.003	0.068±0.003	0.014±0.003	0.072±0.005	0.023±0.006	0.059±0.006	0.020±0.002	0.073±0.011	0.016±0.003	0.063±0.010	0.019±0.005	-
NO_3^-	mg /l	0.58±0.15	0.46±0.05	0.60±0.07	0.51±0.06	0.59±0.07	0.42±0.06	0.46±0.10	0.34±0.06	0.74±0.12	0.57±0.08	0.44±0.05	0.38±0.05	≤ 45
PO_4^{3-}	mg /l	0.31±0.07	0.23±0.05	0.51±0.06	0.39±0.06	0.47±0.13	0.28±0.04	0.52±0.03	0.42±0.04	0.46±0.10	0.33±0.03	0.52±0.05	0.32±0.01	-
Na^+	mg /l	76±4.16	64±3.06	75±3.06	62±2.52	82±5.57	66±5.29	83±7.09	67±4.16	75±1.53	63±4.00	77±4.00	64±4.73	-
K^+	mg /l	36±1.53	30±1.00	33±2.89	30±1.53	33±2.52	28±1.00	34±3.06	28±1.53	35±4.04	27±3.06	33±1.53	29±1.53	-
Ca^{2+}	mg /l	33±1.53	32±1.00	31±1.53	30±1.53	33±1.00	32±1.53	39±1.00	32±1.00	41±2.00	37±1.53	36±1.00	33±2.00	-
Mg^{2+}	mg /l	19±1.52	16±1.54	18±1.00	17±0.57	16±1.15	16±1.00	23±1.52	19±1.53	21±1.53	20±1.00	19±1.00	18±2.08	-
Cu	mg /l	0.077±0.002	0.064±0.001	0.055±0.003	0.021±0.001	0.063±0.002	0.024±0.003	0.047±0.003	0.026±0.001	0.055±0.004	0.029±0.002	0.079±0.003	0.035±0.002	≤ 1.0
Fe	mg /l	0.562±0.13	0.539±0.08	0.271±0.09	0.241±0.04	0.481±0.12	0.465±0.09	0.790±0.15	0.661±0.12	0.888±0.19	0.836±0.12	0.634±0.13	0.532±0.08	≤ 1.0
Mn	mg /l	0.142±0.02	0.136±0.01	0.165±0.03	0.152±0.03	0.238±0.04	0.225±0.01	0.228±0.02	0.198±0.02	0.405±0.05	0.257±0.03	0.285±0.03	0.200±0.02	≤ 0.5
Ni	mg /l	0.045±0.009	0.026±0.008	0.042±0.008	0.028±0.006	0.020±0.005	0.016±0.004	0.032±0.008	0.026±0.006	0.024±0.007	0.022±0.007	0.026±0.005	0.021±0.004	≤ 0.01
Pb	mg /l	0.044±0.004	0.036±0.003	0.039±0.005	0.038±0.005	0.045±0.004	0.029±0.006	0.039±0.007	0.021±0.003	0.042±0.005	0.036±0.004	0.048±0.008	0.032±0.004	≤ 0.05
Zn	mg /l	0.041±0.008	0.039±0.007	0.049±0.006	0.044±0.008	0.043±0.007	0.030±0.004	0.162±0.010	0.141±0.009	0.139±0.011	0.117±0.007	0.132±0.012	0.095±0.010	≤ 1.0

(b) before rehabilitation and manual maintenance (a) after rehabilitation and manual maintenance

Table 5: Mean concentrations (± SD) of chemical properties of sediment in Desonas Canal before and after rehabilitation and manual maintenance

Parameters	Conc.	Location Km. 0.100 (b)	(a)	Km. 1.000 (b)	(a)	Km. 2.200 (b)	(a)	Km. 3.500 (b)	(a)	Km. 4.100 (b)	(a)	Km. 4.900 (b)	(a)
PH	-	6.9±0.12	7.3±0.14	7.2±0.14	7.8±0.16	7.0±0.11	8.0±0.17	6.9±0.15	8.2±0.19	7.4±0.12	8.0±0.18	7.2±0.09	8.0±0.16
EC	dSm^{-1}	0.612±0.04	0.540±0.03	0.646±0.06	0.615±0.05	0.594±0.09	0.539±0.07	0.526±0.06	0.514±0.05	0.591±0.09	0.525±0.08	0.592±0.03	0.580±0.08
NH_4^+	mg /kg	7.78±0.05	6.85±0.12	6.32±0.08	5.98±0.09	8.32±0.13	7.55±0.11	6.95±0.15	6.88±0.14	8.75±0.14	8.01±0.18	5.97±0.21	5.46±0.18
NO_2^-	mg /kg	0.45±0.03	0.42±0.02	0.39±0.04	0.35±0.06	0.49±0.08	0.33±0.04	0.46±0.09	0.42±0.05	0.43±0.07	0.39±0.05	0.52±0.08	0.34±0.03
NO_3^-	mg /kg	11.32±0.25	9.85±0.22	10.22±0.24	8.57±0.21	9.85±0.27	8.87±0.25	9.21±0.25	6.98±0.17	11.03±0.19	8.65±0.21	9.85±0.25	8.95±0.14
P	mg /kg	6.32±0.15	6.31±0.12	6.85±0.18	5.64±0.10	5.32±0.14	4.96±0.11	8.32±0.15	7.45±0.10	6.85±0.14	6.32±0.15	7.11±0.15	6.76±0.12
Na^+	mg /kg	61±2.75	42±2.25	72±3.25	52±3.25	66±2.50	57±3.25	73±2.75	57±3.50	92±2.25	63±2.45	75±2.15	60±2.50
K^+	mg /kg	58±3.45	26±2.15	54±3.25	40±2.75	43±2.50	25±2.65	56±3.75	56±2.45	60±2.15	56±2.35	109±4.15	70±3.50
Ca^{2+}	mg /kg	39±1.95	37±1.75	37±1.85	38±2.05	43±2.10	40±2.00	51±3.15	43±2.15	51±2.45	50±2.55	48±1.95	40±1.75
Mg^{2+}	mg /kg	24±1.35	19±1.25	28±1.45	26±1.15	38±1.20	26±1.10	37±2.15	34±1.85	37±2.10	40±1.85	24±1.65	26±1.50
SAR	%	10.8±0.43	7.9±0.21	12.6±0.35	9.2±0.25	10.4±0.35	9.9±0.30	10.9±0.25	9.2±0.20	13.9±0.45	9.4±0.25	12.5±0.25	10.4±0.15
Cu	mg /kg	17.9±0.35	9.9±0.15	22.7±0.25	11.3±0.28	16.9±0.22	10.4±0.12	14.3±0.15	9.8±0.22	19.6±0.20	16.4±0.24	21.1±0.11	13.2±0.18
Fe	mg /kg	1253.8±8.2	1215.5±7.5	1939.4±9.2	1926.0±8.6	1551.1±7.4	1438.8±9.1	1738.4±10.2	1430.6±11.5	1531.2±12.4	1467.3±14.1	2044.3±21.5	1916.7±22.5
Mn	mg /kg	390.8±6.32	331.4±5.25	323.3±4.52	269.4±3.65	330.2±3.60	310.2±4.15	373.9±4.15	272.8±3.85	425.9±6.25	422.5±7.15	408.9±4.50	388.6±3.95
Ni	mg /kg	21.1±1.20	18.5±0.45	45.4±2.15	37.4±1.28	58.6±2.05	53.7±1.85	31.5±1.75	44.2±2.09	23.8±1.25	26.2±0.95	61.8±4.08	46.2±2.65
Pb	mg /kg	36.6±2.15	26.8±1.85	87.2±3.15	52.6±2.14	54.4±1.89	44.2±1.74	56.6±2.01	48.5±2.11	52.6±2.45	51.2±1.06	85.3±3.25	55.5±1.95
Zn	mg /kg	18.4±0.95	14.6±0.65	19.6±0.75	12.8±0.35	17.9±0.55	15.1±0.65	18.6±0.85	15.3±0.77	17.4±0.86	12.4±0.65	20.9±1.05	13.3±0.65
O.M	g/kg	43.7±2.95	28.9±1.15	73.9±2.05	48.6±2.25	78.5±1.65	35.8±0.85	42.4±2.23	29.3±1.05	58.4±2.08	43.0±1.75	65.8±2.15	48.0±1.85

(b) before rehabilitation and manual maintenance (a) after rehabilitation and manual maintenance

The concentrations values of cations in Desonas Canal sediments for Na^+, K^+, Ca^{2+} and Mg^{2+} before rehabilitation and manual maintenance ranged between 61 – 92, 43 – 109, 37 – 51 and 24 – 38 mg/kg, respectively, while, after rehabilitation and manual maintenance decreased to reach between 42 - 63, 25 – 70, 37 – 50 and 19 – 40 mg/kg, respectively, as shown in Table (5), this decrease may be attributed to decrease of electrical conductivity (EC) in the sediments, which is an indicator to the content of dissolved inorganic salts of sediments. SAR value in Desonas Canal sediments before rehabilitation and manual maintenance ranged between 10.4 – 13.9, then, decreased slightly after rehabilitation and manual maintenance to reach 7.9 – 10.4 as shown in Table (5). This explains that, the properties in sediments of Desonas Canal tend to decrease the dispersion of organic matter and clay particles, rise of aeration, and a general improvement of soil structure.

The concentrations values of heavy elements in Desonas Canal sediments for Cu, Fe, Mn, Ni, Pb and Zn before rehabilitation and manual maintenance ranged between 14.3 – 22.7, 1253.8 – 2044.3, 323.3 – 425.9, 21.1 – 61.8, 36.6 – 87.2 and 17.4 – 20.9 mg/kg, respectively. After rehabilitation and manual maintenance decreased to reach between 9.8 – 14.6, 1215.5 – 1926.0, 269.4 – 422.5, 18.5 – 53.7, 26.8 – 55.5 and 12.4 – 15.3 mg/kg, respectively, as shown in Table (5). The decreased concentration of heavy elements after rehabilitation and manual maintenance, may be attributed to removal the cumulative depositions with time from bed and sides of the canal such as dead plankton, decaying aquatic weeds and other depositions, thus, decreased of the solubility of most heavy elements as a result of increase in the pH value, this result agrees with **(Kabata-Pendias and Pendias 1992)** who stated that the solubility of most metal ions decreased with increasing soil pH.

Organic matter acts as a metal carrier and plays an important role in the metal distribution patterns within the sediment **(Lin and Chen, 1998).** The content of organic matter within the sediment was mainly produced in Desonas Canal from decaying aquatic weeds, dead plankton and other organic depositions. The mean values of the content of organic matter (O.M.) in the sediment (Table 5) before rehabilitation and manual maintenance ranged between 42.4 – 78.5 g/kg, while, after rehabilitation and manual maintenance decreased to reach between 28.9 – 48.6 g/kg. Low organic matter content may be attributed to the removal of sediments containing decaying aquatic weeds, dead plankton and other organic depositions.

To verify the improvement of the aquatic environment of the sediments in Desonas Canal as a result of rehabilitation and manual maintenance, the chemical properties of water were evaluated using the statistical analysis (t test). The results presented in Table (6) showed that sediments adsorbed heavy elements and some nutrients before rehabilitation and manual maintenance from different inputs and they had a tendency to decrease concentration of heavy elements and some nutrients as a result of removed the most of the surface sediments during rehabilitation of some reaches and manual maintenance.

Conclusions and Recommendations

From the results of the research, it can be showed that, the periodic manual weed maintenance on Desonas Canal decreasing the aquatic weed infestation with a percentage ranged from 38 % up to 64 %, and, the implemented rehabilitation of low efficient reaches on the canal leads to increasing flow velocities. Also, the physico-chemical properties of both canal water, and bed sediments were improved with varying rates. This may be attributed to removal of surface layer of canal bed during rehabilitation process, this layer are controls the exchange of elements between sediments and water. This layer containing some decaying aquatic weeds, organic sediment and the residues of agricultural fertilizers accumulated over time. Also, the removal of aquatic weed and increasing flow velocities has improved the physico-chemical properties.

To reduce the aquatic weeds infestation percentage and to improve the water and sediments quality in Desonas Canal, a periodic maintenance program must be implemented to remove the aquatic weed, and bed sediments. The weed infestation must be monitored monthly and the bed level of the canal should be monitored yearly.

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