10. EFA-MRB., 2008, *Environmental Flow Assessment, Mara River Basin, Kenya-Tanzania (EFA-MRB).* 2008, World Wide Fund for Nature- Eastern Africa Regional Programme Office, 39p.Unpublished.
11. (EAC) East African Community, 2009, *Assessing Reserve Flows for the Mara River, Kenya and Tanzania*, Technical Report under the auspices of the Lake Victoria Basin Commission.
12. Hoffman C., Melesse A. & McClain M., 2009, *Geospatial Mapping and Analysis of Water Availability-Demand-Use within the Mara River Basin*, *Hydrological Processes* (in revision). Florida International University, Miami, USA.
13. King J.M., Tharme R., and De Villiers MS., 2000, *Environmental flow assessments for rivers: Manual for the building block methodology*, TT131/00, The Water Research Commission, Private Bag X03, 0031 Rietfontein, Pretoria, South Africa
14. Welcomme, R.L., Winemiller, A.K.O, and Cowx, I.G., 2006, *Fish environmental guilds as a tool for assessment of ecological condition of rivers,* River Research Applications 22: 377–39.
15. Kitheka, J.U., Obiera, M. and Nthenge, P. , 2003, R*iver Discharge, Sediment Transport and Exchange in the Tana Estuary, Kenya*, Accessed March 26, 2009. http://cat.inist.fr/?amodele=afficheN&cpsidt=16814558
16. Republic of Kenya, 1992, *The Study on the National Water Master Plan, Sectoral Report (B), Hydrology*, July 1992. Ministry of Water Resources, Nairobi, Kenya.
17. WREM, 2008, *Mara River Basin Monograph. Draft Final Report. Water Resources and Energy Management (WREM),* International Inc. Atlanta, Georgia Institute of Technology, U.S.A (unpublished).
18. Terer, J. K. , 2005, *The Study of Hydrologic Characteristics and Management Practices in Agricultural River Catchments: The case of Nyongores River Catchment, Mara River Basin M.Phil*, Thesis. Moi University, Eldoret, Kenya. Unpublished.
19. Swallow B., Okono, A., Ong, C. and Place, F., 2003, *Case Three. Project title-Trans Vic: Improved Land Management across the Lake Victoria Basin*, Accessed March 26, 2009 at URL. http://www.fao.org/wairdocs/tac/y4953e/y4953e07.htm .
20. UNEP, 1991, *Freshwater Pollution*, UNEP/GEMS Environmental Library No.6, Nairobi, United Nations Environmental Programme.
21. Chapman, D. (Ed.), 1996, *Water Quality Assessments A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. 2nd edition*, Chapman & Hall, London
22. Pearce, G. R., Chaudry, M. R. and Ghulam, S., 1999, *A Simple Methodology for Water Quality Monitoring*, HR Wallingford, Report OD 142, United Kingdom
23. Muchena F. N., Mbuvi, J.P. and Wokabi, S.M., 1988, *Report on Soil and Land use in Arid and Semi-arid Lands of Kenya*, Ministry of Environment and Natural Resources, National Environment Secretariat, Nairobi.
24. Merck & Co., Inc. ,2003, *The Merck Manual of Medical Information*, Second Home edition, Merck research Laboratories, New Jersey, USA.
25. Republic of Kenya, 2006, *The Environmental Management and Coordination (Water Quality) Regulations (2006)*, Kenya Subsidiary Legislation, 2006, Nairobi
26. (EPA) U. S. Environmental Protection Agency, 2003, U. S. Environmental Protection Agency, *Polluted Runoff (Non point Source Pollution),* http://www.epa.gov/OWOW/NPS/MMGI/Chapter4/ch4-2a.html
27. Kashaigili, J.J., *et al*., 2005, *Physics and Chemistry of the Earth,* 30 (689-697).
28. Haan C.T., Barfield, B.J. and Hayes, J.C., 1994, *Design Hydrology and Sedimentology for Small Catchments*, Academic Press, San Diego, California.
29. Singler, H, and McClain, M., 2006, *Report of the Global Water for Sustainability (GLOWS) Program*, Mara River Basin Water Quality Baseline Assessment – May 2005.

Apportionment of Pollution Sources of El Salam Canal Using Statistical Techniques

Dr. Noha Donia[1]

[1] Assistant Professor, Env. Eng Dep., Institute of Environmental Studies and Researches, Ain Shams University. Email: ndonia@gmail.com

Abstract

Multivariate statistical techniques were applied to the data set on water quality of the EL Salam Canal observed during six years (2001-2006) monitoring for 24 parameters (1728 observations). First, seasonal and spatial variations of water quality along the canal were analyzed delineating indicator parameters responsible for large variations in water quality. Second, multiple regression analysis was conducted between the water quality of inputs to the canal and the canal downstream. This study presents usefulness of multivariate statistical techniques for evaluation and interpretation of large complex water quality data sets and apportionment of pollution sources/factors with a view to get better information about the effect of water quality of different input sources to the canal on its endpoint water quality. Consequently, the results may provide a guide to choose the most suitable pollution sources control scenarios for better water quality.

Key words: Statistics; El Salam canal; Water Quality; Pollution; Regression Analysis

1. INTRODUCTION

Reuse of agricultural drainage water for irrigation is an inevitable choice for Egypt because the present and future demands exceed the available fixed fresh water resources. Being low quality water, it was important to develop tools and guidelines that allow implementing this policy on an economical and environmentally sound basis that also ensure the sustainability of the agricultural system. Egypt started important steps to implement this strategy, by expanding in new agricultural lands, using Nile water mixed with drained agricultural water. El Salam canal project comes beforehand of projects relying on this strategy, by using around 2.3 billion cubic meters annually from agricultural drained water. The canal begins at the mouth of the Damietta Tributary at the city of Adlia and extends 86 km in a southerly direction and then in an easterly direction to the Suez Canal. After crossing under the Suez it is named El Sheikh Gaber El Sabah Canal which extends through Sinai to El Arish as shown in figure 1. The total area planned for irrigation on El Salam canal is around 640 thousand feddans. To benefit from the reuse of some water from Lower Serw drain, Farasquor drain and Bahr Hadous drain, by mean of mixing it with fresh water from the Nile (Damietta Branch) with variable mixing proportion through the year, (El Khouly, 2004). Currently El Salam canal receives about 770 MCM as Nile fresh water from Domiatta branch, 586.7 MCM from Sero drain, and 970 MCM from Hadus drain. The currently mixing ratio is about 2:1 between the drainage water and the Nile fresh water, which makes the average salinity of the mixed water about 1000 mg/l. Currently the total average annual discharge of El Salam canal is about 2,327 BCM, which covers the water requirements for 220,000 feddan in the western of Suez Canal, in addition, about 400,000 feddans east of Suez Canal in the northern Sinai Peninsula, (El Kholy et. al., 2005).

This study is needed to assess and evaluate the effect of the mixed drainage water in El Salam canal on the physical and chemical characteristics of the water of the canal through the application of different multivariate statistical techniques. This is to provide reliable drainage water quantity and quality information about the drainage water which could be reused for El Salam Canal Project. Also, it helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems, allows the identification of possible factors/sources that influence water systems and offers a valuable tool for reliable management of water resources as well as rapid solution to pollution problems (Vega et. al., 1998; Wunderlin et. al., 2001; Reghunath, 2003; Simeonova, 2003). Multivariate statistical techniques have been applied to characterize and evaluate surface and freshwater quality, and it is useful in verifying temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality (Helena, 2000; Singh et. al, 2004; Singh et. al, 2004). However specific studies aimed to correlate the source apportionment of point and non point sources to the observed load of a certain river are still quite scarce (Behrendt, 1998). This thus offers valuable tool for developing appropriate strategies for effective management of the water resources.

The objective of this study is to extract information about the similarities or dissimilarities between sampling sites, identification of water quality variables responsible for spatial and temporal variations in river water quality and the influence of possible sources (natural and anthropogenic) on the water quality parameters of the El Salam Canal.

2. METHODOLOGY

2.1. Monitored Parameters and Analytical Methods

Water Quality is assessed by measuring various physical, chemical and biological variables (Total and Fecal Coliform), BOD, COD, NO3, NH4, TP, TN, Cd, Cu, Fe, Mn, Zn, Pb, Ni, Boron, pH, EC, TDS, SAR, DO, Turbidity, chlorides and sulfates).The National Water Quality Monitoring program of Egypt takes the responsibility of appraising the Nile Delta monitoring network sites in a monthly basis, (DRI, 2005). The reliable data of the national water quality monitoring program for the last six years data from 2001-2006 was used to evaluate the situation with respect to water quality status. All data analysis were conducted as recommended by standard methods for the examination of water and wastewater, (APHA, 1992). All monitoring locations in the canal are shown in figure 2.The first monitoring location is its intake EI21 located 3 km upstream Faraskour dam, the second location is EI18 before mixing with Lower Serw drain at 18.5 km from the intake. The third location is pump station No.1 (EH20) at km 23 after mixing with Lower Serw drain while the forth location is pump station No.2 (EH21) at km 54.3 before mixing with Hadus drain. The fifth location is EI19 after mixing with Hadus drain at km 62. The sixth location (EH24) is situated at the outlet to the siphon of Suez Canal at km 86.

2.2. Basic Statistical Analysis

All of the statistical computations were made using the statistical package SPSS 12.0, (Dareen, 2006). The basic statistics of the monthly measured 6-year data set on El Salam canal water quality have been identified including the mean concentration with associated standard deviation and range values.

2.3. Spatial and Temporal Variations Analysis

Water quality has been the principal limiting factor to water availability. The assessment of short and long term water quality changes is a challenging problem. The result has been the gradual accumulation of reliable water quality records and the examination of the data trends (Helsel, 1992). Without such information of the trend detection of the water bodies, effective water quality management remains impossible. For the first stage of analysis, the canal is divided into three reaches where four seasons (winter, summer, spring and autumn) data are separated for each reach. Reach 1 combines EI18, reach 2 combines EH20 and EH21. Reach 3 combines EI19 and EH24. Four groups for temporal (four seasons) and three groups for spatial (five sampling regions) evaluations have been identified in the SPSS software. Statistical analysis has been conducted to assess the seasonal and spatial variations of water quality along the canal**.** Very useful and concise graphical display for summarizing the distribution of a data set is the box plot (Hirsch, 1992). Box plots have been drawn to provide the visual summaries of:

1. The center of the data (the median= the center line of the box),
2. The variation or spread (inter quartile range= the box height)
3. The Skewness (quartile skew= the relative size of box halves) and
4. The presence or absence of unusual values (outliers and extreme values)

2.4. Source Apportionment using Multiple Regression Analysis

The source apportionment is an important approach aiming to the estimation of contribution of identified sources to the concentration of each parameter. This approach may be generalized to the problem of how to predict a single variable from the weighted linear sum of multiple variables (multiple regression) or to measure the strength of this relationship (multiple correlation). In this research, multiple regression technique is used for the source apportionment calculation in order to predict the exact regression model relationship between variables in order to be used in future for prediction. Multiple regression is an extension of simple linear regression in which more than one independent variable (X) is used to predict a single dependent variable (Y). The predicted value of Y is a linear transformation of the X variables such that the sum of squared deviations of the observed and predicted Y is a minimum. The computations are more complex, however, because the interrelationships among all the variables must be taken into account in the weights assigned to the variables. With two independent variables (X1, and X2) the prediction of Y is expressed by the following equation (1), (Simeonov, 2003).

$$Y = b_0 + B_1 X_1 + B_2 X_2 \quad (1)$$

Where b_0 the constant of the equation and B_1, B_2 are the coefficients of the regression equation. The correlation is significant if the correlation coefficient $R > 0.5$ and the significance of t (B divided by standard error of b) must be <0.05. The relative influence of the entered variables on the dependent variable was identified by calculating the standardized regression coefficient beta (β).

3. RESULTS AND DISCUSSION

3.1 Spatial and Temporal Variation of El Salam Canal Water Quality

Table 1 shows the mean, range and standard deviations of the water quality of El Salam canal .The spatial variation of water quality parameters have been analyzed at stations E18, E19, EH20, EH21 and EH24 along El Salam canal as shown in box plots shown in figure 3. .. The highest value is at EI18 and the lowest value is at EI19. The lowering of pH at sites located downstream El Serw and Hadus drains may be attributed to increase of organic matter, which decomposed by bacteria and releasing acidic gases. In general, pH values within the permissible limits of the Law 48/1982 Egyptian Standards for River Water Quality (Law 48/1982 Standards Article 62) . The mean values of BOD and COD exceed the Egyptian law standard (10 mg/l) all over the canal. The highest concentration is at EH20 which contains high amount of organic pollutants disposed into the canal from El Serw drain to this location. The lowest concentration is at EI18 at the inlet from Damietta Branch. The mean values of Ammonia exceed the Egyptian law standard (0.5 mg/l) all over the canal. The highest concentration is at EH20 which contains high amount of sewage disposed into the canal from Bahr Hadous drain to this location. The lowest concentration is at EI18 at the inlet from Damietta Branch. BOD, COD and Ammonia values are higher in the second and third reaches than in first reach due to effect of El Serw and Bahr Hadous drains. The highest concentration of DO is at EH21 and the lowest concentration is at EH20. Decreasing of DO follows the increasing of BOD. DO is high in the first reach and then decreases in the second reach due to the effect of El Serw drain, and then increases again in the third reach, due to the pump station reaeration effect The highest concentration is at EH20 and the lowest concentration is at EI18. From the above results, it is observed that the area located downstream the feeding drains have higher bacterial densities than the area of the first reach of the canal before mixing with this drain. This is due to the wastewater of the feeding drains that contains highly feacal contamination. The faecal coliform concentration along the Canal was found above the standard limits of law 48, 1982.

The highest value of SAR is at EI19 and the lowest concentration is at EI18. This value of SAR has a slight to moderate restriction on use for irrigation by FAO classification. SAR values are low in the first reach, then become high in the second reach, due to the effect of El Serw drain, and then increases again in the third reach due to Bahr Hadous drain. . The highest TSS value is at EI19 due to the discharge of Bahr Hadous at this location and the lowest at EI18 at Damietta Branch inflow to the canal. The increase of TSS reduces light penetration, restricts plant growth and consequently food resources and habitat for organisms. TSS at the first reach recorded low value in contrast to the values in the second and third reaches. This increase is a good indicator for water pollution by some industrial and domestic wastes. The TSS concentration along the Canal was found above the standard limits of the Law 48/1982. It was observed that the highest nitrate concentration is at EH20 and the lowest value is at EI18. Total Nitrogen in surface water promotes high primary productivity and an excess of nitrate in surface water is taken as a warning for algal blooms The total nitrogen concentration along the Canal were found above the standard limits of law 48, 1982. The highest total phosphorus value is at EI19 and the lowest value is at EI18. The increase of phosphorus level at Hadous drain was attributed to the agricultural runoff that contains phosphate fertilizers as well as domestic wastewater containing detergents. High concentrations of total phosphorus are largely responsible for eutrophic condition. The total phosphorus concentration along the Canal was found within the standard limits of law 48, 1982. For total phosphorus and total nitrogen, the first reach has low values and then it increases in the second and third reaches due to the effect of El Serw and Bahr Hadous drains. The highest concentration of FE and Mn were found at EI 19 and the lowest concentration at EI18. These ranges are found within the standard limits of law 48, 1982. The effect of Bahr Hadous drains appears on the increase of heavy metals concentrations in the second and thirds reaches especially on iron and manganese.

Table 2 shows the mean, range and Standard deviation (S.D.) of El Salam Water Quality Parameters seasonal variation for the period 2001-2006. Figure 4 shows the seasonal variation of water quality parameters along El Salam canal through drawing the median values and the quartiles taking into consideration the outliers. The winter average values of water quality parameters are generally higher then the summer average parameters due to less water discharges in winter than in summer and less drainage discharges as well. The highest pH value is in winter and the lowest value in summer. This decrease in pH is due to more water discharges from drains in summer season.. The highest BOD and COD values are in summer and the lowest value is in autumn. The highest ammonia value is in spring and the lowest value is in autumn. The reason could be the high drainage from dairy factories to Damietta Branch, the drains, and the canals. The highest DO concentration is in spring and the lowest concentration is in summer. It can be noticed that the DO value is lowest in summer because of the temperature effect on oxygen solubility in water and the algae is more active in spring than in summer. These results are in agreement with the high BOD and COD concentrations in summer. The highest SAR is in autumn and the lowest value in summer. The highest TDS value in spring and the lowest is in winter. The highest TSS concentration is in autumn and the lowest concentration is in summer. The highest faecal coliform value is in summer and the lowest value in autumn. These results are in agreement with high organic load in summer.. the highest Total phosphorus and Total nitrogen values are in winter and the lowest in summer. The highest iron value in spring and the lowest is in autumn. The highest manganese value is in spring and the lowest in summer. This seasonal variation between heavy metals concentrations is due to that more water is drained in the spring season. This drained water carries large amounts of heavy industrial wastes.

3.2 Impacts of Pollution Sources on River Water Quality

Multiple linear regression has been performed between the dependent parameter, i.e. the canal downstream (EH24) and the independent parameters, i.e. Damietta water (EI21), El Serw drain (ES02), and Bahr Hadous drain (EH17) to show the direct effect of input concentrations on the canal's endpoint concentration. Table 3 shows the results of the model. Based on the regression analysis and on the criteria predefined of correlation and significant values, the most significant water quality parameters for each group are as follows:

1. Bacteriological (Total coliforms and Faecal coliform)
2. Organic Pollutants (BOD, and COD)
3. Nutrients (TP, TN)
4. Major ions (TDS)
5. Heavy Metals (Cu and Mn)

Total coliform and Faecal coliform concentrations in the canal downstream are mainly affected by coliform concentration of El Serw drain. The domestic sewage drained to El Serw drain has the major effect on high total coliform and faecal coliform concentrations in the drain and therefore to the canal. The El Serw partial correlation of total coliform is 0.941 with relative influence 0.941 and El Serw partial correlation of facecal coliform is 0.919 with relative influence 0.919 with very high significance<0.05 for total and faceacl coliforms. The relative influence of damietta branch and Bahr Hadous drain is negligible on the total and faecal coliforms of El Salam canal. High BOD concentration is mainly due to the greatest influence of El Serw drain followed by influence of Damietta branch due to the domestic sewage drained to El Serw drain and Damietta branch. It shows also that the COD concentration in the canal downstream is mainly affected by COD concentration of Damietta branch, this is due to industrial wastes discharges into the branch followed by the effect of El Serw drain. The El Serw partial correlation of BOD is 0.601 and with relative influence of 0.491. With respect to COD, the Damietta branch has the highest relative influence 0.461 and partial correlation 0.68 followed by El serw drain with relative influence 0.44 and partial correlation 0.52 with very high significance<0.05 for both BOD and COD. TP concentration in the canal downstream is mainly affected by TP concentration of Bahr Hadous drain; Municipal sewage drained to Bahr Hadous drain has the major effect on high TP concentrations in the drain and therefore to the canal. The Bahr Hadous drain has the highest partial correlation 0.547 and the highest relative importance of 0.547 with high significance<0.05. TDS concentration in the canal downstream is mainly affected by TDS concentration of Bahr Hadous drain followed by El Serw drain. Agricultural drainage water drained to Bahr Hadous drain has the major effect on high TDS concentrations in the drain and therefore to the canal. The Bahr Hadous partial correlation of TDS is 0.521 relative importance of 0.45 followed by El Serw Drain of partial correlation of TDS is 0.321 relative importance of 0.321 with high significance<0.05. Manganese concentration in the canal downstream is mainly affected by Manganese concentration of Bahr Hadous drain. Heavy industrial wastes drained to Bahr Hadous drain has the major effect on high Manganese concentrations in the drain and therefore to the canal. The Bahr Hadous partial correlation of Manganese is 0.552 relative importance of 0.487 followed by El Serw Drain of partial correlation of Manganese is 0.398 relative importance of 0.338 with high significance<0.05. Also table 3 shows the Copper concentration in the canal downstream is mainly affected by Copper concentration of El Serw drain due to industrial wastes into the drain. The El Serw drain partial correlation of Copper is 0.54 relative importance of 0.38 followed by Damietta Branch of partial correlation of Copper is 0.246 relative importance of 0.264 with high significance<0.05.

4. CONCLUSIONS

The reuse of drainage water for irrigation is one of the most important issues for strategic management of water resource in Egypt. One of these projects is El Salam canal in Egypt. Therefore it is crucial to study and control the water quality of the canal in order to safely reuse it for agriculture. Statistical Analysis (spatial variation, temporal variation and Multiple Regression Analysis) of the available historical measurements along El Salam canal have been conducted in order to identify how and to what degree several water quality parameter are changing, characterizing the function and response of the locations to seasonal variability and the apportionment of pollution sources to downstream water quality of the canal. Spatial and Temporal variations results show that the influence of El Serw drain and Hadous drain discharges on the water quality of the canal. TDS, BOD, COD, phosphorus, Ammonia and heavy metal concentrations values are higher in the second and third reaches than in first reach due to effect of El Serw and Bahr Hadous drains. Also ammonia Total phosphorus, total nitrogen and heavy metal concentrations are highest in summer. pH, BOD and COD concentrations are lowest in winter. Results of Multiple Regression Analysis show that Damietta Branch has the major effect on increasing COD in the canal. While El Serw drain has the major effect on increasing BOD and Coliform and magnesium concentrations downstream. Bahr Hadous drain has the major effect on increasing TDS, Cu and total phosphates downstream. Therefore, it is recommended that Bahr Hadous and El Serw drains should be treated before discharging into the canal. Awareness should be raised between villagers in order to control waste disposal in the canal and the feeding sources. And finally more research should be made in order to estimate the point and non point sources of pollution into the canal.

5. REFERENCES

1. APHA "American Public Health Association", 1992, *Standard methods for the examination of water and wastewater 18th Ed.,* Washington D.C.
2. Behrendt, H., Bachor, A., 1999, *Point and diffuse load of nutrients to the Baltic sea by river basins of North East Germany (Mecklenburg- Vorpommern)*, Water Sci Technol ; 38(10):147–55.
3. Dareen, George and Paul, Mallery, 2006, *SPSS for windows step by step. A simple guide and Reference 13 update*, sixth edition, Pearson Education.
4. DRI (Drainage Research institute), 2005, *Irrigation and drainage water quality monitoring*, NWRC
5. El Kholy, R. M. S., Kandil, M.I, 2005, *Trend analysis for irrigation water quality in Egypt*, third international conference on River Basin Management, Bologna, Italy.
6. El Khouly, R. M. S, 2004, *Drainage Water Reuse for Land Reclamation:- Risks and Opportunities(case study EL Salam Canal –Egypt),* NAWQAM Project, NWRC.
7. Helsel, D. R. , Hrich, R. M., 1992, *Statistical Methods in Water Resources,* Elsevier, the Netherlands,
8. Helena, B., Pardo, R., Vega, M., Barrado, E., Ferna´ndez, J.M., Ferna´ndez, L., 2000, *Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga river, Spain) by principal component analysis*, Water Research 34:807-816.

9. Hirsch, R. M., Slack, J. R., Smith, R. A., 1991, *Techniques for trend Analysis for monthly Water quality data, Water Resource Research*, 18:107-121.
10. Reghunath, R., Murthy, T.R.S., Raghavan, B.R., 2002, *The utility of multivariate statistical techniques in hydrogeochemical studies: an example from Karnataka, India,* Water Research 36:2437-2442.
11. Simeonova, P., Simeonov, V., Andreev, G., 2003, *Environmetric analysis of the Struma River water quality*, Central European Journal of Chemistry 2:121-126.
12. Simeonov, V., Simeonova, P., Tsitouridou, R.. 2004, *Chemometric quality assessment of surface waters: two case studies*, Chemical and Engineering Ecology 11 (6): 449-469.
13. Singh, K.P., Malik, A., Mohan, D., Sinha, S., 2004, *Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India): a case study,* Water Research 38:3980-3992.
14. Singh, K.P., Malik, A., Sinha, S., 2005, *Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques: a case study*, Analytica Chimica Acta 538:355-374.
15. Simeonov, V., Stratis, J.A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., et. al., 2003, *Assessment of the surface water quality in Northern Greece*, Water Research: 37, 4119- 4124.
16. Wunderlin, D.A., Diaz, M.P., Ame, M.V., Pesce, S.F., Hued, A.C., Bistoni, M.A., 2001, *Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality*, A case study: Suquia river basin (Cordoba, Argentina). Water Research 35:2881-2894.
17. Vega, M., Pardo, R., Barrado, E., Deban, L.. 1998, *Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis*, Water Research 32, 3581-3592.

AUTHORS BIOGRAPHY

Dr. Noha Samir Donia is Associate Professor, Engineering Department, Institute of Environmental Studies and Researches, Ain Shams University. Field of interest: Environmental systems Analysis and Modeling. PhD degree in Environmental Engineering. Institute of Environmental Studies and Research. Ain Shams University. Thesis title: Study of Water Quality Control of Rosetta Branch, Nile River, Egypt. Master of Science with grade distinction, International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, Holland. Thesis title: Integration of GIS & Computer Modeling to study the Water Quality of Lake Naivasha, Kenya.

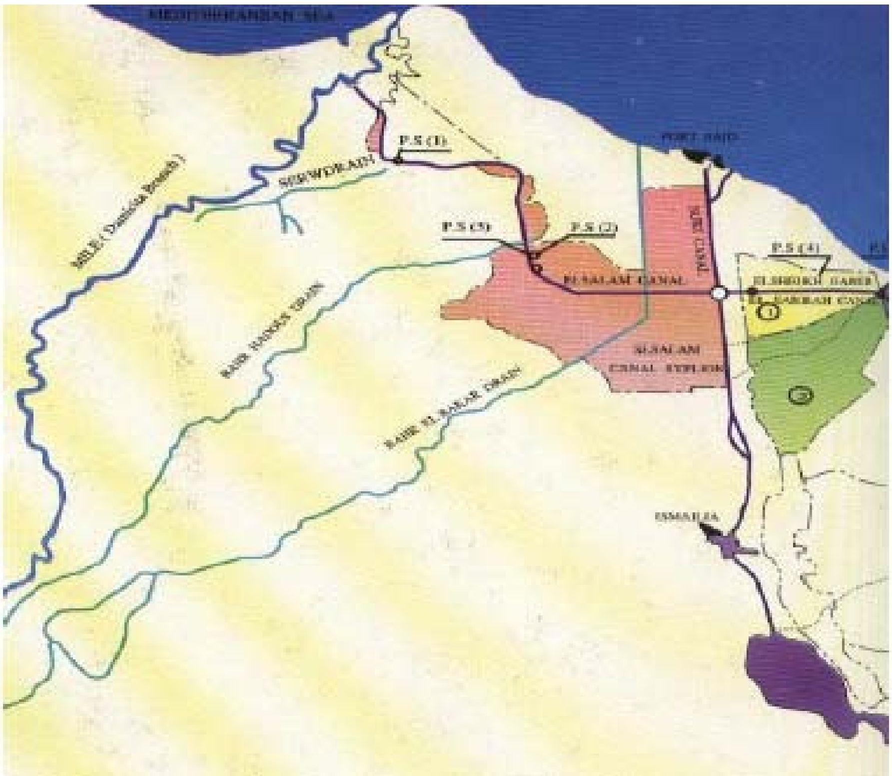

Figure 1: Layout of El Salam project

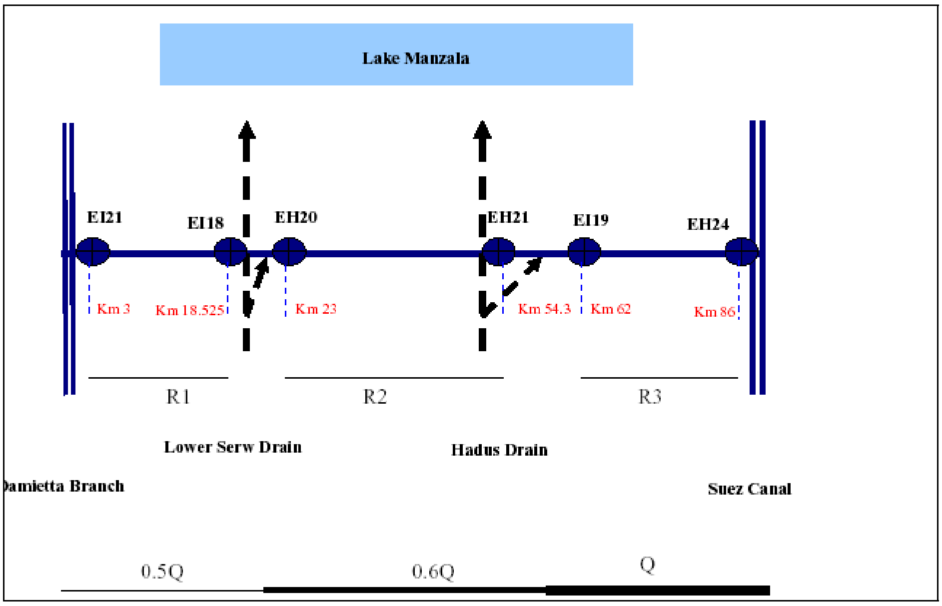

Figure 2: Schematic diagram of El Salam Canal with sample locations

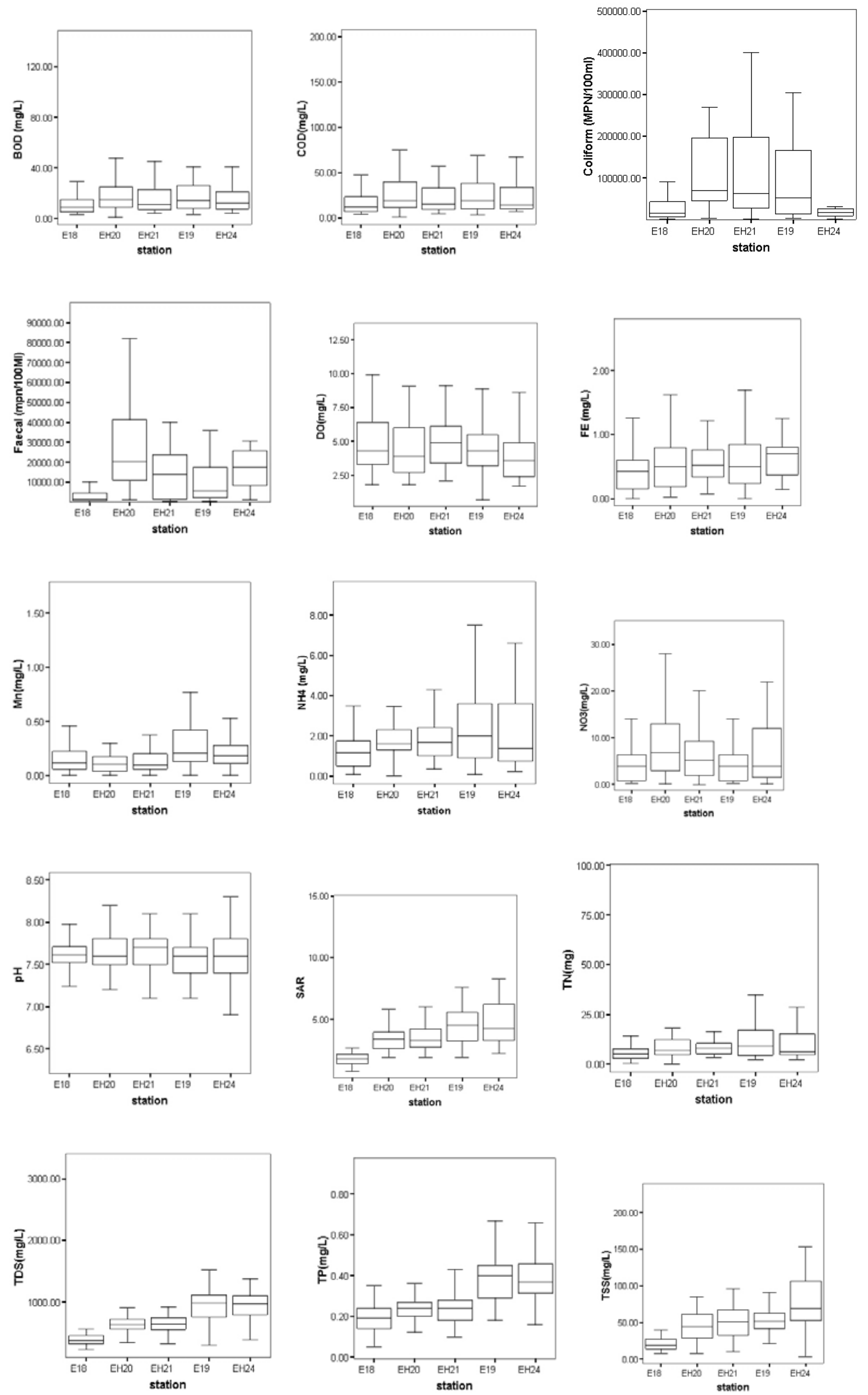

Figure 3: Spatial Variation Of Water Quality Parameters Along Elsalam Canal

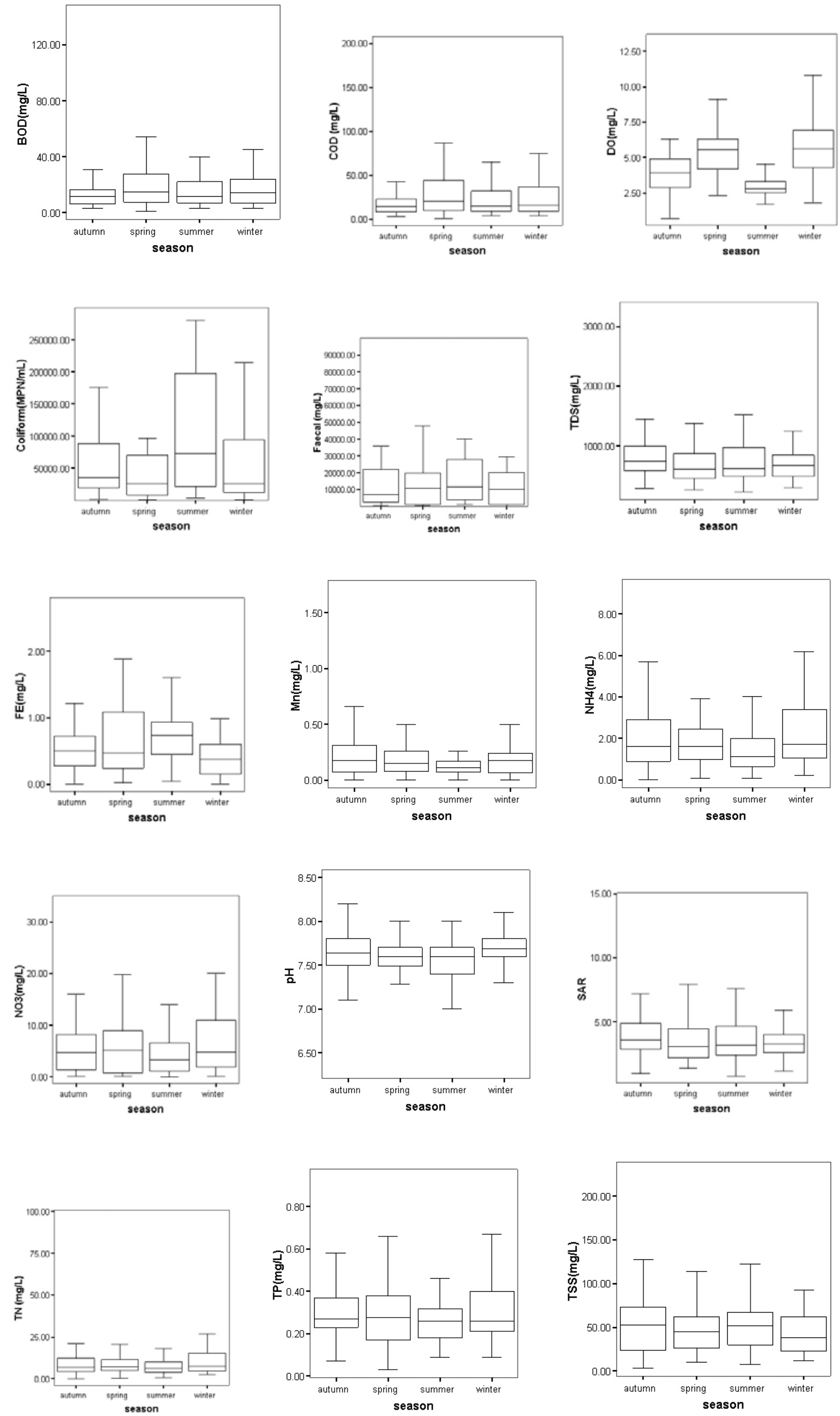

Figure 4: Seasonal Variation Of Water Quality Parameters Along Elsalam Canal

Table 1: Mean, Range and Standard deviation (S.D.) of Water Quality Parameters along El Salam Canal for the period 2001-2006.

Parameter/ Law 48 standard		EI18	EH20	EH21	EI19	EH24
DO	**Mean**	4.9	4.29	5.11	4.5	4.55
(5 mg/L)	**Range**	1.8-9.9	1.8-9	2.1-13.2	0.7-10.8	0.7-13.2
	S.D.	1.98	1.8	2.04	1.745	1.93
PH	**Mean**	7.6	7.616	7.65	7.54	7.601
(7-8.5)	**Range**	6.6-8.4	7-8.4	7.1-8.4	6.3-8.1	6.3-8.5
	S.D.	0.3	0.276	0.268	0.327	0.308
Turb	**Mean**	20.1	22.69	23.28	44.82	33.59
(20 NTU)	**Range**	8-42	10-92	0-93	13-125	0-135
	S.D.	10.4	31.39	32.06	32.57	32.8
NH4	**Mean**	1.19	1.88	1.969	2.48	2.01
(0.5 mg/L)	**Range**	0- 0.5	0.3-5.7	0.35-7.2	0.08-9.3	0-9.3
	S.D.	.818	1.15	1.33	2	1.702
BOD	**Mean**	11.5	24.6	16.5	17.25	18.63
(6 mg/L)	**Range**	3-29	1-143	4-52	3-54	1-143
	S.D.	7.7	30.88	12.6	11.18	20.1
COD	**Mean**	16.35	34.4	21.12	25.2	26.6
(10 mg/L)	**Range**	4-47	1-200	5-73	3-100	1-200
	S.D.	12.1	43.7	15.3	19.65	29.79
TSS	**Mean**	20.6	44.07	57.58	59.9	52.015
(20 mg/L)	**Range**	7.6-40	7.77-85	10-230	7.8-224	3.5-230
	S.D.	8.04	19.67	45.6	43.78	38
TDS	**Mean**	465.1	641	642	935.53	738
(500 mg/L)	**Range**	223-3284	261-1209	318-919.3	290-1517	223-3284
	S.D.	450.9	159	130	275	365
Fecal	**Mean**	3976	23000	11471	13291	4187
Coliform	**Range**	200-25000	1000-82000	600-40000	500-95,000	1200-80000
(1000)	**S.D.**	5843	18879	11492	20,060	4172
TP	**Mean**	0.22	0.24	0.24	0.408	0.302
(0.5)	**Range**	0-0.94	0.09-0.52	0.1-0.58	0-0.8	0-0.94
	S.D.	0.15	0.08	0.087	0.16	0.156
TN	**Mean**	6.32	10.06	9.96	13.4	10.19
(5 mg/L)	**Range**	0.3-45	0.04-54	3.42-56	2.03-97	0.04-97
	S.D.	6.35	9.168	8.525	14.74	10.5
CU	**Mean**	0.03	0.025	0.02	0.04	0.031
(1 mg/L)	**Range**	0-0.19	0-0.237	0-0.242	0-0.55	0-0.55
	S.D.	0.04	0.046	0.04	0.08	0.055
FE	**Mean**	0.48	0.49	0.578	0.66	0.605
(1 mg/L)	**Range**	0-1.6	0-1.62	0.07-1.84	0-2.68	0-2.7
	S.D.	0.39	0.48	0.39	0.58	0.47
Mn	**Mean**	0.17	0.136	0.16	0.269	0.19
(0.5 mg/L)	**Range**	0-0.5	0-0.66	0-1.72	0-0.77	0-1.72
	S.D.	0.14	0.13	0.24	0.204	0.207
Br	**Mean**	0.20	0.18	0.16	0.214	0.21
(0.7 mg/L)	**Range**	0-1.6	0-1.97	0-1.5	0-1.8	0-1.97
	S.D	0.30	0.38	0.315	0.34	0.351
SAR	**Mean**	1.85	3.36	3.56	4.569	3.7
(3)	**Range**	0.8-3.5	1.9-5.8	1.9-6.4	1.9-7.6	0.8-14.5
	S.D	0.65	0.95	1.129	1.576	1.92

Table 2: Mean, Range and Standard deviation (S.D.) of El Salam Water Quality Parameters seasonal variation for the period 2001-2006.

Parameter/ Law 48 standard		Autumn	Spring	Summer	Winter
DO (5 mg/L)	**Mean Range S.D.**	4.3825 1.7-9.9 1.98	5 1.8-9.9 1.71	4.1 1.7-8.38 2	4.7 1.8-9.3 1.97
PH (7-8.5)	**Mean Range S.D.**	7.6 6.9-8.5 0.28	7.59 6.4-8.4 0.3	7.55 6.56-8.3 0.33	7.63 6.56-8.2 0.3
Turb (20 NTU)	**Mean Range S.D.**	17.9 0-92 32	22.2 8-56 14.2	26.4 0-63 16.5	17.9 0-60 16.3
NH4 (0.5 mg/L)	**Mean Range S.D.**	1.41 0.06-5 1.15	1.92 0.1-0..34 1.79	1.67 0.1-6.6 1.35	1.84 0-9 1.69
BOD (6 mg/L)	**Mean Range S.D.**	13.06 1-34 8.7	17.58 3-73 15.98	26.93 4-189 37.42	25.66 4-200 31.98
COD (10 mg/L)	**Mean Range S.D.**	19.2 1-60 15.3	25.20 4-122 25.37	26.93 4-189 37.42	25.66 4-200 31.98
TSS (20 mg/L)	**Mean Range S.D.**	44.53 3.5-148 37.57	42.09 8-118 31.58	38.31 7.63-153 29.77	39.01 7.63-142 28.17
TDS (500 mg/L)	**Mean Range S.D.**	684.91 223-3284 517.6	686.5 261-3284 538.42	596.77 223-2106 355.89	585.80 261-2581.1 344.23
Fecal Coliform (1000)	**Mean Range S.D.**	9109 400-50000 12840.	141183 100-4200000 729802	723372 110-19854000 3344043	245335 200-9300000 1488081
TP (0.5)	**Mean Range S.D.**	0.27 0.07-0.94 0.157	0.253 0.05-0.76 0.15	0.25 0.05-0.6 0.114	0.3 0.09-0.94 0.18
TN (5 mg/L)	**Mean Range S.D.**	7.73 0.3-65 10.64	9.22 0.3-45 8.54	7.94 0.63-28.6 5.79	9.38 0.04-54 9.4
CU (1 mg/L)	**Mean Range S.D.**	0.033 0-0.237 0.049	0.030 0-0.197 0.045	0.024 0-0.161 0.034	0.0296 0-0.254 0.043
FE (1 mg/L)	**Mean Range S.D.**	0.501 0-1.44 0.368	0.5935 0-1.88 0.46	0.57 0.019-1.6 0.426	0.587 0.02-2.7 0.519
Mn (0.5 mg/L)	**Mean Range S.D.**	0.2 0-0.65 0.16	0.204 0-0.76 0.17	0.13 0-0.515 0.106	0.184 0-1.67 0.239
Br (0.7 mg/L)	**Mean Range S.D**	0.114 0-0.55 0.14	0.221 0-1.09 0.30	0.28 0-1.73 0.402	0.26 0-1.97 0.43
SAR (3)	**Mean Range S.D**	2.02 1-3.5 0.969	1.92 1.4-2.7 0.432	1.62 0.8-2.7 0.612	1.8 1.2-2.7 0.51

Table 3: Effects of Damietta branch (EI21), El Serw drain (ES02) and Bahr Hadous drain (EH17) on downstream at Suez Canal syphon (EH24)

Source	B	R	β	Sig
Total Coliform				
Constant	-189,72			
EI21	0	-0.126	-0.042	0.399
ES02	0.798	0.941	0.941	7.35E-17
EH17	0	-0.013	-0.004	7.35E-17
Faecal Coilform				
Constant				
EI21	0	-0.168	0.066	0.34362
ES02	**7.7**	0.919	0.919	7.56E-15
EH17	0	-0.025	0.009	0.88937
BOD				
Constant	-6.628			
EI21	0.8660	0.413	0.348	2.683772
ES02	0.947	0.601	0.491	6.56E-05
EH17	0	-0.118	-0.109	-0.70877
COD				
Constant	-11.383			
EI21	1.098	0.683692	0.461	2.23E-06
ES02	0.921	0.521397	0.441	0.000936
EH17	0	0.317202	0.253	0.055752
TP				
Constant	0.186			
EI21	0	-0.03025	-0.026	-0.17907
ES02	0	-0.28325	-0.283	-1.7473
EH17	0.380	0.547	0.547	0.000385
TN				
Constant	5.083			
EI21	0	-0.095	-0.092	0.588
ES02	0.555	0.551	0.551	0.005
EH17	0	-0.266	-0.271	0.123
TDS				
Constant	-248.353			
EI21	0	-0.072	-0.062	0.666
ES02	0.321	0.366	0.321	0.024
EH17	0.697	0.521	0.45	0.002
Mn				
Constant	-0.036			
EI21	0	-0.052	-0.043	0.631
ES02	0.851	0.398	0.338	0.000125
EH17	0.530	0.552	0.487	2.1E-08
CU				
Constant	0.014			
EI21	0.348	0.246	0.264	0.021
ES02	0.491	0.547	0.382	0.001
EH17	0	0.203	0.236	0.058