Results

Water parameters

Physico-chemical parameters of water

Data recorded in Table (2) revealed that there are no significant differences ($p<0.05$) in water temperature among different water sources (fresh water, agricultural drainage water, and mixed drainage water), while there are highly significant differences among different seasons. The lowest water temperature value (13.25 ± 0.57 ˚C) is recorded in mixed drainage water during winter, while the highest value (25.02 ± 0.002 ˚C) is recorded in fresh water during summer.

The annual over all means of temperature are 20.32 ± 2.1, 19.27 ± 2.3 and 19.25 ± 2.4 ˚C in fresh water, agricultural drainage water, and mixed drainage water respectively.

From Table (2), it is also clear that there are highly significant variations in water temperature among different seasons in different water sources.

Secchi disc (SD) visibility:

As shown in Table (2) there are significant variations among different water types during all seasons. The lowest Secchi disc value is (6.67 ± 0.44 cm) which recorded in mixed drainage water during spring, while the highest one (60.00 ± 2.61 cm) is recorded in fresh water during winter. The annual over all means of Secchi disc readings are 51.43 ± 2.9, 27.4 ± 1.7, and 10.98 ± 2.4 cm in fresh water, agricultural drainage water, and mixed drainage water respectively.

Dissolved oxygen (DO):

Results recorded in Table (2), show that there are significant differences in dissolved oxygen among different water resources. The lowest and highest concentrations of dissolved oxygen are 0.76 ± 0.03 and 9.86 ± 1.02 mg/l in mixed water and agricultural drainage water during summer and winter respectively.

The annual over all means of dissolved oxygen are 5.31 ± 0.46, 7.46 ± 0.93, and 1.59 ± 0.34 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

PH value:

The highest pH value (8.05 ± 0.041) is recorded in fresh water during winter, while the lowest one (7.25 ± 0.028) is recorded in mixed drainage water during spring as shown in Table (2).

The annual over all means of pH are 7.89 ± 0.08, 7.88 ± 0.06, and 7.45 ± 0.10 in fresh water, agricultural drainage water, and mixed drainage water respectively.

Table (2): Seasonal variations of some physico-chemical parameters of water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
Temp. (^{o}C)	Fresh	25.02 ±0.002$^{a\ A}$	19.25 ± 0.68 $^{a\ C}$	15.00 ± 0.6 $^{a\ D}$	22.00 ± 0.72 $^{a\ B}$	20.32 ± 2.1
	Agric	24.57 ± 0.15$^{a\ A}$	18.00 ± 0.76 $^{a\ C}$	13.50 ± 0.65$^{a\ D}$	21.00 ± 0.7 $^{a\ B}$	19.27 ± 2.3
	Mixed	24.75 ± 0.10 $^{a\ A}$	18.00 ± 0.86 $^{a\ C}$	13.25 ± 0.57 $^{a\ D}$	21.00 ± 0.76 $^{a\ B}$	19.25 ± 2.4
SD (cm)	Fresh	47.78 ± 1.68 $^{a\ B}$	50.42 ± 3.1 $^{a\ B}$	60.00 ± 2.61 $^{a\ A}$	47.50 ± 1.2 $^{a\ B}$	51.43 ± 2.9
	Agric	31.78 ± 2.01 $^{b\ A}$	28.75 ± 1.2 $^{b\ AB}$	25.0 ± 3.01 $^{b\ AB}$	24.22 ± 2.19 $^{b\ B}$	27.4 ± 1.7
	Mixed	18.00 ± 1.2 $^{c\ A}$	10.75 ± 0.39 $^{c\ B}$	8.50 ± 0.45 $^{c\ C}$	6.67 ± 0.44$^{c\ C}$	10.98 ± 2.4
DO (mg/l)	Fresh	4.41 ± 0.19 $^{b\ C}$	5.02 ± 0.26 $^{b\ BC}$	6.59 ± 0.31 $^{b\ A}$	5.22 ± 0.17 $^{a\ B}$	5.31 ± 0.46
	Agric	5.67 ± 0.19 $^{a\ B}$	7.97 ± 0.63 $^{a\ AB}$	9.86 ± 1.02 $^{a\ A}$	6.37 ± 0.69 $^{a\ B}$	7.46 ± 0.93
	Mixed	0.76 ± 0.03 $^{c\ D}$	1.43 ± 0.06 $^{c\ C}$	2.38 ± 0.17 $^{c\ A}$	1.82 ± 0.068 $^{b\ B}$	1.59 ± 0.34
pH	Fresh	7.68 ± 0.02 $^{a\ A}$	7.81 ± 0.12 $^{a\ BA}$	8.05 ± 0.041 $^{a\ C}$	8.01± 0.031 $^{a\ CB}$	7.89 ± 0.08
	Agric	7.69 ± 0.02 $^{a\ B}$	7.94 ± 0.04 $^{a\ A}$	8.01 ± 0.046 $^{a\ A}$	7.89 ± 0.05 $^{b\ A}$	7.88 ± 0.06
	Mixed	7.38 ± 0.05 $^{b\ BC}$	7.73 ± 0.04 $^{a\ A}$	7.45 ± 0.08 $^{b\ B}$	7.25 ± 0.028 $^{c\ C}$	7.45 ± 0.10

Data are represented as mean of nine samples **±** standard error

a, b, c Values-having different script at the same column are significantly (P<0.05) different

A, B, C. Values-having different script at the same row are significantly (P<0.05) different

- **Temp:** Water temperature
- **SD:** Secchi disc visibility
- **DO:** Dissolved oxygen

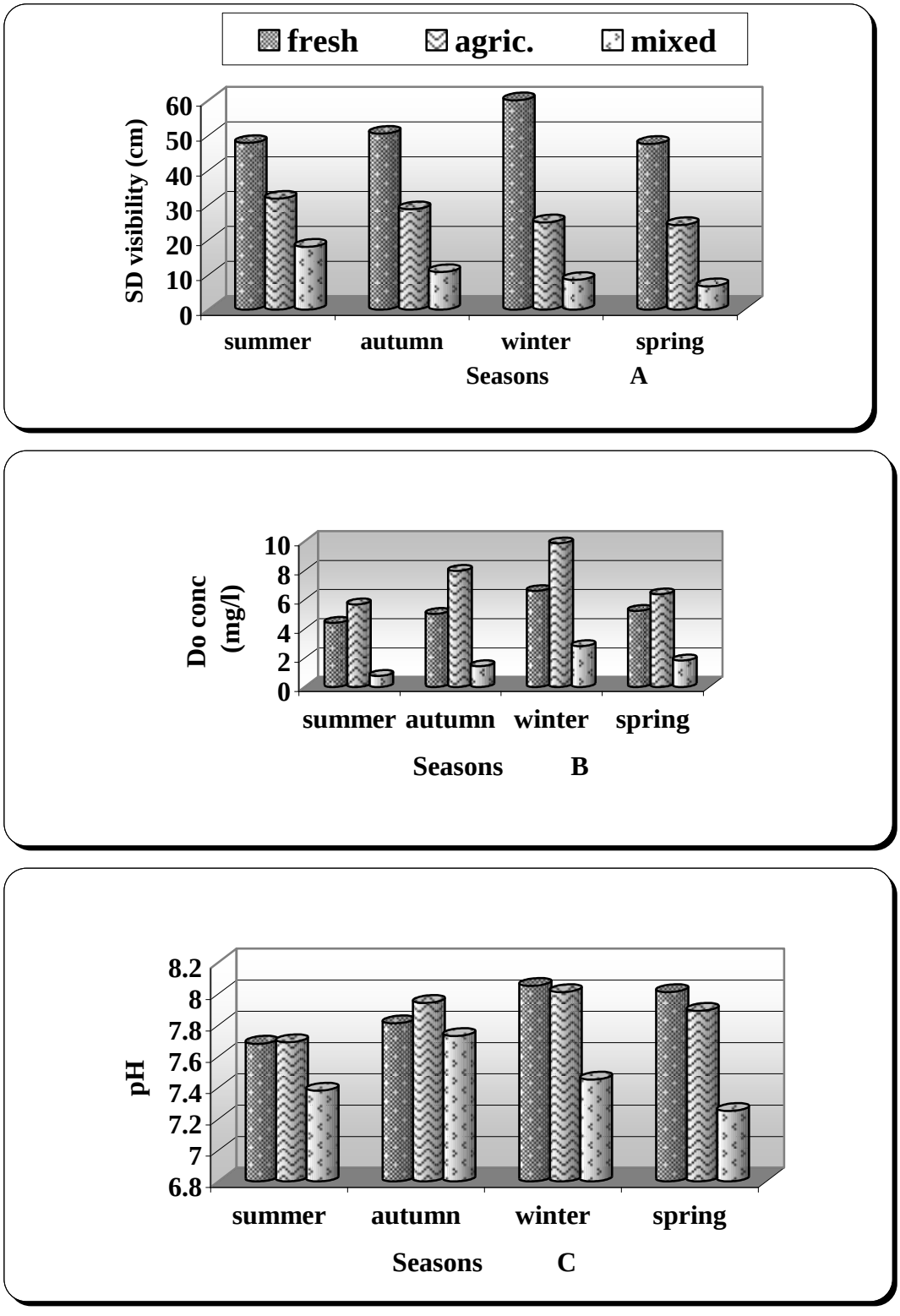

Figure (1): Secchi disc visibility A, dissolved oxygen concentration B, pH value at different water sources during different seasons C.

Water conductivity:

Data recorded in Table (3) revealed that there are highly significant ($p<0.05$) variations in electrical conductivity values among different sampling sites. The highest value (2.63 ± 0.06 µmhos) is recorded in agricultural drainage water during winter, while the lowest one (0.32 ± 0.02 µmhos) is recorded in fresh water during spring. The annual over all means of electrical conductivity are 0.37 ± 0.02, 2.48 ± 0.08, and 2.18 ± 0.06 µmhos in fresh water, agricultural drainage water, and mixed drainage water respectively.

Total dissolved solids:

As shown in Table (3) the annual means of total dissolved solids are 0.25 ± 0.02, 1.57 ± 0.15, and 1.42 ± 0.13 g/l in fresh water, agricultural drainage water, and mixed drainage water respectively. Obtained results showed also that there are highly significant differences in concentrations of total dissolved solids among different water sources. The lowest concentration (0.204 ± 0.003 g/l) is recorded in fresh water during summer, while the highest concentration (1.95 ± 0.04 g/l) is recorded in agricultural drainage water during winter.

Salinity:

Obtained results showed that there are significant differences among different sampling sites especially during autumn and winter. The lowest value is observed in fresh water during summer (0.13 ± 0.01g/l), while the highest value is observed in agricultural drainage water during winter (1.59 ± 0.02g/l).

The annual over all means of salinity are 0.18 ± 0.01, 1.25 ± 0.13, and 1.14 ± 0.09 g/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Table (3): Seasonal variations of some physico-chemical parameters of water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
EC (µmhos)	Fresh	0.33 ± 0.004 $^{c\,B}$	0.41 ± 0.019 $^{c\,A}$	0.41 ± 0.015 $^{c\,A}$	0.32 ± 0.023 $^{b\,B}$	0.37 ± 0.02
	Agric.	2.44 ± 0.09 $^{a\,AB}$	2.59 ± 0.08 $^{a\,A}$	2.63 ± 0.06 $^{a\,A}$	2.26 ± 0.17 $^{a\,B}$	2.48 ± 0.08
	Mixed	2.14 ± 0.04 $^{b\,AB}$	2.27 ± 0.07 $^{b\,AB}$	2.29 ± 0.047 $^{b\,A}$	2.01 ± 0.18 $^{a\,B}$	2.18 ± 0.06
TDS (g/l)	Fresh	0.204 ±0.003 $^{c\,C}$	0.26 ± 0.012 $^{c\,B}$	0.31 ± 0.018 $^{c\,A}$	0.22 ± 0.015 $^{b\,C}$	0.25 ± 0.02
	Agric.	1.39 ± 0.023 $^{a\,BC}$	1.68 ± 0.05 $^{a\,AB}$	1.95 ± 0.046 $^{a\,A}$	1.27 ± 0.255 $^{a\,B}$	1.57 ± 0.15
	Mixed	1.32 ± 0.017 $^{b\,B}$	1.48 ± 0.04 $^{b\,B}$	1.73 ± 0.034 $^{b\,A}$	1.14 ± 0.126 $^{a\,C}$	1.42 ± 0.13
Salinity (g/l)	Fresh	0.13 ± 0.014 $^{b\,B}$	0.20 ± 0.0 $^{c\,A}$	0.20 ± 0.0 $^{c\,A}$	0.19 ± 0.011 $^{b\,A}$	0.18 ± 0.01
	Agric.	1.07 ± 0.027 $^{a\,C}$	1.32 ± 0.04 $^{a\,B}$	1.59 ± 0.025 $^{a\,A}$	1.03 ± 0.13 $^{a\,C}$	1.25 ± 0.13
	Mixed	1.05 ± 0.015 $^{a\,C}$	1.20 ± 0.03 $^{b\,B}$	1.38 ± 0.025 $^{b\,A}$	0.94 ± 0.092 $^{a\,C}$	1.14 ± 0.09

Data are represented as mean of nine samples ± standard error

a, b, c Values-having different script at the same column are significantly ($P<0.05$) different

A, B, C. Values-having different script at the same row are significantly ($P<0.05$) different

- **EC:** Electrical conductivity
- **TDS:** Total dissolved solids

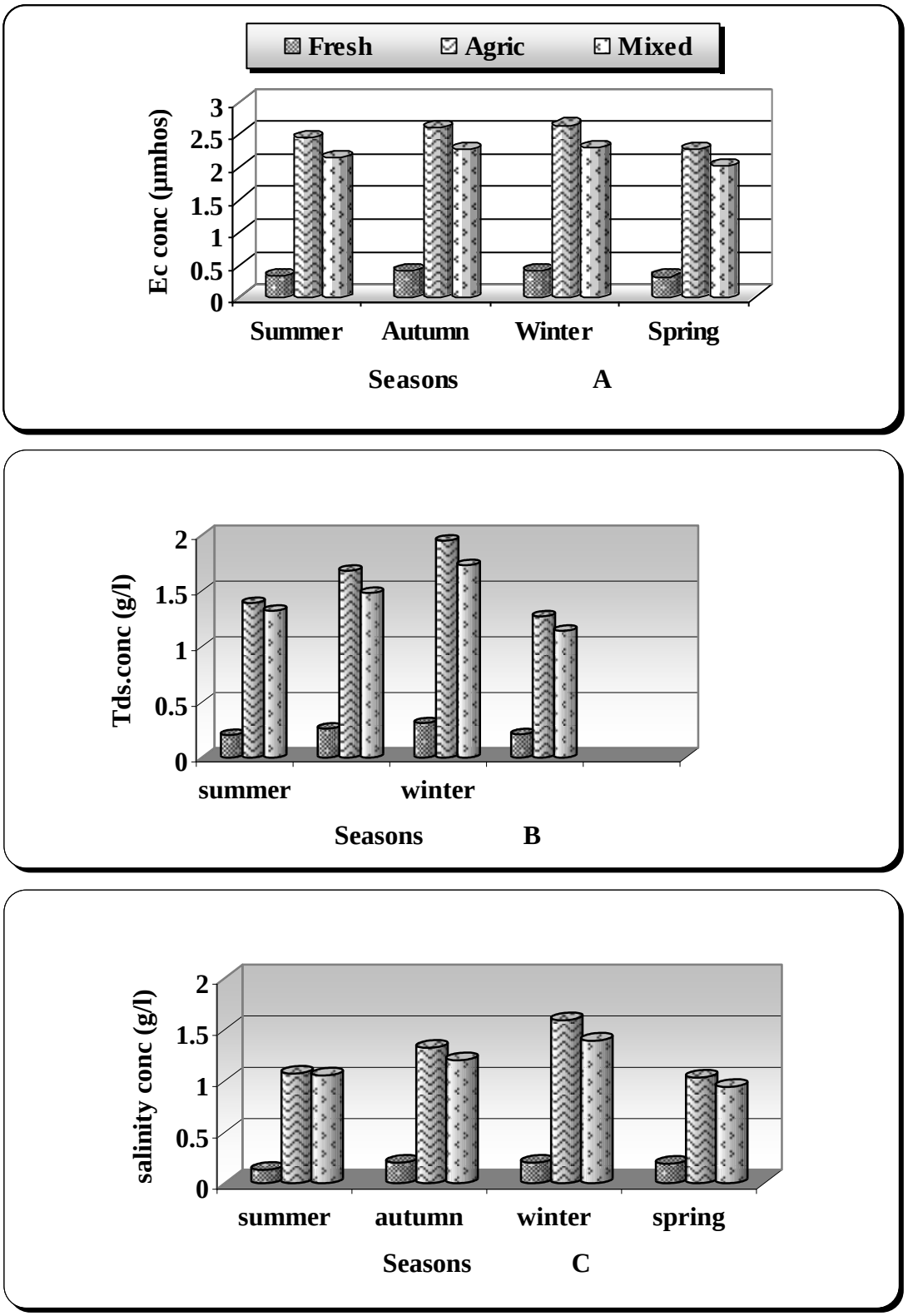

Figure (2): Electrical conductivity A, Total dissolved solids concentration B, Salinity value at different water sources during different seasons C.

Total ammonia:

As shown in Table (4) there are significant differences ($p<0.05$) in total ammonia values among different water sources. The lowest total ammonia value (0.15 ± 0.01 mg/l) is recorded in fresh water during winter, while the highest value (60.00 ± 0.00 mg/l) is recorded in mixed water during summer. The annual over all means of total ammonia are 0.27 ± 0.06, 0.71 ± 0.11, and 56.42 ± 1.9 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Un-ionized ammonia:

The highest un-ionized ammonia concentration (0.98 ± 0.06 mg/l) is recorded in mixed drainage water during summer, while the lowest concentration (0.004 ± 0.0004 mg/l) is recorded in fresh water during winter as shown in Table (4) and illustrated in Figure (4). The annual over all means of un-ionized ammonia are 0.007 ± 0.001, 0.021 ± 0.003, and 0.73 ± 0.14 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Nitrite:

Table (4) showed that the annual means of water-nitrite are 0.04± 0.008, 0.11 ± 0.03, and 0.008 ± 0.002 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively. In mixed drainage water during summer, autumn, winter were 0.01 ± 0.003, 0.01 ± 0.004, 0.01±0.005 mg/l respsctively while it was absent during spring , the highest concentration is 0.185 ± 0.03 mg/l in agricultural drainage water during winter.

Nitrate:

Water-nitrate values as recorded in Table (4) indicated that there are significant differences in its concentrations among different sampling sites and different seasons except in mixed drainage water there are no significant differences among different seasons. The maximum and minimum values are

1.01± 0.19 and 0.03 ± 0.012 mg/l in agricultural drainage water during winter and mixed drainage water during summer, respectively. Water-nitrate annual over all means are 0.13 ± 0.018, 0.67 ± 0.16, and 0.04 ± 0.004 in fresh water, agricultural drainage water, and mixed drainage water respectively.

Table (4): Seasonal variations of some physico-chemical parameters of water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
NH_4 + NH_3-N (mg/l)	Fresh	0.45 ± 0.043 ^{cA}	0.28 ± 0.03 ^{bB}	0.15 ± 0.015 ^{bC}	0.20 ± 0.0 b ^{BC}	0.27 ± 0.06
	Agric.	1.05 ± 0.07 ^{bA}	0.58 ± 0.02 ^{bB}	0.55 ± 0.033 ^{bB}	0.65 ± 0.128 ^{bB}	0.71 ± 0.11
	Mixed	60.00 ± 0.0 ^{aA}	56.50 ± 0.62 ^{aB}	50.88 ± 0.94 ^{aA}	58.33± 0.83 ^{aAB}	56.42 ± 1.9
NH_3-N (mg/l)	Fresh	0.01 ± 0.001 ^{bA}	0.005 ± 0.0004^{bC}	0.004 ± 0.0004^{bC}	0.008 ± 0.0005^{bB}	0.007 ± 0.001
	Agric.	0.03 ± 0.005 ^{bA}	0.02 ± 0.0008 ^{bB}	0.015 ± 0.002 ^{bB}	0.02±0.005 ^{bAB}	0.021 ± 0.003
	Mixed	0.98 ± 0.067 ^{aA}	0.96 ± 0.026 ^{aA}	0.46 ± 0.089 ^{aB}	0.51 ± 0.047 ^{aB}	0.73 ± 0.14
NO_2-N (mg/l)	Fresh	0.02 ± 0.002 ^{bC}	0.03± 0.003 ^{bBC}	0.056 ± 0.011^{bA}	0.047± 0.009 ^{aAB}	0.04 ± 0.008
	Agric.	0.03 ± 0.003 ^{aC}	0.14 ± 0.02 ^{aAB}	0.185 ± 0.03 ^{aA}	0.076± 0.016 ^{aBC}	0.11 ± 0.03
	Mixed	0.01 ± 0.003 ^{bA}	0.01 ± 0.004 ^{bA}	0.01±0.005^{bA}	ND	0.008 ± 0.002
NO_3-N (mg/l)	Fresh	0.13 ± 0.014 ^{bA}	0.15 ± 0.015 ^{bA}	0.15 ± 0.006 ^{bA}	0.07 ± 0.011^{bB}	0.13 ± 0.018
	Agric.	0.39 ± 0.06 ^{aB}	0.89 ± 0.06 ^{aA}	1.01 ± 0.19 ^{aA}	0.38 ± 0.068 ^{aB}	0.67 ± 0.16
	Mixed	0.03 ± 0.012 ^{bA}	0.04 ± 0.004 ^{bA}	0.047 ± 0.021^{bA}	0.05 ± 0.0024 ^{bA}	0.04 ± 0.004

Data are represented as mean of nine samples ± standard error

a, b, c Values-having different script at the same column are significantly ($P<0.05$) different

A, B, C. Values-having different script at the same row are significantly ($P<0.05$) different

- **NH_4 + NH_3 -N:** total Ammonia **NO_2-N: Nitrite**
- **NH_3-N:** Unionized ammonia **NO_3-N: Nitrate**

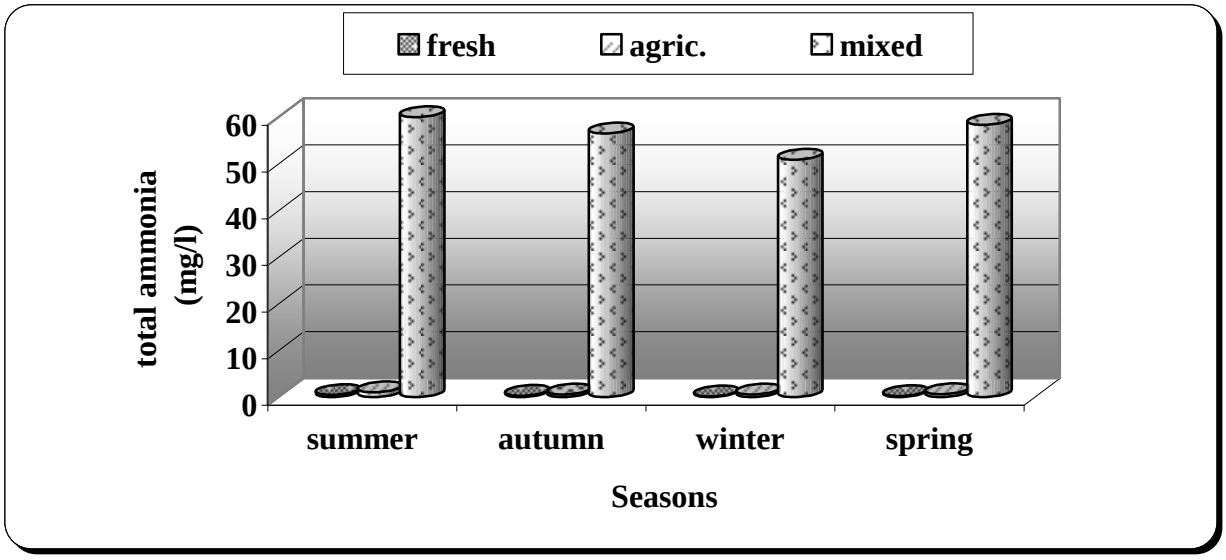

Figure (3): Total ammonia concentrations at different water sources during different seasons.

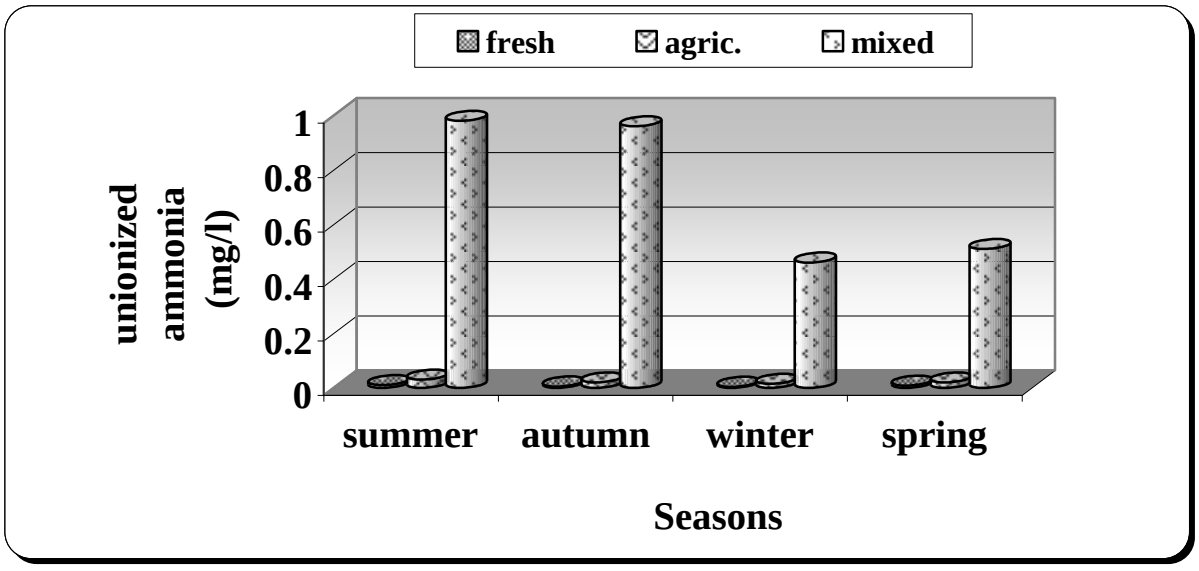

Figure (4): Un- ionized ammonia concentrations at different water sources during different seasons.

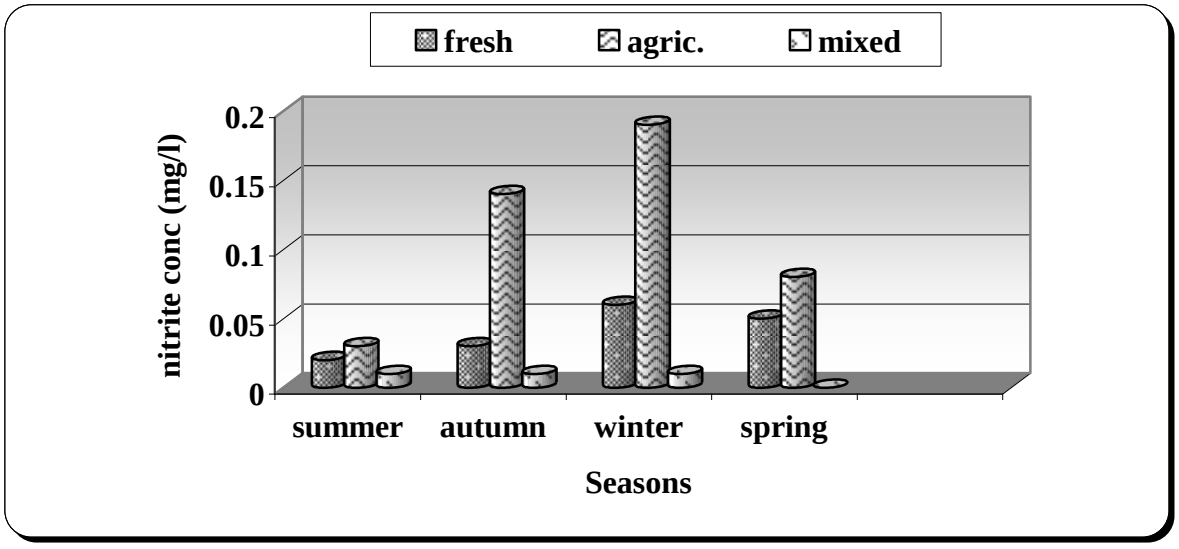

Figure (5): Nitrite concentrations at different water sources during different seasons.

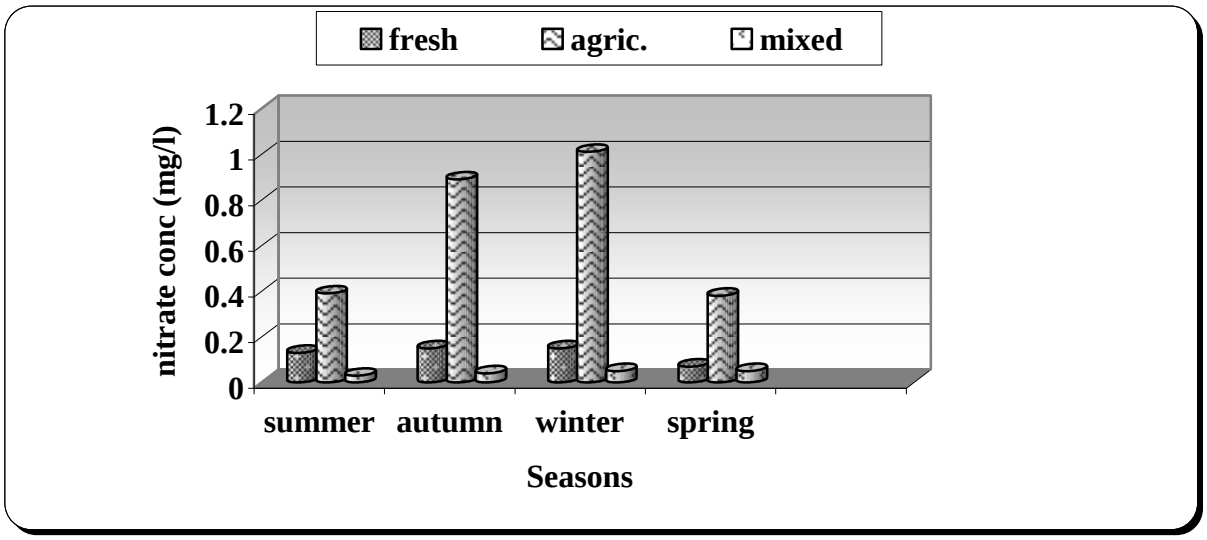

Figure (6): Nitrate concentrations at different water sources during different seasons.

Total alkalinity:

As shown in Table (5) and Figure (7) there are significant differences in total alkalinity values among different sampling sites during all seasons. The lowest total alkalinity value (145.88 ± 2.17 mg/l as $CaCO_3$) is recorded in fresh water during summer, while the highest value (842.50 ± 32.8 mg/l as $CaCO_3$) is recorded in mixed drainage water during winter. The annual over all means of total alkalinity are 174.04 ± 20.5, 349.63 ± 30.8, and 690.85 ± 62.1 mg/l as $CaCO_3$ in fresh water, agricultural drainage water, and mixed drainage water respectively.

Total hardness:

Table (5) indicated that there are significant differences in total hardness values among different water resources. The lowest and highest concentrations of total hardness are 156.67 ± 5.54 and 660.83 ± 39.2 mg/l as $CaCO_3$ as recorded in fresh water during spring and agricultural drainage water during winter, respectively.

The annual over all means of total hardness are 178.29 ± 7.3, 574.38 ± 66.8, and 493.78 ± 54.9 mg/l as CaCO3 in fresh water, agricultural drainage water, and mixed drainage water respectively.

Orthophosphate:

The highest concentration of OP (1.44 ± 0.04 mg/l) is recorded in mixed drainage water during autumn, while the lowest concentration of OP is 0.01 ± 0.002 mg/l in fresh water during summer, autumn and spring as shown in Table (5). The annual over all means of orthophosphate are 0.01 ± 0.007, 0.02 ± 0.004, and 1.17± 0.07 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Table (5) revealed that there are no significant differences in agricultural drainage water and fresh water among different seasons.

Total phosphorus:

Table (5) showing that the total phosphorus annual means are 0.13± 0.002, 0.40 ± 0.06, and 1.99 ± 0.2 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively. The lowest total phosphorus concentration (0.11 ± 0.042 mg/l) is recorded in fresh water during summer, while the highest concentration (2.44 ± 0.13 mg/l) is recorded in mixed drainage water during autumn.

Table (5): Seasonal variations of some physico-chemical parameters of water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
T.A (mg/l)	Fresh	145.88±2.17 ^{cC}	188.75±3.2 ^{cA}	190.00 ±3.25 ^{cA}	171.56 ±2.5 ^{bB}	174.04 ± 20.5
	Agric.	338.89 ± 10.9 ^{bC}	377.08 ± 12.6 ^{bB}	413.33 ± 4.3 ^{bA}	269.22 ± 8.8 ^{bD}	349.63 ± 30.8
	Mixed	557.29 ± 31.2 ^{aC}	630.63 ±18.9 ^{aBC}	842.50 ± 32.8 ^{aA}	733.00 ± 61.7 ^{aB}	690.85 ± 62.1
T.H (mg/l)	Fresh	182.33 ± 2.77 ^{cA}	185.00 ± 5.0 ^{cA}	189.16 ± 7.9 ^{cA}	156.67 ± 5.54 ^{bB}	178.29 ± 7.3
	Agric.	607.78 ± 23.09 ^{aA}	625.00 ± 11.5 ^{aA}	660.83 ± 39.2 ^{aA}	376.89 ± 55.4 ^{aB}	574.38 ± 66.8
	Mixed	551.00 ± 19.3 ^{bA}	540.00 ± 2.13 ^{bA}	555.00 ± 30.6 ^{bA}	329.11 ± 14.9 ^{aB}	493.78 ± 54.9
OP (mg/l)	Fresh	0.01 ± 0.002 ^{bA}	0.01 ± 0.002 ^{bA}	0.0 2 ± 0.013 ^{bA}	0.01 ± 0.003 ^{bA}	0.01 ± 0.007
	Agric.	0.03 ± 0.02 ^{bA}	0.02 ± 0.006 ^{bA}	0.01±0.002 ^{bA}	0.02 ± 0.007 ^{bA}	0.02 ± 0.004
	Mixed	1.14 ± 0.05 ^{aB}	1.44 ± 0.04 ^{aA}	1.35 ± 0.05 ^{aA}	1.15 ± 0.08 ^{aB}	1.17 ± 0.07
TP (mg/l)	Fresh	0.11 ± 0.042 ^{cA}	0.13 ± 0.02 ^{cA}	0.12 ± 0.016 ^{cA}	0.15 ± 0.017 ^{bA}	0.13 ± 0.002
	Agric.	0.32 ± 0.022 ^{bB}	0.37± 0.016 ^{bAB}	0.59 ± 0.12 ^{bA}	0.33 ± 0.03 ^{bB}	0.40 ± 0.06
	Mixed	1.46 ± 0.084 ^{aB}	2.44 ± 0.13 ^{aA}	2.06 ± 0.11 ^{aA}	2.03 ± 0.17 ^{aA}	1.99 ± 0.2

Data are represented as mean of nine samples **±** standard error

a, b, c Values-having different script at the same column are significantly ($P<0.05$) different

A, B, C. Values-having different script at the same row are significantly ($P<0.05$) different

- **T.A:** Total Alkalinity
- **T.H:** Total Hardness
- **O.P:** Ortho Phosphate
- **T.P:** Total Phosphorus

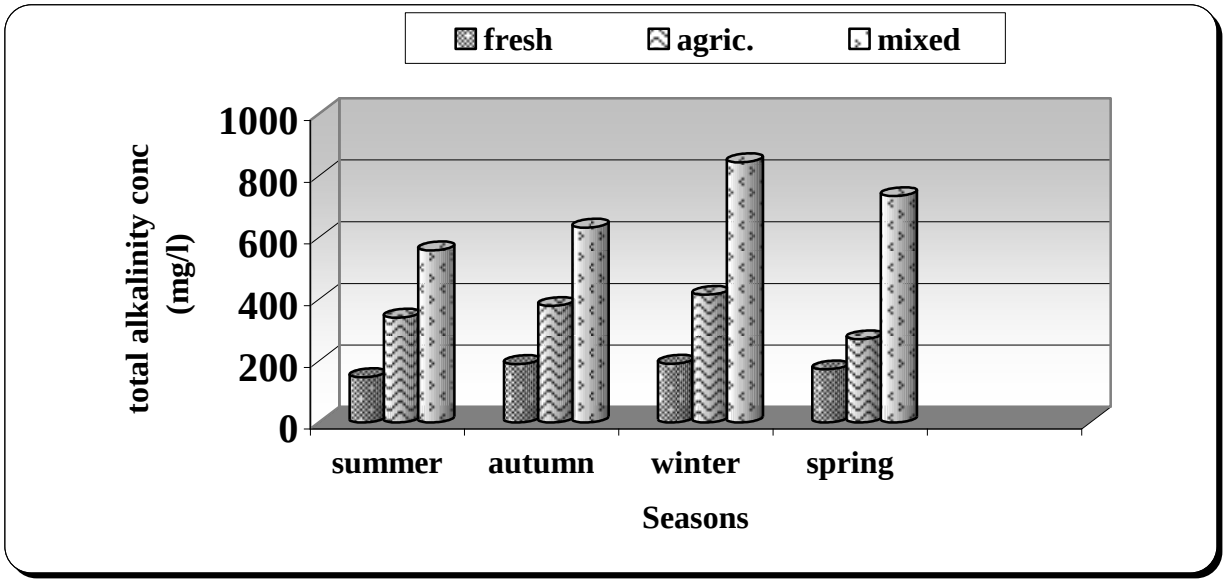

Figure (7): Total alkalinity concentrations at different water sources during different seasons.

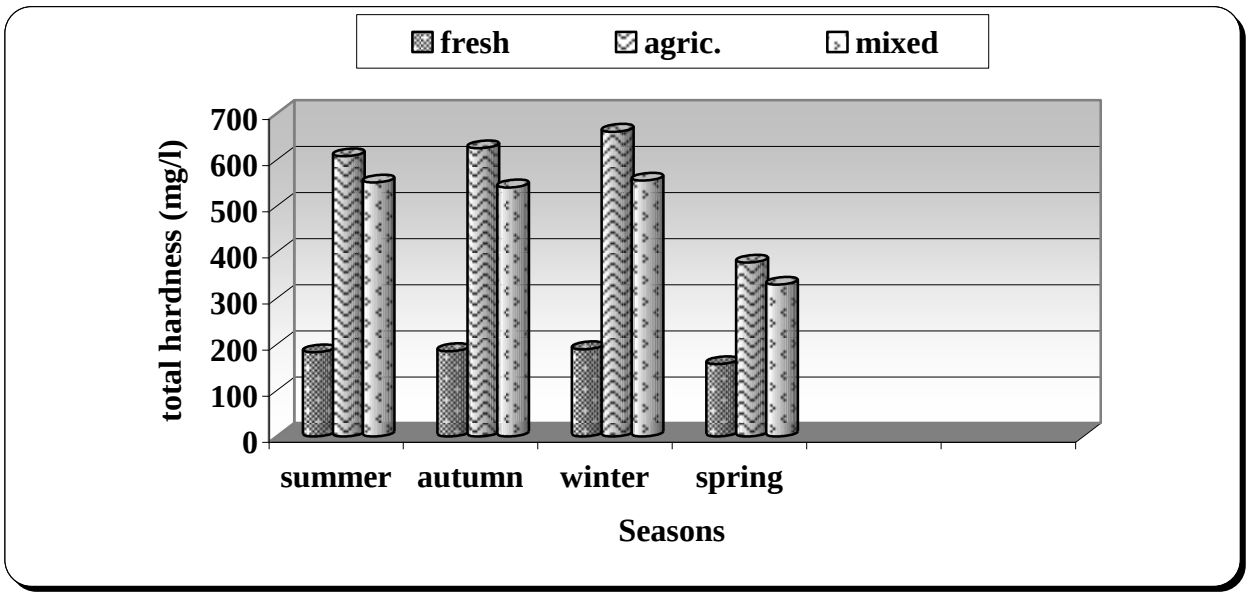

Figure (8): Total hardness concentrations at different water sources during different seasons.

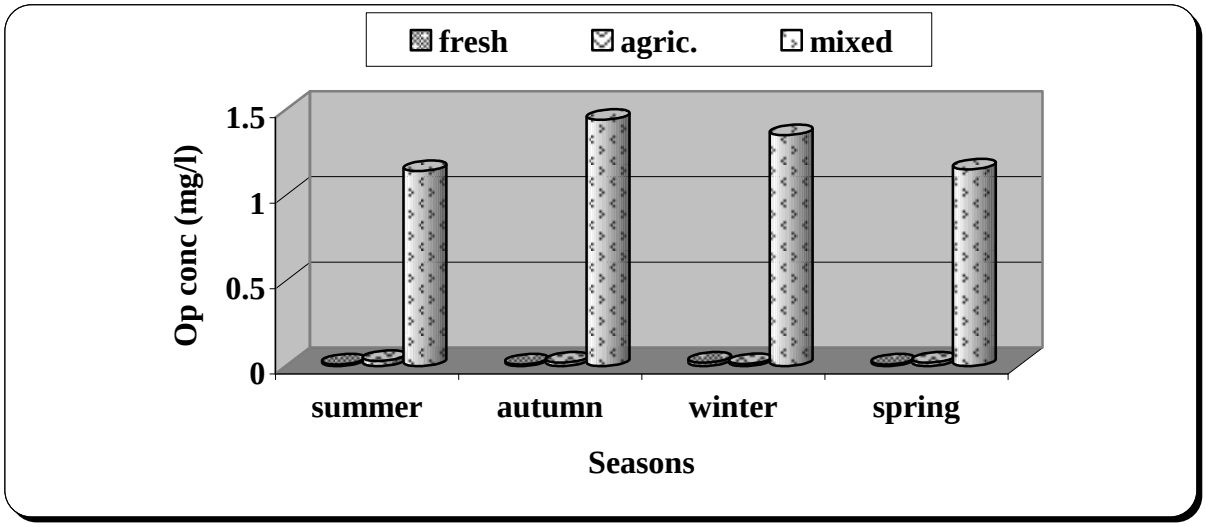

Figure (9): Ortho phosphate concentrations at different water sources during different seasons.

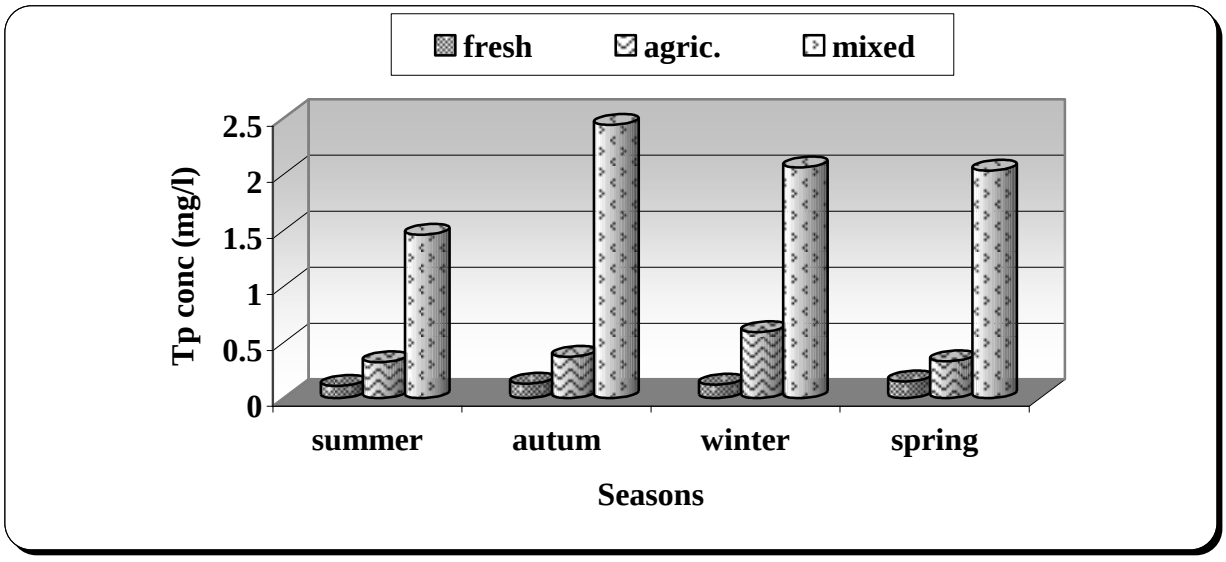

Figure (10): Total phosphorus concentrations at different water sources during different seasons.

Heavy metals residues in water:

Iron (Fe):

Table (6) show that there are no significant differences in iron concentration among different water sources during summer, while there are significant differences during autumn, winter, and spring. The highest iron concentration is 6.60 ± 0.77 mg/l which recorded in mixed drainage water during spring, while the lowest one is 0.39 ± 0.08 mg/l in fresh water during summer. The annual over all means of iron concentrations are 1.26 ± 0.42, 2.41 ± 0.97, and 3.52 ± 1.41 mg/l in fresh water, agricultural drainage water, and mixed drainage water respectively**.**

Zinc (Zn):

Data recorded in Table (6) revealed that there are significant differences in zinc concentration among different water sources during a particular season. Zinc concentrations in a particular water source varied according to season with the exception of fresh water where there are no significant differences among different seasons. The lowest concentration of zinc is 4.04 ± 1.29 µg/l in fresh water during winter while the highest one is 25.89 ± 4.23 µg/l in mixed drainage water during autumn. The annual over all means of zinc concentrations are 6.02 ± 0.66, 9.16 ± 2.09 µg/l in fresh water, agricultural drainage water, and mixed drainage water respectively**.**

Copper (Cu):

Table (6) show that there are significant differences in copper concentrations among different water sources, where its levels in mixed drainage water are significantly higher than in the other two water sources. It's noticeable that there are no significant differences in Cu concentrations in fresh water among different seasons, while its levels varied significantly in the other

two water sources according to season.The lowest and highest concentrations of cupper are 1.19 ± 0.12 µg/l which recorded in fresh water during summer and 6.55 ± 0.59 µg/l which recorded in mixed drainage water during autumn respectively. The annual over all means of cupper concentrations are 1.83 ± 0.22, 2.96 ± 0.70, and 4.86 ± 1.01 µg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Cadmium (Cd):

Table (6) indicates that the cadmium concentrations annual means are 0.41 ± 0.07, 0.94 ± 0.21, and 0.64 ± 0.09 µg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.Table (6) revealed that there are no significant differences in cadmium concentration among different water sources during summer and spring, while there are significant differences during autumn and winter.

The lowest cadmium concentration is 0.28 ± 0.07 µg/l which recorded in fresh water during autumn while the highest concentration of cadmium is 1.55 ± 0.31 µg/l in agricultural drainage water during winter.

Lead (Pb):

Data concerning water lead concentrations indicated that there are significant differences among different water sources during autumn, winter and spring, while there are no significant differences during summer.The highest lead concentration is 5.40 ± 1.17 µg/l which recorded in mixed drainage water during spring. Lead concentrations are below the used method detecting limit in agricultural drainage water and fresh water during winter and spring seasons.

The lead concentrations annual means are 0.05 ± 0.02, 0.11 ± 0.07, and 1.79 ± 1.2 µg/l in fresh water, agricultural drainage water, and mixed drainage water respectively.

Table (6): Seasonal variations of some heavy metals in water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				mean	*PL
		Summer	Autumn	Winter	Spring		
Fe(mg/l)	fresh	0.39±0.08^{aB}	0.69±0.06^{bB}	1.94±0.23^{bA}	2.05±0.21^{cA}	1.26±0.42	0.3 mg/l
	agric	0.48±0.08^{aC}	1.42 ±0.14 ^{aC}	2.79±0.18 ^{bB}	4.96±0.23^{bA}	2.41 ± 0.97	
	mixed	0.51± 0.12 ^{aB}	1.54 ± 0.17^{aB}	5.43±0.73$^{a A}$	6.60±0.77^{aA}	3.52 ± 1.41	
Zn (µg/l)	fresh	6.96±0.81 $^{b A}$	6.51±1.02 $^{c A}$	4.04 ±.29$^{b A}$	6.58±0.32^{bA}	6.02 ± 0.66	120 µg/l
	agric	8.23 ±1.01$^{b B}$	15.19±1.96$^{b A}$	5.96 ±0.64$^{b B}$	7.25±1.09^{bB}	9.16 ± 2.09	
	mixed	24.9±2.33$^{a A}$	25.89±4.23 ^{aA}	12.2±0.95^{aB}	12.08±0.48^{aB}	18.77±3.82	
Cu (µg/l)	fresh	1.19±0.12$^{b A}$	2.09±0.51 $^{b A}$	1.84±0.25$^{b A}$	2.20±0.26^{bA}	1.83 ± 0.22	13 µg/l
	agric	1.27±0.18$^{b C}$	3.88±0.79 ^{bAB}	4.34±0.84^{abA}	2.37±0.26$^{b BC}$	2.96 ± 0.70	
	mixed	2.06±0.33$^{a B}$	6.55±0.59 $^{a A}$	6.14± 1.4 $^{a A}$	4.72±0.74^{aA}	4.86 ± 1.01	
Cd (µg/l)	fresh	0.29 ±0.02^{aA}	0.28±0.07 $^{b A}$	0.43±0.11$^{b A}$	0.50±0.13^{aA}	0.41 ± 0.07	4.3 µg/l
	agric	0.56±0.21$^{a B}$	0.89±0.19^{aAB}	1.55 ±0.31$^{a A}$	0.76±0.11^{aAB}	0.94 ± 0.21	
	mixed	0.35±0.04$^{a A}$	0.76±0.12 $^{a A}$	0.73±0.21$^{b A}$	0.71±0.14^{aA}	0.64 ± 0.09	
Pb (µg/l)	fresh	0.11±0.02$^{a A}$	0.08±0.02 $^{b A}$	ND $^{b B}$	ND $^{b B}$	0.05 ± 0.02	2.5 µg/l
	agric	0.12±0.03$^{a B}$	0.31±0.10$^{a bA}$	ND $^{b B}$	ND $^{b B}$	0.11 ± 0.07	
	mixed	0.35±0.10$^{a B}$	0.59±0.15 $^{a B}$	0.84 ±0.19$^{a B}$	5.04±1.17^{aA}	1.79 ± 1.20	

Data are represented as mean of nine samples ± standard error

a, b, c Values-having different script at the same column are significantly ($P<0.05$) different

A, B, C. Values-having different script at the same row are significantly ($P<0.05$) different

*PL: Permissible limits of heavy metals concentration in water according to (USEPA, 1999).

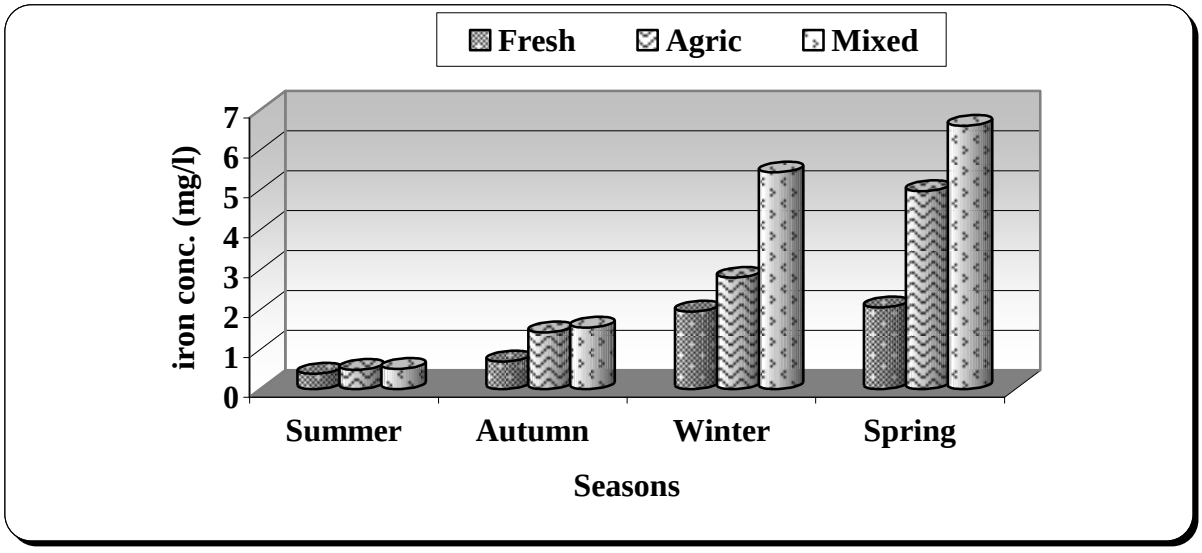

Figure (11): Iron concentrations at different water sources during different seasons.

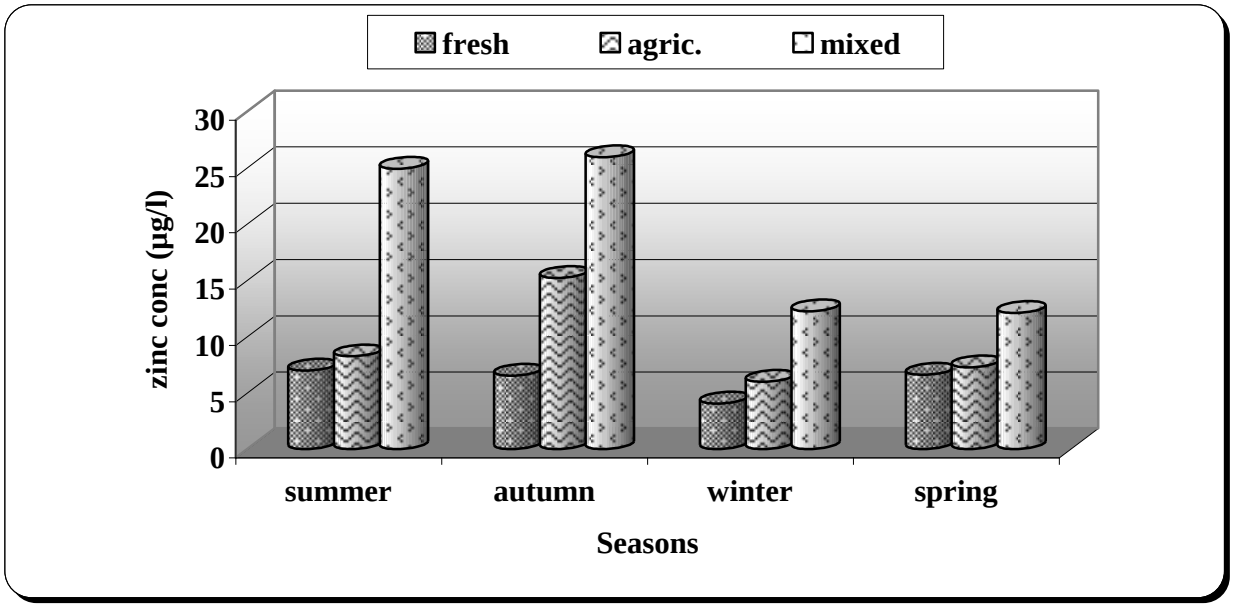

Figure (12): Zinc concentrations at different water sources during different seasons.

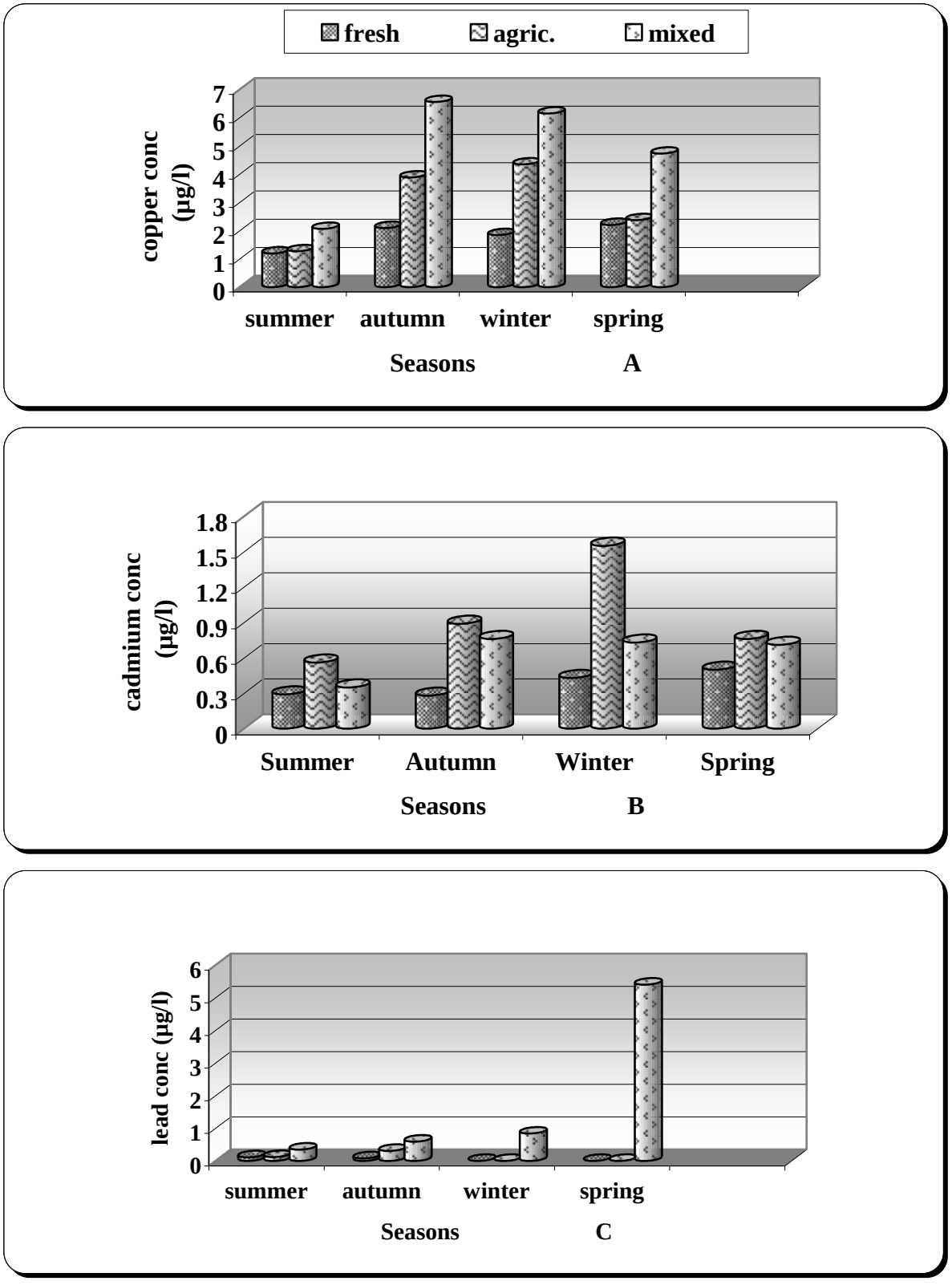

Figure (13): Copper concentrations A, Cadmium concentration B and Lead concentration C at different water sources during different seasons.

Heavy metals in fish (*Oreochromis niloticus*):

In muscles:

Iron:

The lowest iron concentration in *O. niloticus* muscles is 0.24 mg/g in fish caught from fresh water during spring, while the highest muscle iron concentration is 1.14 mg/g in fish caught from agricultural drainage water during autumn.

Zinc:

Data recorded in Table (7) revealed that the maximum zinc concentration in *O. niloticus* muscles is 6.67 µg/g of fish collected from agricultural drainage water during autumn, while the minimum one is 2.45 µg/g of fish caught from fresh water during spring.

Copper:

The maximum and minimum muscles copper levels are 6.19 µg/g of fish caught from agricultural drainage water during autumn and 1.49 µg/g in fish caught from fresh water and during spring respectively, as shown in Table (7).

Cadmium:

The lowest cadmium concentration in *O. niloticus* muscles is 0.12 µg/g in fish caught from fresh water during summer, while the highest muscle cadmium concentration is 1.22 µg/g in fish caught from agricultural drainage water during autumn.

Lead:

As shown in Table (7) lead is not detectable in muscles tissues of fish neither from agricultural drainage water nor from fresh water during different seasons.

In gills:

Iron:

Data recorded in Table (7) revealed that the maximum gills iron concentration is 2.35 mg/g in fish caught from agricultural drainage water during autumn, while the minimum gills iron concentration is 0.73 mg/g in fish caught from fresh water during summer.

Zinc:

The maximum and minimum gills zinc concentrations are 9.42 µg/g in fish caught from agricultural drainage water during autumn and 4.03 µg/g in fish caught from fresh water during summer, respectively as shown in Table (7).

Copper:

The lowest gills copper concentration is 2.92 µg/g in fish caught from fresh water during summer, while the highest cupper concentration is 5.02 µg/g in fish caught from agricultural drainage water during autumn.

Cadmium:

Data recorded in Table (7) revealed that the maximum gills cadmium concentration is 1.23 µg/g in fish caught from agricultural drainage water during autumn, while the minimum gills cadmium concentration is 0.16 µg/g in fish caught from fresh water during summer.

Lead:

As shown in Table (7) lead concentrations are not detectable in gills tissues neither for fish raised in agricultural drainage water nor for those raised in fresh water.

Fish livers:

Iron:

The maximum and minimum liver iron concentrations are 3.55 mg/g in fish caught from agricultural drainage water during autumn and 1.21 mg/g in fish caught from fresh water during summer, respectively as shown in Table (7).

Zinc:

Data recorded in Table (7) revealed that the maximum liver zinc concentration is 384.22 µg/g in fish caught from agricultural drainage water during autumn, while the minimum concentration is 23.63 µg/g in fish caught from fresh water during summer.

Copper:

The maximum and minimum liver copper concentrations are 8.78 µg/g in fish caught from agricultural drainage water during summer and 4.57 µg/g in fish caught from fresh water during autumn, respectively as shown in Table (7).

Cadmium:

The lowest cadmium concentration is 0.30 µg/g in fresh water during summer, while the highest cadmium concentration is 1.69 µg/g in agricultural drainage water during autumn.

Lead:

As shown in Table (7) the highest lead concentration is 2.60 µg/g in agricultural drainage water during summer.

Table (7): Heavy metals concentrations in the muscle, gill, and liver tissues of (*Oreochromis niloticus*) which collected from agricultural drainage water and fresh water during different seasons.

ter rces	Summer			Autumn			Winter			Spring	
	Muscle	gills	liver	Muscle	gills	liver	Muscle	gills	liver	Muscle	gills
h	0.33	0.73	1.21	0.37	1.23	2.27	0.50	1.10	1.68	0.24	1.01
c.	0.41	1.70	2.93	1.14	2.35	3.55	0.91	1.51	3.43	0.46	1.94
h	3.83	4.03	23.63	4.41	7.25	93.23	3.64	5.34	143.93	2.45	5.54
c	4.09	5.46	87.03	6.67	9.42	384.22	5.82	8.09	164.21	5.38	7.95
h	1.58	2.92	7.81	2.08	3.49	4.57	2.12	4.14	5.51	1.49	3.58
c	2.16	4.03	8.78	6.19	5.02	6.93	3.00	4.36	6.60	1.52	4.89
h	0.12	0.16	0.30	0.21	0.22	1.40	0.19	0.64	0.98	0.16	0.19
c	0.16	0.21	0.44	1.22	1.23	1.69	0.53	0.94	1.48	0.19	0.43
h	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
c	ND	ND	2.60	ND	ND	ND	ND	ND	ND	ND	ND

- MAL = maximum acceptable limit (µg/g) according to WHO, 1984 for iron and FAO, 1983 for the other metals.
- ND: not detectable

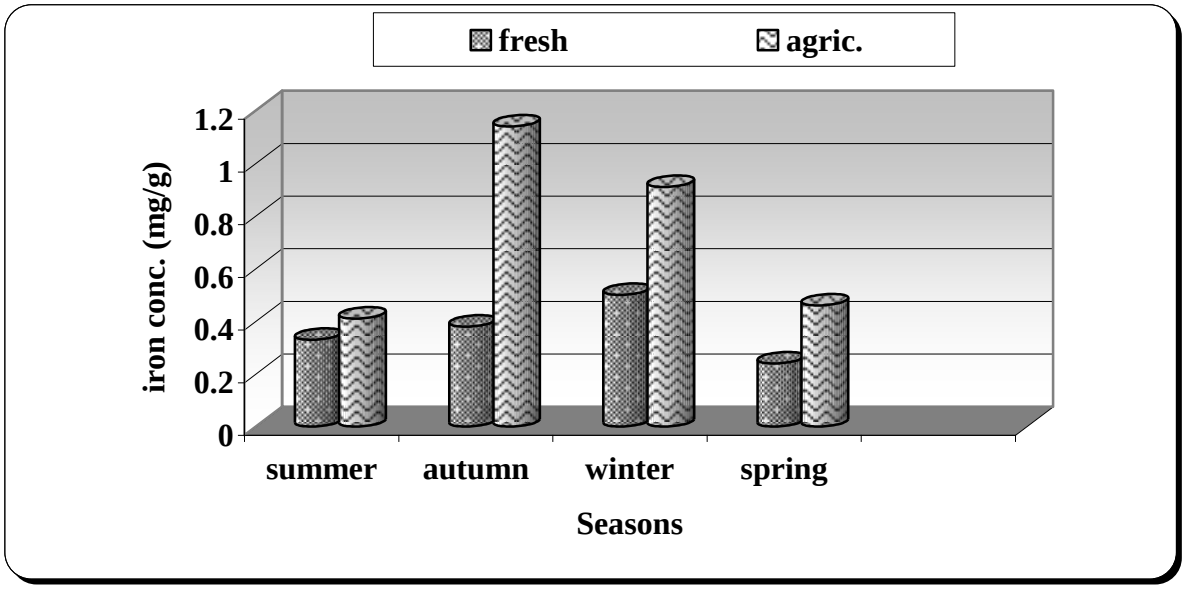

Figure (14): Iron concentrations in muscle samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

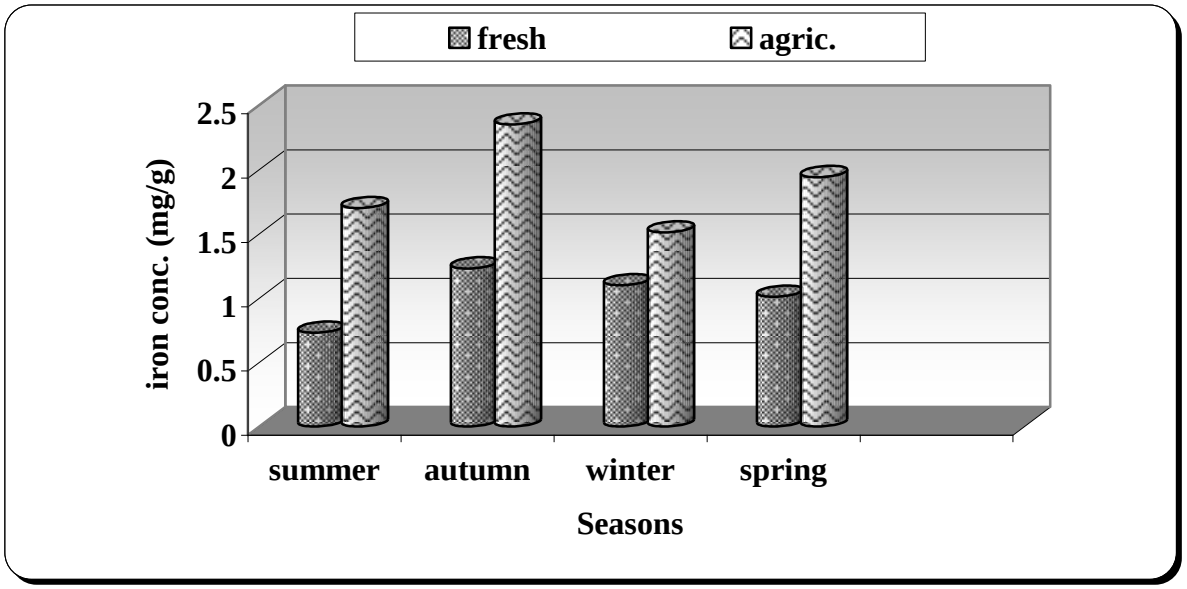

Figure (15): Iron concentrations in gills samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

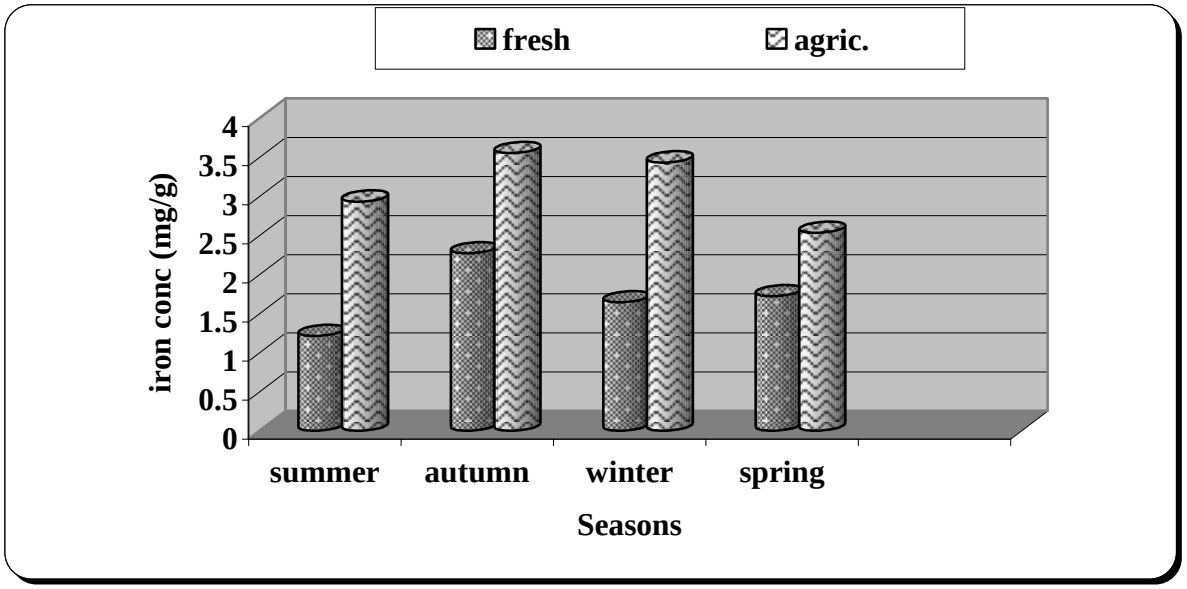

Figure (16): Iron concentrations in liver samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

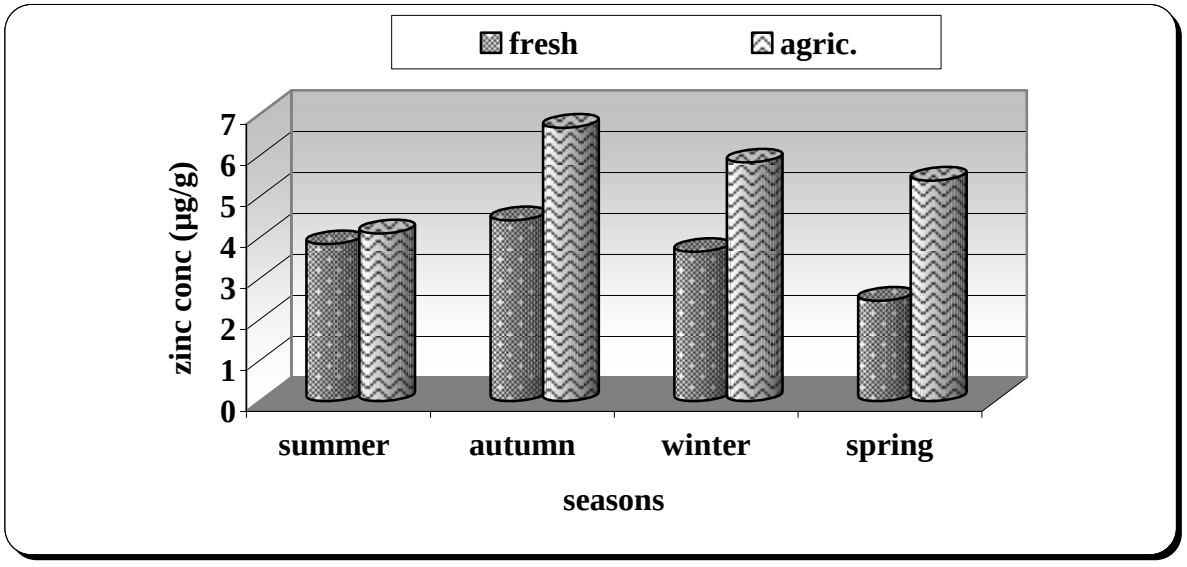

Figure (17): Zinc concentrations in muscle samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

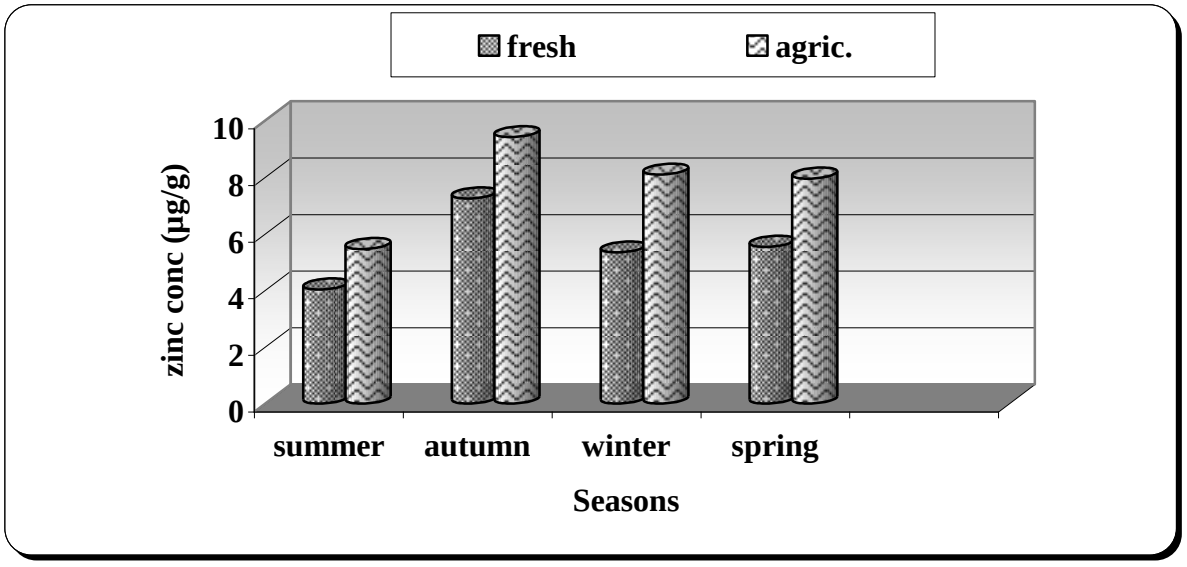

Figure (18): Zinc concentrations in gills samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

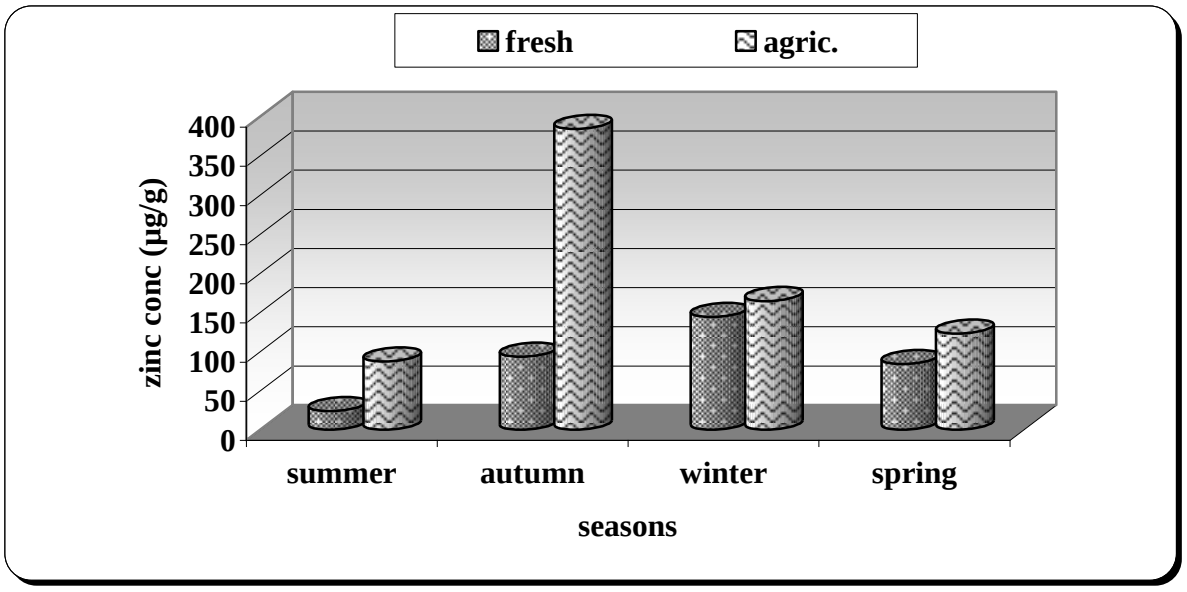

Figure (19): Zinc concentrations in liver samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

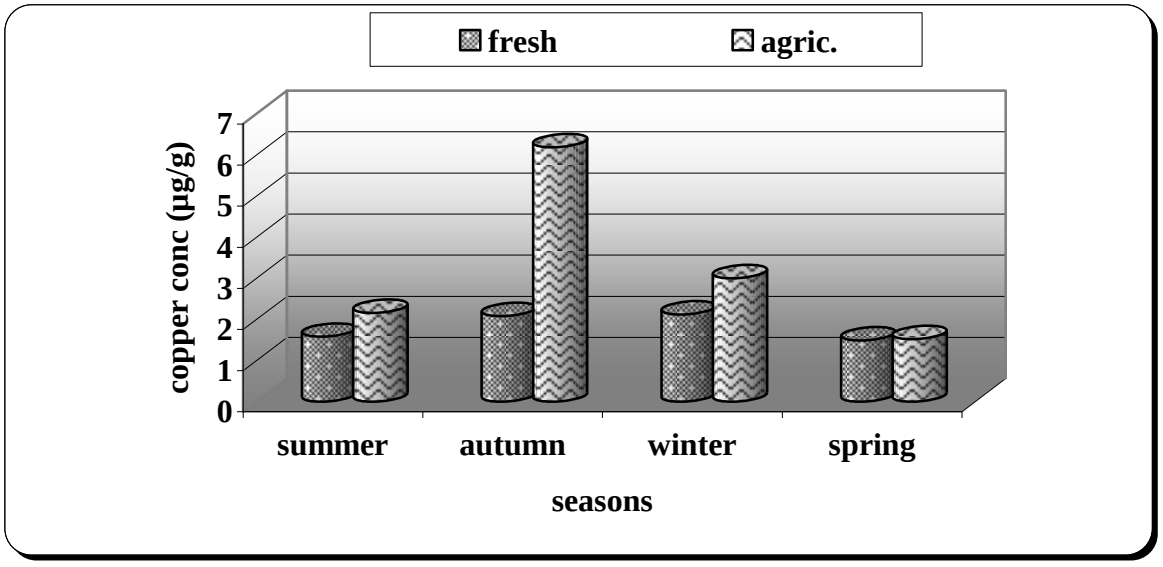

Figure (20): Copper concentrations in muscle samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

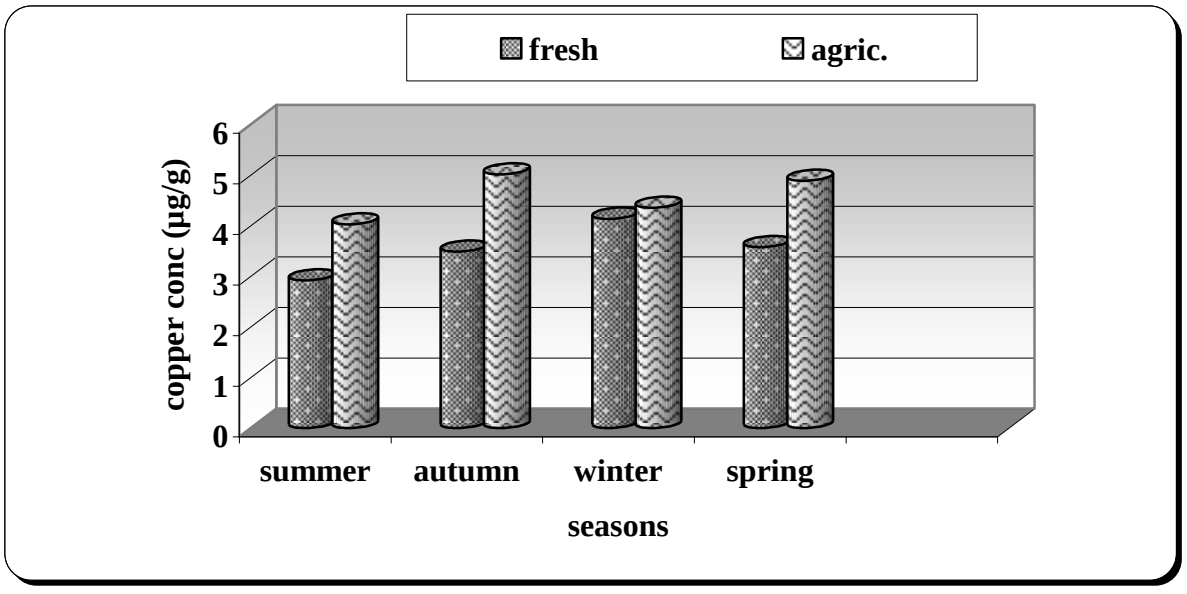

Figure (21): Copper concentrations in gills samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

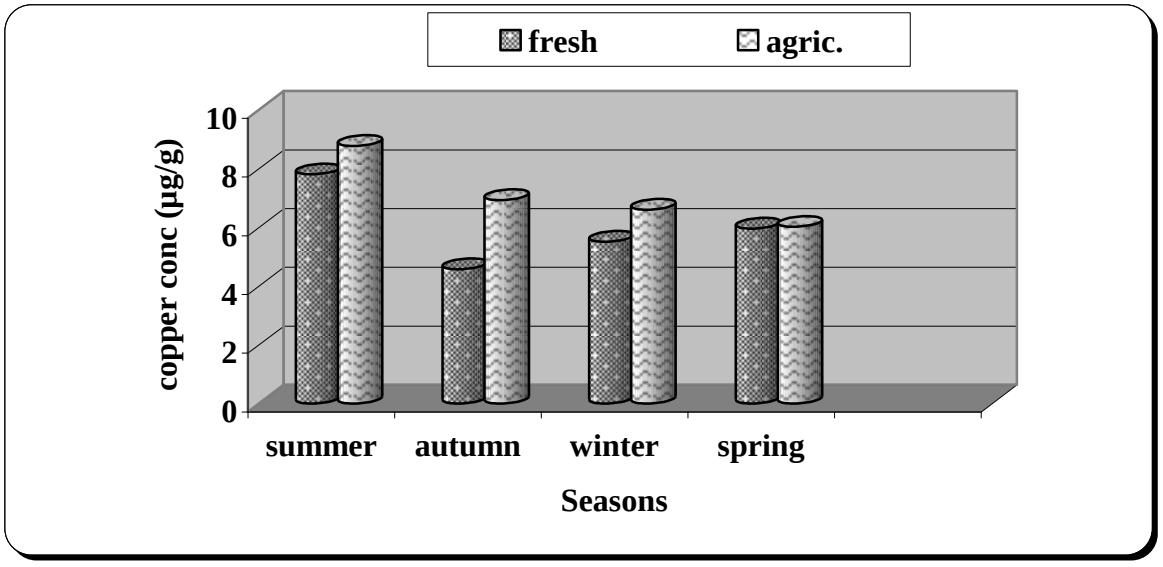

Figure (22): Copper concentrations in liver samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

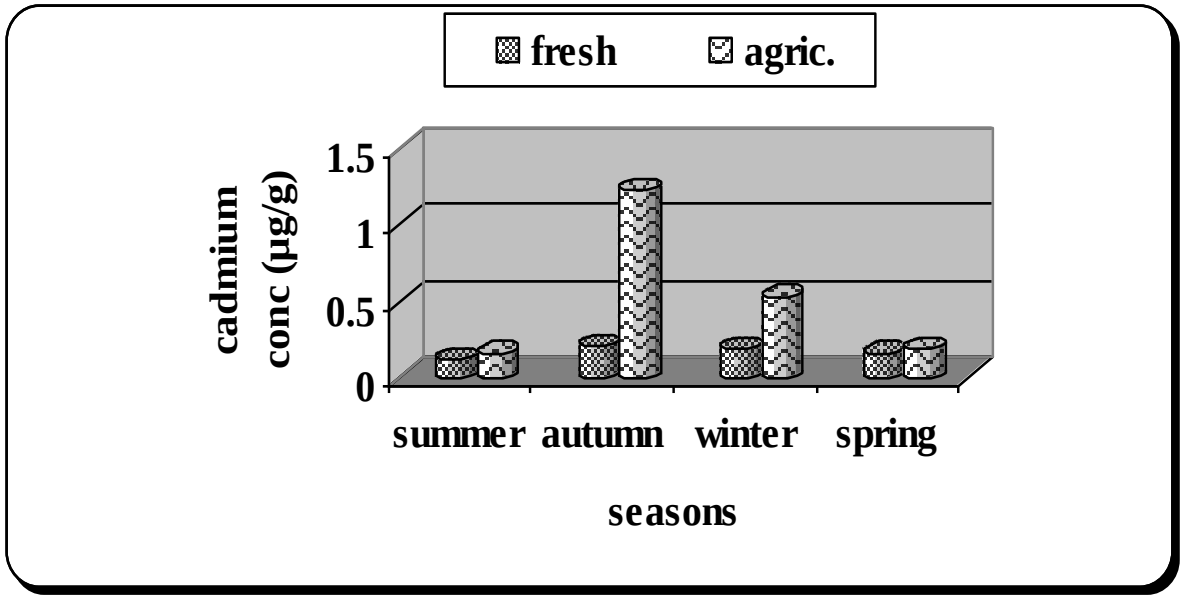

Figure (23): Cadmium concentrations in muscle samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

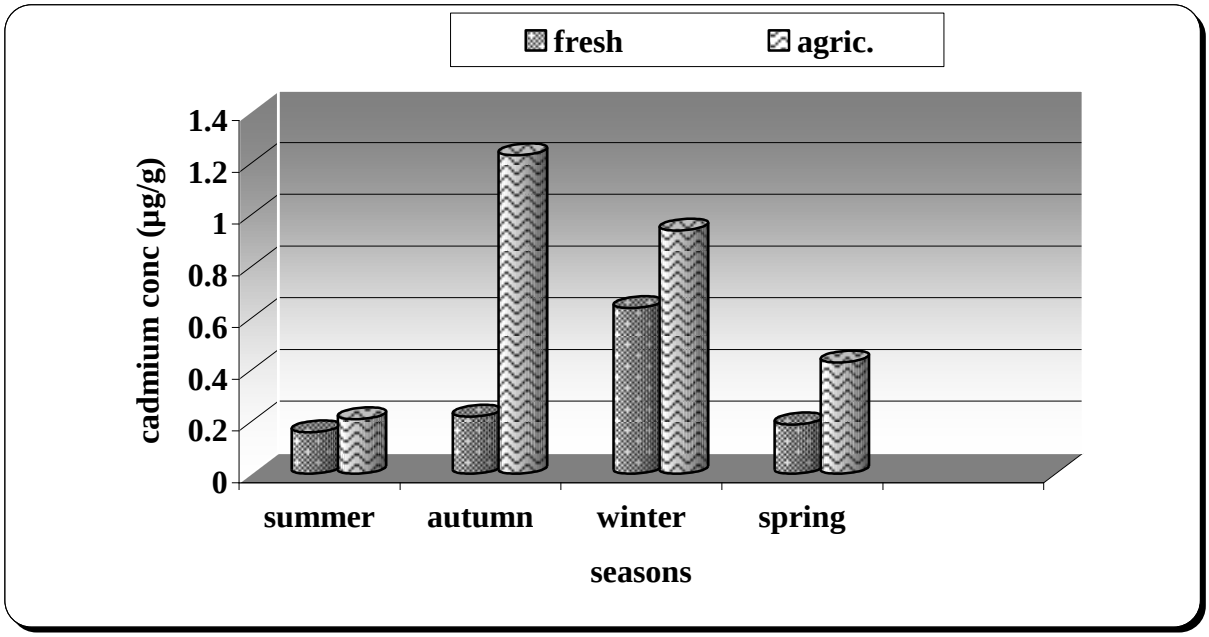

Figure (24): Cadmium concentrations in gills samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

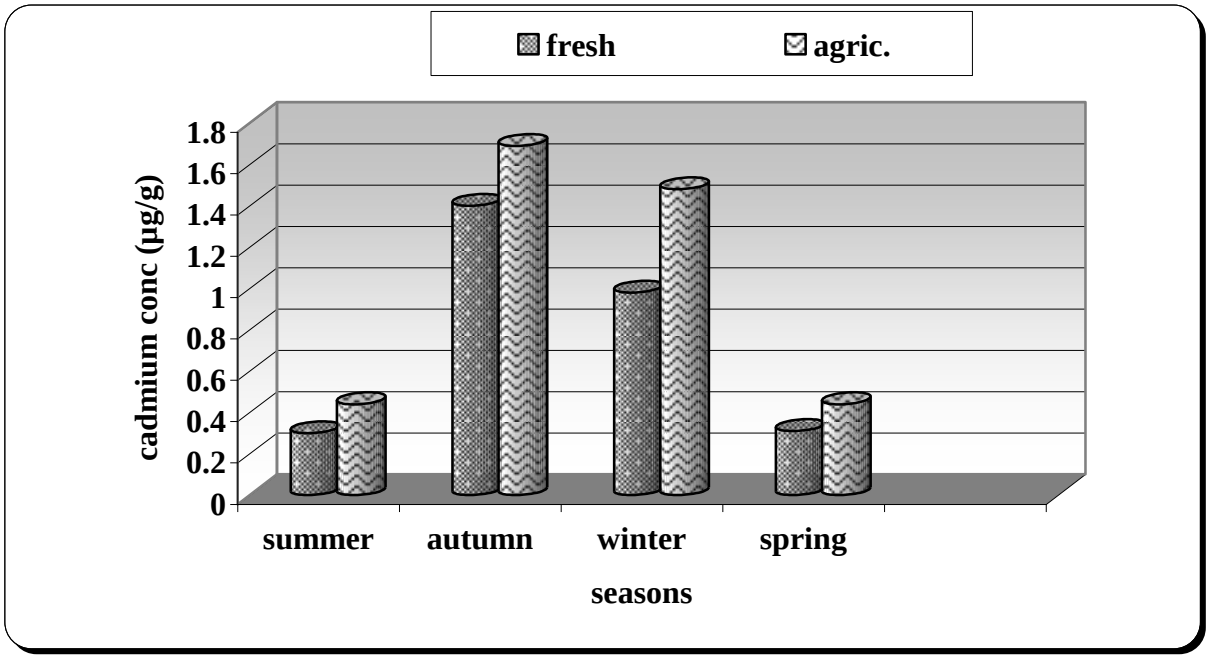

Figure (25): Cadmium concentrations in liver samples of *Oreochromis niloticus* which collected from agricultural drainage water and fresh water during different seasons.

Plankton estimation:

Chlorophyll a:

The highest chlorophyll "a" concentration (128.42± 33.2 µg/l) is recorded in agricultural drainage water during winter, while the lowest concentration (21.14 ± 2.6 µg/l) is recorded in fresh water during summer as shown in Table (8) and illustrated in Figure (26).

The annual over all means of chlorophyll "a" concentration are 84.43 ± 25.2, 62.72 ± 15.7, and 23.71 ± 1.8 µg/l in agricultural drainage water, mixed drainage water, and fresh water respectively

The same table indicates that there are significant differences concerning chlorophyll "a" concentrations among different sampling sites and different seasons.

Table (8): Seasonal variations of chlorophyll concentrations of water samples collected from fresh water, agricultural drainage water, and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
Chlo"a". (µg/l)	Fresh	21.14 ±2.6 b A	21.79 ± 1.8 c A	22.63 ± 1.7 b A	29.35 ± 6.1 b A	23.71 ± 1.8
	Agric.	32.24 ± 3.7 a B	126.81 ±11.2a A	128.42±33.2a A	50.23± 4.6 a B	84.43 ± 25.2
	Mixed	30.25 ± 2.5 a B	72.19 ±13.4b AB	102.12 ±13.1a A	46.34 ± 9.4 a B	62.72 ± 15.7

Data are represented as mean of nine samples ± standard error

a, b, c Values-having different script at the same column are significantly (P<0.05) different

A, B, C. Values-having different script at the same row are significantly (P<0.05) different

- **Chlo"a":** chlorophyll "a"

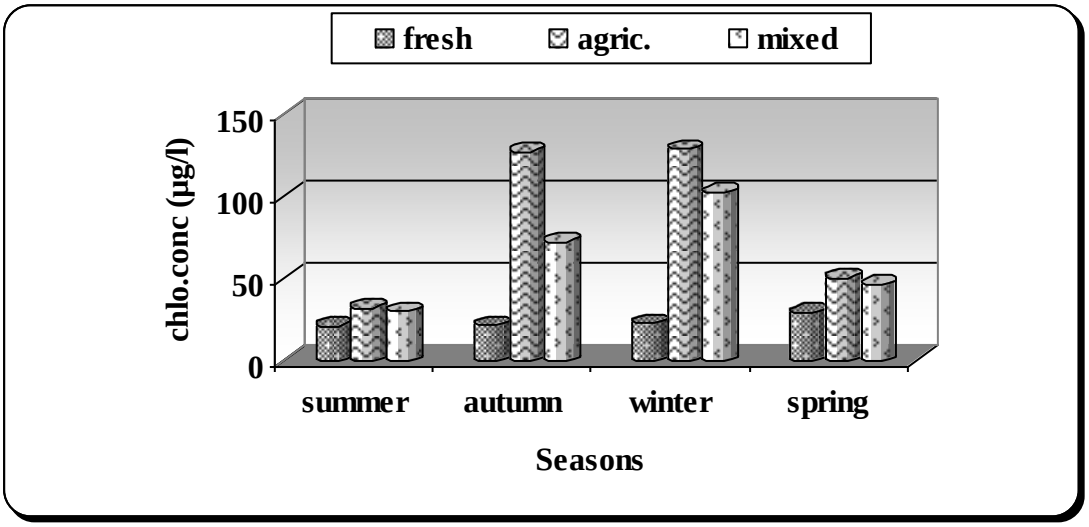

Figure (26): Concentrations of Chlorophyll at different water sources during different seasons.

Phytoplankton:

Tables (9, 10, and 11) indicating the seasonal variation of phytoplankton distribution in the different water sources.

Seasonally, the highest counts are observed in winter (3260 cell/ml) then is followed by a pronounced decrease during summer (1192 cell/ml) in the agricultural drainage water, while in mixed drainage water, the highest counts are recorded in winter and autumn (2934, 2287 cell/ml) respectively then followed by a pronounced decrease during summer and spring (1314, 1529 cell/ml) respectively.

The lowest and highest counts are recorded in autumn and spring (1026, 1339 cell/ml) in fresh water respectively.

In general, the annual average standing crop of phytoplankton attained its highest values in the agricultural drainage water (2229 cell/ml) then followed by (2016 cell/ml) in mixed drainage water and finally by (1179 cell/ml) in fresh water.

Concerning the phytoplankton classes, it is clear that Chlorophyceae are the most dominant group of phytoplankton standing crop in the mixed drainage water, and fresh water. Their recorded annual average numbers are (3085, and 1808 cell/ml) respectively. While in agricultural drainage water Bacillariophyceae represent the dominant group with annual average (3348 cell/ml)

Euglenophyceae represents a minor group of phytoplankton community. Their recorded annual average numbers are (148, 154 and 65 cell /ml) in the agricultural drainage water, mixed drainage water, and fresh water respectively.

Concerning species composition, it is clear that *Microcystis* sp is the dominant genus among Cyanobacteria in mixed drainage water during autumn and spring with average cell number (2502 and 1383 cell/ml) respectively. But in summer, the most dominant genus is *Cyclotella* sp among Bacillariophyceae with an average cell number 928 cell/ml and in winter *Chroococcus* sp is the dominant genus with an average cell number 3310 cell/ml.

In agricultural drainage water the most dominant genus are *Cosmarium* sp and *Scendesmus* sp with an average cell number 3639 and 2707 cell/ml during autumn and winter respectively, while in summer and spring *Chlorella* sp and *Closterium* sp become most dominant genus with an average cell number 1101 and 1889 cell/ml respectively. But in fresh water it is clear that the most dominant genus are *Chlorella* sp, *Melosira* sp, *Pediastrum* sp, and *Synedra* sp with an average cell number 1456, 682, 1858, and 1149 cell/ml during summer, autumn, winter and spring respectively.

Figures (28, 29, and 30) show the percentage of phytoplankton species in the different water sources, which is represented by Chlorophyceae (37%), Cyanobacteria (36%), Bacillariophyceae (26%), and Euglenophyceae (1%) in fresh water, while in the agricultural drainage water is represented by Bacillariophyceae (37%), Chlorophyceae (34%), Cyanobacteria (27%), and Euglenophyceae (2%). But in mixed drainage water the percentage is represented by Chlorophyceae (39%), Cyanobacteria (37%), Bacillariophyceae (22%), and Euglenophyceae (2%).

Table (9): Seasonal mean of phytoplankton divisions in water samples collected from fresh water.

division	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Chlo	1942	1287	2414	1587	1808
Cyano	1239	1797	1502	2168	1677
Bac	1009	875	1241	1532	1164
Eug.	0	146	47	68	65
total	4190	4105	5204	5355	4714

Data are represented as mean of samples

Chlo: Chlorophyceae

Cyano: Cyanobacteria

Bac: Bacillariophyceae

Eug: Euglenophyceae

Table (10): Seasonal mean of phytoplankton divisions in water samples collected from agricultural drainage water.

division	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Chlo	1449	4549	3563	2454	3003
Cyano	1434	2652	3820	1753	2415
Bac	1884	4404	5458	1645	3348
Eug.	0	178	199	214	148
total	4767	11783	13040	6066	8914

Data are represented as mean of samples

Chlo: Chlorophyceae

Cyano: Cyanobacteria

Bac: Bacillariophyceae

Eug: Euglenophyceae

Table (11): Seasonal mean of phytoplankton divisions in water samples collected from mixed drainage water.

division	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Chlo	1959	3587	4505	2287	3085
Cyano	2287	3168	4414	1797	2917
Bac	1009	2213	2541	1875	1910
Eug.	0	181	275	158	154
total	5255	9149	11735	6117	8064

Data are represented as mean of samples.

Chlo: Chlorophyceae

Cyano: Cyanobacteria

Bac: Bacillariophyceae

Eug: Euglenophyceae

Table (12): Total Phytoplankton divisions in water samples collected from fresh water, agricultural drainage water and mixed drainage water.

Item	Group	Seasons				Mean
		Summer	Autumn	Winter	Spring	
Total phyto	Fresh	4190	4105	5204	5355	4714
	Agric.	4767	11783	13040	6066	8914
	Mixed	5255	9149	11735	6117	8064

Total phyto: Total Phytoplankton

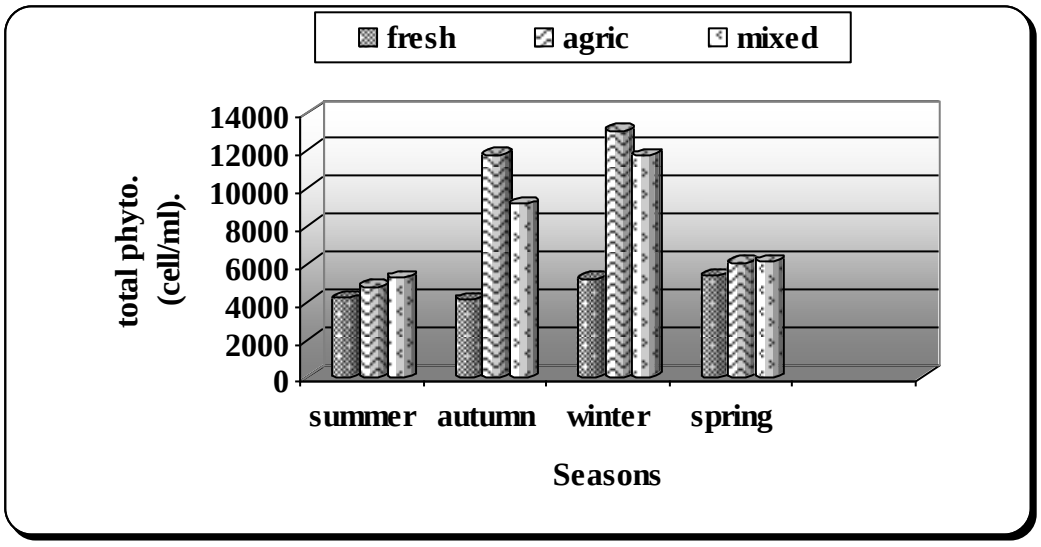

Figure (27): Total Phytoplankton concentrations at different water sources during different seasons.

Table (13): The qualitative composition of the phytoplankton genera in the different water sources during different seasons (+: present, ++: common, +++: dominant,-: not present)

	Summer			Autumn			Winter			Spri	
	Fresh	Agric	Mixed	Fresh	Agric	Mixed	Fresh	Agric	Mixed	Fresh	Agr
	+	+	+	+	+	+	+	+ + +	+	-	+
	+ + +	+ + +	+ +	+	+	+	+	+	+	+ +	+ +
	+	+	+	+	+	+	+ + +	+	+	+	+
	+ +	+ +	-	+	-	-	+	-	-	+ +	+ +
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	+	+	-	+	+	-	+	+	-	+	+
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	+ +	+ +	+	+	+	+	+ +	+	+	+ +	+
	+ +	+	+	+	+	+	+	+	+	+	+
	+	+	+	+ + +	+	+	+	+	+	+	+

Table (14): The most dominant phytoplankton genera in water samples collected from fresh water, agricultural drainage water and mixed drainage water during different seasons.

Water source		Seasons			
		Summer	**Autumn**	**Winter**	**Spring**
Fresh	Dominant Sp	*Chlorella* sp	*Melosira* sp	*Pediastrum* sp	*Synedra* sp
	No of cell	1456 cell/ml	682 cell/ml	1858 cell/ml	1149 cell/ml
	Percentage	75%	78%	77%	75%
Agric.	Dominant Sp	*Chlorella* sp	*Cosmarium* sp	*Scenedesmus* Sp	*Closterium* sp
	No of cell	1101 cell/ml	3639 cell/ml	2707 cell/ml	1889 cell/ml
	Percentage	76%	80%	76%	77%
Mixed	Dominant Sp	*Cyclotella* sp	*Microcystis* sp	*Chroococcus* sp	*Microcystis* sp
	No of cell	928 cell/ml	2502 cell/ml	3310 cell/ml	1383 cell/ml
	Percentage	92%	79%	75%	77%

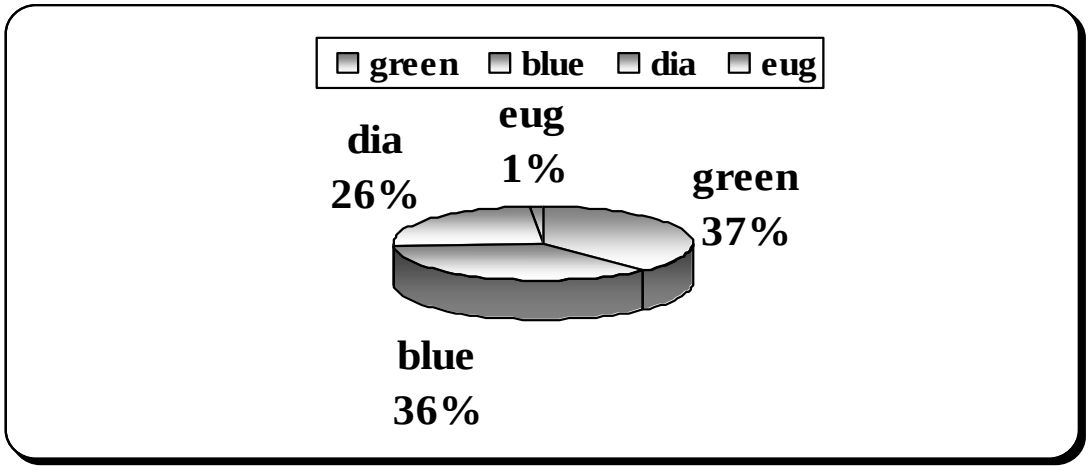

Figure (28): Percentage of Phytoplankton species at fresh water.

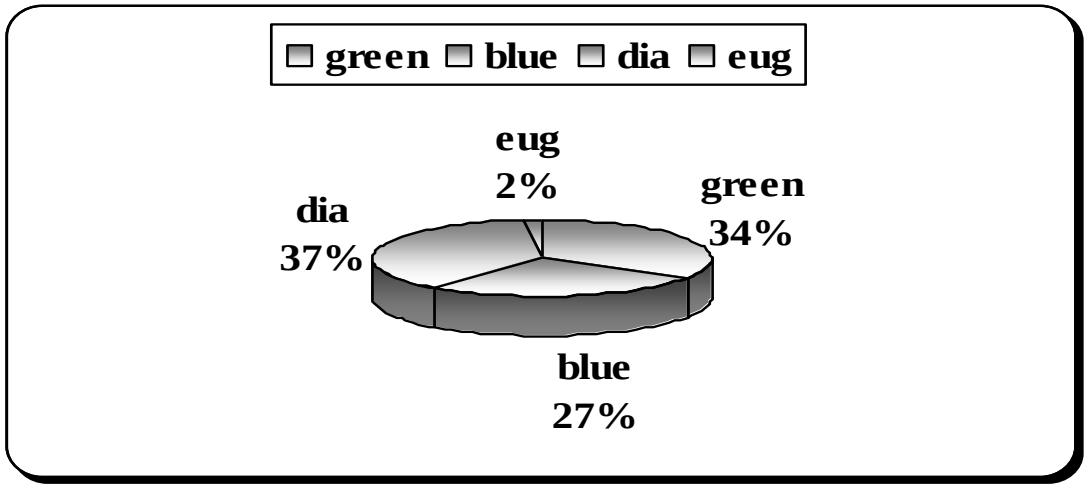

Figure (29): Percentage of Phytoplankton species at agricultural drainage water.

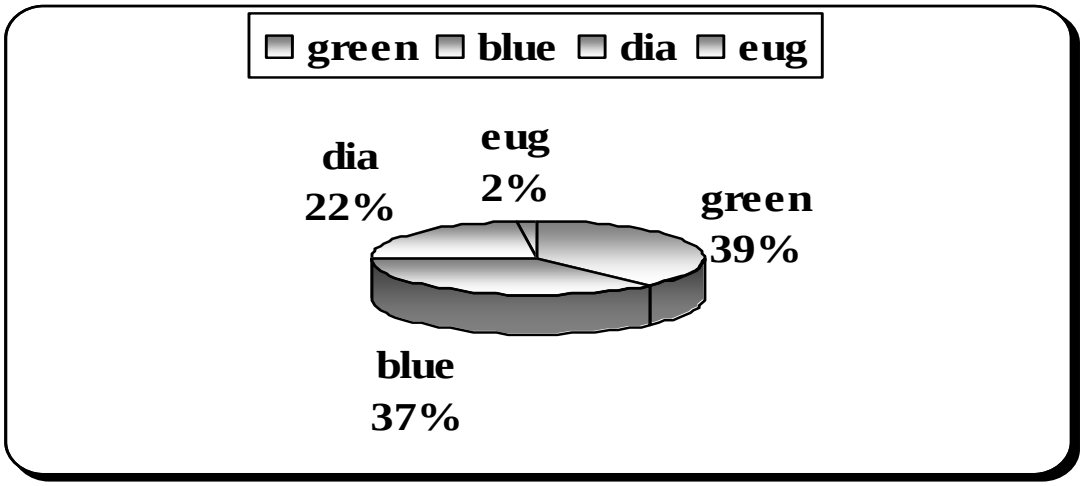

Figure (30): Percentage of Phytoplankton species at mixed drainage water.

Zooplankton:

Data recorded in Table (15, 16, and 17) showed the seasonal variation of total zooplankton numbers in fresh water, agricultural drainage water and mixed drainage water.

Seasonally, the highest counts are observed in spring (158 organism/l) then is followed by a pronounced decrease during summer (40 organism/l) and increase again in autumn (95 org./l) and winter (86 org./l) in the agricultural drainage water, while in the fresh water the highest counts are recorded in spring (34 org./l) and summer (31 org./l) while the lowest counts is in winter (4 org./l) and autumn (9 org./l).

The annual average of zooplankton populations attained its highest values in the agricultural drainage water (95 org./l) while the lowest value is recorded in fresh water (20 org./l).

Rotifera individuals occupy the first order of abundance (annual average 231 organism/l) followed by Copepoda individuals (annual average 129 org./l) while the Ostrocoda and Cladocera individuals are less abundance (annual average 10 org./l) and (8 org./l) respectively in the agricultural drainage water.

In the fresh water, Rotifers individuals occupy the first order of abundance (annual average 54 org./l) followed by Copepoda and Cladocera individuals (annual average 12 and 10 org./l) respectively then Ostrocoda individuals are the less abundance (annual average 3 org./l).

However in mixed drainage water, there are zooplankton individuals during winter only as shown in Table 17.

Figures (32, 33, and 34) showing the percentage of Zooplankton species in the different water sources, which is represented by Rotifers (68%), Copepoda (15%), Cladocera (13%), and Ostrocoda (4%) in fresh water, while in the agricultural drainage water is represented by Rotifers (61%), Copepoda (34%), Ostrocoda (3%), and Cladocera (2%). But in mixed drainage water the percentage is represented by Rotifers (67%), and Ostrocoda (33%).

Table (15): Seasonal mean of zooplankton genera in water samples collected from fresh water.

genera	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Rot	60	24	10	122	54
Cop	29	7	4	7	12
Clad	28	5	3	4	10
Ostr	7	1	0	4	3
total	124	37	17	137	79

Data are represented as mean of samples.

Rot: Rotifera

Cop: Copepoda

Clad: Cladocera

Ostr: Ostracoda

Table (16): Seasonal mean of zooplankton genera in water samples collected from agricultural drainage water.

genera	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Rot	137	338	189	261	231
Cop	4	18	152	342	129
Clad	10	19	0	3	8
Ostr	7	4	2	27	10
total	158	429	343	633	391

Data are represented as mean of samples

Rot: Rotifera

Cop: Copepoda

Clad: Cladocera

Ostr: Ostracoda

Table (17): Seasonal mean of zooplankton genera in water samples collected from mixed drainage water.

genera	Seasons				Mean
	Summer	Autumn	Winter	Spring	
Rot	0	0	16	0	4
Cop	0	0	0	0	0
Clad	0	0	0	0	0
Ostr	0	0	8	0	2
total	0	0	24	0	6

Data are represented as mean of samples.

Rot: Rotifera

Cop: Copepoda

Clad: Cladocera

Ostr: Ostracoda

Table (18): Total Zooplankton species in water samples collected from fresh water, agricultural drainage water and mixed drainage water.

Item	Water source	Seasons				Mean
		Summer	Autumn	Winter	Spring	
Total Zoo.	Fresh	124	37	17	137	79
	Agric.	158	429	343	633	391
	Mixed	0	0	24	0	6

Total Zoo: Total Zooplankton

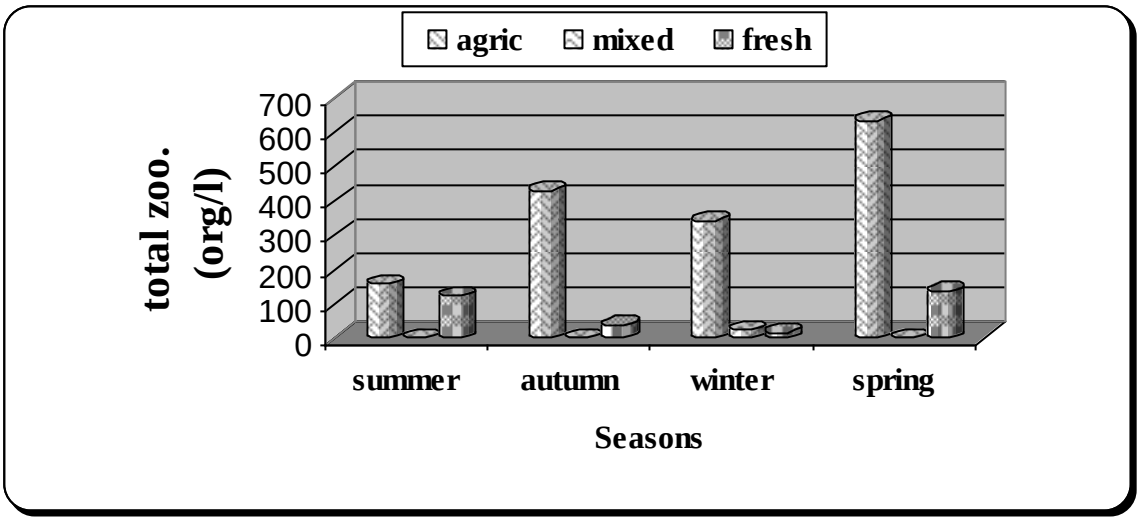

Figure (31): Total Zooplankton concentrations (organism/l) at different water sources during different seasons.

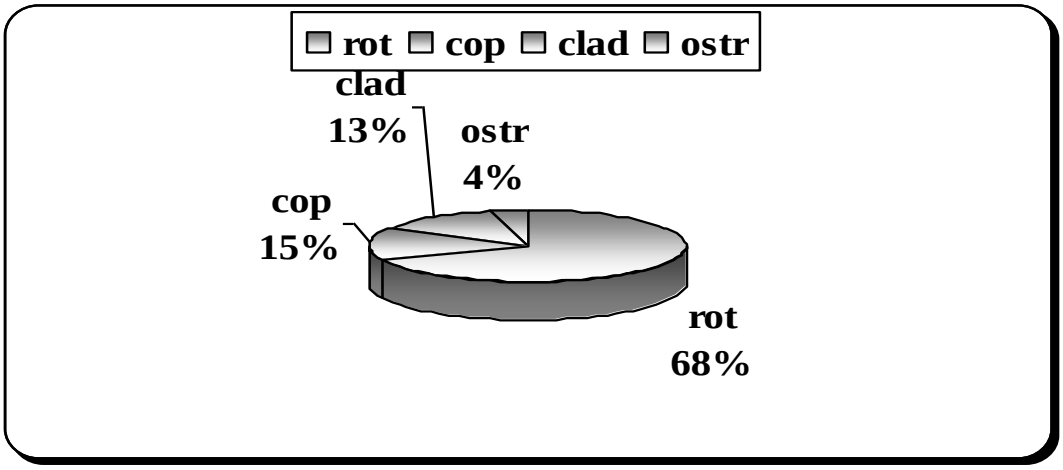

Figure (32): Percentage of Zooplankton species at fresh water.

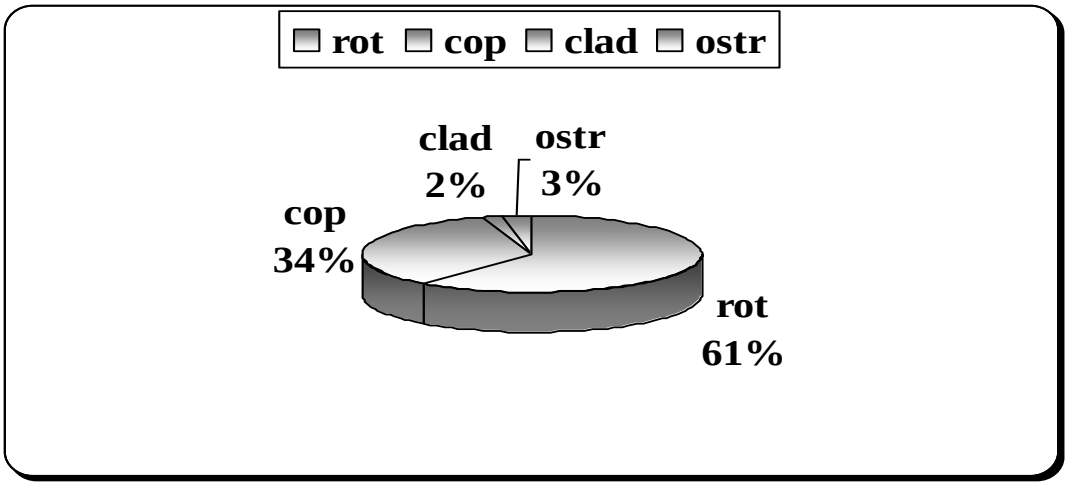

Figure (33): Percentage of Zooplankton species at agricultural drainage water.