Quality Assessment of Waste Waters Generated by some Important Hospitals from Cluj County

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ABSTRACT

Hospitals produce large quantities of waste water that may contain various potentially hazardous materials. Moreover, these effluents usually do not undergo any specific treatment before being discharged into the urban sewage networks. As a consequence, a proper management of the hospitals effluents is vital. In the present study, the quality of the effluents, generated by 11 important hospitals from Cluj County was investigated. The analyzed parameters were: pH, chemical and biochemical oxygen demand, total suspended solids, residual free chlorine, and detergents. For all the effluents, the biochemical oxygen demand and the detergents content were within the permissible limits for waste water discharged in the urban sewerage system, while the other parameters exceeded the permissible limits.

Keywords: *hospital effluent, waste water, water quality, physicochemical parameter*

INTRODUCTION

During the last decades, the production and the consumption of pharmaceuticals have increased rapidly due to the development of medical science. Approximately 3000 compounds are used as medicine, and the annual production amount exceeds hundreds of tons (Kümmerer, 2009; Sim *et al.*, 2011). Hospitals use a variety of chemical substances such as pharmaceuticals, radionuclides, solvents and disinfectants for medical purposes as diagnostics, disinfections and research (Sim *et al.*, 2011). They are the main source of pharmaceutical compounds (PhCs) released into the environment. Hospitals are important water consumers too. Generally, the hospitals water demand varies from 400 to

1200 l/bed/day, with a minimal domestic water consumption of 100 l/person/day (Emmanuel *et al.*, 2005). In the developing countries the hospital average water consumption is estimated at 500 l/bed/day, while in the developed countries this value can be double, for example in the USA reaches 968 l/bed/day (Emmanuel *et al.*, 2005). As a consequence, hospitals generate significant volumes of waste water which end into the municipal sewerage network or surface water. Sometimes the hospital effluents are discharged without a preliminary treatment, releasing many toxic substances into the aquatic environment (Emmanuel *et al.*, 2005). These waste waters can have potential negative effects on biological balance of natural environments, because of

the exposure to hazardous substances like viruses, pathogenic bacteria disinfectants, non-metabolized pharmaceuticals and radionuclides (Emmanuel *et al.*, 2005). There are many studies (Emmanuel *et al.*, 2004; Emmanuel *et al.*, 2005; Heberer, 2002) which have reported the toxic effects of hospital waste water on the aquatic organisms.

The objectives of the present study were to investigate the quality of several effluents generated by 11 important hospitals located in Cluj County. The analyzed parameters were pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), total suspended solids (TSS), detergents and residual free chlorine content. The analyzed effluents are discharged into the urban sewerage system, finally ending into the surface waters. The levels of the analyzed physicochemical parameters were compared with the permissible limits set by the Romanian and UE legislation, for waste water discharge into the urban sewerage systems. The Council Directive 91/271/EEC concerning the urban waste water treatment was fully transposed into the Romanian legislation through the Governmental Decision no. 188/2002 (revised by the Governmental Decision no. 352/2005), regarding the approval of certain norms concerning the conditions of waste water discharge into the aquatic environment. The Annex no.3 (NTPA 001/2005) contains the "Normative establishing the pollutants limits for urban and industrial waste water discharged into natural receivers", while the Annex no.2 (NTPA 002/2005) contains the "Normative establishing the pollutants limits for urban and industrial waste water discharged into the local sewerage networks and waste water treatment plants".

MATERIALS AND METHODS

In the present study, 11 important hospitals were investigated. These hospitals are located in Cluj County, north-western Romania, a county with a total surface of 6674 km² and 680000 of inhabitants. 9 of the hospitals are located in Cluj-Napoca, one in Dej and another in Huedin (Fig. 1). The selected hospitals have a wide spectrum of wards and services. The general characteristics of the investigated hospitals are summarized in Table 1. The main classes of drugs used in these hospitals are: antibiotics (oxacillin, penicillin G, amoxicillin, ampicillin, ceftazidime,

ceftriaxone, cefuroxime, ciprofloxacin, ofloxacin, cefaclor, tetracycline, doxycycline, azithromycin); analgesics and anti-inflammatories (oxycodone, dihydrocodeine, tramadol, lansoprazole, tenoxicam, diclofenac, ketoprofen, ibuprofen); cytostatics (busulfan); anaesthetics (thiopental, inactin, propofol, ketamine); antihypertensives (irbesartan, indapamide); disinfectants (triclosan, glutaraldehyde); psychiatric drugs (alprazolam, zolpidem, carbamazepine, haloperidole, aripiprazole); antidiabetics (exenatide) and hormones (estradiol, estriol, estrone).

The samples were collected at their discharge point. The waters were sampled in plastic containers that were previously cleaned by washing in non-ionic detergent, rinsed with tap water and later soaked in 10% HNO₃ for 24 hours and finally rinsed with deionised water prior to usage. During sampling, the sample bottles were rinsed with sampled water three times and then they were filled to the brim. The samples were labelled and transported to the laboratory, stored in the refrigerator at 4°C, at dark and analyzed within 24 hours from sampling. The effluent samples were collected during 2008 and 2011. The samples were analyzed for various physicochemical parameters using specific standard procedures: pH (SR ISO 10523:2009), COD (SR ISO 6060:1996), BOD₅ (SR ISO 1899/1:2008), TSS (SR EN 872:2009), detergents (SR EN 903:2003), and residual free chlorine (SR EN 7393/2:2002). The pH was measured in the field, while the other parameters were analyzed in the laboratory within 24 hours from the sampling. The field meters and the equipment were checked and calibrated according to the manufacturer's specifications.

RESULTS AND DISCUSSION

pH

The water pH influences most of the chemical and biochemical reactions. As a consequence, the pH values of the studied effluents affect the physicochemical properties of the water and have an important impact on the aquatic life.

The pH values of the effluents varied significantly (6.2 - 10.2), being in general slightly alkaline. As it is shown in Fig. 2, the highest pH levels were determined in the effluents collected from the Cluj-Napoca hospitals (6.3 - 10.2, with a mean value of 7.8). The pH values were lower in

Dej (6.6 - 8.4, with an average value of 7.2) and Huedin (6.7 - 7.65, with an average value of 7.2).

The pH values of the effluents generated by several hospitals from Cluj-Napoca exceeded the pH permissible limit (6.5 - 8.5) for waste water discharge in the urban sewerage system. Occasionally, the effluents generated by C_2, C_4 and C_7 were too basic (for C_4 levels up to 10.2), while other times C_4 effluents were too acidic than the limit values. These fluctuations demonstrate the types and amount of some drugs which were

administrated in the hospitals shortly before the sampling time. The data results demonstrate that the pH fluctuation is slightly dependent by seasons (Fig. 3 A). The pH values were higher in the summer and autumn than in winter.

The effluents collected from Dej and Huedin hospitals had the pH values within the allowed limits. This can be due to the low hospital dynamics; the hospitals are located in small urban agglomerations and rarely are functioning at their maximum capacity. The high pH levels registered

Fig. 1. Location of the sampling points

Tab. 1. General characteristics of the investigated hospitals

Hospital code	Location	Type	No. of beds	Main classes of compounds
C_1	Cluj-Napoca	Oncologic	310	Antibiotics Analgesics and anti-inflammatory Cytostatics Anaesthetics Antihypertensives Disinfectants Psychiatric drugs Antidiabetics Hormones
C_2	Cluj-Napoca	Clinic	about 60	
C_3	Cluj-Napoca	Paediatric	90 (C_3_I) 80 (C_3_II) 30 (C_3_III) 44 (C_3_VI)	
C_4	Cluj-Napoca	Clinic	237	
C_5	Cluj-Napoca	Pneumology	230	
C_6	Cluj-Napoca	Dialysis	< 50	
C_7	Cluj-Napoca	Clinic	< 50	
C_8	Cluj-Napoca	Gynaecologic	12	
C_9	Cluj-Napoca	Urologic	< 50	
H	Huedin	Clinic	137	
D	Dej	Clinic	373	

in the C_2, C_4 and C_7 effluents represent a risk for the aquatic life, because a pH over 8.5 can have a negative impact on the aquatic organisms. For example, it affects the dissolved oxygen level, slowing down the aquatic plants photosynthesis, or it inhibits the growth of the aquatic macrophytes by impairing iron and phosphorus uptake, and it reduces the fish production (Kumar *et al.*, 2010). Such high pH levels can also damage the waste water collection and treatment facilities (reducing germicidal potential of chloride) and prevent the biological treatment processes (Kumar *et al.*, 2010; WHO, 1996). High pH can also induce the formation of toxic substances like trihalomethanes.

Chemical oxygen demand (COD) and biochemical oxygen demand (BOD₅)

The COD and BOD₅ parameters are used in order to characterize the amount of the organic matter from the waste water. COD shows the pollutant loading from the water through the presence of the organic and inorganic matters. The organic and inorganic matters are chemical oxidized by strong agents such as potassium dichromate and concentrated sulphuric acid. BOD₅ is an indicator of the oxygen-request properties of the biodegradable material from the water. High COD levels can demonstrate the toxic condition and reflect the presence of the resistant organic substances from biological point of view. The

high levels of BOD₅ demonstrate the waste waters pollution strength and the oxygen low level disposable for the living organisms.

The results obtained in the present study demonstrate that the values of COD and BOD₅ parameters had a significant variation with the effluent origin. The highest values of the COD parameter were obtained in the case of the effluents collected from the Huedin hospital (up to 1875 mg O₂/l) and by the dialysis (C_6) and oncologic (C_1) hospitals from Cluj-Napoca, where this parameter reached 991.8 mg O₂/l and 862.5 mg O₂/l, respectively.

In four (C_1, C_2, C_6 and H) of the investigated hospitals the COD concentration exceeded considerably the permissible limits (NTPA 002/2002) for waste water discharge in urban sewerage system, showing that these effluents are heavily loaded with organic material (Fig. 4). The data of the present study indicated a seasonal variation for the COD level. As it is shown in Fig. 4 A, the COD concentrations were higher during spring and autumn than in winter and summer. These fluctuations are correlated with the volume and composition of the waste water, the types and quantities of particular drugs which were administrated in the hospitals at those times.

The BOD₅ level was lower than the COD and it had a relatively similar variation. The highest BOD₅ level (up to 244.2 mg O₂/l) was registered

Fig. 2. The pH values of the analyzed effluents

Fig. 3. The pH values of the studied effluents

in one of the paediatric clinic (C_3) waste water from Cluj-Napoca, while the other effluents had a lower BOD₅ level (under 105.6 mg O₂/l) (Fig. 5). For all the analyzed samples, the BOD₅ level did not exceed the permissible limits (300 mg O₂/l) set by the Romanian legislation (NTPA 002-2002) for effluents discharge into the sewerage network.

The high COD concentrations registered in the up mentioned effluents are a consequence of the use of large amounts of drugs. These effluents have a high oxygen demand which causes dissolved oxygen (DO) depletion. The DO is the most important water quality parameter (Peirce *et al.*, 1997) and it is a fundamental requirement for the aquatic life, especially for the aerobic organisms. The high COD levels can affect the aerobic organisms growth, which can lead to the excessive growth of the anaerobic organisms

(Al-Momani *et al.*, 2002), produce an unaesthetic water colour, and decrease recreational value of water bodies. In the literature, there are many studies where even higher COD and BOD₅ levels are reported. As such, in the effluents generated by a central hospital located in a big city from the southeast of France, the COD level reached 2664 mg O₂/l, while the BOD₅ value was up to 1559 mg O₂/l (Emmanuel *et al.*, 2005).

The COD and BOD₅ values indicate the biodegradability of the hospital effluents. Many studies (Al-Momani *et al.*, 2002; Koch *et al.*, 2002) use the BOD₅/COD ratio as biodegradability index. The waste water can be considered readily biodegradable if it has a BOD₅/COD ratio between 0.4 and 0.8 (Al-Momani *et al.*, 2002). Values lower than 0.4 suggest that the waste water is difficult to biodegrade. A BOD₅/COD ratio less than 0.1

Fig. 4. Details of COD fluctuation in the investigated effluents

indicate the presence of substances resistant to conventional biological treatment (Koch *et al.*, 2002).

The BOD_5/COD ratio of the analyzed effluents ranged between 0.18 and 0.99 (Fig. 6).

Most of the effluents collected from different departments of the paediatric clinic (C_3) and the C_2 had the BOD_5/COD ratio ranged between 0.4 - 0.8, values which indicates the presence of the biodegradable substances. Conversely, the

other analyzed effluents had a lower BOD_5/COD ratio (under 0.4) demonstrating that these waste waters can be very hard biodegraded using the conventional biological treatment. The low BOD_5/COD ratio indicate the presence some substances that are persistent such as antibiotics, hormones, cytostatics, carbamazepine, X-ray contrast media, carbamazepine and other acidic drugs such as clofibric acid which are very hard biodegradable (Emmanuel *et al.*, 2005).

Fig. 5. Details of BOD_5 fluctuation in the investigated effluents

Fig. 6. The BOD_5/COD ratio of the analyzed effluents

Total suspended solids (TSS)

Total suspended solids is another important parameter used to characterize the waste water (TSS). The TSS content of the studied effluents was between 18 - 581 mg/l. In the case of the oncologic hospital (C_1) the TSS values were up to 581 mg/l (Fig. 7). For TSS were registered values up to 329.4 mg/l for the C_4 clinic hospital from Cluj-Napoca and up to 362 mg/l for the central hospital from Dej. The lower values of the TSS were obtained in the case of effluents collected from clinic hospital (C_7), and the gynaecologic (C_8) and urologic (C_9) hospitals from Cluj- Napoca (under 30 mg/l). An important situation is the decreasing trend of TSS value obtained for oncologic (C_1) hospital, which had in 2011 an annual average value of 84.25 mg/l in comparison with 223.1 mg/l which was the average value in 2008 (Fig. 7 A).

The data indicated a seasonal fluctuation for TSS parameter. In general, the TSS values were higher in the winter and spring than in the summer

(Fig. 7 A). In the literature data are presented studies with similar TSS values for the hospitals effluents (Emmanuel *et al.*, 2005; Abd El-Gawad and Aly, 2011).

The permissible limit for the TSS parameter is 350 mg/l for effluent discharge in urban sewerage system was exceeded by the effluents collected the oncologic (C_1) hospital from Cluj-Napoca and the one from Dej. Elevated TSS levels can increase the water hardness which will lead to scale formation in pipe-lines and other equipment but they can also be a threat for the aquatic life. A high amount of suspended solids can reduce the light penetration into the water, suppressing photosynthetic activity of phytoplankton, algae, and macrophytes and it can reduce the DO level of waste water (Delée *et al.*, 1998).

Detergents

Both phosphate and surfactant detergents are often detected in the hospital effluents. The

Fig. 7. The variation of TSS values obtained for the studied effluents

Fig. 8. Detergents content of the analyzed effluents

Fig. 9. Residual free chlorine content of the analyzed effluents

detergents that contain phosphates are highly caustic, while the surfactant detergents are very toxic (Adewoye, 2010). The presence of detergents in water will decrease the surface tension of the water, which will increase the absorption of organic chemicals such as pesticides and phenols by the fish. For example, the detergent concentration of 2 mg/l can double the amount of chemicals normally absorbed by the fish (Adewoye, 2010). At higher concentrations, the impact on the aquatic life is more adverse, for example concentrations up to 5 mg/l will kill the fish eggs, while at levels of 15 mg/l, most fish die (Adewoye, 2010).

In the present study the detergents concentrations ranged between 0.15 - 3.55 mg/l, being higher in the C₂ clinic (between 0.5 - 3.55 mg/l) than in the oncologic hospital (C₁) (between 0.15 - 0.23 mg/l) (Fig. 8). The detergent content of the analyzed effluents had a significant annual fluctuation, especially during 2009 and 2010. The data indicated a seasonal variation, with higher values during the spring and summer time than in winter and autumn.

In all the analyzed samples the detergent level was lower than the permissible limit of 25 mg/l for effluent discharge into urban sewerage system (NTPA 002/20002).

Residual free chlorine

Hospitals use a variety of disinfectants based on chlorine. In order to ensure that water is sufficiently treated through the whole distribution system, an excess of chlorine is usually added before the effluent discharge into the urban sewerage system. However, it is important to

maintain a careful balance. An excess of chlorine is not necessary and it may lead to adverse health effects.

In the analyzed effluents the residual free chlorine ranged between 0.04 - 1.44 mg/l. The lower levels (under 0.25 mg/l) were registered in the oncology (C₁) and pneumology (C₅) hospitals from Cluj-Napoca and in the one from Huedin (Fig. 9). The paediatric clinics (C₃) had considerably higher residual chlorine, up to 1.44 mg/l.

The high level registered in the paediatric clinic is almost triple than the permissible limit (0.5 mg/l) for waste water discharge in sewerage system. One of the causes for this high chlorine level is the important quantity of chlorine disinfectant used in this clinic. Because of the high amount of chlorine and COD, the discharge of these effluents into the urban sewerage system can have adverse impact on aquatic life and human health. For example the chlorine can react with the organic material in order to form trihalomethanes which proved to be potentially carcinogenic to humans.

CONCLUSIONS

- (1) The analyzed parameters varied significantly with the effluent source.
- (2) The parameters annual and seasonal variation was dictated by the types/quantities of drugs administrated in hospitals at those times. Generally the values were higher during the hot season.
- (3) The pH, COD, TSS and residual free chlorine content of some effluents exceeded the permissible limit for sewerage discharge.

- (4) The effluents discharge may have immediate or long-term harmful effect on the aquatic ecosystem and human health. They can produce unaesthetic colour and decrease water recreational value.
- (5) Some of the effluents must be treated properly using advanced treatment methods.

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