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WASTEWATER SAFE REUSE FOR IRRIGATION OF PLANTS SPECIES AND DESERTED SOILS IN AGRICULTURAL AND FOREST LAND OF WESTERN GREECE BY THE USE OF IN SITU MEASUREMENTS, LABORATORY, GIS AND GPS METHODS

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ABSTRACT

The scope of this research was to study the possibility of reuse of humid urban sewage effluents of the treated outflows of the municipal wastewater treatment plant (MWTP) of the Holy City of Messolonghi in Western Greece, for irrigation and especially in safe applications in soils and plants. In the research area have been examined various parameters that affect the soil-plant-water relationship, like chemical characteristics and mineral composition of the effluents of MWTP, macro and microelements in soils, climatic conditions, geological and hydrological data. Various samples of processed wastewaters were collected from the MWTP output on different dates, and were analysed in the laboratory. Regarding soil, the sampling procedure was used to extract soil samples in various locations (logged by 2 GPS (Global Positioning System) monitors) in the study area with auger-hole method. Soil samples were analysed in the laboratory using various methods. The GPS monitors were also used to verify the spatial location of ground truth data (MWTP, fields, deserted land, etc), and the recorded data were used in the GIS environment with the laboratory results for land use and soil mapping of the study area.

Results showed that the mean values of the wastewater parameters were: pH=7.76, SAR=3.9, EC=1.2 dS/m at 25 ^{o}C, TDS=791.8 (ppm), the mean concentrations of elements in (mg/l) were N=12.2, P=0.4, K=17.1, Na^{+}=164.5, cations Ca^{++}=93.4 and Mg^{++}=21.2, anion Cl^{-}=227.8, B=1.1, and the concentrations of elements in (μg/l) of As=0.7, Cr=1.2, Cu=2.8, Fe=121.5, Mn=108.3, Zn=95.6 and also the values of physicochemical properties and concentrations of soils elements for the area of MWTP, were within the limits that the World Health Organization has defined and that the wastewaters can be safely reused for the irrigation of plants and deserted soils. So, it is a necessity the proper planning, operation and safe disposal of the MWTPs outflows, per Prefecture and Region, according to the local character of its region (soil conditions, wastewater quality, environmental risk, social impacts and stackeholders' approval, etc), through safe wastewater irrigation networks, integrated water resources management (IWRM) and application in suitable soils, crops, plant and tree species in order to be minimized the negative effects to the environment (soil, air and aquatic resources), the human health and the natural ecosystems. The major challenge in this environmental theme is to optimize the benefits of wastewater as a resource of both the water and the nutrients it contains, and to minimize the negative impacts of its use on human health.

Key words: Wastewater safe reuse, irrigation of plants and deserted soils, GIS and GPS methods and mapping, soils elements measurements, agricultural and forestland irrigation.

1. INTRODUCTION

Nowadays, as the environmental pressures are increased, a lot of communities around the world approach or reach the limits of their available water reserves, so, the safe reuse of wastewater it is presented as an attractive choice for the maintenance of available water resources. On the other hand, environmental pollution of rivers, streams, torrents, lakes, seas and groundwater resources, due to wastewaters and bio-sludge disposal is one of the most important problems of the modern society, and it becomes more complicated in situations of coastal cities and in islands which are usually popular tourist destinations.

Greece as a Mediterranean country, it's characterized by a severe water imbalance particularly in the summer months, due to low precipitation and, at the same time, increased demands for irrigation and potable water use due to thrifty tourism. The climate of Greece is subhumid Mediterranean with humid and relatively cold winters and dry and warm summers with an average of rainfall of 870 mm/yr [1]. Also, Greece with an estimated today population of 11 million has to comply with the 91/271/EC directive on urban wastewater treatment [2]. Thus, today about 350 municipal wastewater treatment plants (MWTPs) can serve about 65% of the country's permanent population. For the remaining 21% it is estimated that 1500 MWTPs will be needed. The remaining 14% of the population is in agglomerations for which on site sanitation technologies should be required [3]. So, the reuse of treated municipal wastewater in land irrigation constitutes today a practical method of disposal which is expected to contribute decisively in the immediate future towards the handling and the minimization of the environmental problems arising from the disposal of wastewater on land and in aquatic systems [4].

Water reuse applications fall under one of seven categories: a) agricultural irrigation, b) landscape irrigation, c) groundwater recharge, d) industrial reuse, e) environmental and recreational uses, f) non-potable urban uses, and g) indirect or direct potable reuse [5], [6]. Institutional, administrative and managerial factors should be taken seriously into account when planning water and sanitation policies [7]. Part of these factors, are the following water quality factors which are particularly significant in groundwater recharge with reclaimed wastewater: a) microbiological quality, b) total dissolved solids, c) the concentrations of stable and potentially harmful organic substances d) the concentrations in heavy metals [8], [5], [6], [4].

The objectives of this project are to analyze the current status of the wastewater and soil quality, and study the suitability of soils and wastewater, for irrigation of plants and deserted soils, in Western Greece, with the use of in situ measurements and laboratory, GIS and GPS methods, in terms of wastewater availability, quality and safe reuse.

2. EXPERIMENTAL PART

2.1. Materials

Data and samples collection: A study was performed in the water region of West Central Greece, on soil status and wastewater (MWTP of the Holy city of Messolonghi) quality. They have been examined various parameters that affect the soil-plant-water relationship. Various samples of processed wastewaters and of soils were collected on different dates.

2.2. Instruments-devices

Regarding soil, two GPS (Global Position System) devices were used to log spatial data of the various locations where soil samples were extracted. The pH of the soils was measured as a saturated paste extract with a pH instrument (pH electronic meter). Various elements concentrations were measured by an ICP-AES instrument (Inductively Coupled Plasma Atomic Emission Spectroscopy).

Wastewater's EC was measured using a DO instrument (Dissolved Oxygen meter) and TDS with a TDS electronicmeter. The determination of various wastewater elements was made through the process of atomic adsorption spectroscopy furnace instrument (2100 Perkin Elmer Spectrometer).

2.3. Methods

Regarding soil, samples in various locations were extracted with auger-hole method and at the same time 2 GPS monitors were used to log spatial data.

Laboratory analysis of soil samples: In the soil samples were measured the following parameters pH, $CaCO_3$, EC (electrical conductivity in Mmhos/cm), organic matter (%), P (Olsen in ppm), K (ppm), Ca and Mg in me/100g and also the concentrations of elements B, Mn, Zn, Fe, Co, Ni, Cd, Pb, Cu, in ppm. Soil samples were air dried ground with a pestle and mortar and finally dried at 50 ^oC for 4h. For the determination of soil's texture it was used the Bougioukou method, for the organic matter the method of humid combustion of sample with divine acid, the pH was measured as a saturated paste extract with a pH electronicmeter and soil EC was measured on saturated paste extract with conductivity cell. Replicate samples (0.25g sieved and ground in a team that will have cocoid size of 100μm) were digested by Aqua Regia Acid HCl/HNO_3 and analyzed for their elements concentrations by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Available P was determined by the method of Olsen *et al.* (1954), while B was extracted by boiling water and determined by the curcumin method.

Laboratory analysis of wastewater samples: In the wastewaters samples were measured the following parameters: pH, SAR, EC (electrical Conductivity in dS/m at 25 ^oC), TDS (total dissolved solids in ppm), N, P, K, Na^+, Ca^{++}, Mg^{++}, Cl^- and B in mg/l, and the concentration of elements As, Cr, Cu, Fe, Mn and Zn in (μg/l). The pH was measured with a pH electronicmeter, the EC was measured using a dissolved oxygen meter and TDS with a TDS electronicmeter. The determination of the elements was made through the process of atomic adsorption spectroscopy furnace technique (2100 Perkin Elmer Spectrometer). The SAR which is an index of the Sodium Adsorption Ratio was calculated by the following equation (1):

$$SAR = \frac{\left[Na^+\right]}{\sqrt{\frac{\left[Ca^{2+}\right] + \left[Mg^{2+}\right]}{2}}} \qquad (1)$$

where all the cations concentrations are in meq/l.

3. RESULTS-DISCUSSION

a) Wastewater quality, correlations and safe irrigation: Regarding safe irrigation, the key to this theme is the wastewater quality. The comprehensive wastewater analysis of Messolonghi's MWTP will indicate its suitability for irrigation use (*Table I*). From the statistical data analysis (statistical t-test) of the wastewater samples parameter data, that was conducted with the use of SPSS statistical software, it is observed that there isn't significant statistical difference among the samples of the MWTP for the following parameters: pH, SAR, EC, TDS, N, P, K, Na^+, Ca^{++}, Mg^{++}, Cl^-, B, As, Cr, Cu, Fe, Mn and Zn, at level of significance $p<0.05$.

Table I. *Physicochemical properties and concentrations of chemical elements of wastewaters for the area of MWTP in Messolonghi, Western Greece.*

		WASTEWATER SAMPLES OF MESSOLONGHI MWTP													
SN	PARAMETER	WWS1	WWS2	WWS3	WWS4	WWS5	WWS6	WWS7	WWS8	WWS9	WWS10	WWS11	WWS12	Mean	Sig. (p-value)
1	pH	7.41	6.91	8.82	7.86	7.67	7.25	8.40	7.52	7.49	7.71	7.94	8.12	7.76	0.0000
2	SAR	4.20	4.00	3.98	4.06	4.58	4.32	3.80	3.26	4.41	3.73	3.62	3.94	3.99	0.0000
3	EC (dS/m at 25° C)	1.37	1.50	1.09	0.98	1.19	1.27	1.32	1.08	0.98	1.17	1.49	1.42	1.24	0.0000
4	TDS (ppm)	875.00	962.00	695.00	628.00	761.00	814.0	843.0	689.0	625.0	748.0	953.0	909.0	791.83	0.0000
5	N (mg/l)	13.50	17.50	14.00	11.50	6.00	12.10	14.20	14.70	9.00	5.40	12.60	15.80	12.19	0.0000
6	P (mg/l)	0.42	0.60	0.42	0.46	0.18	0.44	0.57	0.63	0.48	0.47	0.25	0.38	0.44	0.0000
7	K (mg/l)	25.00	24.00	13.10	11.60	13.60	22.00	15.60	20.70	11.40	12.30	21.90	14.20	17.12	0.0000
8	Na (mg/l)	160.00	160.00	160.00	160.00	200.00	165.00	150.00	140.00	205.00	155.00	150.00	170.00	164.58	0.0000
9	Ca (mg/l)	71.00	80.00	92.90	92.80	108.00	87.10	79.70	111.30	118.00	94.80	82.50	103.60	93.48	0.0000
10	Mg (mg/l)	23.40	24.70	17.70	14.90	21.60	13.90	22.80	16.90	27.20	21.30	28.40	22.10	21.24	0.0000
11	Cl (mg/l)	320.00	340.00	203.20	178.00	230.00	165.40	201.90	245.20	242.70	217.90	184.70	205.30	227.86	0.0000
12	As (μg/l)	0.60	0.29	1.38	0.97	0.40	0.42	0.51	0.46	0.66	0.88	1.40	0.73	0.73	0.0000
13	B (mg/l)	1.10	0.90	1.90	1.30	0.90	1.05	0.85	1.26	0.95	1.20	0.90	1.47	1.15	0.0000
14	Cr (μg/l)	1.29	1.25	1.29	1.25	1.29	1.25	1.28	1.24	1.25	1.22	1.27	1.26	1.26	0.0000
15	Cu (μg/l)	4.10	2.50	3.30	2.20	2.20	2.00	2.40	3.80	2.60	2.10	4.20	2.80	2.85	0.0000
16	Fe (μg/l)	210.00	256.00	20.00	120.00	40.00	75.00	91.00	178.00	265.00	18.00	52.00	134.00	121.58	0.0006
17	Mn (μg/l)	97.30	150.00	200.00	30.00	19.00	84.60	142.80	203.40	88.70	28.00	92.60	163.70	108.34	0.0001
18	Zn (μg/l)	100.00	65.00	205.00	61.80	49.00	97.00	45.00	124.00	207.00	82.00	57.00	55.00	95.65	0.0001

Also, the statistical data analysis (statistical regression and Pearson Correlation) and the diagrams of the wastewater elements correlations (*Figure 1 and 2*), revealed the positive and negative correlations among elements. The pH has a high correlation with As(0.656). The wastewater's SAR has a high correlation with Na(0.841). The EC has high correlation with TDS(1.000), K(0.661) and Ca(-0,629).

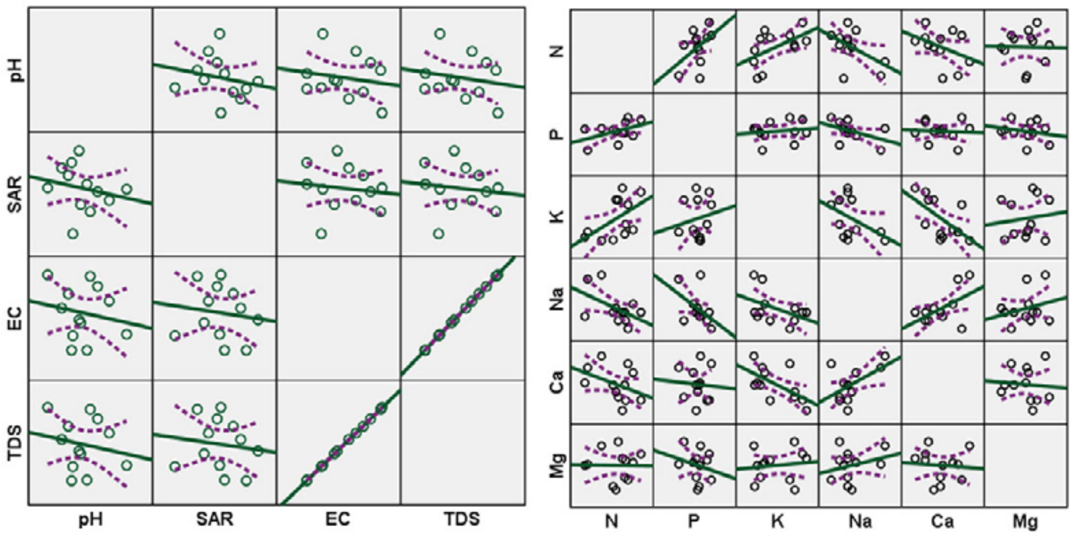

Figure 1: *Diagrams with wastewater's elements correlations (pH, SAR, EC, TDS, N, P, K, Na, Ca, Mg), with linear regression model fit lines and mean confidence interval curves.*

The Ca has high correlation with EC(-0.629) and TDS(-0.629). The CI has high correlation with Fe(0.695). The As has high correlation with pH(0.656). The B has high correlation with Zn(0.749). The Fe has high correlation with CI(0.695). The Mn has high correlation with N(0.797). The Zn has high correlation with B(0.749) and pH(0.656). The TDS has high correlation with EC(1.000), K(0.661) and Ca(-0,629). The Nitrogen has high correlation with Mn(0.797). The Potassium has high correlation with EC(0.661) and TDS(0.661). The Na has high correlation with SAR(0.841).

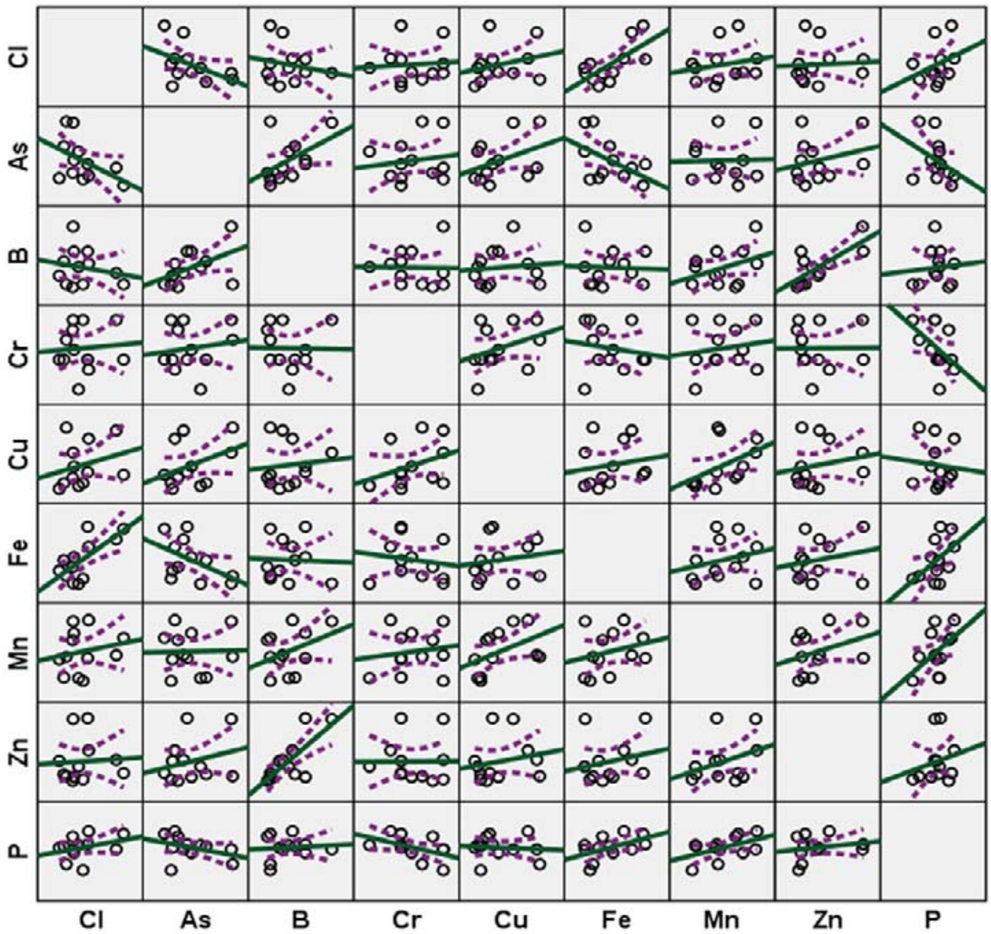

Figure 2: *Diagrams with wastewater's elements correlations (CI, As, B, Cr, Cu, Fe, Mn, Zn, P), with linear regression model fit lines and mean confidence interval curves.*

The acidity or basicity of irrigation water is expressed as ***pH*** (< 7.0 acidic; > 7.0 basic). The normal (safe) ***pH*** range for irrigation water is from 6.5 to 8.4 [8], and the Messolonghi's MWTP wastewater is fall in these limits (safe).
EC (1.24 dS/m***)*** is an important and reliable indicator of the total dissolved solids (salts) content of the water, and has a degree of restriction on use, slight to moderate and is acceptable (possibly safe).
Also, the rest of the parameters are considered according to WHO classification [9].
Sodium Adsorption Ratio (SAR) is an indicator of the sodium hazard of water and the degree of restriction on use is none (safe).
The mean value of wastewater's ***TDS*** is 791.83 ppm and the degree of restriction on use is slight to moderate, and is considered acceptable (possibly safe).
Nitrogen's degree of restriction on use is slight to moderate (possibly safe).
Chloride's degree of restriction on use is slight to moderate (possibly safe).

Boron (B) is very toxic to most crops at very low levels. Boron's degree of restriction on use is slight to moderate, and is considered acceptable (possibly safe).
Arsenic, chromium, copper, zinc are on acceptable levels (safe), bellow of threshold levels of trace elements for crop production, according to Pescod (1992), [10] and WHO (2006), [9]. ***Iron's*** and ***Manganese's*** degree of restriction on use is slight to moderate and are considered acceptable (possibly safe).

b) Soils quality: The laboratory results of the physicochemical properties and the concentrations of elements of soils for the study area (*Figure 3.A*) are listed in *Table II*. From the statistical data analysis (statistical t-test) of the soil samples parameter data, that was conducted with the use of SPSS statistical software, it is observed (*Table II*) that there is significant statistical difference among the soil samples for the following parameters: pH, $CaCO_3$, organic matter, P, K, Ca, Mg, B, Mn, Zn, Fe, Cu, Cd and Pb at level of significance $p<0.05$.

Table II. *Physicochemical properties and concentrations of chemical elements of soils for the greater area of MWTP in Messolonghi, Western Greece.*

SOIL SAMPLES OF MESSOLONGHI'S MWTP GREATER AREA															
	PARAMETER	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12	Mean	Sig. (p-value)
1	Soil texture	L	L	CL	CL	L	CL	CL	L	L	CL	CL	L		
2	pH	8.47	8.36	7.85	8.25	8.32	8.42	7.96	8.37	8.34	7.90	8.44	8.42	8.26	0.0000
3	free $CaCO_3$	3.50	7.90	11.00	7.00	4.10	11.80	6.91	6.30	5.70	6.70	11.82	7.30	7.50	0.0000
4	E.C. mmhos/cm 25 ° C	2.98	1.65	49.80	0.65	0.84	40.49	0.32	2.91	1.87	0.62	29.27	2.01	11.12	0.0544
5	Organic matter OM %	1.65	2.38	0.98	3.95	0.05	0.07	0.34	0.03	0.71	0.79	0.25	0.13	0.94	0.0190
6	P (Olsen) ppm	17.32	10.98	26.16	36.61	4.63	14.39	17.28	5.78	7.49	15.63	9.35	4.82	14.20	0.0003
7	K ppm	310.00	320.00	390.00	410.00	302.00	418.55	398.52	307.00	305.00	392.37	419.51	311.00	357.00	0.0000
8	Ca me/100 g	3.55	4.49	4.75	4.13	3.42	5.05	3.99	3.51	3.47	3.95	5.06	3.54	4.08	0.0000
9	Mg me/100 g	1.01	0.50	0.98	0.70	0.72	1.04	0.68	0.78	0.69	0.67	1.04	0.94	0.81	0.0000
10	B ppm	4.88	2.43	1.43	2.54	2.11	1.52	2.46	2.39	2.27	2.43	1.52	2.47	2.37	0.0000
11	Mn ppm	6.22	7.00	3.92	5.05	4.51	4.16	5.03	5.02	4.55	4.83	4.17	5.36	4.99	0.0000
12	Zn ppm	1.54	0.84	1.92	1.97	0.79	2.04	1.96	0.85	0.82	1.89	2.04	0.93	1.47	0.0000
13	Fe ppm	16.77	28.27	9.27	28.72	12.42	9.84	28.63	14.22	13.09	27.49	9.86	15.96	17.88	0.0000
14	Cu ppm	2.21	3.59	1.88	3.34	1.95	1.98	3.32	2.07	1.98	3.20	1.98	2.19	2.47	0.0000
15	Cd ppm	0.05	0.11	0.11	0.10	0.07	0.12	0.10	0.10	0.09	0.10	0.12	0.11	0.10	0.0000
16	Co ppm	0.00	0.10	0.08	0.00	0.05	0.08	0.00	0.07	0.05	0.00	0.08	0.90	0.12	0.1307
17	Ni ppm	0.47	0.73	0.07	1.35	0.11	0.00	0.03	0.00	0.02	0.07	0.03	0.05	0.24	0.0659
18	Pb ppm	2.86	2.69	4.94	2.92	2.57	5.19	2.90	2.77	2.61	2.79	5.20	2.91	3.36	0.0000

Additionally we observe that there is not important difference among the samples of soils for EC, Co, and Ni at the 0.05 significance level. The values of physicochemical properties and concentrations of chemical elements of soils of Messolonghi MWTP *greater* area are in the limits of WHO (2006).

c) Conditions for safe irrigation development: Issues and conditions to be assessed when dealing with wastewaters that are "Possibly Safe" are as follows:
Climate of the area, Irrigation Practices, Soils Internal drainage and Crops Selection.

c.1) Climate of the study area: The mean annual rainfall of the study area is 405.3 mm with 57.39 % falling in rainy season (September-December). The higher mean monthly rainfall is r_w = 112.7 mm and it is observed in November. The lower mean monthly rainfall is r_d = 1.9 mm at the month of August. The average monthly temperature ranges

from 9.3 °C in January to 29.0 °C in July. Also, the mean effective rainfall was calculated with the USDA method and it is presented in *Figure 3.B.*
The study area (Western Central Greece) (*Figure 3.A*) has a subhumid Mediterranean climate with humid and relatively cold winters and dry and warm summers.

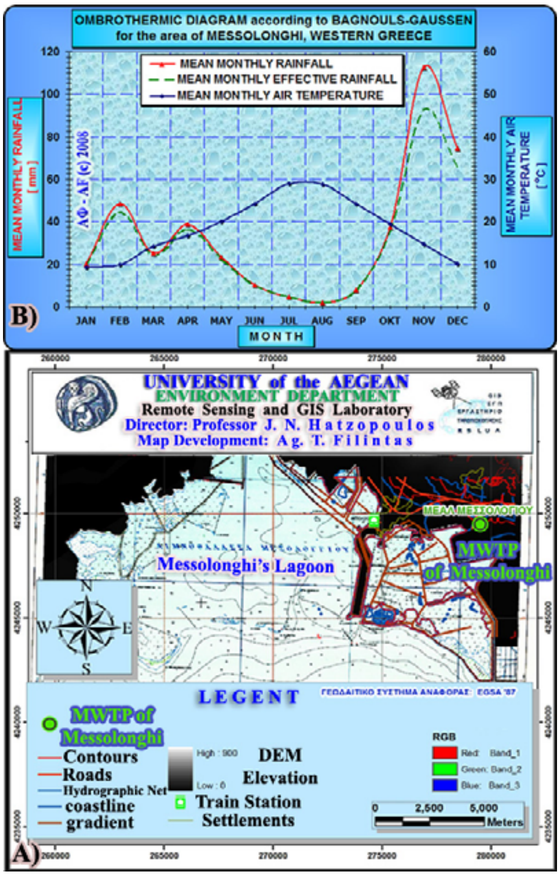

Figure 3: *A) GIS map of the study area. B) Ombrothermic diagram of the study area and monthly effective rainfall.*

From the meteorological data (*Figure 3.B*) appears that at summer time the study region had deficit of moisture and it is necessary the application of irrigation in plants and trees. The deficit dictates the amount of water applied and consequently the amount of salt applied.

c.2) Irrigation Practices: Light, frequent irrigation (LFI) results in less leaching than less frequent water applications and in more evaporation [1]. So, the proposed method of irrigation with safe or/and possibly safe water quality is Localized irrigation (LI) LFI through safe wastewater irrigation networks. LI irrigation, particularly when the soil surface is covered with plastic sheeting or other mulch, uses effluent more efficiently and it can often produce higher crop yields. Also, LI application provides the greatest degree of health protection for farm workers and consumers.
The most suitable irrigation systems for the study area are: Trickle and Drip Irrigation, Subsurface Drip Irrigation and Intermittent Drip Irrigation.

c.3) Soils Internal drainage: The good internal drainage of the study area facilitates rapid leaching of salts out of the root zone.

c.4) Crops Selection: Crops with high consumptive use require more irrigation water which results in higher salt applications. Considering the wastewater quality parameters laboratory results, of Messolonghi's MWTP effluents and the performed classification (safe, possible safe, hazardous), the acceptable threshold levels of trace elements for crop production and the maximum tolerable soil concentrations of various toxic chemicals based on health protection, we were be able to conclude that under these conditions it is possible for the stakeholders' (interested farmers, local authorities) to cultivate and irrigate with wastewaters some rural plants and forestry species. The selected and proposed rural crops, classified from medium to high tolerance for various chemical elements of the studied parameters, are: *Broccoli, lettuce, corn, corn forage, alfalfa, Trefoil (narrowleaf birdsfoot and broadleaf), zucchini squash, wheat durum,* *sorghum, soybean, sugar beet, barley, cotton and asparagus.* The selected and proposed forestry-tree species are: *Pinus maritima, Pinus sylvestris, Nerium oleander, Myoporum spp., Olea europaea.*

Conclusively, results showed that it is a necessity the proper planning, operation and wastewater disposal of the MWTPs outflows, per Prefecture and Region, according to the local character of its region (soil quality and internal drainage, wastewater quality, climate, irrigation practices, crops selection, environmental risk and stackeholders' approval, etc), through safe wastewater irrigation networks, IWRM and application in suitable soils, crops, plant and tree species in order to be minimized the negative effects to the environment (soil, air and aquatic resources), the human health and the natural ecosystems. The major challenge in this environmental theme is to optimize the benefits of wastewater as a resource of both the water and the nutrients it contains, and to minimize the negative impacts of its use on human health.

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BIBLIOGRAPHY

1. Filintas, T.Ag. 2005. Land Use Systems with Emphasis on Agricultural Machinery, Irrigation and Nitrates Pollution, with the Use of Satellite Remote Sensing, Geographic Information Systems and Models, in Watershed Level in Central Greece, M.Sc. Thesis, University of Aegean, Faculty of Environment, Department of Environmental Studies, Mytilene, Greece (In Greek with English abstract).
2. EU, 1991. Council Directive Concerning Urban Wastewater Treatment, 91/271 EC of May 21, 1991. Official Journal L135/40, May 30.
3. Angelakis, A.N., K.P. Tsagarakis, O.N. Kotselidou, and E. Vardakou. 2000. The Necessity for Establishment of Greek Regulations on Wastewater Reclamation and Reuse. Report for the Ministry of Public Works and Environment and Hellenic Union of Municipal Enterprises for Water Supply and Sewage. Larissa-Greece, pp.110(in Greek).
4. Kalavrouziotis, I., K., Hortis, T. and Drakatos, P., 2004. The reuse of wastewater and sludge for cultivation forestry trees in dessert areas in Greece. *International Journal of Environment and Pollution,* 21, 5, 425-439.
5. Asano, T., 1998. Wastewater, reclamation and reuse. Technomic Publishing Co. Lancaster-Basel, 10, 1060-061.
6. Asano, T., 2003. Water Reuse: A Future Perspective, Water Resources and Water Supply, in the Supply in the 21st Century. Edited by Y. Watanabe and N. Funamizu, Hokkaido University Press, Sapporo, 33-46.
7. Tsagarakis, K.P., Mara, D.D., Horan, N.J., Angelakis, A.N., 2001. Institutional status and structure of wastewater quality management in Greece. *Water Policy*, 3 (1): 81-99.
8. WHO, 1989. Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture. WHO: Geneva, Switzerland. 187 pp.
9. WHO, 2006. Guidelines of the Safe Use of Wastewater, Excreta and Grey Water: Wastewater Use in Agriculture, Vol. 2. World Health Organization, Geneva, Switzerland.
10. Pescod, M.B., 1992. Wastewater treatment and use in agriculture. Rome, Food and Agriculture Organization of the United Nations (FAO Irrigation and Drainage Paper 47).