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

Ocsana OPRIS¹⁾, Carmen ROBA^{2)*}, Florina COPACIU³⁾, and Andrea BUNEA³⁾

¹⁾ National Institute for Research and Development of Isotopic and Molecular Technologies, 67-103 Donat Street, Cluj-Napoca, 400293, Romania

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

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

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

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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 hospital effluents is vital. In the present study, the quality of the effluents generated by 11 important hospitals in Cluj County was investigated. The analysed 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, physicochemical parameter, waste water, water quality*

INTRODUCTION

During the last decades, the production and the consumption of pharmaceuticals have increased rapidly due to the development of medical science. Approximately 3,000 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

1,200 l/bed/day, with a minimal domestic water consumption of 100 l/person/day (Emmanuel *et al.*, 2005). In the developing countries, a hospital's 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, it reaches 968 l/bed/day (Emmanuel *et al.*, 2005). As a consequence, hospitals generate significant volumes of waste water, which end up in the municipal sewerage network or surface water. Sometimes, 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 the biological balance of natural environments, because

of 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 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 analysed parameters were pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS), detergents and residual free chlorine content. The analysed effluents are discharged into the urban sewerage system, and further into the waste water treatment plant. The levels of the analysed physicochemical parameters were compared with the permissible limits set by the Romanian and UE legislation, for waste water discharge into the urban sewerage systems. Council Directive 91/271/EEC concerning 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. Annex no.3 (NTPA 001/2005) contains the "Norms for establishing pollutant limits for urban and industrial waste water discharged into natural receivers", while Annex no.2 (NTPA 002/2005) contains the "Norms for establishing pollutant limits for urban and industrial waste water discharged into 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 6,674 km² and 680,000 inhabitants. Nine 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 from hospitals, before entering the local sewerage network. 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 a refrigerator at 4°C, and analysed within 24 hours from sampling. A total of 95 effluent samples were collected seasonally during January 2008 and September 2011. The samples were analysed for various physicochemical parameters using specific standard procedures: pH (SR ISO 10523:2009), COD (SR ISO 6060:1996), BOD_5 (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 analysed in the laboratory within 24 hours from the sampling. The equipment was 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 19% of the analysed effluents, generated by several hospitals from Cluj-Napoca, exceeded the pH permissible limit (6.5 - 8.5) for waste water discharged 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 at other times C_4 effluents were more 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 demonstrate that the pH fluctuation is slightly dependent on the season (Fig. 3 A). The pH values were higher in summer and autumn than in winter.

The effluents collected from Dej and Huedin hospitals had pH values within the allowed limits. This can be due to the low hospital dynamics; the hospitals are located in small urban centres and they rarely operate at their maximum capacity. 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 organic matter in waste water. COD shows the pollutant load in the water through the presence of organic and inorganic matters. The organic and inorganic matters are chemically 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 in the water. High COD levels can demonstrate the toxic condition and reflect the presence of biologically resistant organic substances. The high levels of BOD₅ indicate the intensity of pollution in waste waters and the low level of oxygen for living organisms.

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	Oncology	310	
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)	Antibiotics Analgesics and anti-inflammatories Cytostatics
C_4	Cluj-Napoca	Clinic	237	Anaesthetics
C_5	Cluj-Napoca	Pneumology	230	Antihypertensives
C_6	Cluj-Napoca	Dialysis	< 50	Disinfectants
C_7	Cluj-Napoca	Clinic	< 50	Psychiatric drugs
C_8	Cluj-Napoca	Gynaecologic	12	Antidiabetics
C_9	Cluj-Napoca	Urologic	< 50	Hormones
H	Huedin	Clinic	137	
D	Dej	Clinic	373	

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 1,875 mg O₂/l) and by the dialysis (C_6) and oncology (C_1) hospitals in Cluj-Napoca, where this parameter reached 991.8 mg O₂/l and 862.5 mg O₂/l, respectively.

In 15% of the analysed effluent samples, generated by four (C_1, C_2, C_6 and H) of the investigated hospitals, the COD concentration exceeded considerably the permissible limits (NTPA 002/2005) for waste water discharge in urban sewage systems, 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 recorded 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 analysed samples, the BOD₅ level did not exceed the permissible limits (300 mg O₂/l)

Fig. 2 The pH values of the analysed effluents

set by the Romanian legislation (NTPA 002/2005) for effluents discharge into the sewage network.

The high COD concentrations recorded in the above-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). In literature, many studies report even higher COD and BOD₅ levels. For example, in the effluents generated by a central hospital located in a big city from the southeast of France, the COD level reached 2,664 mg O₂/l, while the BOD₅ value was up to 1,559 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 the biodegradability index. 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 indicate the presence of substances resistant to conventional biological treatment (Koch *et al.*, 2002).

The BOD₅/COD ratio of the analysed effluents ranged between 0.18 and 0.99 (Fig. 6).

Most of the effluents collected from different departments of the paediatrics clinic (C_3) and

Fig. 3 The pH values of the studied effluents

the C_2 had the BOD₅/COD ratio ranging between 0.4 - 0.8, values which indicate the presence of biodegradable substances. Conversely, the other analysed effluents had a lower BOD₅/COD ratio (under 0.4) demonstrating that these waste waters can be very hard to biodegrade using the conventional biological treatment. The low BOD₅/COD ratio indicates the presence of some persistent substances such as antibiotics, hormones, cytostatic drugs, carbamazepine, X-ray contrast media, carbamazepine and other acidic drugs such as clofibric acid, which are very hard biodegradable (Emmanuel *et al.*, 2005).

Total suspended solids (TSS)

Total suspended solids is another important parameter used to characterise waste water (TSS). The TSS content of the studied effluents was between 18 - 581 mg/l. In the case of the oncology hospital (C_1) the TSS values were up to 581 mg/l (Fig. 7). For TSS recorded values up to 329.4 mg/l for the C_4 clinic hospital in Cluj-Napoca and up to 362 mg/l for the central hospital in Dej. Lower

values of TSS were obtained in the case of effluents collected from the clinic hospital (C_7), and the gynaecologic (C_8) and urologic (C_9) hospitals in Cluj-Napoca (under 30 mg/l). An important situation is the decreasing trend of TSS value obtained for the oncology (C_1) hospital, which in 2011 had 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 summer (Fig. 7 A). In literature, there are studies which found similar TSS values for hospital effluents

Fig. 4 Details of COD fluctuation in the investigated effluents

Fig. 5 Details of BOD₅ fluctuation in the investigated effluents

Fig. 6 The BOD₅/COD ratio of the analysed 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 the urban sewage system was exceeded by the effluents collected at the oncology (C_1) hospital in Cluj-Napoca and the one in Dej. Elevated TSS levels can increase water hardness, which will lead to scale formation in pipe-lines and other equipment.

Detergents

Detergents are often detected in hospital effluents. The detergents that contain phosphates are highly caustic, while the surfactant detergents are very toxic (Adewoye, 2010).

In the present study, detergent concentrations ranged between 0.15 - 3.55 mg/l, higher in the C_2 clinic (between 0.5 - 3.55 mg/l) than in the oncology hospital (C_1) (between 0.15 - 0.23 mg/l) (Fig. 8). The detergent content of the analysed 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 analysed samples, the detergent level was lower than the permissible limit of 25 mg/l for effluent discharge into the urban sewage system (NTPA 002/2005).

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 analysed 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 (C_1) and pneumology (C_5) hospitals in Cluj-Napoca and in the one in Huedin (Fig. 9).

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

Fig. 8 Detergent content of the analysed effluents

Fig. 9 Residual free chlorine content of the analysed effluents

The paediatric clinics (C_3) had considerably higher residual chlorine, up to 1.44 mg/l.

The high level registered in the paediatric clinic is almost three times higher than the permissible limit (0.5 mg/l) for waste water discharged in the sewage system. One of the causes for this high chlorine level is the large quantity of chlorine disinfectant used in this clinic.

CONCLUSIONS

(1) The analysed parameters varied significantly with the effluent source.

(2) The parameters' annual and seasonal variation was dictated by the types/quantities of drugs administered 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 effects on the aquatic ecosystem and human health. They can produce un-aesthetic colour and decrease the water's recreational value.

(5) Some of the effluents must be treated properly using advanced treatment methods.

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