Production, characterization and treatment of wastewater from textile manufacturing installations at Asopos river area

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Abstract— This work investigated the wastewater characteristics of textile industrial installations located in the wider region of Oinofita–Schimatari at Viotia, Greece, one of the most industrialized areas in Greece. For the needs of this work, waste water samples have been collected and the results of wastewater sample analysis are presented. The assessment of monitoring and analysis results for the five participating installations is being made in comparison to the limit values for indirect discharge to sewer, as this is the proper discharge method that should be followed. It is worth noting that all these industrial units have installed and applied biological treatment in order to achieve the desired reduction of the pollutant load of their waste water. From the results of the samples analysis, it is concluded that some parameters are above the limits for disposal in a sewer system (indirect discharge). The fact that the limit values for direct discharge to Asopos river (based on Ministerial Decree 20488/2010) are very strict and difficult Industrial wastewater will be below them, advocates the need to establish a central wastewater treatment plant which will serve and the other industrial sectors in the region.

Index Terms— Textile manufacturing, Industrial wastewater, Treatment processes, Polluting parameters, Central treatment plant, Asopos river, Central treatment plant

1 Introduction

Textile and Clothing (T&C) is one of the largest and oldest industries present on a global scale. Despite the drastic changes in the number of installations and the total installed capacity in the European Union (EU) member states during the last 15 years, it still remains one of the main industrial sectors with significant share in terms of income and employment [1].

The textile industry is one of the longest and most complicated industrial chains in manufacturing industry. It is a fragmented and heterogeneous sector dominated by SMEs, with a demand mainly driven by three main end-uses: clothing, home furnishing and industrial use[2].

The Manufacture of textiles is classified into four main categories, based on the NACE codes classification: C13.1 - Preparation and spinning of textile fibres, C13.2 - Weaving of textiles, C13.3 - Finishing of textiles and C13.9 - Manufacture of other textiles (C13.9.1 - Manufacture of knitted and crocheted fabrics, C13.9.2 - Manufacture of made-up textile articles, except apparel, C13.9.3 - Manufacture of carpets and rugs, C13.9.4 - Manufacture of cordage, rope, twine and netting , C13.9.5 - Manufacture of non-wovens and articles made from non-wovens, except apparel , C13.9.6 - Manufacture of other technical and industrial textiles and C13.9.9 - Manufacture of other textiles n.e.c.).

The textile industry is considered of having a significant environmental impact. The main environmental concern is related to the amount of water discharged and its chemical load. Other important issues are energy consumption, air emissions, solid wastes and odours, which can be a significant nuisance in certain processes [3].

There is a long-term background on controlling emissions to air but this is not the case for emissions to water bodies. Various waste water streams, originated from different processes are mixed together and result in a complex combination of wastewater effluent that is related to various factors, like: the type of raw materials used (fibres), the applied production processes and techniques, the chemicals and other auxiliaries used [3], [4].

The textile industry utilizes various chemicals and a large amount of water during the production process. About 200 L of water are used to produce 1 kg of textile. The water is mainly used for application of chemicals onto the fibers and rinsing of the final products. The waste water produced during this process contains a large amount of dyes and chemicals containing trace metals such as Cr, As, Cu and Zn which are capable of harming the environment and human health. The textile waste water can cause hemorrhage, ulceration of the skin, nausea, skin irritation and dermatitis. The chemicals present in the water block the sunlight and increase the biological oxygen demand thereby inhibiting photosynthesis and reoxygenation process [5].

This study deals with the assessment of wastewater characteristics of 18 textile industrial installations located in the wider region of Oinofita–Schimatari at Viotia, Greece. This is one of the most industrialized areas in Greece, as a significant num-

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ber of industrial installations is concentrated in this zone. Therefore, the area is facing immense environmental problems, mainly due to the discharge of untreated or poorly treated industrial wastewater in the Asopos River.

It should also be noted that despite the fact that the majority of industrial units operating in the area have installed systems for the collection and treatment of waste water (waste water treatment facilities –wwtf), the problem of quality degradation of natural recipients and aquifer in general, remains acute. This is either due to the unsatisfactory operation of waste water treatment facilities, due to technical or operational problems or due to the small efficiency of existing treatment facilities in relation to the required (undersizing). The above have led to a situation that makes Asopos River one of the most contaminated water streams in Greece that affects both the areas crossed and the coastal area Chalkoutsiou where flows [6].

2 EXPERIMENTAL PROCEDURES

For the needs of the current study, waste water samples have been collected from a total of 5 industrial installations. The samples were collected in plastic 10-l bottles preserved at 4 °C before analysis and were analyzed within 1–2 days. Pollutants in wastewater from textile factories vary greatly and depend on the chemicals and treatment processes used. Pollutants that are likely to be present include suspended solids, biodegradable organic matter, toxic organic compounds (e.g. phenols), and heavy metals [4].

In the area there is a total of six industrial installations belonging to the sector C13.1 - Preparation and spinning of textile fibers (industrial units with serial numbers 1, 2, 3, 4, 5 and 6), of which only three units (serial number 1, 2 and 3) were in operation during the sampling period. In particular, of the three operating installations, those with serial numbers 2 and 3 are active in weaving cotton yarn, by using the proper machinery for the production of textile, while the installation with serial number 1 is dedicated to weaving cotton, wool and blended yarns such as nylon, polyesters, polyamides and polyacrylates. It should be noted that during the manufacturing process of these units, there is no water use and therefore no wastewater production.

In addition, in the study area, there are eleven (11) industrial installations engaged in dyeing and finishing of fabrics, i.e. installations with serial number 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17. Five (5) of these installations (serial numbers 13, 14, 15, 16 and 17) were not in operation during the elaboration of the study while the remaining installations are devoted to the dyeing and / or printing has and cotton finish-mixed and polyester textiles. The installation with serial number 8 has a very little amount of wastewater effluent and it has not been taken into account. The installation with serial number 18 is engaged in manufacturing of hosiery and finishing.

The activities for each textile production installation as well as the processes that originate the wastewater effluents are summarized in Table 1.

It should be noted that these industries were selected, taking into consideration that their waste water treatment facilities apply different treatment methods.

The most important parameters in wastewater from textile industry are: COD (Chemical Oxygen Demand), BOD5 (Biological Oxygen Demand), pH, fats, oil, nitrogen, phosphorus, sulphate and SS (suspended solids) [7].

TABLE 1:

SOURCES OF INDUSTRIAL WASTEWATER

Serial Number	Activity	Wastewater production	Processes producing wastewater
1	Preparation and spinning of textile fibers	NO	
2	"	NO	
3	"	NO	
4*	"	-	
5*	"	-	
6*	"	-	
7	Finishing of textiles	ϒES	- Cold dyeing and finishing - Washing, prebleaching, bleaching and dyeing (main waste stream) - Spinning - Finishing - Discharges during regeneration of softening unit - Bleed-off water from the paint tank cooling
8	Finishing of textiles	YES	-Pretreatment
9	Finishing of textiles	YES	- Washing - Bleaching - Mercerizing - Dyeing - Finishing - Floor and machine washing
10	Finishing of textiles	YES	- Washing - Bleaching - Dyeing - Finishing - Floor and machine washing
11	Finishing of textiles	YES	- Washing - Dyeing - Bleaching - Finishing - Bleed-off from the cooling towerDischarges during regeneration of softening unit - Floor and equipment rinsing
12	Finishing of textiles	YES	- Washing, Mercerizing - Dyeing - Finishing - Floor and equip-

			ment rinsing
13*	"	-	
14*	"	-	
15*	"	-	
16*	"	-	
17*	"	-	

Note: * Installation not in operation

The influent and effluent characteristics and efficiencies of treatment plants of the mills, most of which are cotton-fabric refining mills and polyester, wool, acrylic, were investigated in this study. The parameters of pH, total suspended solids (TSS) and dissolved solids (DS), were determined using standard methods of analysis [8]. Colour was measured photometrically according to ASTM D 1209 (ASTM, 2000). Lead, copper, zinc, nickel, cadmium, chromium, sodium, potassium, calcium and magnesium were determined using the fast sequential atomic absorption spectrometry (model AA240FS of Varian). Heavy metal measurements were conducted according to standard methods of analysis 3111 (APHA, 5522 Water Air Soil Pollut (2012) 223:5519–5534 AWWA, WEF, 1998). Chemical oxygen demand (COD), total phosphorous (Ptotal), ortho-phosphates (PO4-P), sulphates (SO42−), ammonium nitrogen (NH4-N), nitrate nitrogen (NO3-N), total nitrogen (Ntotal) and chlorides (Cl−) were determined using the Merck Spectroquant Nova 60 photometer and Spectroquant Merck kits.

3 Results and Discussion

In this chapter, the results of wastewater sample analysis from five industrial installations belonging to the 'the production of textiles and textile products' sector, for the most important polluting parameters are presented.

It is worth-noticed that wastewater characteristics and parameters produced from installations of the same industrial sector have significant differences depending on the installation-specific production process, and the raw materials that were used.

The applied waste water treatment processes at the wwtf for the installations of the current study are summarized in table 2 below

The results of sample analysis for the five installations (serial numbers 7, 9, 10, 11, 12) are presented in table 3

At this point, it is worth-noticed the corresponding discharge limit values for various parameters that are applicable according to the Greek legislation for the direct and indirect discharge of waste water flows. The corresponding limit values are presented in the following Table 4.

The assessment of monitoring and analysis results for the five participating installations is being made in comparison to the limit values for indirect discharge to sewer, as this is the proper discharge method that should be followed based on the data analysis. For comparison reasons, the corresponding limit values for direct discharge to Asopos River are also presented.

Table 4:
Limit values by the Greek legislation for direct and indirect waste water discharge

Quality parameters	Limit values for indirect discharge to sewer	Limit values for direct discharge to Asopos river (based on Ministerial Decree 20488/2010)
pH	6.0-9.0	**6.5-8.5**
BOD_5 [mg/l]	500	**≤ 10**
COD [mg/l]	1.000	**≤ 125**
TSS [mg/l]	500	**≤ 10**
TDS [mg/l]	3.000	**≤ 1500**
Grease - oil[mg/l]	40	**≤ 8**
NO_3-N [mg/l]	20	**≤ 7**
PO_4-P [mg/l]	10	**≤ 1**
Cu [μg/l]	1	**≤ 200**
Fe [μg/l]	15	**≤ 3000**
Pb [μg/l]	5	**≤ 100**
Zn [μg/l]	20	**≤ 2000**

TABLE2 :

QUANTITY, TREATMENT PHASES AND PROCESSES AND DISCHARGE PATHS OF WASTE WATER ORIGINATED BY 5 TEXTILE INSTALLATIONS

Installation code number	Waste water quantity (m^3/ day)		Primary treatment								Secondary treatment		Decontamination				Tertiarytreatment				Discharge
		Without any treatment	Screening	Desanding	Fats collection	Balanching	pH adjustment	Coagulation	Sedimentation	Floatation	Aerobic	Anaerobic	Chlorination	Ultraviolet radiation (UV)	Ozonation	Hydrogen Perioxide	Filtration on sand filters	Filtration on activated carmon filters	Reverse osmosis	Ion exchange	
7			✓			✓	✓	✓	✓	✓	✓										River
8	0,03	✓																			Under-ground
9	150		✓			✓		✓	✓		✓		✓								River
10	25		✓			✓	✓	✓	✓		✓		✓								River
11	250		✓	✓		✓	✓	✓	✓		✓		✓								River
12	1.300		✓			✓	✓	✓	✓		✓		✓								River

In the following figures, the measured (inflow and outflow) concentrations for the analyzed parameters are presented.

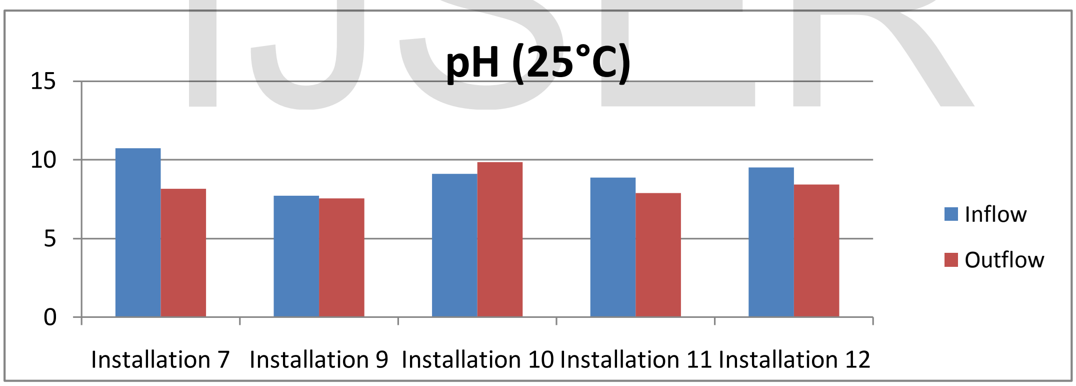

Fig. 1. Inflow and outflow pH values for the 5 participating installations

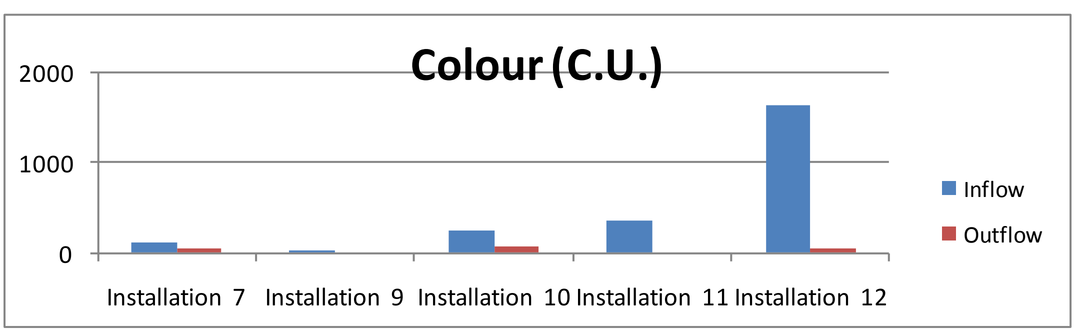

Fig. 2. Inflow and outflow Colour values for the 5 participating installations

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TABLE3:
INFLOW AND OUTFLOW WASTEWATER CHARACTERISTICS FOR THE 5 PARTICIPATING INSTALLATIONS

Parameter	Installation 7		Installation 9		Installation10		Installation 11		Installation12	
	Inflow	Out-flow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
pH, 25°C	10,73	8,14	7,70	7,52	9,10	9,85	8,85	7,87	9,50	8,41
Colour[C.U.]	112,00	50,00	3,60	2,83	251,00	73,00	366,00	17,00	1.650	60,00
COD [mg/l]	583,00	136,00	29,00	15,00	660,00	94,00	433,00	35,00	1.220	36,00
BOD_5 [mg/l]	-	2,22	1.014	23,00	-	12,43	-	20,50	-	2,26
TDS [mg/l]	10.250	3.835	-	9,64	4.325	2.485	3.075	1.095	2.613	2.365
TSS [mg/l]					137,50	81,50			211,40	20,70
Pb [mg/l]	0,740	0,524	0,240	0,060	0,810	0,070	n.d.	n.d.	n.d.	n.d.
Cu [mg/l]	-	-	n.d.	n.d.	0,036	n.d.	7,850	0,547	0,155	n.d.
Zn [mg/l]	0,198	0,159	0,191	0,103	0,122	0,049	0,489	0,180	1,758	0,065
Fe [mg/l]	2,430	1,620	n.d.	n.d.	n.d	n.d.	10,880	0,944	2,571	n.d.
Ni [mg/l]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7,550	0,650	n.d.	n.d.
Cd [mg/l]	0,055	0,022	0,046	0,035	0,012	n.d.	0,030	0,010	0,064	0,060
Mn [mg/l]	0,678	0,397	n.d.	n.d.	n.d.	n.d.	3,770	0,349	n.d.	0,337
Ag [mg/l]	0,298	0,147	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0,090	n.d.
Co [mg/l]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total Cr [mg/l]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	14,03	1,10	n.d.	n.d.
Cr^{+6} [mg/l]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K [mg/l]			32,60	27,60	272,70	221,00	168,80	85,70		
Na [mg/l]	935,00	291,00	337,00	79,00	1.039	465,00	1.026	672,00		
Ca [mg/l]			558,00	355,00			405,00	121,00		
Mg [mg/l]			326,00	246,00	101,00	82,00	72,00	31,00	n.d.	36,40
Phenols [mg/l]	0,46	0,24	0,66	0,06	2,84	0,33	3,74	0,13	132,00	0,17
NH_4 - N [mg/l]	1,45	0,32	0,38	0,18	1,40	0,61				
NO_2 - N [mg/l]	0,23	0,08	0,03	n.d.	0,18	0,05	0,38	0,36	-	-
NO_3 - N [mg/l]	5,40	1,00	5,00	4,70	21,00	10,80	20,00	5,00	-	-
N_{Total} [mg/l]	30,10	20,00	8,97	5,90	34,70	21,00	26,51	9,06	26,00	23,00
$N_{organic}$[mg/l]	23,02	18,60	3,56	1,02	12,12	9,54	4,60	2,10	21,92	11,55
PO_4 - P [mg/l]	2,42	1,58	0,20	0,03	0,13	0,08	0,72	0,15	2,13	0,26
P_{Total} [mg/l]	4,51	2,86	0,75	0,13	2,77	0,32	8,50	0,12		
SO_3^{2-} [mg/l]	2,70	1,10	1,30	0,00	2,00	1,30	n.d.	n.d.	n.d.	n.d.
SO_4^{2-} [mg/l]	6.200	1.680					540,00	380,00	-	-
S^{2-} [mg/l]	n.d.	n.d.	0,02	n.d.					-	-
CN^- [mg/l]	0,01	0,01	0,03	n.d.	0,02	0,01	0,22	n.d.	0,30	0,01
F^- [mg/l]	0,22	n.d.	n.d.	n.d.	0,52	0,19	1,30	0,15	-	-

Cl^-[mg/l]			1.040,0	520,00			1.130	465,00	540,00	160,00
ClO_2 [mg/l]	1,43	1,35	0,81	0,70	2,04	0,42	3,55	0,04	-	-
Cl_2 - Free[mg/l]	0,43	0,15	0,07	0,03	0,95	0,13	1,41	0,09	-	-
Oil&grease[mg/l]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Amount of produced waste (m^3/day)	200		150		25		250		1.300	

n.d.:not detected (less that the detection limit of the analysis method)

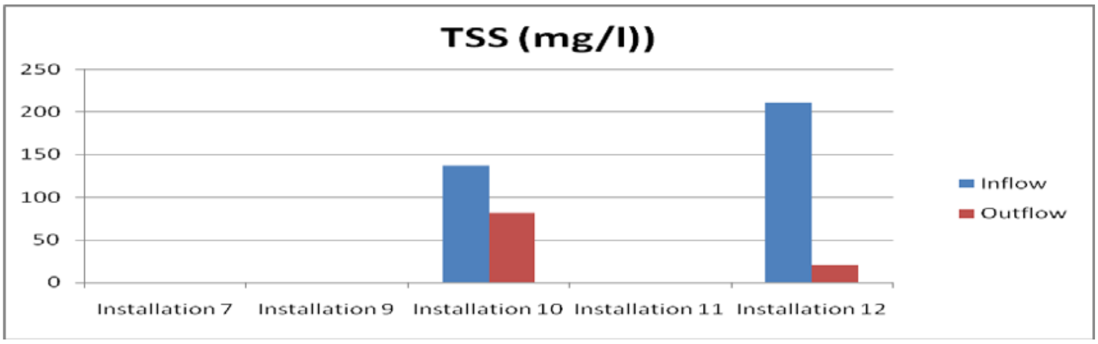


Fig. 3. Inflow and outflow TDS values for the 5 participating installations

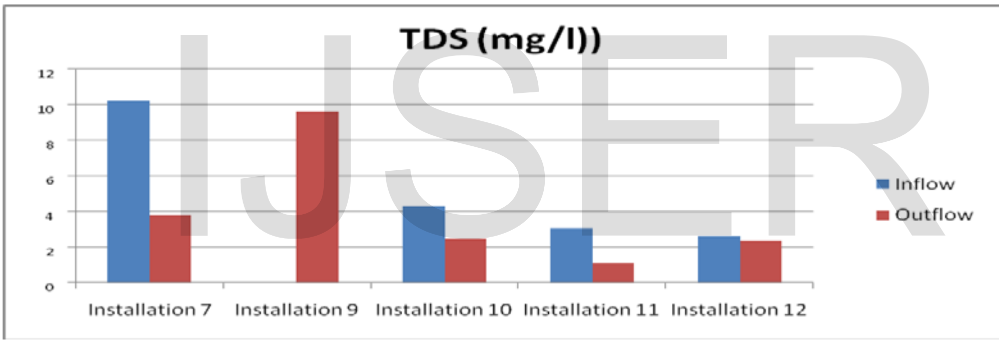


Fig. 4. Inflow and outflow TDS values for the 5 participating installations

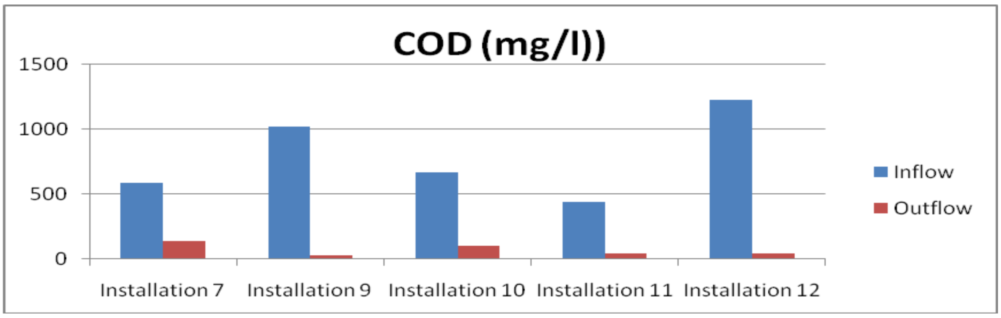


Fig. 5. Inflow and outflow COD values for the 5 participating installations

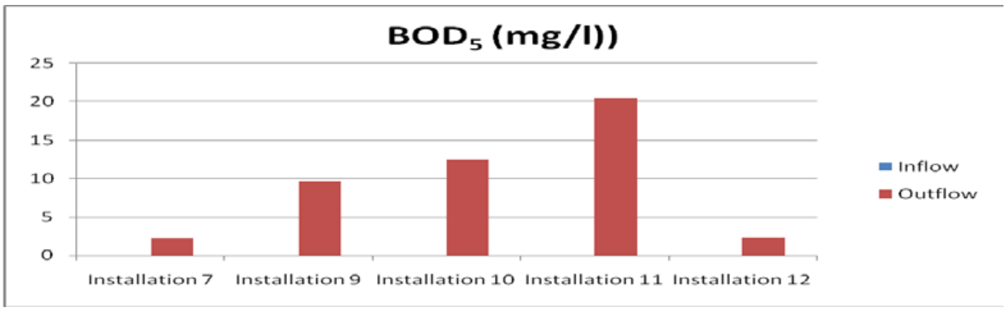


Fig. 6. Inflow and outflow BOD_5 values for the 5 participating installations

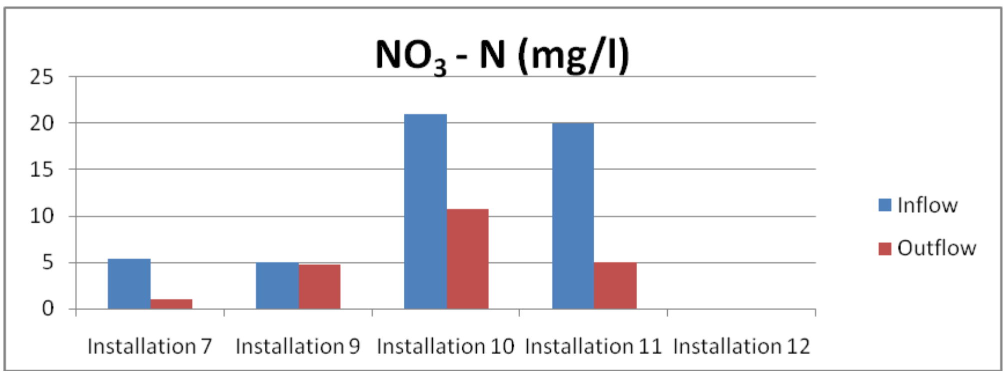


Fig. 7. Inflow and outflow NO_3-N values for the 5 participating installations

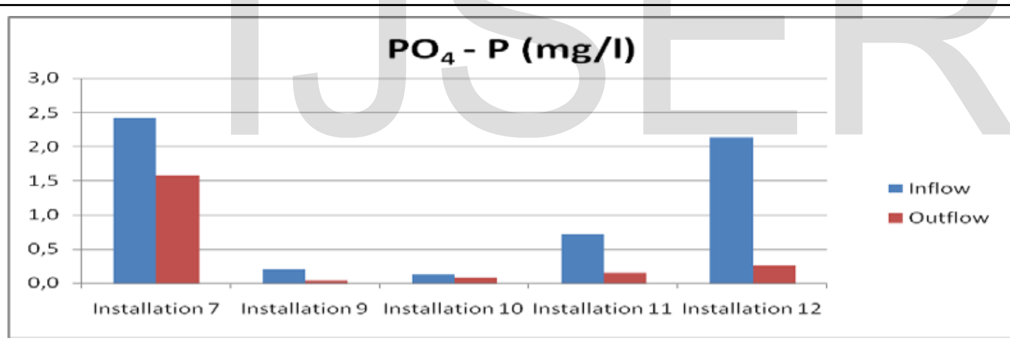


Fig. 8. Inflow and outflow PO4-P values for the 5 participating installations

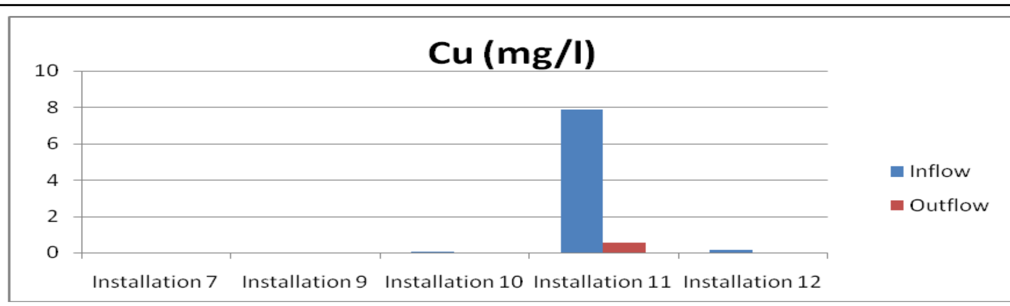
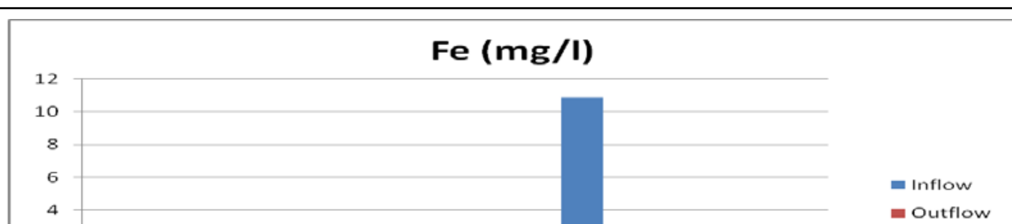


Fig. 9. Inflow and outflow Cu values for the 5 participating installations



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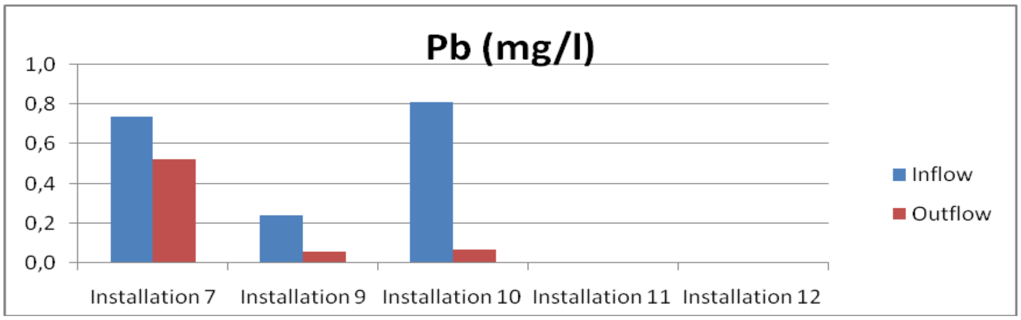

Fig. 11. Inflow and outflow Pb values for the 5 participating installations

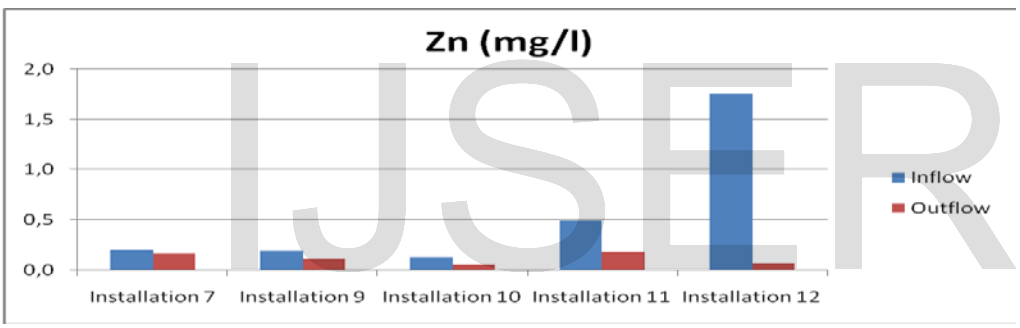

Fig. 12. Inflow and outflow Zn values for the 5 participating installations

An overall synopsis of the achieved reduction percentages as deducted by the analysis of inflow and outflow data for the 5 participating installations is presented in the following figure.

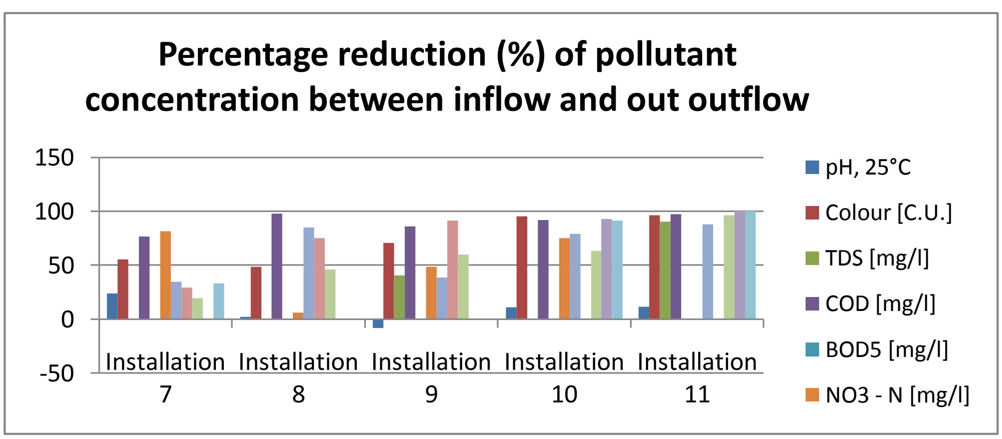

Fig. 13. Percentage reduction (%) of pollutant concentration (specific difference between inflow and outflow concentration) for the assessed parameters for the 5 participating installations.

Based on the assessment of the observed results, the following

mples ranging from 7.70 to 10.73, and at three of the five installations the values are above the limit values required by the Greek Regulations for indirect discharge.

As regard the treated effluents of these three industrial units, there is a limit value exceedance only for one installation, while for the other two, a satisfactory pH adjustment (values 6-9) is achieved.

Regarding the levels of color, which is an important environmental parameter for the wastewater of textile industry, the results of untreated waste samples are ranging from 29 C.U to 1.650 C.U (Figure 2). The biological treatment plants of these units achieve a significant reduction of color with the applied treatment systems (removal rate 48% to 96%) but there is scope for the further removal of color.

Levels of total suspended solids, TSS (Figure 3) of untreated waste are ranging from 137,5 mg / l to 211,4 mg / l. These values are lower than the corresponding limit value for indirect discharge (TSS = 500 mg/l), while the existing treatment systems achieve sufficient reduction of total suspended solids concentrations.

The total dissolved solids (TDS) concentrations of untreated waste water (Figure 4) are ranging from 2.613 mg/l up to 10.250 mg/l. For three installations values exceed the corresponding limit for indirect discharge, which is 3.000 mg/l. It seems that the waste water treatment facilities of the relevant installations, don't achieve satisfactory reduction of total dissolved solids concentrations (reduction rate 10% to 64%). Specifically, the TDS concentration of the treated effluent of the installation with serial number 7 is still above the required limit for indirect discharge of 3.000 mg / l (Figure 4).

The values of concentration levels of the chemical oxygen demand, COD, measured at samples of untreated effluents, are ranging from 433 mg/l to 1.220 mg/l.

Specifically, at two of the five installations, COD levels are higher than the corresponding limit of 1.000 mg/l. However, the treatment process used in these installations wwtf achieves significant levels of reduction of COD (efficiency of about 97% and 98%) resulting in COD concentrations at the effluent below the required limit (Figure 5).

Moreover, the Biochemical Oxygen Demand (BOD) concentrations as measured in samples of treated wastes of the industrial units (Figure 6), range from 2.2 to 20,5 mg/l, which are below the corresponding limit of 500 mg/l.

Values of nitrate concentrations (NO3-N) measured in samples of untreated effluents ranging from 5,4 mg/l to 21 mg/l (Figure 7). Exceed of the limit value for indirect discharge (20 mg/l) is observed in the case of one installation. The reduction of nitrate concentration below the discharge limit is achieved with the treatment method used by this installation's wwtf.

Regarding the concentration of phosphate (PO_4-P) measured in samples of untreated effluents, the values range from 0,13 mg/l to 2,42 mg/l (Figure 8) which are below the limit concentration of 10 mg/l.

Copper (Cu) concentration values measured in samples of untreated waste range from 0,03 mg/l to 7,85 mg/l (Figure 9). Specifically, only one value (Cu = 7,85 mg/l) is higher than 1 mg/l, which is the corresponding limit for indirect discharge. However, the treatment method used by the installation's wwtf, achieve reduction of Cu concentration of the order of 93% so that the concentration of the effluent (0,55 mg/l), is lower than the limit.

Finally, the concentrations of metals, Fe, Pb and Zn of untreated waste samples are significantly lower than the relevant limits for indirect discharge, which is equal to 15,5 mg/l and 20 mg/l respectively (Figures 10, 11 and 12).

4 Conclusions and Recommendations

The area of Asopos River is facing immense environmental problems, mainly due to the discharge of untreated or poorly treated industrial wastewater in the Asopos river.

It should also be noted that despite the fact that the majority of industrial installations operating in the area, have installed systems for the collection and treatment of wastewater, the problem of quality degradation of natural recipients and aquifer in general, remains acute.

This is either due to the unsatisfactory operation of waste water treatment facilities, originated by technical or operational problems or due to the small efficiency of existing treatment facilities in relation to the required(under sizing).

In this study, results of the main pollutants analysis from textile installations wastewater streams, are presented. It is worth noting that all these industrial units have installed and applied their biological treatment in order to achieve the desired reduction of the pollutant load of their waste water. From the results of the samples analysis, it is concluded that despite the treatment some parameters are above the limits for disposal in a sewer system.

The fact that the limit values for direct discharge to Asopos river (based on Ministerial Decree 20488/2010) are very strict and difficultly Industrial wastewater will be below them, advocates the need to establish, in the area, a central wastewater treatment plant that will serve and the other industrial sectors in the region.

In particular, for the installations belonging to the sector of "Manufacture of textiles and textile products, it is necessary to establish a secondary biological treatment which reduces the organic load. This process is mainly carried out to reduce the BOD, phenol, and oil contents in the wastewater and to control its color. Oxidation is another efficient technique to remove color, while tertiary treatment (such as reverse osmosis or ion exchange) is focused on the reduction of the total dissolved solids (TDS). Membrane Bioreactors (MBRs) are also successfully employed for the biological treatment of wastewater. Their advantages include the production of high quality treated effluent, good disinfection capability, compactness and flexibility in operation. MBRs do not allow suspended solids to penetrate into the final effluent and thus metals attached to sludge flocs are effectively rejected. Following this treatment sequence, the treated effluent will be within the required limits for discharge. [9, 10]

The purpose of a central treatment plant is not to substitute the pre-treatment facilities and processes of industrial wastewater in the study area, but to ensure the avoidance of the contamination of the final recipient from failures of these industrial sites pretreatment facilities. Furthermore to facilitate the operation of industrial installations by settings discharge limits for their treated waste water (after the pretreatment stage) the corresponding limits for acceptance by urban wastewater treatment facility.

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REFERENCES

[1] Gereffi G (2002) *Outsourcing and Changing Patterns of International Competition in the Apparel Commodity Chain*.

[2] Elliott A, Hanby W, Malcolm B (1954) *The Near Infra-Red Absorption Spectra of Natural and Synthetic Fibres*. Br J Appl Phys.

[3] European IPPC Bureau, Reference Document on Best Available Reference Document for the textile industries, July 2003, http://eippcb.jrc.ec.europa.eu/

[4] http://water.nr.state.ky.us/ww/waterres.htm

[5] Shaolan Ding; Zhengkun Li; Wangrui (2010). *Overview of dyeing wastewater treatment technology*. Water resources protection 26(2010) 73-78

[6] http://www.ypeka.gr

[7] Tufekci, N., San, H.A., Aydın, S., Ucar, S. and Barlas, H. 1998. *Wastewater Treatment Problems in the Operation of Woven and Knit Fabric Industry*, FEB, 7: 795-802

[8] American Public Health Association (APHA-AWWA-WPCH). 1998. *Standard Methods for the Examination of Water and Waste Water*. 20th ed. APHA Washington D.C., 1270 pp.

[9] Das S (2000) *Textile effluent treatment -A Solution to the Environmental Pollution*

[10] Simos Malamis, Evina Katsou, Konstantinos Takopoulos, Prokopis Demetriou, Maria Loizidou, 2012. *Assessment of metal removal, biomass activity and RO concentrate treatment in an MBR–RO system*. Journal of Hazardous Material. 209-210 (2012) 1-8