Scientific Research

Sustainable Mangement of Drainage Water of Fish Farms in Agriculture as a New Source for Irrigation and Bio-Source for Fertilizing

Abdelraouf Ramadan Eid[1*], Essam Mohamed Hoballah[2], Sahar E. A. Mosa[3]

[1]Water Relations & Field Irrigation Department, National Research Centre, Cairo, Egypt
[2]Agricultural Microbiology Department, National Research Centre, Cairo, Egypt
[3]Bio-Engineering Department, Agricultural Engineering Research Institute (AEnRI), Agricultural Research Center (ARC), Ministry of Agriculture, Giza, Egypt
Email: *abdelrouf2000@yahoo.com

Abstract

Two field experiments were carried out during growing seasons 2011 and 2012. It was executed in research farm of National Research Center in Nubaryia region, Egypt to study the effect of irrigation systems, fertigation rates by using the wastewater of fish farms "WWFF" in irrigation of potato. Study factors were irrigation systems (sprinkler irrigation system "SIS" and trickle irrigation system "TIS"), water quality (traditional irrigation water "TIW" and WWFF) and fertigation rates "FR" (20%, 40%, 60%, 80% and 100% NPK). The following parameters were studied to evaluate the effect of study factors: 1) Calculating the total amount of WWFF per season; 2) Chemical and biological description of WWFF; 3) Clogging ratio of emitters; 4) Yield of potato; 5) Irrigation water use efficiency of potato "$IWUE_{potato}$". Statistical analysis indicated that, maximum values were obtained of yield under SIS × $FR_{100\% NPK}$ × WWFF, also, there were no significant differences for yield values under the following conditions: SIS × $FR_{100\% NPK}$ × WWFF > SIS × $FR_{80\% NPK}$ × WWFF > SIS × $FR_{60\% NPK}$ × WWFF > TIS × $FR_{100\% NPK}$ × TIW. This means that, using WWFF in the irrigation can save at least 40% from mineral fertilizers and 100% from irrigation water under sprinkler irrigation system.

Keywords

Wastewater of Fish Farms, Potato, Arid Regions, Fertigation Rates, Irrigation Systems

---

*Corresponding author.

1. Introduction

Whenever good quality water is scarce, water of marginal quality will have to be considered for use in agriculture. Although there is no universal definition of "marginal quality" water, for all practical purposes it can be defined as water that possesses certain characteristics which have the potential to cause problems when it is used for an intended purpose. Many countries have included wastewater reuse as an important dimension of water resources planning. In the more arid areas of the world, wastewater is used in agriculture, releasing high quality water supplies for potable use.

This diverted attention to fish farming. However, recycling the drainage water (DW) of fish farming, rich with organic matter for agriculture use can improve soil quality and crops productivity [1], and reduce the total costs since it decreases the fertilizers use, whose demand became affected by the prices and the framer's education [2]. Meanwhile, organic matter content supports the cation exchange process in soils, which is important to the nutrition of plants [3]. Plants grow rapidly with dissolved nutrients that are excreted directly by fish or generated from the microbial breakdown of fish wastes. In closed recirculating systems with very little daily water exchange (less than 2 percent), dissolved nutrients accumulate in concentrations similar to those in hydroponic nutrient solutions. Dissolved nitrogen, in particular, can occur at very high levels in recirculating systems. Fish excrete waste nitrogen, in the form of ammonia, directly into the water through their gills. Bacteria convert ammonia to nitrite and then to nitrate. Aquaponic systems offer several benefits. Dissolved waste nutrients are recovered by the plants, reducing discharge to the environment and extending water use (*i.e.*, by removing dissolved nutrients through plant uptake, the water exchange rate can be reduced). Minimizing water exchange reduces the costs of operating aquaponic systems in arid climates and heated greenhouses where water or heated water is a significant expense. Having a secondary plant crop that receives most of its required nutrients at no cost improves a system's profit potential. The daily application of fish feed provides a steady supply of nutrients to plants and thereby eliminates the need to discharge and replaces depleted nutrient solutions or adjusts nutrient solutions as in hydroponics. The plants remove nutrients from the culture water and eliminate the need for separate and expensive biofilters. Directly absorbed and assimilated by plants, these compounds stimulate growth, enhance yields, increase vitamin and mineral content, improve fruit flavor and hinder the development of pathogens. The potato is the 5th most important crop in the world. It is nutritious and highly productive, and has a good value when sold, and is an effective cash crop for a developing country that has both local and export markets [4]. Quality of irrigation water also affects the degree of emitter clogging [5]. A high concentration of soluble salts in the water is the most important factor in clogging. When the concentrations of calcium, magnesium, bicarbonate and sulfate are high, the calcium carbonate, calcium sulfate and magnesium sulfate can occur. Calcium carbonate precipitation will also depend on the pH of the water. Precipitation of insoluble salts can also occur due to chemical reactions among the elements added as fertilizers in irrigation water [6]. Precipitated salts can easily clog emitters. Fertilizers injected into a microirrigation system may contribute to plugging [7]. The most important disadvantage of fertigation is precipitation of chemical materials and clogging of emitters [8]. Any fertilizer with calcium should not be used with sulfates together because they could form insoluble gypsum [7] [9] [10]. The objective of this study was maximizing utility from wastewater of fish farms in agriculture (potato cultivation) under arid regions conditions.

2. Materials and Methods

2.1. Site Description

Field experiments were conducted during two wheat seasons from Jan. to May of 2011-2012 at the experimental farm of National Research Center, El-Nubaria, Egypt (latitude 30°30'1.4"N, and longitude 30°19'10.9"E, and mean altitude 21 m above sea level). The experimental area has an arid climate with cool winters and hot dry summers prevailing in the experimental area. The monthly mean climatic data for the two growing seasons 2011 and 2012, for El-Nubaria city, are nearly the same. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from "Central Laboratory for Agricultural Climate (CLAC)". There was no rainfall that could be taken into consideration through the two seasons, because the amount was very little and the duration didn't exceed few minutes as shown in **Table 1**.

2.2. Estimation of the Seasonal Irrigation Water for Potato Plant

Seasonal irrigation water was estimated according to the meteorological data of the Central Laboratory for

Table 1. The monthly mean climatic data for the two growing seasons 2011 and 2012.

Items	Precipitation [mm]	Wind speed [m/sec]		HC Air temperature [°C]			HC Relative humidity [%]
	Sum	Aver.	Maxi.	Aver.	Mini.	Maxi.	Aver.
	0.3	0.5	2.1	14.1	9.6	19.1	78.9
	0.1	0.6	2.2	14.3	9.7	19.7	79.6
2011	0.0	0.6	2.3	17.3	11.6	24.0	75.6
	0.0	0.6	2.3	20.0	14.1	26.4	73.2
	0.0	0.5	2.1	14.1	9.6	19.1	78.9
	0.4	0.7	2.5	11.8	7.5	17.1	81.2
	0.0	0.6	2.1	11.7	7.7	16.4	79.7
2012	0.1	0.6	2.2	14.8	8.6	21.9	80.4
	0.0	0.6	2.2	18.8	12.1	27.1	74.4
	0.1	0.6	2.3	22.0	15.3	30.3	74.1

Agricultural Climate (CLAC) depending on Penman-Monteith equation shown in **Figure 1**. The volume of applied water increased with the growth of plant then declined at the end of the growth season. The seasonal irrigation water applied was found to be 2847 m^3/fed/season for sprinkler irrigation system and 2476 m^3/fed/season for trickle irrigation system.

2.3. Some Physical and Chemical Properties of Soil and Irrigation Water

Some Properties of soil and irrigation water for experimental site are presented in (**Table 2**, **Table 3** and **Table 4**). **Table 5** showed that, the determination of total bacteria, total fungi and some algal microorganisms and some physical and chemical determinations of wastewater of fish farm.

2.4. Potato Variety

Spunta Netherland production was used.

2.5. Experimental Design

Irrigation system components consisted of a control head and a pumping unit. It consisted of submersible pump with 45 m^3/h discharge driven by electrical engine back flow prevention device, pressure regulator, pressure gauges, flow-meter and control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) connected to the main line. Manifold lines: PE pipes of 63 mm in diameter (OD) were connected to the sub main line through control valve 2" and discharge gauge. Layouts of experiment design consisted of two irrigation systems. Sprinkler is a metal impact sprinkler 3/4" diameter with a discharge of 1.17 m^3h^{-1}, wetted radius of 12 m, and working pressure of 250 kPa. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 30 m in length (emitter discharge was 4 lph at 1.0 bar operating pressure and 30 cm spacing between emitters and all details about the experiment design and the source of wastewater of fish farm collected from 12 basin (5 m × 5 m × 2 m depth) are shown in **Figure 2**.

2.6. Methods

2.6.1. Sampling Site Description
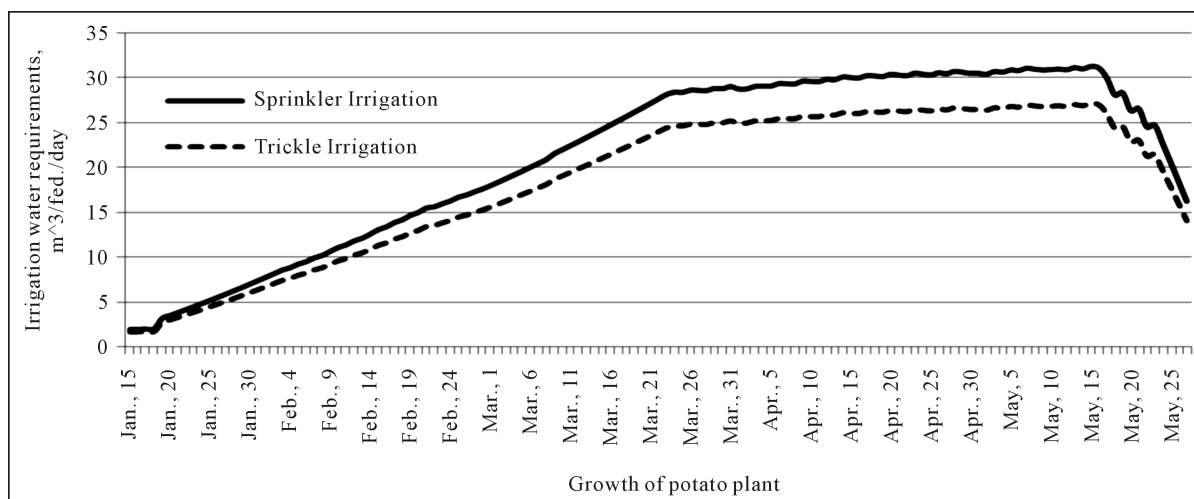Wastewater for fish farm samples were collected at the outlet of water basin used for fish breeding and production.

Figure 1. The relation between growth of potato plant and irrigation water requirements.

Table 2. Some chemical and mechanical analyses of soil.

Depth	Chemical analysis				Mechanical analysis, %			Texture
	OM (%)	pH (1:2.5)	EC (dSm^{-1})	CaCO$_3$ %	Course sand	Fine sand	Clay + Silt	
0 - 20	0.65	8.7	0.35	7.02	47.76	49.75	2.49	
20 - 40	0.40	8.8	0.32	2.34	56.72	39.56	3.72	Sandy
40 - 60	0.25	9.3	0.44	4.68	36.76	59.40	3.84	

Table 3. Characteristics of soil.

Depth	SP (%)	F.C (%)	W.P (%)	A.W (%)	Hydraulic conductivity (cm/hr)
0 - 20	21.0	10.1	4.7	5.4	22.5
20 - 40	19.0	13.5	5.6	7.9	19.0
40 - 60	22.0	12.5	4.6	7.9	21.0

Table 4. Some chemical characteristics of irrigation water of open channel.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR%
		Cations				Anions				
		Ca^{+2}	Mg^{+2}	Na$^+$	K$^+$	CO$_3^-$	HCO$_3^-$	Cl$^-$	SO$_2^-$	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

### 2.6.2. Physico Chemical Characters of Wastewater for Fish Farm

The physicochemical characteristics were carried out according to [11]. pH, EC, N, P, K and potential toxic elements (Cu, Zn, Pb,… etc.)

2.6.3. Biological Parameters

1) Total Viable Count of Bacteria: TVCB was determined using the standard plate count method and nutrient agar culture medium according to [11]; 2) Total count of fungi: was determined using the standard plate count method and Rose-bengal agar culture medium according to [12]; 3) Faecal coliform bacteria were counted using MacConky broth [13] and most probable number method [14]; 4) Total counts of free N$_2$ fixers using Ashby's

Table 5. Some physical and chemical and biological determinations of drainage water of fish farm under search.

Physical Determinant		Value	Biological Determinant	Counts as CFU/ml
EC		1.82 dsm^{-1}	Total counts of bacteria	1.5×10^4
pH		7.02	Total count of faecal coliform	3×10^2
Chemical elements			Total counts of fungi	500
Chromium	Cr	0.0 ppm	Total counts of free N$_2$ fixers	600
Copper	Cu	0.33 ppm	Green algae	
Nickel	Ni	0.0 ppm	*Chlorella* sp. Count	400
Zinc	Zn	1.1 ppm	*Scenedesmus* sp. Count	150
Nitrogen	N	4.79 ppm	*Pediastrum* sp. Count	120
Phosphorus	P	10.2 ppm	Cyanobacteria	
Potassium	K	35 ppm	*Oscillatoria* sp. Count	100
Sodium	Na	205 ppm	*Nostoc* sp. Count	50
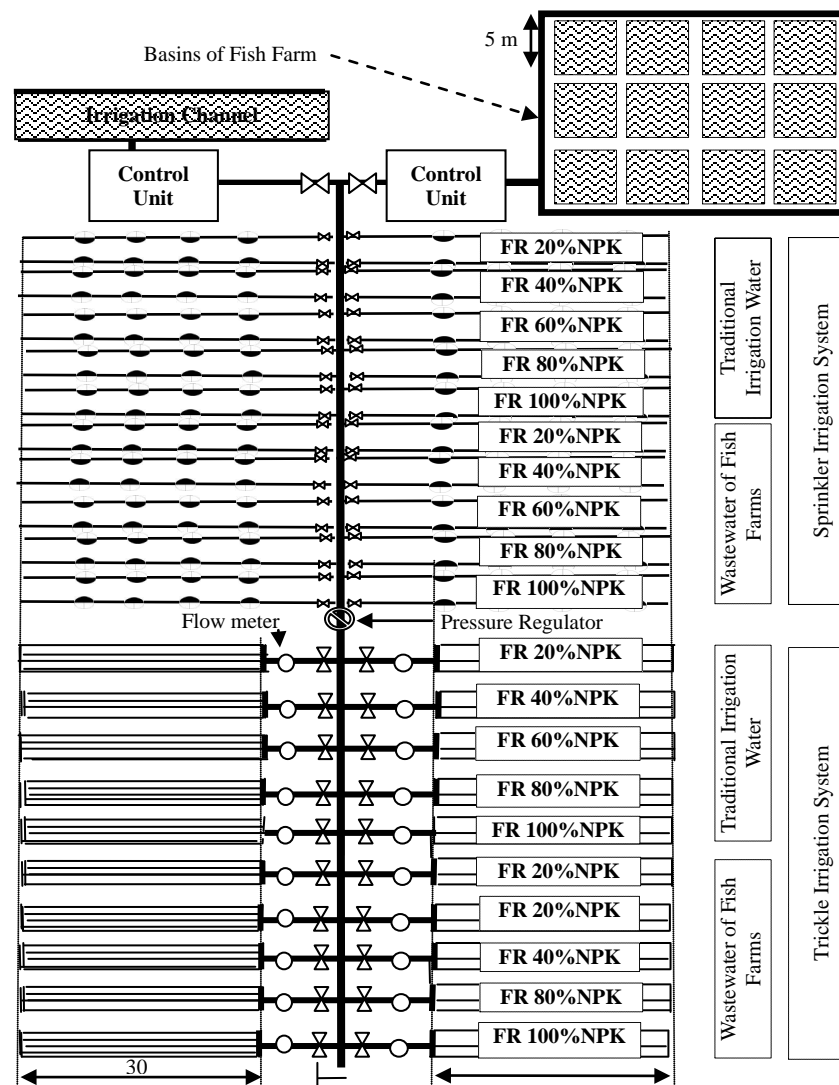
Figure 2. Layout of experiment design.

medium [15]; 5) Algae enumeration: The grouping of green algae and blue-green algae were accomplished and counted depending on morphological shape under light microscope using the Sedgwick-Rafter (S-R) cell count chamber according to [11], then calculated algae counts from the following equation:

$$\text{No./mL} = \left(C*1000 \text{ mm}^3\right)\big/\left(L*D*W*S\right)$$

where: C = number of organisms counted, L = length of each strip (S-R cell length), mm, D = depth of a strip (S-R cell depth), mm, W = width of a strip (Whipple grid image width), mm, and S = number of strips counted.

2.6.4. Determination of Clogging Ratio
The flow cross section diameter of the long-path emitter was 0.7 mm; discharging 4 L/h with lateral length of 30 m. Distance between emitter along the lateral was 30 cm. The emitter is considered laminar-flow-type (Re < 2000) [16]. To estimate the emitter flow rate cans and a stopwatch were used. Nine emitters from each lateral had been chosen to be evaluated by calculating their clogging ratio at the beginning and at the end of the growing season for the two seasons. Three emitters at the beginning, three at middle and three at the end of the lateral were tested for the flow rate. Clogging ratio was calculated according to [17] using the following equations:

$$E = \left(\text{qu/qn}\right)\times100$$
$$CR = \left(1-E\right)\times100$$

where: E = the emitter discharge efficiency (%), qu = emitter discharge at the end of the growing season (L/h), qn = emitter discharge, at the beginning of the growing season (L/h), CR = clogging ratio of emitters (%).

2.6.5. Determination Yield of Potato Crop
At the end of the growing season, potato yields were determined, Ton/Fadden for each treatment by the following steps; step 1 measuring the area to determine the yield, step 2 collecting the potato for each treatment on the buffer zone and step 3 weighing potato for each treatment.

2.6.6. Determination of Irrigation Water Use Efficiency of Potato Crop
Irrigation water use efficiency "IWUE" is an indicator of effectiveness use of irrigation unit for increasing crop yield. Water use efficiency of potato yield was calculated according to [16] as follows: IWUE_{potato} (kg/m^3) = Total yield (kg$_{tuber}$/fed)/Total applied irrigation water (m^3/fed/season)

2.6.7. Fertigation Method
The recommended doses of chemical fertilizer were added as fertigation *i.e.* nitrogen fertilizer was added at a rate of 120 kg/Fadden as ammonium sulfate (20.6% N), 150 kg calcium super phosphate/fed (15.5% P_2O_5) and 50 kg potassium sulfate (48% K_2O)) were added.

2.6.8. Statistical Analysis
The standard analysis of variance procedure of split-split plot design with three replications as described by [18] was used. All data were calculated from combined analysis for the two growing seasons 2011 and 2012. The treatments were compared according to L.S.D. test at 5% level of significance.

3. Results and Discussion
3.1. Calculating the Total Amount of Wastewater of Fish Farm per Season
To calculate the total amount of wastewater for fish farm in NUBARIA farm, the volume of water discharged per week must be calculated. There are 12 basin in the fish farm and the dimensions of the basin are 5 m × 5 m × 2 m, but the depth of the actual exchange is 1.5 m and therefore the size of the outgoing water per week = 5 × 5 × 1.5 × 12 basin = 450 m^3 of water. If we consider that potato cultivation needs 18 weeks, the total volume lost from this farm during the potato growing season = 18 × 450 = 8100 m^3/season of water as shown in **Figure 3**.

3.2. Chemical and Biological Description of Wastewater of Fish Farm
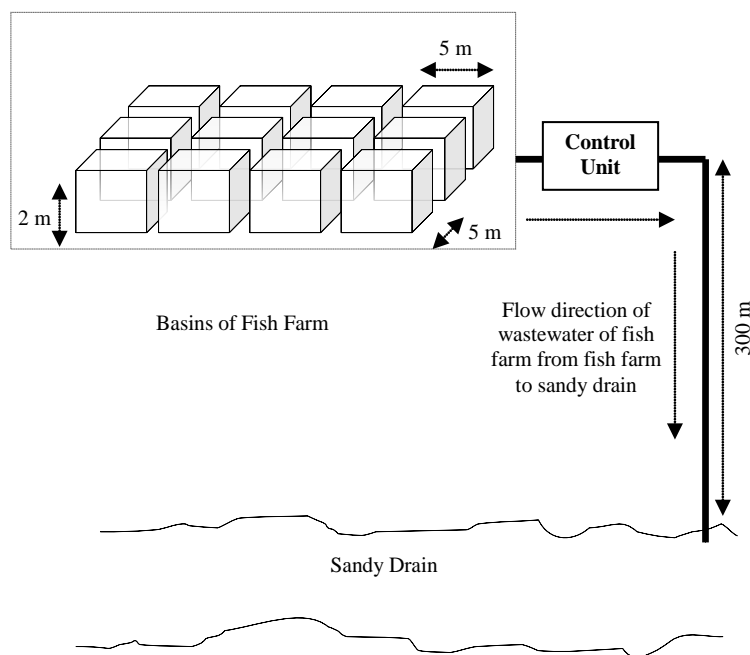The data aforementioned in **Table 5** showed that, the EC was 1.82 ds/m, pH was 7.02. On the other hand, the

Figure 3. Loss of wastewater of fish farm.

results in **Table 5** showed that Chromium, Copper, Nickel, Zinc, total Nitrogen as N_2, Phophorus as P, Potassium and Sodium reached 0.0, 0.33, 0.0, 1.1, 4.79, 10.2, 35 and 205 ppm, respectively. The data mentioned above showed quantitative fertigation capacity of the wastewater of fish farm under study to be used as irrigation water. Wastewater of fish farm could supply seasonally the soil with 13.637 and 11.86 kg of nitrogen/Fed. from the whole quantities of irrigation water to sprinkler and trickle irrigation methods used, respectively, that are equivalent to 64.938 and 56.476 kg of ammonium sulphate fertilizer (21% N) to sprinkler and trickle irrigation methods used, respectively. Also, this water could supply seasonally the soil with 29.039 and 25.252 kg of phosphorus from the whole quantities of irrigation water to sprinkler and trickle irrigation methods used, respectively, that are equivalent to 351 and 306 kg of superphosphate fertilizer (8.25% P) to sprinkler and trickle irrigation methods used, respectively.

3.2.1. Quantitative Estimation of Bacteria and Fungi
The data aforementioned in **Table 4** showed that, the total counts of bacteria reached 1.5×10^4 CFU/ml; also total counts of free N_2 bacterial fixers determined by Ashby's medium [15] (Kizilkaya, 2009) were 600 CFU/ml however the total count of faecal coliform was 3×10^2 CFU/ml. On the other hand, total counts of fungi reached 500 CFU/ml. The results aforementioned before are partially in agreement with the findings stated by [19] in which the possible counts of total counts of bacteria in domestic wastewater reached between 10^3 to 10^5 CFU/ml and also, the Coliform group of bacteria comprises mainly species of the genera *Citrobacter*, *Enterobacter*, *Escherichia* and *Klebsiella* and includes Faecal Coliforms, of which *Escherichia coli* is the predominant species were 10^2. Several of the Coliforms are able to grow outside the intestine, especially in hot climates; hence their enumeration is unsuitable as a parameter for monitoring wastewater reuse systems. The Faecal Coliform test may also include some non-faecal organisms which can grow at 44˚C, so the *E. coli* count is the most satisfactory indicator parameter for wastewater used in agriculture.

3.2.2. Quantitative Estimation of Phytoplankton
The morphological studies using a light microscope were done on the water samples under estimation. Water samples showed various phytoplankton structures belonging to two main groups, namely, Chlorophyceae (Green Algae) and Cyanophyceae (Blue-Green Algae). The general distribution of phytoplankton is demonstrated in **Table 4**. It may be important to note that genera, *chlorella*, *Pediastrum* and *Scenedesmus* as green algae were detected, whereas, *Oscillatoria* and *Nostoc* represented the most abundant genera of cyanobacteria in the inves-

tigated samples. The algae biomass contains nutrients such as C, N, P and k essential for microorganism development. The general microalgae biochemical structure has been successfully utilized as feedstock for digesters and as nutrient supplements in dairy farming. Algae biomass components such as protein, carbohydrates, poly-unsaturated fatty acids, are rich in nutrients vital for development of fish and shellfish consumption and other aquatic microorganisms as shown in **Figure 4**.
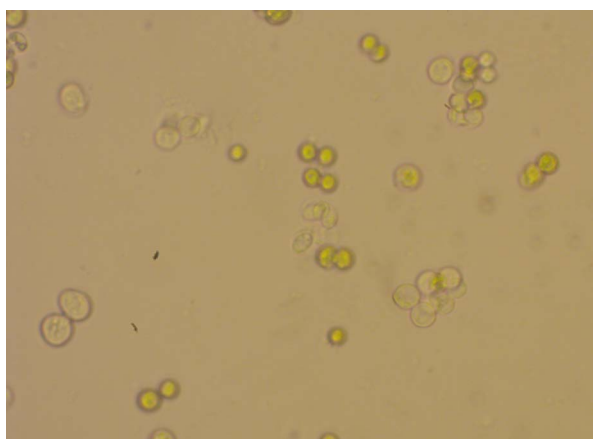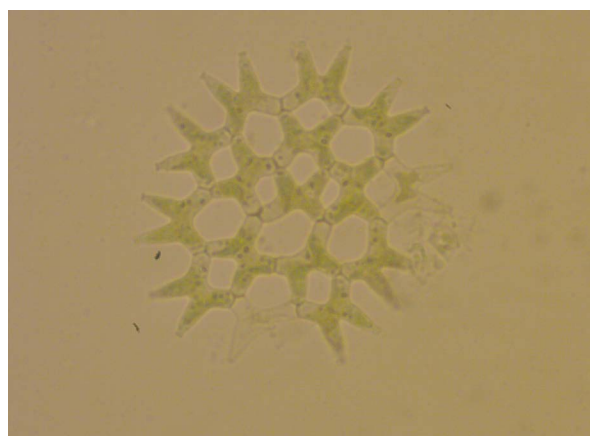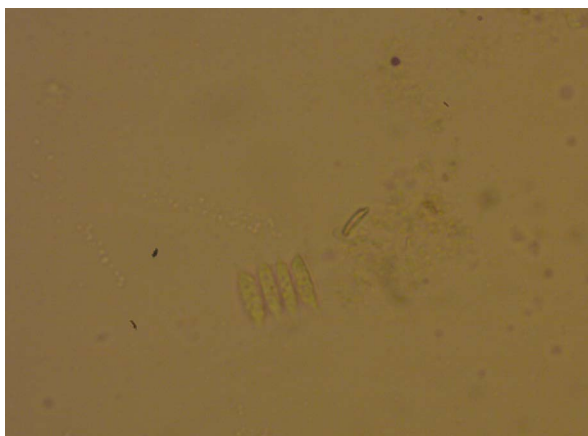

Chlorella sp.

Nostoc sp.

Oscillatoria sp.

Pediastrum sp.

Scenedesmus sp.

Figure 4. Types of *Chlorella* sp., *Nostoc* sp., *Oscillatoria* sp., *Pediastrum* sp. and *Scenedesmus* sp. were found in the wastewater of fish farm.

3.3. Effect of Irrigation Systems, Wastewater of Fish Farms and Fertigation Rates on Clogging Ratio, Yield of Potato and Irrigation Water Use Efficiency of Potato

3.3.1. Effect of Irrigation Systems on Clogging Ratio, Yield of Potato and Irrigation Water Use Efficiency of Potato Crop

Table 6 showed that, the effect of irrigation systems on clogging ratio, yield of potato and irrigation water use efficiency of potato crop (**Table 6**). Clogging ratio was increased under trickle irrigation system more than sprinkler irrigation system this may be due to the increase in orifices diameter of sprinkler than dripper especially in the absence of a filtering system (**Table 6**). Yield of potato was decreased under trickle irrigation system more than sprinkler irrigation system this may be due to water stress under trickle irrigation system more than sprinkler irrigation system which comes from the increasing in clogging ratio (**Table 6**). Increasing of irrigation water use efficiency of potato under trickle irrigation system compared with sprinkler irrigation system this may be due to increasing of water requirements under sprinkler irrigation system.

3.3.2. Effect of Wastewater of Fish Farms on Clogging Ratio, Yield of Potato and Irrigation Water Use Efficiency of Potato

Table 6 showed that, the effect of wastewater of fish farms on clogging ratio, yield of potato and irrigation water use efficiency of potato crop (**Table 6**). Clogging ratio was increased under WWFF more than WIT this may be due to the increasing in increase the proportion of suspended materials such as organic material and algae in WWFF than WIT (**Table 6**). Yield of potato was decreased under WIT more than WWFF this may be due to increasing of bio-components in WWFF than in WIT. **Table 6** indicated that increasing of irrigation water use efficiency of potato under WWFF and the difference between WWFF and WIT were nonsignificant.

3.3.3. Effect of Fertigation Rates on Clogging Ratio, Yield of Potato and Irrigation Water Use Efficiency of Potato

Table 6 and **Figure 5** show the relation between fertigation rates and clogging ratio, yield of potato and irrigation water use efficiency of potato crop. **Figure 5(a)** shows that clogging ratio was increased by increasing the fertigation rates this may be due to increasing the amount and concentration of dissolved mineral fertilizers in irrigation water that lead to the increase in clogging ratio (**Figure 5(b)**). Yield of potato was increased by increasing fertigation rates this may be due to increasing the amount and concentration of mineral fertilizers in the root zone. **Figure 5(c)** indicated the increase of irrigation water use efficiency of potato by increasing the fertigation rates this may be due to increasing the yield of potato by increasing the fertigation rates.

3.4. Effect the Interaction between Irrigation Systems, Wastewater of Fish Farms and Fertigation Rates on Clogging Ratio, Yield of Potato and Irrigation Water Use Efficiency of Potato

Table 7 and **Figure 6** show the effect of the interaction between irrigation systems, wastewater of fish farms

Table 6. Effect of irrigation systems, wastewater of fish farms and fertigation rates on clogging ratio, yield of potato and irrigation water use efficiency of potato (IWUE).

Study Factors	Clogging Ratio, %	Yield, Ton/Fed	IWUE, kg/m^3
SIS	1.3 b	10.0 a	2.9 a
TIS	33.2 a	5.7 b	2.9 a
WWFF	28.2 a	8.0 n.s	2.9 n.s
TIW	6.3 b	7.8 n.s	2.9 n.s
FR$_{20\% NPK}$	13.5 e	5.4 d	2.0 d
FR$_{40\% NPK}$	15.6 d	6.3 c	2.4 c
FR$_{60\% NPK}$	17.1 c	8.5 b	3.1 b
FR$_{80\% NPK}$	18.8 b	8.9 b	3.3 b
FR$_{100\% NPK}$	21.3 a	10.1 a	3.7 a

SIS: Sprinkler Irrigation System, TIS: trickle Irrigation System, WWFF: wastewater of fish farms, TIW: Traditional Irrigation Water, FR: Fertigation Rates. Letters a, b, c, d and e represent the significant between values.
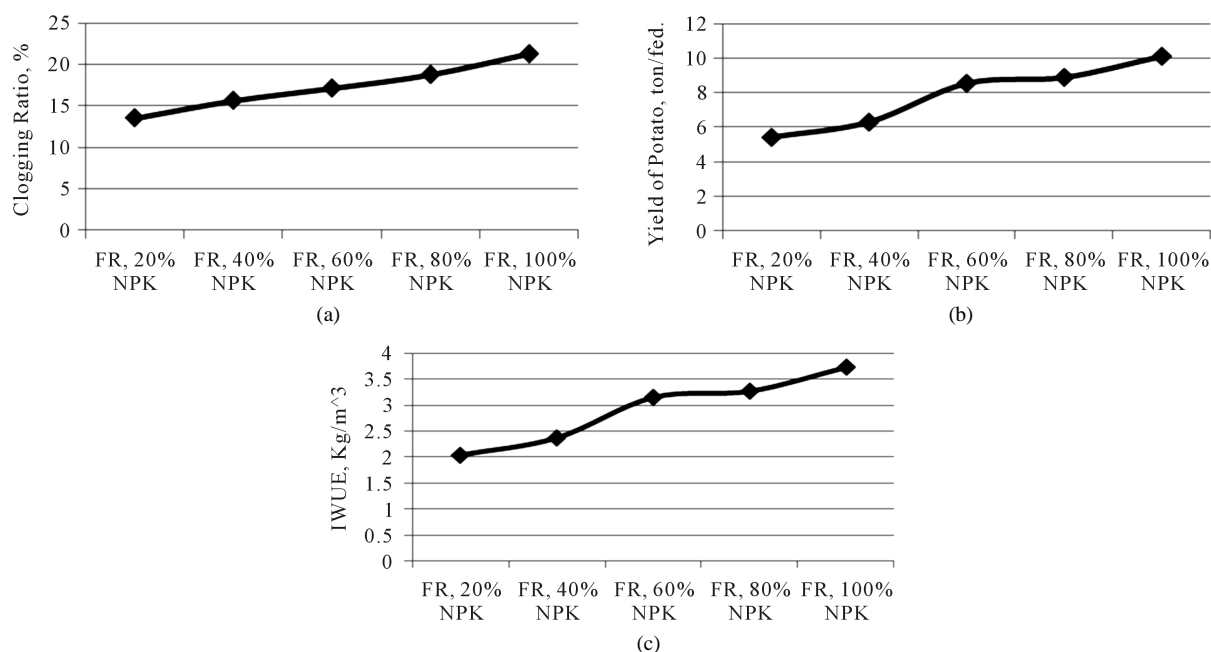
Figure 5. Effect of fertigation rates "FR" on (a) Clogging ratio, (b) Yield of potato and (c) Irrigation water use efficiency of potato "IWUE".

Table 7. Effect the interaction between irrigation systems, wastewater of fish farms and fertigation rates on clogging ratio of emitters, yield of potato and irrigation water use efficiency of potato crop.

Study Factors			Clogging ratio, %	Yield, Ton/Fed	IWUE, kg/m^3
IS	Water quality	FR			
SIS	WWFF	FR, 20% NPK	1.0 jk	7.7 fg	2.7 g
		FR, 40% NPK	1.4 jk	8.3 f	2.9 fg
		FR, 60% NPK	2.2 jk	15.2 a	5.3 a
		FR, 80% NPK	2.5 j	14.9 ab	5.2 ab
		FR, 100% NPK	2.5 j	15.7 a	5.5 a
	TIW	FR, 20% NPK	0.4 k	5.0 i	1.8 ij
		FR, 40% NPK	0.5 k	6.0 f	2.1 h
		FR, 60% NPK	0.6 k	7.6 fg	2.7 g
		FR, 80% NPK	0.8 jk	9.3 e	3.3 e
		FR, 100% NPK	0.9 jk	10.5 d	3.7 d
TIS	WWFF	FR, 20% NPK	44.8 e	4.1 j	1.6 j
		FR, 40% NPK	50.8 d	4.0 j	1.6 j
		FR, 60% NPK	55.1 c	3.7 jk	1.5 jk
		FR, 80% NPK	59.3 b	3.2 kl	1.3 kl
		FR, 100% NPK	62.3 a	2.9 l	1.2 l
	TIW	FR, 20% NPK	7.9 i	5.0 i	2.0 hi
		FR, 40% NPK	9.8 h	7.0 g	2.8 g
		FR, 60% NPK	10.6 h	7.7 fg	3.1 ef
		FR, 80% NPK	12.4 g	8.2 f	3.3 e
		FR, 100% NPK	19.3 f	11.3 c	4.6 c

SIS: Sprinkler Irrigation System, TIS: trickle Irrigation System, WWFF: wastewater of fish farms, TIW: Traditional Irrigation Water, FR: Fertigation Rates. Letters a, b, c, d and e represent the significant between values.
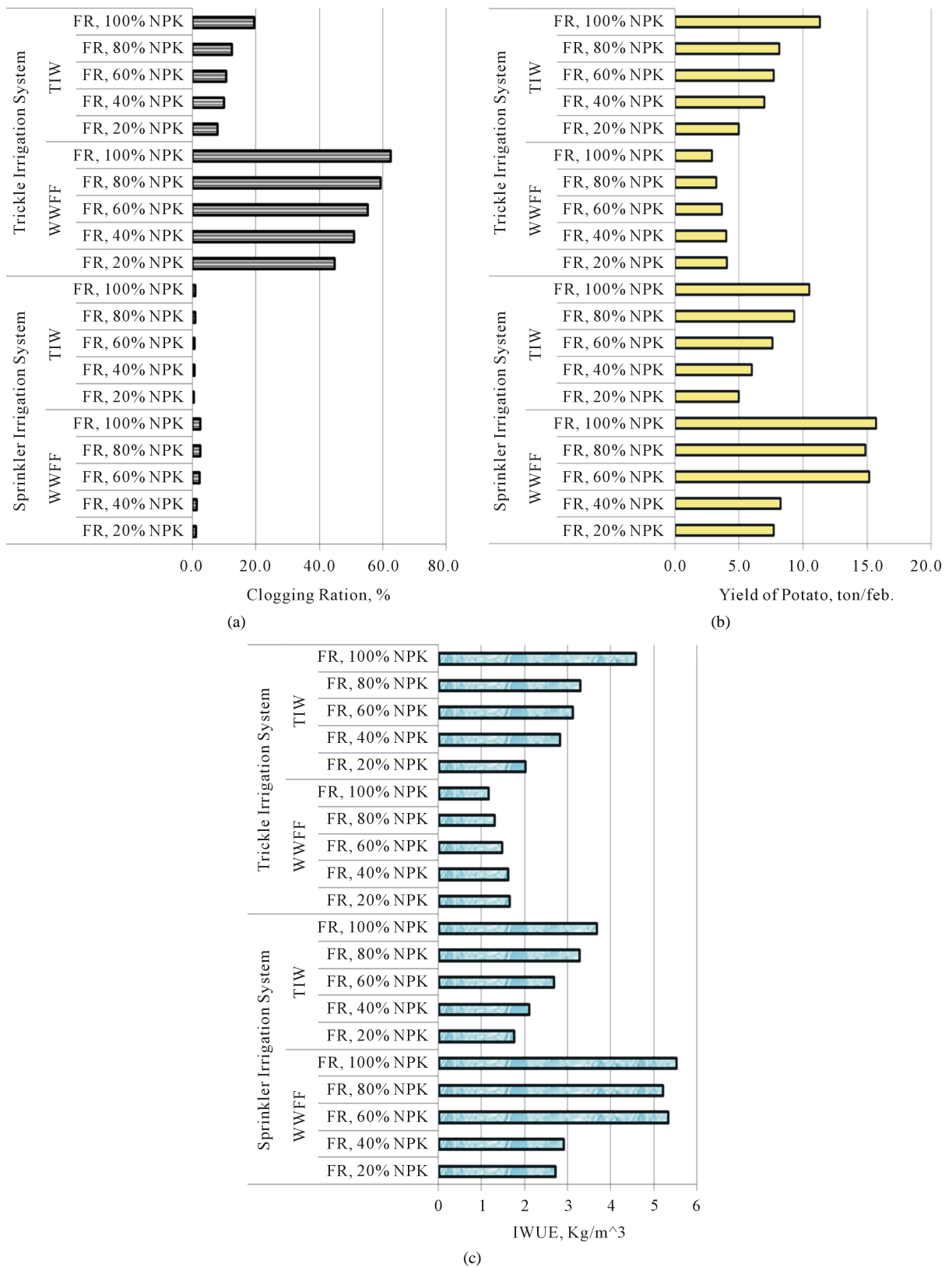
(a)

(b)

(c)

Figure 6. Effect of the interaction between irrigation systems, wastewater of fish farms "WWFF" and fertigation rates "FR" on (a) Clogging ratio, (b) Yield of potato and (c) Irrigation water use efficiency of potato crop.

"WWFF" and fertigation rates "FR" on clogging ratio, yield of potato and irrigation water use efficiency of potato crop. **Figure 6(a)** show the relation between study factors on clogging ratio. Maximum values of clogging ratio occurred under trickle irrigation system + WWFF + $FR_{100\% \text{ NPK}}$ > $FR_{80\% \text{ NPK}}$ > $FR_{60\% \text{ NPK}}$ > $FR_{40\% \text{ NPK}}$ > $FR_{20\% \text{ NPK}}$ this may be due to the increase in orifices diameter of sprinkler than dripper and the increase in proportion of suspended materials such as organic material and algae in WWFF than WIT in addition to increasing the amount and concentration of dissolved mineral fertilizers in irrigation water. **Figure 6(a)** show the relation between study factors on yield of potato. Minimum values of clogging ratio occurred under sprinkler irrigation system + WWFF and WIT. **Figure 6(b)** show the relation between study factors on yield of potato. Maximum values of yield of potato occurred under sprinkler irrigation system + WWFF + $FR_{100\%, 80\%, 60\% \text{ NPK}}$ this may be due to reduction in water stress resulting from reduction in clogging ratio under sprinkler irrigation system and increasing of bio-components in WWFF in addition to increasing the amount and concentration of mineral fertilizers in the root zone by increasing of FR. **Figure 6(c)** showed the relation between study factors on IWUE. Maximum values of IWUE occurred under sprinkler irrigation system + WWFF + $FR_{100\%, 80\%, 60\% \text{ NPK}}$ this may be due to increasing the yield of potato.

4. Conclusion

Recycling the drainage water of fish farming, rich with organic matter for agriculture use can improve soil quality and crops productivity and reduce the total costs of fertilizers by adding minimum doses from minerals fertilizers and using sprinkler irrigation system.

References

[1] Elnwishy, N., Salh, M. and Zalat, S. (2006) Combating Desertification through Fish Farming. The Future of Drylands. *Proceedings of the International Scientific Conference on Desertification and Drylands Research*, Tunisia 19-21 June 2006, UNESCO, 855.

[2] Ebong, V. and Ebong, M. (2006) Demand for Fertilizer Technology by Smallholder Crop Farmers for Sustainable Agricultural Development in Akwa, Ibom State, Nigeria. *International Journal of Agriculture and Biology*, **8**, 728-733.

[3] Altaf, U., Bhattihaq, N., Murtaz, G. and Ali, M. (2000) Effect of pH and Organic Matter on Monovalent-Divalent Cation Exchange Equilibria in Medium Textured Soils. *International Journal of Agriculture and Biology*, **2**, 1-2.

[4] Dave, D. (2003) Egypt and the Potato Tuber Moth. Michigan State University, 280.
http://potatobg.css.msu.edu/commercial_releases.shtml

[5] Bucks, D.A., Nakayama, F.S. and Gilbert, R.G. (1979) Trickle Irrigation Water Quality and Preventive Maintenance. *Agricultural Water Management*, **2**, 149-162. http://dx.doi.org/10.1016/0378-3774(79)90028-3

[6] Tuzel, I.H. and Anac, S. (1991) Emitter Clogging and Preventative Maintenance in Drip Irrigation Systems. *Journal of Agriculture Faculty*, **28**, 239-254.

[7] Pitts, D.J., Haman, D.Z. and Smajstrla, A.G. (1990) Causes and Prevention of Emitter Plugging in Microirrgation Systems. Bulletin 258, Florida Cooperative Extension Service, Institute of Food and Agricultural Science, University of Florida, Gainesville. http://edis.ifas.ufl.edu/AE032

[8] Papadopoulos, I. (1993) Agricultural and Environmental Aspects of Fertigation-Chemigation in Protected Agriculture under Mediterranean and Arid Climates. *Proceedings of the Symposium on Environmentally Sound Water Management of Protected Agriculture under Mediterranean and Arid Climates*, Bari, 16-18 July 1993, 1-33.

[9] Burt, C.M., Connor, K.O. and Ruehr, T. (1995) Fertigation Irrigation Training and Research Center. California Polytechnic State University, San Luis Obispo, 295.

[10] Burt, C.M. (1998) Fertigation Basics. I.T.R.C. California Polytechnic State University san luis obispo ca 93407 Pacific Northwest Vegetable Association Convention Pasco. Washington.

[11] APHA (1998) Standard Methods for the Examination of Water and Wastewater. 20th Edition, American Public Health Association.
http://www.worldcat.org/title/standard-methods-for-the-examination-of-water-and-wastewater/oclc/807586782?referer=di&ht=edition

[12] Tsao, P.H. (1970) Selective Media for Isolation of Pathogenic Fungi. *Annual Review of Phytopathology*, **8**, 157-186. http://dx.doi.org/10.1146/annurev.py.08.090170.001105

[13] Atlas, R. (2005) Handbook Media for Environmental Microbiology. CRC Press, Taylor & Francis Group 6000 Broken Sound Parkway NW Boca Raton, 33487-2742.

[14] Munoz, F.E. and Silverman, M.P. (1979) Rapid, Single-Step Most-Probable-Number Method for Enumerating Fecal Coliforms in Effluents from Sewage Treatment Plants. *Applied and Environmental Microbiology*, **37**, 527-530.

[15] Kizilkaya, R. (2009) Nitrogen Fixation Capacity of *Azotobacter* spp. Strains Isolated from Soils in Different Ecosystems and Relationship between Them and the Microbiological Properties of Soils. *Journal of Environmental Biology*, **30**, 73-82.

[16] James, L.G. (1988) Principles of Farm Irrigation System Design. John Willey & Sons. Inc., Washington State University, 73, 152-153, 350-351.

[17] El-Berry, A.M., Bakeer, G.A. and Al-Weshali, A.M. (2003) The Effect of Water Quality and Aperture Size on Clogging of Emitters.
http://afeid.montpellier.cemagref.fr/old/Mpl2003/AtelierTechno/AtelierTechno/AtelierEdite/Edite-Res-Atelier-oral/El-BerryResu-N48.pdf

[18] Snedecor, G.W. and Cochran, W.G. (1982) Statistical Methods. 7th Edition, Iowa State University Press, Towa, 511.

[19] Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D. (1983) Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. World Bank Studies in Water Supply and Sanitation 3, Wiley, Chichester.

List of Abbreviations

Abbreviations	Definitions
WWFF	Wastewater of fish farms
SIS	Sprinkler irrigation system
TIS	Trickle irrigation system
TIW	Traditional irrigation water
FR	Fertigation rate
$IWUE_{potato}$	Irrigation water use efficiency of potato

Scientific Research Publishing (SCIRP) is one of the largest Open Access journal publishers. It is currently publishing more than 200 open access, online, peer-reviewed journals covering a wide range of academic disciplines. SCIRP serves the worldwide academic communities and contributes to the progress and application of science with its publication.

Other selected journals from SCIRP are listed as below. Submit your manuscript to us via either submit@scirp.org or Online Submission Portal.