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Evaluation of the Efficiency of Activated Sludge Process in Cefazolin and Doxorubicin Antibiotics Removal from Hospital Wastewater

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A B S T R A C T

Antibiotics and anticancer drugs have particular importance because of their environmental pollutants. The efficacy of the activated sludge process in the removal of Cefazolin and Doxorubicin from hospital wastewater in Sari city (Mazandaran Province) was investigated. The hospital effluent was investigated in different months from different parts of the effluent treatment system and their residual amount was determined by HPLC. The residual amounts of Cefazolin and Doxorubicin in the effluent were 1.96 µg. L^{-1} and 0.95 mg. L^{-1}, respectively. Results showed 36.24% Doxorubicin and 51.6% Cefazolin removal through the activated sludge process. After chlorination, a 45.64% Doxorubicin and 66.42% Cefazolin removal was achieved. It was found that the effect of initial treatment or settling is low in reducing the amount of studied drugs, but the efficacy of different stages of biological treatment varies with the type of contaminant. The effect of the activated sludge process on the polar antibiotic Cefazoline is higher than the anticancer drug Doxorubicin. The unknown risk assessment of these drugs in the environment and the inability of wastewater treatment plants to remove them requires the use of more advanced methods.

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INTRODUCTION

One of the most important environmental contaminants is the residual drug used to treat or prevent microbial infections in humans and animals [1]. These compounds can enter the environment through different sources such as the pharmaceutical industry, hospital effluent, and household resources [2, 3]. Currently, about 3000 different compounds as well as a wide range of different chemicals, are used as medicinal products [4]. It has been estimated that about 630 types of these chemicals and medicines are used at the hospitals and almost 300 cases are identified as hazardous materials [5]. Hospital wastewater can contain hazardous substances such as residual drugs, chemical hazards, pathogens and radioisotopes that can pose a chemical, biological and physical health hazard [6–8].

About 30-90% of antibiotics does not metabolize in the human and animal body and enter the environment as active compounds through urine and feces [9–11]. One of the major routes of antibiotics to the environment is through the entry of laboratory, research and hospital effluents. The inability of wastewater treatment plants to remove highly polar contaminants such as antibiotics causes these compounds to reach surface and groundwater and eventually enters the drinking water distribution network as a result of inadequate treatment. Thus, hospital wastewater can be a rich source of antibiotic-resistant bacteria [12, 13].

Considering the high consumption of antibiotics and consequently their entry into wastewater and the potential for contamination of surface and groundwater resources as well as the acute and chronic health effects of these pollutants, it is necessary to consider an effective method to remove these contaminants from drinking water sources [14]. Most antibiotics used in medical and veterinary medicine are metabolized about 30 to 75% in the body, with the remainder being discharged to the sewage system [15]. Antibiotics can remain unchanged in the environment for a long time because they are highly resistant to biodegradation, thus causing toxicity to aquatic organisms and disturbing their environmental balance is their most prominent environmental effect [16]. Increased exposure to antibiotics in the natural treatment system leads to the development of resistant strains of bacteria [17, 18]. On the other hand, removal

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and biodegradation of antibiotics is difficult due to their persistent naphthol ring as the main structure. Even at low concentrations in waters and soils, they have some impacts such as high toxicity to aquatic invertebrates, algae and the endocrine system, lower biodegradability, mutagenicity and carcinogenicity, allergies in humans, accumulate in the food chain and cause unknown effects on humans and animals [19, 20].

Cefazoline is an antibacterial antibiotic from the cephalosporins family that is often used as a therapeutic agent for some bacterial infections including respiratory, urinary, skin, gastrointestinal, blood, bone and articular and genital infections. This drug is excreted unchanged through the kidney. Urinary excretion increased by approximately 60% in 6 h and by 70-80% within 24 h [21]. Cefazolin is not absorbed through the gastrointestinal tract and should be used by injection [22]. Doxorubicin is an effective antibiotic in the broad treatment of cancer including some leukemia, lymphoma, hodgkin, bladder, breast, stomach, lung, ovary, thyroid, and anthracyclines. These antibiotics originate from a microorganism belonging to the genus *Streptomyces pessidius*. The elimination half-life of Doxorubicin is triple and includes 12 min, 3.3 h, and 30 h, but generally takes an average of 1-3 h. It is metabolized in the liver and is excreted in bile by 40% in 5 days. 5-12% of the drug is excreted in the urine within 5 days and 40-50% is excreted in the faces. So Doxorubicin is mainly excreted through the bile [23, 24].

Activated sludge is an aerobic suspended growth process accepted as a secondary treatment. Bacteria are one of the most important microorganisms because they decompose organic matter. In the aeration tank, a portion of the organic waste is consumed by aerobic bacteria to obtain the energy needed to synthesize the remaining organic matter into new cells [25]. Biological aeration filters have been reported as an effective method in the removal of amoxicillin from aqueous solutions [26]. Other studies showed cytotoxic compounds can not be harvested effectively by conventional biological treatment systems. They stated that non-biological techniques, such as advanced oxidation processes can lead to satisfactory results in the removal of pharmaceutical compounds from effluents [27]. A combination of advanced wastewater treatment strategies following conventional filtration technology as a viable solution has been introduced as an effective way to remove cytostatic compounds [28]. Degradation of Doxorubicin with iron-nickel nanoparticles showed that these metals have properties that can destroy Doxorubicin in an environmentally friendly manner. These particles can effectively reduce or even eliminate the toxicity of Doxorubicin [29]. Examination of the Cefazolin conversion during the chlorination process and evaluation of the products, mechanisms, and genotoxicity showed that two types of reactions occur during Cefazolin clearing. Oxidation of sulfur atoms in Cefazolin, and the replacement of chlorine on the base catalyst on the carbon atom next to the carbonyl group. The formation of chlorine and sulfoxide products in the Cefazolin chlorination process increased genotype toxicity. Thus, the possible fate of cephalosporins poses a serious environmental risk for these antibiotics [30].

By reviewing the literature in the available scientific information sources it can be concluded that very little research has been done on the removal of antibiotic residues from hospital wastewaters through activated sludge process. The present study investigated the efficacy of the conventional and in use activated sludge process in the removal of Cefazolin and Doxorubicin from hospital wastewater.

MATERIALS AND METHODS

This study was conducted on the effluent of a hospital in Sari city (Mazandaran, Iran). The study samples included samples including different types of drugs for the identification of in-hospital antibiotics, Cefazolin and Doxorubicin.

Materials

Pure Doxorubicin and Cefazolin were purchased from EBEWE Pharma GmbH Nfg. KG Co. (Austria) and Loghman Co. (Iran). Sodium Chloride, HPLC grade acetonitrile, water, monopotassium phosphate, triethylamine, and 0.1% phosphoric acid were prepared from Sigma-Aldrich and Merck companies.

To prepare phosphate buffer solution for HPLC analysis of Doxorubicin and Cefazolin, 2.7218 gr of potassium phosphate dihydrogen was dissolved in 100 mL of HPLC grade water and makeup to volume in a 1000 mL balloon. For Doxorubicin assay, buffer pH adjustment was performed using 0.1% phosphoric acid and droplet adding to phosphate buffer until pH reached 2.6. However, for Cefazolin analysis, buffer pH adjusted on 8, through droplet adding of triethylamine. Also, a control sample containing distilled water and 0.9% sodium chloride without any antibiotics were prepared.

Sampling, collection, and storage of samples

The sampling method was compound and started from the closest location to the normal and comprehensive cancer center. To determine the efficacy of the treatment process, sampling of raw wastewater was carried out before entering the effluent treatment plant and then continued after logging into the activated sludge. After analyzing the variables, their mean values were reported.

Samples were collected in a glass container. The samples were transferred to the laboratory by maintaining the optimum temperature in the cold box. Experiments were performed immediately after sampling.

Turbidity, chemical oxygen demand (COD), biologycal oxygen demand (BOD), total soluble solids, total suspended solids and dissolved oxygen were measured for wastewater samples based on the Iran National standards.

Measurements

HPLC analysis for Doxorubicin

The mobile phase consisted of phase A: phosphate buffer at a pH of 2.6 consisting of 20 mM monopotassium phosphate and 0.1% phosphoric acid and the organic phase B: acetonitrile. The trial began with 75% of Phase A and 25% of Phase B (the best conditions for Doxorubicin recovery). Injection speed was adjusted on 1 mL. min^{-1}. The device was first washed with HPLC grade water. The control, standard and original samples were injected respectively. Chromatograms were analyzed using a fluorescence detector with an excitation wavelength of 550 nm (the best wavelength to measure doxorubicin). Doxorubicin retention time in acetonitrile-water solution was evaluated as 9.5 min. Standard samples of 0.5, 1, 5, 10, 20 µg. L^{-1} was prepared by volume upping of 1 mL Doxorubicin solution (with a concentration of 2000 mg. L^{-1}) to 100 mL using distilled water and then, dilute them. The calibration curve was determined and plotted for Doxorubicin (Figure 1).

HPLC analysis for Cefazolin

The mobile phase consisted of phase A: HPLC grade water at a pH of 8 and the organic phase B: acetonitrile. The trial began with 75% of Phase A and 25% of Phase B (the best conditions for Doxorubicin recovery). Injection speed was adjusted on 0.5 mL. min^{-1}. The device was first washed with HPLC grade water. The control, standard and original samples were injected respectively. Chromatograms were analyzed using a UV detector with a wavelength of 270 nm (the best wavelength to measure Cefazolin). The injection volume was 20 µl. Cefazolin retention time in acetonitrile-water solution was evaluated as 4.6 min. Standard samples of 1, 5, 10, 20, 30, 40, 50, 60, 80 and 100 µg. L^{-1} was prepared by volume upping of 2 mg Cefazolin to 100 mL using distilled water and then, dilute them. The calibration curve was determined and plotted for Cefazolin (Figure 2).

HPLC analysis

High-Performance Liquid Chromatograph, HPLC (KNAUER, 1050, Germany) was used with a fluorescence detector for analysis and identification of Doxorubicin (SHIMADZU, Japan) and UV detector for analysis and identification of Cefazolin (KNAUER, Germany). C18 columns (250× 6.4 mm, and 5 µm particle size) were used at ambient temperature.

The sample injector was designed to inject the sample as a thin line. A fraction of the sample was inserted into the outer ring of a stainless steel tube by a micro-syringe. Then, the valve was rotated and the sample was circulated with the solvent stream throughout the system and was quickly introduced into the column. Due to the complexity of the wastewater environments and the possibility of the presence of micro-colloids in the effluent, all wastewater samples were filtered using a 0.45-micron syringe filter before injection into the HPLC apparatus.

RESULTS AND DISCUSSIONS

Quantity of hospital wastewater

The most important principle in the planning and management of hospital wastewater is to estimate the amount of its wastewater production. The amount of consumed water and the produced effluent in the hospital were determined (Table 1). The results showed that the highest amount of wastewater production was due to bed occupancy rate in the mentioned months as well as general hospital conditions in January and the lowest amount of effluent produced in April. Samples were collected from various treatment sites including hospital wastewater inlet to the treatment plant, aerated outlet

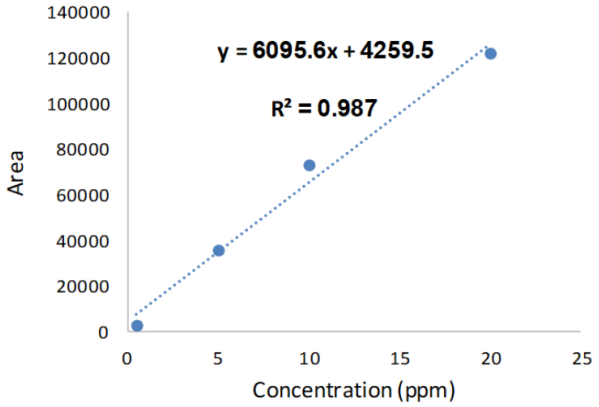

Figure 1. The calibration curve for Doxorubicin

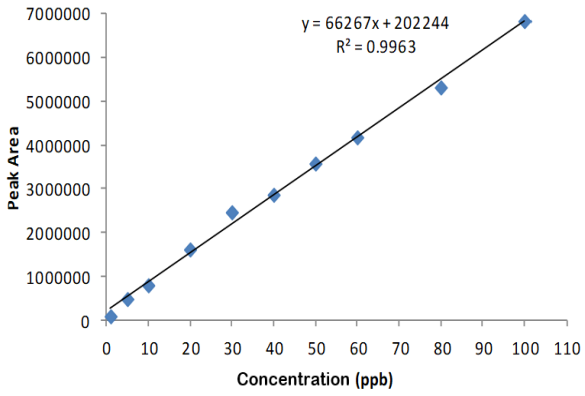

Figure 2. The calibration curve for Cefazolin

TABLE 1. Water consumption fluctuations and effluent production rate in the studied hospital for a 10 month period

Month	Number of beds admitted	Hospital water consumption (L)	The amount of effluent produced (L)
January	10022	501100	430946
February	9863	493150	424109
March	8758	437900	376594
April	6709	335450	288487
May	9672	483600	415896
June	8711	435550	374573
July	9447	472350	406221
August	9339	466950	401577
September	9618	480900	413574
October	9750	487500	419250

(pre-chlorination), final effluent after chlorination, and sludge storage and concentrations of Cefazolin and Doxorubicin were measured.

A direct comparison of the statistics of hospital water supply and wastewater production showed that the weather, bed occupancy rate during the month, construction at different intervals of the year, correct cantilever service, and quality of water supply have a significant impact on hospital wastewater production. The minimum hospital effluent flow occurred in the early hours of the morning when water consumption reached its lowest level. Also, the first peak flow occurred in the later hours, when the morning used water reached the sewage treatment plant. The peak of effluent production was also repeated between 11 and 12 am and 7 to 9 pm.

Physical and chemical properties of wastewater

The wastewater from the studied hospital includes organic particles (feces, hair, food, vomiting, paper, fibers), organic matter (urea, protein, drugs), mineral particles (sand, sand, metal particles), soluble minerals (ammonia, cyanide, hydrogen sulfide, thiol sulfate) and other substances. Secondary wastewater treatment standards involved the separation of biodegradable organic matter, suspended solids and pathogens, enforced stringent environmental regulations and consequently standardized effluent in the mentioned cases. The most important physical characteristic of wastewater and effluent is the total suspended solids (TSS), including floating materials, settable materials, colloids, and other solutes. Other important physical properties are turbidity and electrical conductivity. The chemical components of wastewater are divided into two categories: mineral and organic. Their inorganic chemical constituents include nutrients, non-metallic constituents, metals and gases, and the organic chemical constituents of wastewater fall into two separate classes of materials. Adhering organic components also contain a number of distinct compounds that cannot be separately identified, both of which are substantially present in purification, disposal, and reuse processes. The results of the first step of the experiment are presented in Table 2. The following analyses were performed over two six-month periods by a trusted environmental laboratory. The first measurement was conducted in the first six-month period and the second measurement was conducted in the second six-month period. Based on the results, the highest chemical oxygen demand (COD) removal efficiency was observed in the aeration basin due to the high activity of bacteria in the ponds and the high amount of oxygen required by the bacteria.

The average use of Cefazolin and Doxorubicin

The average dose of Cefazolin per month in the studied hospital was 7719 vials. The results showed that the highest antibiotic use during the year was related to Cefazolin antibiotics and the predicted antibiotic use rate was higher with respect to bed occupancy rate and type of hospitalization in higher wards.

In the case of genotoxic drugs, among the 12 genotoxic drugs available in the hospital, Doxorubicin is considered as an indicator drug in the genotoxic group due to the similar nature of the performance of conventional antibiotics on microorganisms. The average dose of Doxorubicin 10 and Doxorubicin 50 per month in the studied hospital were 830 and 527 vials. Actually, In a 12-month period, of the 229 patients received the Doxorubicin 10, 191 patients received outpatient chemotherapy and were then discharged. Also, of the 310 patients received the Doxorubicin 50, 256 patients received outpatient chemotherapy and were then discharged. According to the disposal standards, 501 patients require follow-up medication at home. The results indicated that the number of patients admitted to outpatient wards and outpatients in outpatient chemotherapy must be higher numbers.

TABLE 2. Chemical and biological characteristics of hospital wastewater

Characterisitic factor	Unit of factor	The amount of factor	
		First measurement	Second measurement
pH	-	7.48	7.1
Visual quality	-	a little cloudy	a little cloudy
Total soluble solids	Mg. L^{-1}	71	38
Total suspended solids (TSS)	Mg. L^{-1}	64	48
Dissolved oxygen	Mg. L^{-1}	2.73	3.58
Biological oxygen demand (BOD)	Mg. L^{-1}	14	27
Chemical oxygen demand (COD)	Mg. L^{-1}	24	44
Turbidity	NTU	11.8	10.27
Free chlorine	Mg. L^{-1}	1.5	-
Total *Coliform*	MPN/100	43	-
Color	PCU	0	-
Temperature	^{o}C	26.1	26.1

The study found that of the 24 widely used genotoxic drugs, the most widely used anticancer drugs in the hospital were Ifosfamide, Cisplatin, Vincristine, Cyclophosphamide, Doxorubicin, Vinblastine, Bleomycin, and Epirubicin. Also, among the usual antibiotics, Cefazolin was the most used, which led to this study comparing two conventional and anti-cancer antibiotics. Due to the antimicrobial activity of Doxorubicin, this drug is known in the group of anticancer antibiotics. Identification and study of medicines found in hospital effluents revealed that most of the diagnostic classes in hospital effluents are anti-inflammatory drugs, analgesics, antibiotics, lipid regulators, steroids and related hormones, beta-blockers, and cancer treatments. These substances may be heavily or partially metabolized by various mechanisms through pharmacological action and may cause irreparable damage if they are not adequately treated in an environmental release [31]. The bioavailability or percentage of the drug that enters the bloodstream is 5% in Doxorubicin and the half-life of this drug is excreted in the urine and feces (between 12 and 18.5 hours), thus tracking patients at the outpatient center, Doxorubicin (with a stay of fewer than 10 hours) is very important. The half-life of Cefazolin is 1.8 hours for intravenous injection and 2 hours for intramuscular injection. Excretion of this drug is mainly through the kidneys and without high metabolic changes. Patients dispense their chemotherapy drugs several times. Depending on the type of cancer and its severity, patients may receive 2 to 12 injections, although repeated if necessary. During each injection, patients can take a single drug with modern injector protocols, which may include up to 9 different drugs. 85% of these injections are done, outpatient. For this, the patient goes to the oncology center for several hours, injects and arrives home. Some of the medicines received are completely degraded by the patient's body and are not difficult for others or to supply with water. However, some dangerous drugs (Doxorubicin being one of the most dangerous) are used by the patient as a parent drug or active metabolite. And is excreted unchanged. Disposal of these drugs is very common and can even be detected in sweat, vomiting, urine, and feces of the patient. In other words, the patient and their families are exposed to dangerous amounts of these mutagenic substances through the biological waste that is discharged from the patient.

Removal efficacy of Cefazolin and Doxorubicin in activated sludge process

Wastewater collection at the comprehensive cancer center of the studied hospital is performed by a separate plumbing system. Pre-aeration was conducted by 15 deep diffusers to pre-purify effluents containing genotoxic drugs and then led to the hospital's comprehensive wastewater treatment system. Table 3 shows the obtained results of Cefazolin and Doxorubicin concentration measurement at different parts of the hospital wastewater treatment system.

Inlet 1 of raw wastewater comes from normal inpatient wards and inlet 2 comes from comprehensive cancer center. Results showed 36.24% Doxorubicin removal and also 51.6% Cefazolin removal from hospital wastewater through ctivated sludge process. After chlorination a 45.64% Doxorubicin and also 66.42% Cefazolin removal from hospital wastewater was

TABLE 3. Cefazolin and Doxorubicin concentrations in different parts of waste treatment system

Sampling place	Cefazolin concentration (µg. L^{-1})	Doxorubicin concentration (mg. L^{-1})
Raw wastewater (inlet 1)	1.89	0.29
Raw wastewater (inlet 2)	6.21	2.69
After activated sludge process	1.96	0.95
Chlorinated wastewater	1.36	0.81
Sludge collection depot	1.68	0.96

achieved. It has been reported that the efficiency of disinfection process through ozonation in phenol removal from wastewater decreased with increasing the concentration of initial wastewater pollutants [32, 33]. In this study, the source of Cefazolin was higher than Doxorubicin. This drug also has more metabolic changes than Doxorubicin. Evaluation of the effect of contaminant concentration on degradation showed that removal efficiency was inversely proportional to the initial concentration of Cefazolin and Doxorubicin. This explanation could be due to the increase in the initial contaminant concentration could cause to the increase in the number of Cefazolin and Doxorubicin molecules adsorbed on the catalyst surface. Therefore, more hydroxyl radicals are needed to destroy pollutant molecules. Due to the fact that the amount of hydroxyl radicals, the ozone emission potential and the dose of the catalyst against the contaminant increase are stable, the efficiency will decrease. On the other hand, by degradation of Cefazolin and Doxorubicin, the production of byproducts is predictable. Higher concentration of the contaminant could cause to the higher the production of byproducts from degradation. Increasing by-products, in turn, react with and consume free radicals in the environment, which will have a negative impact on process efficiency [33]. The process of activated sludge to remove some drugs was more efficient than other methods. Beta-lactam and quinolone drugs in particular appear to be sensitive to aerobic oxidation. At a sewage station in Australia, beta-lactam antibiotics showed high biodegradation. Lincomycin and sulfonamides were affected by the activated sludge treatment process. Similar studies also found that process efficiency depends on the composition studied. Ibuprofen, naproxen, bisphosphate and estrogen (estrone, estradiol, and ethylene estradiol) experienced high levels of harvesting. Sulfamethoxazole, carbamazepine and diclofenac had limited elimination [34–36]. The elimination efficiency usually depends on the properties of the drug under investigation, such as polarity. The activated sludge process can destroy part of the estrogen [34]. But it does not work for fat regulators such as jam fibrizol and clafibric acid [37]. Chlorine use in hospital wastewater disinfection is able to reduce the amount of studied antibiotics, but the potential for ozone and ultraviolet radiation has been greater in extensive studies than chlorine and has a better effect on reducing the population of bacteria and antibiotics in hospital wastewater [38].

The results showed a direct relationship between the percentage of removal and the molecular structure of the drugs studied. Of the two drugs studied, Doxorubicin is more resistant to metabolic changes and requires more careful deletion. This drug is released relatively unchanged from the body without major metabolites. In general, drugs resistant to major metabolic changes are more resistant to elimination by conventional purification methods such as activated sludge. Therefore, due to the nature of anticancer drugs, Cefazolin has a higher removal efficiency than Doxorubicin by the activated sludge process [39]. Generally, polar drugs such as Cefazolin are eliminated with higher efficiency through biodegradation in activated sludge systems. In this study, it was found that the effect of initial treatment or settling is very low in reducing the amount of drug, but the efficacy of different stages of biological treatment varies with the type of contaminant. As shown in the present study, the percentage of Cefazoline reduced in the input wastewater was higher than Doxorubicin in comparison with the initial settling tank. In addition, removal efficiencies may vary significantly from hot to cold seasons.

It must be noted that the obtained data in this research is appropriate to geographical and climatic conditions, type of sewage, irrigation and agricultural management and soil of the under investigation area. Thus the results may not completely comparable with the other similar studies.

CONCLUSION

The present study showed that solid phase extraction and liquid chromatography analysis can be used as a reliable and simple method to quantify antibiotics in complex environments such as wastewater. The results and methodology presented can also be used as a specific guideline for the extraction and quantification of

Cefazolin and Doxorubicin and the different types of drugs in hospital wastewater and similar environments. In addition to the above, various types of chemicals are also used in the hospital for various laboratory and research activities, surgery, pharmaceuticals, disinfectants and more. Therefore, the use of an advanced wastewater treatment method makes it more necessary. According to the obtained results, it is important to note that the most important source of these compounds in wastewater or in the environment is the excretion of urine and feces of patients undergoing medical treatment with active metabolites. They are transferred to the wastewater so that even the hospital wastewater systems are not likely to be completely eliminated so these increase the potential risks of medications in the hospital wastewater. It has been well documented that some of them lead to the development of secondary cancer. Specific concentrations for Doxorubicin in particular were higher than expected. However, due to the half-life of this drug and the type of hospital wastewater treatment that involved the conventional treatment process, this rate is not very far from reality and with some simple measures a higher removal percentage will be observed. The residual amount of Cefazolin in the effluent is more in line with existing standards and this fact is more justified due to its low half-life in the aquatic environment and demonstrates the efficacy of effluent treatment. In general, high concentrations of drugs in the effluent indicated that the treatment facilities for complete removal of the residual drugs were ineffective. But it can be predicted that by refining the treatment process by increasing the hydraulic retention time, the use of plants in the removal of pharmaceuticals or ozonation, in addition to being cost-effective, will effectively increase the efficacy of drug removal in hospital treatment plants.

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REFERENCES

1. Gadipelly, C., Pérez-González, A., Yadav, G. D., Ortiz, I., Ibáñez, R., Rathod, V. K., & Marathe, K. V., 2014, Pharmaceutical industry wastewater: Review of the technologies for water treatment and reuse, Industrial and Engineering Chemistry Research, 53(29): 11571-11592. https://doi.org/10.1021/ie501210j
2. Gunnarsdóttir, R., Jenssen, P. D., Erland Jensen, P., Villumsen, A., & Kallenborn, R., 2013, A review of wastewater handling in the Arctic with special reference to pharmaceuticals and personal care products (PPCPs) and microbial pollution, Ecological Engineering, 50: 76–85. https://doi.org/10.1016/j.ecoleng.2012.04.025
3. Fadaei-Kermani, E., Barani, G. A., & Memarzadeh, R., 2019, Drought Utilization Management of Surface and Ground Water (Case study: Qaryat-Al-Arab Watershed), Iranian (Iranica) Journal of Energy and Environment, 10(4): 275–280. https://doi.org/10.5829/ijee.2019.10.04.08
4. Derakhshan, Z., Mokhtari, M., Babaei, F., Ahmadi, R. M., Ehrampoush, M. H., & Faramarzian, M., 2016, Removal Methods of Antibiotic Compounds from Aqueous Environments– A Review, Journal of Environmental Health and Sustainable Development, 1(1): 43–62. Retrieved from http://jehsd.ssu.ac.ir/article-1-26-en.html
5. Aga, D. S., Lenczewski, M., Snow, D., Muurinen, J., Sallach, J. B., & Wallace, J. S., 2016, Challenges in the Measurement of Antibiotics and in Evaluating Their Impacts in Agroecosystems: A Critical Review, Journal of Environmental Quality, 45(2): 407–419. https://doi.org/10.2134/jeq2015.07.0393
6. Rahman-Al Ezzi, A. A., & Alhamdiny, S. H., 2019, Elimination of Chloroform ($CHCl_3$) from Drinking Water via a Synergistic Effect of Stripping, Oxidation and Adsorption Process in Air Lift Loop Reactor, Iranian (Iranica) Journal of Energy and Environment, 10(2): 85–90. https://doi.org/10.5829/ijee.2019.10.02.03
7. Guan, Y., Wang, B., Gao, Y., Liu, W., Zhao, X., Huang, X., & Yu, J., 2017, Occurrence and Fate of Antibiotics in the Aqueous Environment and Their Removal by Constructed Wetlands in China: A review, Pedosphere, 27(1): 42–51. https://doi.org/10.1016/S1002-0160(17)60295-9
8. Carraro, E., Bonetta, S., Bertino, C., Lorenzi, E., Bonetta, S., & Gilli, G., 2016, Hospital effluents management: Chemical, physical, microbiological risks and legislation in different countries, Journal of Environmental Management, 168: 185-199. https://doi.org/10.1016/j.jenvman.2015.11.021
9. Liu, H., Liu, W., Zhang, J., Zhang, C., Ren, L., & Li, Y., 2011, Removal of cephalexin from aqueous solutions by original and Cu(II)/Fe(III) impregnated activated carbons developed from lotus stalks Kinetics and equilibrium studies, Journal of Hazardous Materials, 185(2–3): 1528–1535. https://doi.org/10.1016/j.jhazmat.2010.10.081
10. Rivera-Utrilla, J., Sánchez-Polo, M., Ferro-García, M. Á., Prados-Joya, G., & Ocampo-Pérez, R., 2013, Pharmaceuticals as emerging contaminants and their removal from water. A review, Chemosphere, 93(7): 1268-1287. https://doi.org/10.1016/j.chemosphere.2013.07.059
11. El-Ghenymy, A., Oturan, N., Oturan, M. A., Garrido, J. A., Cabot, P. L., Centellas, F., Brillas, E., 2013, Comparative electro-Fenton and UVA photoelectro-Fenton degradation of the antibiotic sulfanilamide using a stirred BDD/air-diffusion tank reactor, Chemical Engineering Journal, 234: 115–123. https://doi.org/10.1016/j.cej.2013.08.080
12. Ngigi, A. N., Magu, M. M., & Muendo, B. M., 2020, Occurrence of antibiotics residues in hospital wastewater, wastewater treatment plant, and in surface water in Nairobi County, Kenya, Environmental Monitoring and Assessment, 192(1): 1–16. https://doi.org/10.1007/s10661-019-7952-8
13. Wang, Q., Wang, P., & Yang, Q., 2018, Occurrence and diversity of antibiotic resistance in untreated hospital wastewater, Science of the Total Environment, 621: 990–999. https://doi.org/10.1016/j.scitotenv.2017.10.128
14. Lien, L., Hoa, N., Chuc, N., Thoa, N., Phuc, H., Diwan, V., Lundborg, C., 2016, Antibiotics in Wastewater of a Rural and an Urban Hospital before and after Wastewater Treatment, and the Relationship with Antibiotic Use—A One Year Study from Vietnam, International Journal of Environmental Research and Public Health, 13(588): 1–13. https://doi.org/10.3390/ijerph13060588
15. Ledezma Estrada, A., Li, Y. Y., & Wang, A., 2012, Biodegradability enhancement of wastewater containing cefalexin

by means of the electro-Fenton oxidation process, Journal of Hazardous Materials, 227–228: 41–48. https://doi.org/10.1016/j.jhazmat.2012.04.079

16. Kumar, M., Jaiswal, S., Sodhi, K. K., Shree, P., Singh, D. K., Agrawal, P. K., & Shukla, P., 2019, Antibiotics bioremediation: Perspectives on its ecotoxicity and resistance, Environment International, 124: 448-461. https://doi.org/10.1016/j.envint.2018.12.065
17. Ahmed, I., Rabbi, M. B., & Sultana, S., 2019, Antibiotic resistance in Bangladesh: A systematic review, International Journal of Infectious Diseases, 80: 54-61. https://doi.org/10.1016/j.ijid.2018.12.017
18. Ogawara, H., 2019, Comparison of Antibiotic Resistance Mechanisms in Antibiotic-Producing and Pathogenic Bacteria, Molecules, 24(3430): 1–55. https://doi.org/10.3390/molecules24193430
19. Santiago-Morales, J., Agüera, A., Gómez, M. del M., Fernández-Alba, A. R., Giménez, J., Esplugas, S., & Rosal, R., 2013, Transformation products and reaction kinetics in simulated solar light photocatalytic degradation of propranolol using Ce-doped TiO_2, Applied Catalysis B: Environmental, 129: 13–29. https://doi.org/10.1016/j.apcatb.2012.09.023
20. Haidar, M., Dirany, A., Sirés, I., Oturan, N., & Oturan, M. A., 2013, Electrochemical degradation of the antibiotic sulfachloropyridazine by hydroxyl radicals generated at a BDD anode, Chemosphere, 91(9): 1304–1309. https://doi.org/10.1016/j.chemosphere.2013.02.058
21. Kanehisa, M., Furumichi, M., Tanabe, M., Sato, Y., & Morishima, K., 2017, KEGG: New perspectives on genomes, pathways, diseases and drugs, Nucleic Acids Research, 45(D1): D353–D361. https://doi.org/10.1093/nar/gkw1092
22. Alqahtani, S. A., Kleiner, D. E., Ghabril, M., Gu, J., Hoofnagle, J. H., & Rockey, D. C., 2015, Identification and characterization of cefazolin-induced liver injury, Clinical Gastroenterology and Hepatology, 13(7): 1328-1336. https://doi.org/10.1016/j.cgh.2014.11.036
23. Tacar, O., Sriamornsak, P., & Dass, C. R., 2013, Doxorubicin: An update on anticancer molecular action, toxicity and novel drug delivery systems, Journal of Pharmacy and Pharmacology, 65(2): 157-170. https://doi.org/10.1111/j.2042-7158.2012.01567.x
24. Borišev, I., Mrdanovic, J., Petrovic, D., Seke, M., Jović, D., Srdenović, B., Djordjevic, A., 2018, Nanoformulations of doxorubicin: How far have we come and where do we go from here?, Nanotechnology, 29(33): 332002. https://doi.org/10.1088/1361-6528/aac7dd
25. Karami, N., Mohammadi, P., Zinatizadeh, A., Falahi, F., & Aghamohammadi, N., 2018, High rate treatment of hospital wastewater using activated sludge process induced by high-frequency ultrasound, Ultrasonics Sonochemistry, 46: 89–98. https://doi.org/10.1016/j.ultsonch.2018.04.009
26. Baghapour, M. A., Shirdarreh, M. R., & Faramarzian, M., 2015, Amoxicillin removal from aqueous solutions using submerged biological aerated filter, Desalination and Water Treatment, 54(3): 790–801. https://doi.org/10.1080/19443994.2014.888014
27. Lutterbeck, C. A., Wilde, M. L., Baginska, E., Leder, C., Machado, Ê. L., & Kümmerer, K., 2015, Degradation of 5-FU by means of advanced (photo) oxidation processes: UV/H_2O_2, $UV/Fe^{2+}/H_2O_2$ and UV/TiO_2 - Comparison of transformation products, ready biodegradability and toxicity, Science of the Total Environment, 527–528: 232–245. https://doi.org/10.1016/j.scitotenv.2015.04.111
28. Shraim, A., Diab, A., Alsuhaimi, A., Niazy, E., Metwally, M., Amad, M., Dawoud, A., 2017, Analysis of some pharmaceuticals in municipal wastewater of Almadinah Almunawarah, Arabian Journal of Chemistry, 10: S719–S729. https://doi.org/10.1016/j.arabjc.2012.11.014
29. Kadu, B. S., Wani, K. D., Kaul-Ghanekar, R., & Chikate, R. C., 2017, Degradation of doxorubicin to non-toxic metabolites using Fe-Ni bimetallic nanoparticles, Chemical Engineering Journal, 325: 715–724. https://doi.org/10.1016/j.cej.2017.05.097
30. Kennedy Neth, N. L., Carlin, C. M., & Keen, O. S., 2017, Doxycycline transformation and emergence of antibacterially active products during water disinfection with chlorine, Environmental Science: Water Research and Technology, 3(6): 1086–1094. https://doi.org/10.1039/c7ew00215g
31. Nikolaou, A., Meric, S., & Fatta, D., 2007, Occurrence patterns of pharmaceuticals in water and wastewater environments, Analytical and Bioanalytical Chemistry, 387(4): 1225–1234. https://doi.org/10.1007/s00216-006-1035-8
32. Moussavi, G., khavanin, A., & Alizadeh, R., 2010, The integration of ozonation catalyzed with MgO nanocrystals and the biodegradation for the removal of phenol from saline wastewater, Applied Catalysis B: Environmental, 97(1–2): 160–167. https://doi.org/10.1016/j.apcatb.2010.03.036
33. Zhang, J., Chang, V. W. C., Giannis, A., & Wang, J. Y., 2013, Removal of cytostatic drugs from aquatic environment: A review, Science of the Total Environment, 445-446: 281-298. https://doi.org/10.1016/j.scitotenv.2012.12.061
34. Joss, A., Andersen, H., Ternes, T., Richle, P. R., & Siegrist, H., 2004, Removal of estrogens in municipal wastewater treatment under aerobic and anaerobic conditions: Consequences for plant optimization, Environmental Science and Technology, 38(11): 3047–3055. https://doi.org/10.1021/es0351488
35. Joss, A., Keller, E., Alder, A. C., Göbel, A., McArdell, C. S., Ternes, T., & Siegrist, H., 2005, Removal of pharmaceuticals and fragrances in biological wastewater treatment, Water Research, 39(14): 3139–3152. https://doi.org/10.1016/j.watres.2005.05.031
36. Clara, M., Strenn, B., Gans, O., Martinez, E., Kreuzinger, N., & Kroiss, H., 2005, Removal of selected pharmaceuticals, fragrances and endocrine disrupting compounds in a membrane bioreactor and conventional wastewater treatment plants, Water Research, 39(19): 4797–4807. https://doi.org/10.1016/j.watres.2005.09.015
37. Snyder, S. A., Adham, S., Redding, A. M., Cannon, F. S., DeCarolis, J., Oppenheimer, J., Yoon, Y., 2007, Role of membranes and activated carbon in the removal of endocrine disruptors and pharmaceuticals, Desalination, 202(1–3): 156–181. https://doi.org/10.1016/j.desal.2005.12.052
38. Hashemi, H., Bovini, A., Hung, Y., & Amin, M., 2013, A review on wastewater disinfection, International Journal of Environmental Health Engineering, 2(1): 22-30. https://doi.org/10.4103/2277-9183.113209
39. Emara, Y., Siegert, M.-W., Lehmann, A., & Finkbeiner, M., 2018, Life Cycle Management in the Pharmaceutical Industry Using an Applicable and Robust LCA-Based Environmental Sustainability Assessment Approach, In Designing Sustainable Technologies, Products and Policies (pp. 79–88). Springer International Publishing. https://doi.org/10.1007/978-3-319-66981-6_9

Persian Abstract

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چکیده

آنتی‌بیوتیک‌ها و داروهای ضد سرطان دارای اهمیت خاصی از نظر آلایندگی زیست محیطی هستند. تحقیق حاضر به بررسی کارایی فرایند لجن فعال در حذف سفازولین و دوکسوروبیسین از پساب یک بیمارستان در شهر ساری (استان مازندران) پرداخته است. پساب بیمارستان در ماه‌های مختلف و از قسمت‌های متفاوت سیستم تصفیه پساب بررسی شد و مقدار باقیمانده داروها با استفاده از روش کروماتوگرافی مایع با کارایی بالا تعیین گردید. مقادیر باقیمانده سفازولین و دوکسوروبیسین در پساب تصفیه شده به ترتیب برابر با ۱/۹۶ میکروگرم در لیتر و ۰/۹۵ میلی گرم در لیتر بود. نتایج نشان داد که ۳۶/۲۴٪ دوکسوروبیسین و ۵۱/۶٪ سفازولین در فرایند لجن فعال حذف شدند. پس از کلرزنی، درصد حذف دوکسوروبیسین به ۴۵/۶۴٪ و سفازولین به ۶۶/۴۲٪ رسید. اثر مراحل تصفیه مقدماتی و ته‌نشینی در کاهش باقیمانده داروها ناچیز ارزیابی شد اما کارایی مراحل مختلف تصفیه بیولوژیکی بسته به نوع آلاینده، متفاوت بود. اثر فرایند لجن فعال بر روی آنتی‌بیوتیک قطبی سفازولین بیشتر از داروی ضد سرطان دوکسوروبیسین بود. ناشناخته بودن ارزیابی ریسک این داروها در محیط زیست و عدم توانایی واحدهای تصفیه پساب برای حذف کامل این داروها لزوم استفاده از روش‌های پیشرفته‌تر را ایجاد می‌کند.