Assessment of Industrial Effluents Quality and their Possible Impact on Surface Water

Florina COPACIU¹⁾, Carmen ROBA^{2)*}, Ocsana OPRIȘ³⁾, Andrea BUNEA¹⁾ and Vioara MIREȘAN¹⁾

¹⁾ Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine, 400372 Cluj-Napoca, 3-5 Mănăștur Street, Romania

²⁾ Faculty of Environmental Science and Engineering, Babeș-Bolyai University, 400294 Cluj-Napoca, 30 Fântânele Street, Romania

³⁾ National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, 67-103 Donat Street, 400293, , Romania

*Corresponding author, e-mail: carmen.roba@ubbcluj.ro

Bulletin UASVM Animal Science and Biotechnologies 72(2) / 2015

Print ISSN 1843-5262; Electronic ISSN 1843-536X

DOI:10.15835/buasvmcn-asb:11436

Abstract

The printing, textile, wood and plastics industries have an important environmental impact, since they consume large amounts of water and produce highly polluted waste waters (Sostar-Turk *et al.*, 2005). The current study aimed to investigate several effluents generated by different industries based on their physicochemical parameters and to evaluate their possible impact on the water body. Effluents from two printing, a textile, a wood and a plastics industry from Cluj County were analysed for various physicochemical parameters such as temperature, pH, biochemical and chemical oxygen demand, total dissolved solids, total suspended solids, total nitrogen, total phosphorus, ammonium, chloride, sulphate, petroleum ether extractable substances, and detergents. The samples were analysed using the corresponding standard procedures SR ISO 105523-97, SR ISO 1899/1-03, SR ISO 6060-96, STAS 9187-84, STAS 6953-81, Merck 14543, Merck 14537, SR ISO 7150/1-01, EPA 375.4/05, SR IS 9297-01, SR ISO 7150/1-01, and SR EN 903-03. The temperature, total dissolved solids, chloride, sulphate and detergent content of the effluents were within the permissible limits for surface water discharge, while the other parameters exceeded the limit set by legislation. The data of the present study showed that the analysed physicochemical parameters significantly varied with the effluent source. The study indicated a seasonal variation for several parameters, dictated by the production schedule of the manufacturer. In many cases, the quality of the studied effluents was below the limits set by Romanian and UE legislation.

Keywords: azo-dye related industries, physicochemical parameters, textile effluents, toxic effects

INTRODUCTION

A serious problem in developing countries is the inadequate management of waste waters generated by several anthropogenic activities. Owing to the increased need for printing, textile, furniture and plastics products, these industries and the amount of the generated waste waters have increased proportionally, becoming important water polluters (Adewoye, 2010; Roșu *et al.*, 2015). From the above mentioned industries, textile manufacturing is the major water consumer, generating high amounts of waste

waters. The textile and printing effluents have a complex composition due to the usage of a variety of chemicals, which include dyes, detergents, insecticides, pesticides, grease and oils, solvents, heavy metals or inorganic salts (Sostar-Turk *et al.*, 2005). These effluents often have strong colour, high chemical and biochemical oxygen demand, suspended solids, salts, and highly fluctuating pH (Hannan *et al.*, 2011). The wood industry uses different kinds of materials, such as paints, wood treatments, stains, varnishes, polishes, and adhesives. As a consequence, the wood industry

generates a diversity of residues, including wood residues, metal, plastic, glass, fabric, glues, organic solvents, removers, paints and varnishes. The quantities and characteristics of the generated residues depend on the raw material and product nature, on the water consumption and on the average daily production (Roy *et al.*, 2010). Environmental problems associated with the textile and dye-related industries are mainly caused by waste water treatment and discharge (Hannan *et al.*, 2011). A number of studies (Wells *et al.*, 1994; Mathur *et al.*, 2005) have demonstrated that these effluents contain chemicals with genotoxic and mutagenic activity, and are a real threat to public health. Some of these toxic compounds cannot be removed by conventional waste water treatment methods and they are highly stable, accumulating through food chain and causing deleterious biological effects (Kannan *et al.*, 2005).

The objectives of the present study were to characterize several dye-using industry effluents generated by two printings, one textile, one furniture and one plastic products plant, by analysing their pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), ammonium (NH_4^+), chloride (Cl^-), sulphate (SO_4^{2-}), petroleum ether extractable substances (PEES) and detergent content. The printing, furniture and plastic products effluents were discharged into the Someş River after they had been treated using conventional treatment methods, while the textile effluents were discharged into the sewerage system after prior treatment. Based on the analysed parameters, the possible impact

on the Someş River of the effluent withdrawal was evaluated. The effluents were monitored during 2007 and 2011 in order to establish the monthly and seasonal correlations between various parameters at different sites. The levels of the analysed physicochemical parameters were compared with the permissible limits for surface water discharge set by Romanian and UE legislation. The Council Directive 91/271/EEC regarding municipal waste water treatment was entirely adopted in Romanian legislation by Governmental Decision no. 188/2002 (amended by Governmental Decision no. 352/2005, with Annex no. 2 - NTPA 002/2005 and Annex no. 3 - NTPA 001/2005) for the approval of special norms regarding the conditions of waste water discharge in aquatic environments.

MATERIALS AND METHODS

Site selection and sampling

The investigated industries are located in Cluj County, in north-western Romania. The Cluj County water network comprises three basins: the Someş, the Crişul Repede and the Mureş. The main industries in Cluj County are: mechanical components, wood processing, textiles, plastics processing, glass manufacturing, pharmaceuticals, cosmetics, and food stuffs processing. The discharge of the effluents generated by these industries into surface waters can have a negative impact especially on the perimeter covered by the Someşul Mic Basin, which is the principal receptor of these effluents. The general characteristics of the investigated companies are summarized in Table 1.

Tab. 1. The general characteristics of the evaluated companies

Company	Founded	Employees	Size	Main activity
Printing 1	2006	50-100	medium	-flexible packaging for food -bags
Printing 2	1994	6-10	micro/ small	-magazines -flyers
Textile	2000	64-78	medium	-clothing (sweaters, skirts, pants, jackets) -footwear
Furniture	2003	240	medium	-wood processing -furniture manufacturing for external market
Plastics	1955	400	big	-plastic processing for kitchen, bathroom, garden, packing and bottle

* Size defined according to the classification of Law no. 133 of 20 July 1999: micro companies - from 1 to 9 employees; small companies - from 10 to 49 employees; medium companies - from 50 to 249 employees; big companies - over 250 employees.

Fig. 1. The pH of the analysed effluents

We collected our samples at the location where effluents are discharged into the Someşul Mic River. These samples were collected in plastic recipients previously washed with non-ionic detergent and rinsed with distilled water. After the labelling and transportation of the samples to the laboratory, these were stored at 4°C away from sunlight and analysed within 24 hours from sampling. The effluent samples were collected during May 2007 and April 2011 (for printing), between March 2007 and June 2011 (for furniture), between April 2007 and December 2007 (for plastics), and during January 2011 and September 2011 (for textile).

Analysis of the physicochemical parameters

The collected samples were analysed for the following physicochemical parameters: pH, COD, BOD, TSS, TDS, TP, TN, NH_4^+ , SO_4^{2-} , Cl⁻, PEES, and detergents content using the corresponding standard procedures SR ISO 105523-97, SR ISO 1899/1-03, SR ISO 6060-96, STAS 9187-84, STAS 6953-81, Merck 14543, Merck 14537, SR ISO 7150/1-01, EPA 375.4/05, SR IS 9297-01, SR ISO 7150/1-01, SR EN 903-03.

RESULTS AND DISCUSSION

pH

The water pH influences most of the chemical and biochemical reactions. As a consequence, the effluents' pH modify the water's physical-chemical properties with a significant impact on aquatic life (Nosheen *et al.*, 2005).

The effluents' pH values obtained in the present paper were between 6.17 and 10.35, with a slightly alkaline value. Only the plastic effluents had the pH level (7.31 - 7.92) within the admitted value of 6.5 to 8.5 prescribed by legislation (Figure 1). In both printing and furniture effluents, the pH was within the admitted value with one exception. The highest pH variance (6.18 - 10.35) was registered in the textile effluents, where several samples exceeded the lower and upper limits for effluent disposal into surface water. A high pH value recorded in the textile effluents presents a risk for the aquatic life, because a pH value over 8.5 inhibits the growth of the aquatic macrophytes by impairing iron and phosphorus uptake and reducing fish production (Argo, 2003).

Chemical and biological oxygen demand

COD represents the quantity of oxygen needed by both potassium dichromate and concentrated sulphuric acid for breaking down inorganic and organic matters existing in water. BOD measures the quantity of oxygen needed by bacteria to break down the decomposable organic matter into simpler substances present in any water. High levels of BOD indicate the pollution strength of the waste waters and the low level of oxygen available for living organisms. High COD levels imply toxic conditions and the presence of biologically resistant organic substances.

The data of the present study showed that the values of COD and BOD varied significantly with the effluent source. The highest COD values were registered in the textile effluents (1812.5 - 6481 mg O_2 /l, with a mean value of 4488 mg O_2 /l), while the printing (37.8 - 346 mg O_2 /l, with a mean value of 93.9 mg O_2 /l), furniture (50.1 - 129.2 mg O_2 /l, with a mean value of 105 mg O_2 /l) and plastic (72 - 81.6 mg O_2 /l, with a mean value of 76.7 mg O_2 /l) effluents had a considerably lower COD level (Fig. 2).

The BOD level was lower than the COD and it had a relatively similar variation with the exception of the plastic effluents. The BOD level was lower in the printing (8.22 - 45.3 mg O_2 /l) and furniture (24.16 - 32.13 mg O_2 /l) effluents compared to the plastic (220 - 240 mg O_2 /l) and textile (695.4 - 1280.7 mg O_2 /l) effluents.

The highest COD and BOD levels were recorded in the textile effluents, proving that these effluents have a high oxygen demand, which causes dissolved oxygen (DO) depletion. The DO

Fig. 2. Variation of chemical and biochemical oxygen demand (COD and BOD) levels in the investigated effluents

is the most important parameter of water quality (Peirce *et al.*, 1997) and it is a fundamental requirement for aquatic life, especially for aerobic organisms. The high BOD and COD levels from the analysed effluents, which are discharged into the Someşul Mic River, can affect aerobic organism growth, which could lead to the excessive growth of anaerobic organisms and to the transformation of the water body in an uninhabitable environment for the gill-breathing aquatic organisms (Yusuff and Sonibare, 2004; Nergis *et al.*, 2009).

Total suspended and total dissolved solids

Solids concentration represents an important waste water characteristic. The TSS content of the analysed effluents ranged between 17 - 126 mg/l depending on the source.

As shown in Figure 3, the highest TSS level was recorded in the effluents generated by the second printing house (27.5 - 126 mg/l), with its mean value of 64.8 mg/l considerably higher than the first printing TSS values ranging from 17.7 to 47 mg/l, with 25.9 mg/l as its mean, or the furniture industry values of 17 - 54 mg/l, with their 31.9 mg/l as mean value, or the textile industry values between 30.3 - 43 mg/l, 36 mg/l being its mean, and plastics industry values ranging from 29.8 to 51.8

mg/l, and a calculated mean of 38.8 mg/l effluents. The printing, furniture and plastic effluents exceeded the TSS effluent discharge in surface water maximum permissible limit of 35 mg/l. As regards textile effluents, their TSS level is lower than 350 mg/l, the sewage network admissible discharge limit. Penetration of light into water can be reduced by a high amount of suspended solids, thus suppressing photosynthetic activity of algae, phyto- plankton and macrophytes. In addition, waste water purification capacity by microorganisms will be decreased if the DO level of waste water is reduced due to deficient light penetration into water (Delee *et al.*, 1998). The same cause can accelerate the growth of algae or increase water hardness, which in turn leads to formation of scale in pipe-lines and other equipment. The analysed effluents had a TDS relatively low level, between 310.2 - 934.4 mg/l. In the furniture effluents the TDS values found ranged between 376 - 934.4 mg/l, with 563.1 mg/l as a mean value, and thus were higher than the values of 310.2 to 592.2 mg/l, with 497.5 mg/l as mean, found in the printing effluents. The TDS concentrations of all the effluents were lower than

Fig. 3. Fluctuation of the total suspended and dissolved solids (TSS and TDS) levels in the investigated effluents

2000 mg/l, the permissible limit for surface water discharge.

Total nitrogen and total phosphorus

Though essential nutrients in plant growth, excessive inputs of nitrogen and phosphorus in fresh water can seriously affect the aquatic ecosystem, due to the fact that it stimulates rapid growth of algae and aquatic plants. That is why, with respect to water pollution, TN and TP are important indicators (Campbell *et al.*, 2001; Wetzel, 2001). In our study, we found the lowest TP concentrations in the textile effluents, ranging between 0.7 - 2.38 mg/l (1.29 mg/l mean) (Fig. 4). The printing effluents had a higher TP level, between 0.05 - 5.66 mg/l (1.66 mg/l mean), while furniture effluents had the highest TP concentrations between 0.28 - 13.25 mg/l (2.4 mg/l mean). Thus we found that the average TP value recorded in the case of printing and

furniture effluents surpassed the permissible limit for surface water discharge (1 mg/l), while the same parameter was beneath the permissible limit for sewerage network discharge (5 mg/l) in textile effluents. For the investigated effluents, the TN level surpassed the TP one. While the textile effluents with 4.9 - 34.4 mg/l (15.23 mg/l mean) and the printing effluents with 1.7 - 29.3 mg/l (10.7 mg/l mean) had a lower concentration of TN in the furniture effluents, this ranged between 5.6 - 70.9 mg/l (15.4 mg/l mean), thus being the highest.

The permissible limit for TN of 10 mg/l was exceeded in printing and furniture effluents. The highest fluctuations, for both TN and TP, were recorded during 2008 and 2009 for printing effluents, and during 2010 and 2011 for furniture effluents. The peak values were recorded in the cold season (November - February) and they are

Fig. 4. The monthly fluctuation of total nitrogen (TN) and total phosphorus (TP) levels in the investigated effluents

directly correlated with the companies' production schedule.

Excess nitrogen and phosphorus can stimulate the rapid growth of aquatic plants and algae leading to water eutrophication, which has many negative effects on aquatic ecosystems including: oxygen depletion, water transparency decrease, unpleasant taste and odour, decrease in animal and plant diversity (Codd, 2000; Voutsas *et al.*, 2001).

Ammonium

High levels of TN in waste water can lead to high values of free ammonia (NH_3) and ionized-ammonia (NH_4^+), which are two forms of reduced

inorganic nitrogen. The free ammonia is a gaseous chemical, whereas the ionized form remains soluble in water. The free ammonia is considerably more toxic to organisms than the ionized-ammonia (Zorpas *et al.*, 2010).

In the present study, only the ionized-ammonia was analysed, which had a high level especially in the textile effluents (25 - 38.8 mg/l, with a mean value of 34.6 mg/l) (Fig. 5).

In the furniture effluents, NH_4^+ concentration ranged between 1.2 - 57.6 mg/l, with a mean value of 6.7 mg/l, while in the printing effluents this parameter had the lowest levels, between 1.6 - 2.3 mg/l, with a mean value of 2 mg/l. The

Fig. 5. The level of ammonium (NH_4^+) in the analysed effluents

permissible limit for surface water (2 mg/l) and sewage network (30 mg/l) discharge was often exceeded in all types of effluents. For the printing and textile effluents, there were no significant fluctuations in NH_4^+ level, as compared to the furniture effluents, where significant fluctuations were recorded during 2009 and 2010.

The high NH_4^+ level, recorded especially in the textile effluents, is a consequence of the high TN level of these waters. The data indicated a positive correlation, with a Pearson correlation factor (r) of 8.4, between NH_4^+ concentration and the TN level of the investigated effluents.

The slightly alkaline pH of the analysed effluents can change the equilibrium between the ionized and free ammonia by converting more ammonium ions into ammonia molecules, leading to high free ammonia content. Even in small quantities (under 1 mg/l), ammonia inflicts stress and damage to gills and other tissues. Fish can have gill damage when levels reach 0.06 mg/l, while at concentrations of 0.2 mg/l, susceptible fish like salmon and trout die (Chambers *et al.*, 2001). Fish exposed to low amount of ammonia in time become more sensitive to bacterial infections and may have decreased growth (Francis-Floyd *et al.*, 1990). A major percentage of water pollution is waste water leaked by sewage and industries, which has as a consequence the increase in oxygen demand, toxic algal blooms, and which in turn cause unbalance in the aquatic ecosystem (Akan *et al.*, 2008).

Chloride

Chloride is one of the major inorganic anions in water and waste water. High Cl^- levels

can destroy several micro-organisms that are significant in the food cycle of aquatic life (Kumar, 1989). Furthermore, high Cl^- concentrations are corrosive for metallic pipes and the usage of these waste waters for irrigation purposes can damage agricultural crops (Nosheen *et al.*, 2005). The Cl^- content of the analysed effluents showed fluctuations within a range of 27.7 - 250 mg/l. The printing effluents had higher Cl^- content (between 48.3 - 250 mg/l, (168.7 mg/l mean) than the furniture effluents with values between 27.7 - 116.2 mg/l (63.6 mg/l mean) (Fig. 6).

During the hot season, lower values of Cl^- were usually recorded as compared to the cold season, which might be caused by dilution during the rainy season. During 2007, the printing effluents recorded the highest fluctuations (Fig. 6). Legislation limits the Cl^- concentration level to 500 mg/l in surface water withdrawals, and this limit was not surpassed by any of the analysed effluents. This demonstrated that there was no threat for the aquatic life as a result of the discharge of these effluents into the Somesul Mic River. In the study conducted by Tripathi *et al.*, 1991 similar Cl^- levels were registered.

Sulphate

Another threat to aquatic life is the high levels of hydrogen sulphide that result from deficient oxygen conditions and high levels of sulphate SO_4^{2-} or organic materials (Hannan *et al.*, 2011). Consequently, of great importance is the continuous SO_4^{2-} monitoring. In the printing related effluents, the SO_4^{2-} concentration was between 9.2 - 72.2 mg/l (47.9 mg/l mean), while in the furniture ones SO_4^{2-} levels were between 26.7 - 87.9 mg/l (65.6 mg/l

Fig. 6. Chloride (Cl⁻) content of the analysed effluents

Fig. 7. Sulphate (SO₄²⁻) level of the analysed effluents

mean) (Fig. 7). Monthly fluctuations of SO₄²⁻ level were not significant except the printing sample from May 2007. As proven by data in Figure 7, the SO₄²⁻ levels in all the effluents were lower than 600 mg/l, the permissible limit for surface water and sewage network discharge. So we can conclude that in the analysed effluents, the presence of SO₄²⁻ does not present a risk for aquatic life.

Petroleum ether extractable substances

Generally speaking, water insoluble organic materials include oils, greases, waxes, surfactants, fatty acids, petroleum hydrocarbons, and a variety of other substances from chemical manufacturing and other various industrial processes.

In our research, the concentration of PEES found was between 2.5 - 39 mg/l. The second printing effluents registered the highest values

between 9.5 - 39 mg/l (20.6 mg/l mean). While the first printing effluents and the furniture effluents had lower concentrations, for the former between 3.5 - 15.7 mg/l (8.6 mg/l mean), and for the latter between 2.5 - 20.2 mg/l, (11.3 mg/l mean), the plastics effluents registered the lowest levels between 3.5 - 4.2 mg/l (3.9 mg/l mean) (Fig. 8). In the second printing and the furniture effluents, the PEES level exceeded the permissible limit for effluents discharge in surface water.

Some of these water insoluble organic materials are volatile, being potential air pollution sources. Annual average temperature and wind speed are important meteorological conditions (US-EPA, 2002) to be taken into consideration.

Due to fact that some molecules have higher kinetic energy, liquids are able to evaporate at any

Fig. 8. Petroleum ether extractable substance (PEES) level in the analysed effluents

temperature. As the liquid temperature increases, evaporation also increases. The consequence of high temperatures in long dry seasons leads to different organic pollutants being released from effluents into the air.

Detergents

Detergents are often used in the textile and other azo-dye related industries. Detergents are organic compounds, which have both polar and non-polar characteristics. There are two kinds of detergents with different characteristics: phosphate and surfactant detergents. The surfactant detergents are used to enhance the wetting, foaming, dispersing and emulsifying properties of detergents, and the phosphate detergents are used to soften hard water and help suspend dirt in water. The detergents that contain phosphates are highly caustic, while the surfactant detergents are very toxic (Adewoye, 2010).

Studies have shown that at a level of 15 mg/l of detergents, most fish die, while concentrations up to 5 mg/l will kill fish eggs (Adewoye, 2010). Another problem caused by the presence of detergents in water is that they lower the surface tension of the water, which will increase the

absorption of organic chemicals, such as pesticides and phenols by the fish.

In the present study, the detergents level of the analysed effluents ranged between 0.04 - 0.32 mg/l, higher in printing/furniture (between 0.1 - 0.32 mg/l, with a mean value of 0.2 mg/l) and plastics (0.2 - 0.32 mg/l, with a mean value of 0.27 mg/l) effluents than in the textile effluents (0.04 - 0.2 mg/l, with a mean value of 0.12 mg/l) (Fig. 9).

There are studies (Jobling and Sumpter, 1993; Ogundiran *et al.*, 2007; Adewoye, 2010) which have proved that even the detergents considered perfectly biodegradable degrade poorly in waters, and they can bio accumulate in plant and animal tissue reaching level which may be toxic to aquatic fauna and flora, and can also induced severe damage to vital organs and even haematological, hormonal and enzyme disturbance.

CONCLUSION

The data of the present study showed that the analysed physicochemical parameters varied significantly with the effluent source.

The study indicated a seasonal variation for several parameters, dictated by the manufacturer'

Fig. 9. Detergents content of the analysed effluents

production schedule. In many cases, the quality of the studied effluents was below the limits set by Romanian and UE legislation. The total dissolved solids, chloride, sulphate and detergents content of the effluents were within the permissible limits for surface water discharge, while the other parameters exceeded the limits set by legislation. The most significant permissible limit excesses were recorded in the second printing and textile effluents proving that their discharge into the Someş River or the sewage system (finally ending in the surface waters, too) can seriously affect the aquatic ecosystem. Such polluted effluents must be treated properly before their discharge into surface water or the sewerage network in order to minimize their effect on the aquatic ecosystem.

REFERENCES

- Adewoye SO (2010). Effects of detergent effluent discharges on the aspect of water quality of ASA River, Ilorin, Nigeria. *Agric Biol J N Am* 1(4):731-736.
- Akan JC, Abdulrahman FI, Dimari GA, Ogugbuaja VO (2008). Physicochemical determination of pollutants in wastewater and vegetable samples along the Jakara wastewater Channel in Kano Metropolis, Kano State, Nigeria. *Eur J Sci Res* 23(1):122-133.
- Argo B (2003). Understanding pH management and plant nutrition part 1: Introduction. *Int Phalaenopsis Alliance J* 12(4):1-2.
- Campbell KL, Edwards DR (2001). Phosphorus and water quality impacts, p.91-109. In: Ritter WF, Shirmohammadi A (Eds.). *Agricultural Nonpoint Source Pollution: Watershed Management and Hydrology*. CRC Press, Boca Raton, Florida.
- Chambers PA, Guy M, Roberts ES, Charlton MN, Kent R, Gagnon C, Grove G, Foster N (2001). Nutrients and their impact on the Canadian environment (Minister of Public Works and Government Services Canada).
- Codd GA (2000). Cyanobacterial toxins, the perception of water quality and the prioritization of eutrophication control. *Ecol Eng* 16(1):51-60.
- Delee W, Niel CO, Hawkes FR, Pinheiro HM (1998). Anaerobic treatment of textile effluents: A Review. *J Chem Tech Biotechnol* 73:323-325.

8. Francis-Floyd R, Watson C, Petty D, Pouder BD (1990). Ammonia in aquatic systems, FA16, p 1-5, <http://edis.ifas.ufl.edu/pdffiles/FA/FA03100.pdf>
9. Hannan MA, Rahman MA, Haque MF (2011). An investigation on quality characterization and magnitude of pollution implications with textile dyeing industries' effluents using bleaching powder. *Duet Journal* 1(2):49-59.
10. Jobling S, Sumpter JP (1993). Detergent components in sewage are weakly oestrogenic to fish: An in vitro study using rainbow trout (*Oncorhynchus mykiss*) hepatocytes. *Aquat Toxicol* 27(3-4):361-372.
11. Kanna V, Ramesh R, Sasikumar C (2005). Study on ground water characteristics and the effects of discharged effluents from textile units at Karur District. *J Environ Biol* 26(2):262-272.
12. Kumar A (1989). Environmental chemistry. Wiley Eastern Limited, New Delhi, India.
13. Mathur N, Bhatnagar P, Nagar P, Bijarnia MK (2005). Mutagenicity assessment of effluents from textile/dye industries of Sanganeer, Jaipur (India): a case study. *Ecotoxicol Environ Saf* 61(1):105-113.
14. Nergis Y, Sharif M, Akhtar NA, Hussain A (2009). Quality characterization and magnitude of pollution implication in textile mills effluents. *Journal of Quality and Technology Management* 5(11):27-40.
15. Nosheen S, Nawaz H, Rehman K (2000). Physico-chemical characterization of effluents of local textile industries of Faisalabad, Pakistan. *Int J Agr Biol* 2(3):232-233.
16. Ogundiran MA, Fawole OO, Adewoye SO (2007). Effects of soap detergent effluents on the hematological profiles of *Clarias gariepinus*. *Science Focus* 12(1):84-88.
17. Peirce JJ, Weiner RF, Vesilind PA (1997). Environmental pollution and control, p.57-74, Butterworth-Heinemann, Woburn, MA, 4th Edition USA.
18. Roşu C, Piştea I, Roba C, Miha M, Ozunu A (2014). Surface water quality assessment. Case study: Târnava Mare river, Mediaş Town-Romania. *Indian J Appl Res* 4(5):70-72.
19. Roy R, Fakhruddin ANM, Khatun R, Islam MS, Ahsan MA, Neger AJMT (2010). Characterization of textile industrial effluents and its effects on aquatic macrophytes and algae. *Bangladesh J Sci Ind Res* 45(1):79-84.
20. Šostar-Turk S, Simonič M, Petrinič I (2005). Wastewater treatment after reactive printing. *Dyes Pigments* 64(2):147-152.
21. Tripathi BD, Sikandar M, Shukla SC (1991). Physico-chemical characterization of city sewage discharged into river Ganga at Varanasi, India. *Environ Int* 17:469-478.
22. United States Environmental Protection Agency (US-EPA) (2002). Industrial waste air model technical background document 530-R-02-010.
23. Voutsas D, Manoli E, Samara C, Sofoniou M, Stratis I (2001). A study of surface water quality in Macedonia, Greece: specification of nitrogen and phosphorus. *Water Air Soil Poll* 129(1-4):13-32.
24. Wells MJM, Rossano AJ, Roberts EC (1994). Textile wastewater effluent toxicity identification evaluation. *Arch Environ Contam Toxicol* 27:555-560.
25. Wetzel RG (2001). Limnology: Lake and river ecosystems, 3rd edition. Academic Press, San Diego CA, 985 p.
26. Yusuff RO, Sonibare JA (2004). Characterization of textile industries effluents in Kaduna, Nigeria and pollution implications. *Global Nest: The Int J* 6(3):212-221.
27. Zorpas AA, Inglezakis VJ, Stylianou M, Voukkali I (2010). Sustainable treatment method of a high concentrated NH₃ wastewater by using natural zeolite in closed-loop fixed bed systems. *Open Environmental Sciences* 4:1-7.