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Research Article

Detection of Antibiotics in Drinking Water Treatment Plants in Baghdad City, Iraq

Ansam R. Mahmood,[1] Halah H. Al-Haideri ,[2] and Fikrat M. Hassan [2]

[1] *The Ministry of Science and Technology, Baghdad, Iraq*
[2] *Department of Biology, College of Science for Women, University of Baghdad, Baghdad 10072, Iraq*

Correspondence should be addressed to Halah H. Al-Haideri; hhmalhaideri@gmail.com

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Persistence of antibiotics in the aquatic environment has raised concerns regarding their potential influence on potable water quality and human health. This study analyzes the presence of antibiotics in potable water from two treatment plants in Baghdad City. The collected samples were separated using a solid-phase extraction method with hydrophilic-lipophilic balance (HLB) cartridge before being analyzed. The detected antibiotics in the raw and finished drinking water were analyzed and assessed using high-performance liquid chromatography (HPLC), with fluorometric detector and UV detector. The results confirmed that different antibiotics including fluoroquinolones and *B*-lactams were detected in the raw and finished water. The most frequently detected antibiotics were ciprofloxacin with highest concentration of 1.270 μg L^{-1} in the raw water of Al-Wihda plant, whereas the highest concentration of levofloxacin was 0.177 μg L^{-1}, while amoxicillin was not detected in this plant. In contrast, ciprofloxacin was found in both raw water and finished water of Al-Rasheed plant and recorded highest concentration of 1.344 and 1.312 μg L^{-1}, respectively. Moreover, the residual amount of levofloxacin in the raw water was up to 0.414 μg L^{-1}, whereas amoxicillin was shown to be the most detectable drug in the raw water of Al-Rasheed plant, with a concentration of 1.50 μg L^{-1}. The results of this study revealed the existence of antibiotic drugs in raw and finished water and should be included in the Iraqi standard for drinking water quality assessment.

1. Introduction

Wide-spread distribution and persistence of resistant pathogenic bacteria and environmental pollution have led to the use of a wide spectrum of drug compounds for treatment. Active drug substances are chemical compounds that can damage the environment but have received little attention as potential environmental pollutants, particularly in the developing countries [1, 2]. Furthermore, their effects on the biotic environment can be serious. Antibiotics are produced in large quantities as they are widely used in veterinary therapy as well [3, 4]. The significant existence of antibiotics in the environment can be attributed to multiple factors including the release of unabsorbed antibiotics by animals and humans into the water stream. Moreover, most of the residual unused antibiotics from medicinal practices, laboratories, factories, residential, and commercial institutes are discarded into common waste water [5–7]. The detection of traces of drugs in the drinking water sources of various countries is due to the improper discarded of these drugs in our water supplies, which then affect directly and indirectly the environment and human [8]. The presence of these drugs at low levels in the environment is more than enough to have a harmful and deleterious impact; particularly, the long exposure time of pregnant women to the trace amount of these antibiotics may resulted in malformation of infants and children [9, 10]. Although antibiotics are considered as a harmful factor for human health, its existence in the environment is critical factor of contamination [11], so if these drugs are not disposed properly, they will lead to emergence of resistance bacteria in the environment. On the other hand, some unused antibiotics are usually thrown to the sewage system to be eliminated; however, if the drugs are not eliminated or degraded, they will directly move to the surface water, ground water, and drinking water [12]. Although there are different ways to eliminate the antibiotics from the sewage system, not all drugs were completely treated, then it may release into the natural waters. According to the high water solubility and weak degradability of antibiotics, it can easily pass across the membrane through filtration steps and reach to the drinking water [13]. The risk of existing of antibiotics in wastewater treatment has gained more attention, because it may lead to development of the antibiotic-resistant bacteria in nature, as well as in different environmental conditions [14].

Antibiotics have attracted significant attention due to the aggravation of resistant pathogens. Most notably, fluoroquinolones such as ciprofloxacin (CIP) and levofloxacin (LEV) and *B*-lactam amoxicillin (AMO) are wide-spectrum antibiotics that are effective against a broad range of infectious diseases. It was recorded that ciprofloxacin is able to inhibits the growth of multidrug-resistance microorganism, which exert resistant pattern to other antibiotics such as macrolide, beta-lactam and aminoglycosides [15]. Drugs like clofibric acid and diclofenac have been detected in different water sources including surface water, ground water, river, and sewage water in Berlin [16–18]. Drug contamination in drinking water units in Canada and United States has been confirmed [19, 20]. In addition, the presence of low levels of antibiotics has been associated with increased appearance of resistant pathogens that affect human health. Many studies have revealed the presence of antibiotic-resistant bacteria in drinking water supplies in the United States of America and Europe [21, 22]. In addition, similar composition of veterinary and human antibiotics can create cross-resistance [23, 24]. The antibiotic contamination of water also represents challenges for the water industry and water resource planning. Therefore, considerable attention has been paid to the presence of antibiotics in the environment and various aquatic media such as industrial wastewater, ground water, municipal wastewater, hospital wastewater, drinking water, and surface water [25–27]. As long as antibiotics are considered as environmental pollutants, they require robust preclinical and clinical approaches to assess their efficiency before commercialization. In UK, Australia, and US, the human risk assessments of antibiotics have been reviewed, where the concentration of antibiotics in drinking water is generally more than 1000-fold below the minimum therapeutic dose (MTD), which refers to the lowest active dose [28]. The extraction of antibiotics from different samples by solid-phase extraction techniques has been reported in many literatures [29, 30], as well as the identification and quantification methods using capillary electrophoresis, thin layer chromatography, and high-performance liquid chromatography [31–33]. The most recent advance in analytical techniques to investigate the antibiotics in different samples is HPLC technique [34]. Evaluating the presence of antibiotics in drinking water leads to realizing the critical development of antibiotic-resistant bacteria in the environment. The present study is conducted to investigate the presence of antibiotics in raw and finished drinking water in treatment plants in Iraq, which can serve as a reference to develop new strategies for drinking water treatment in the future and to determine the level of antibiotics at both beginning and end of water treatment.

2. Material and Methods

2.1. Study Area. Baghdad is a big city with a population exceeding seven million. Several factories and hospitals drain their wastewater illegally to the river. Many direct and indirect sources are responsible for the contamination of the river drainage area in Bagdad [26, 35]. In this study, two water treatment plants were selected for water sample collection: Al-Rasheed and Al-Wihda plants (Figure 1). Al-Rasheed plant is located in the south of Baghdad City within the site of multiple wastewater discharges and the waste of factories. It was firstly initiated in 1963, and the amount of production is estimated by 61.668 m^3/day. This plant provides Al-Zufraniah area and Al-Rasheed district. Al-Wihda plant is located on the eastern bank of Tigris River and acts as a source to feed the surrounding area such as Al-Karrada area and the industrial era. The total capacity is 75.000 m^3, where the available capacity is around 73.000 m^3. Al-Wihda plant was firstly constructed in 1959.

2.2. Chemicals and Materials. Three antibiotic standards, including *B*-lactam antibiotic amoxicillin and fluoroquinolones (ciprofloxacin and levofloxacin) synthesized by Sigma-Aldrich (Germany), were utilized. LC grade methanol and deionised distil water (DD) were procured from the local market. Analytical grade reagents included sulfuric acid (purity 99%) from Fluke and sodium thiosulfate ($Na_2S_2O_3$) from Sigma-Aldrich. Formic acid, acetonitrile from Sigma-Aldrich hydrophilic-lipophilic balance (HLB) oasis cartridges (200 mg 6 mL^{-1}; Milford, MA, Waters, USA), was used. Furthermore, 0.45 μL cellulose acetate Millipore filters (Millifilter, Milford, USA) and Whatman filters (Sigma-Aldrich) were used.

2.3. Sample Collection. A total of 36 samples, including 18 raw water samples from the Al-Wihda (W1) and Al-Rasheed water treatment plants (R1), and 18 finished water samples from the Al-Wihda (W3) and Al-Rasheed (R3) water treatment plants were collected from May to July 2017. Samples of 1 liter were collected from the raw and finished water before its entry in the distribution system from water treatment facilities. Sodium azide was added to the raw sample to eliminate microbial activity. Sodium thiosulfate was added to quench the residual chlorine disinfectants in the finished water at the time of sample collection. After preparation, samples were collected in 1 L amber glass bottles, which were kept on ice during transportation, and stored at 4°C and extracted within 5 days of collection.

All samples were tested for their turbidity, temperature and pH prior to HPLC determination. The pH of samples was measured using pH meter, and the temperature of each sample was measured throughout the study period and taken into consideration the variability of temperatures within the season. Turbidity was measured to determine the cloudiness

Figure 1: The location of Al-Wihda and Al-Rasheed water treatment plants in Baghdad City. The image is adapted from Google Earth Pro.

of samples and indicates the existing of suspended particles such as clay, organic particles, or microorganisms.

2.4. Sample Preparation: Solid-Phase Extraction (SPE). The solid-phase extract was prepared according to the manufacturer's protocol with some modifications. The Oasis HLB cartridge was preconditioned before use by adding 4 mL MeOH and 6 mL distil water (DW). The pH of the raw water samples and finished water samples was adjusted to 6 and 3, respectively. One liter of the sample was filtered using 0.45 μm Millipore filter to remove any impurities. The water sample was passed through the cartridge at flow rate of 5–8 mL /min using a vacuum extraction manifold. Next, 10 mL of ultra-pure water was used to wash the cartridge, which was subsequently air-dried for 5 min. Acidified methanol (10 mL of MeOH, 3 mL of 0.5 N HCL) was used to elute the analyte into a glass test tube. The extracts were reduced to a volume of 100 μL under a gentle flow of nitrogen, and the volume was increased to 250 μL using a mix of water/methanol (9:1). The extracts were filtered through 0.45 μm filters, transferred to auto sampler vials, stored at −15°C, and were analyzed within one week.

2.5. Analytical Methods

2.5.1. Devices. Devices used included the LC high gradient pump system (S1122, Sykam, Germany), auto sampler, degasser, heated oven, and fluorometric detector (RF) detector.

Chemical analysis of antibiotic content in the water samples was performed according to [36, 37]. Briefly, mobile phase A constituted of 0.1% formic acid and mobile phase B constituted of acetonitrile (v/v 30:70). Flow rate was 0.7 mL/min. RF detector with excitation wavelength of 278 nm; and emission wavelength of 450 nm for ciprofloxacin and levofloxacin, and UV detector of 230 nm for amoxicillin, was used. Chromatography was performed using 50 μL of the injected liquid at ambient temperature on a Pursuit Column C-18 (250 mm × 4.6 mm, 10 μm).

2.5.2. Standard Stock Solution. Stock solutions of 10 mg L^{-1} were prepared by weighing the pure substances (ciprofloxacin, levofloxacin, or amoxicillin) and dissolving them in DD water [38, 39]. These solutions were used to prepare all working solutions and standards. All solutions were stored in amber glass vials at −20°C. The standards (0.05, 0.15, 0.25, and 0.5 $\mu g\ L^{-1}$) were prepared by diluting portions of the stock with DD water, and filtered using 0.45 μm filters. About 50 μL of the sample was injected into the HPLC column. The determination of antibiotics in the environmental samples was conducted by comparing the HPLC peaks with the corresponding standard solution peaks. The concentration was calculated based on the internal standards and retention times.

2.5.3. Quantification. Quantification procedure suggested by Hussain *et al.* [7] was employed. Analyte quantification was based on external calibration curves, which were plotted on the ratio of the peak area of the analytes signal for highest intensity and concentration.

2.6. LOD Analysis. In order to determine the detection limit of antibiotics in raw and finished water, signal-to-noise approach was performed according to [40]. Briefly, samples were measured and the signal with known concentrations of analyte was compared with the relative blank samples. The minimum concentration was established at which the

Table 1: Turbidity and pH values of samples.

Samples	Nature	pH	Tm °C
W1	Highly turbid	7.35	26
W3	Less turbid	7.24	26
R1	Highly turbid	7.53	27
R3	Less turbid	7.36	25

analyte can be reliably detected. The signal-to-noise ratio 2:1 was used in this study, which is acceptable to estimate the detection limit. The LOD was expressed as 3X standard deviation according to the SD of the response and slop.

2.7. Statistical Analysis. The statistical analysis was performed using GraphPad Prism program and SAS-software system 2012 to analyze data of detected antibiotics in the study area by HPLC. The least significant difference (LSD) test (ANOVA) was used to determine the significant difference between detected drugs in raw and finished water plants at $p < 0.05$.

3. Results and Discussion

All the 36 collected samples (18 of Al-Wihda plant and 18 of Al-Rasheed plant) were subjected to HPLC to qualitative evaluation of remaining antibiotics in raw and finished water. The samples of raw and finished water of Al-Wihda and Al-Rasheed plants were coded as W1, W3, R1, and R3, respectively, and the turbidity, nature, Tm, and pH were determined and depicted in Table 1, which indicated that all samples were neutral in nature and temperature were ranged about 25-27°C. The results showed that all target analytes were detected in the drinking water treatments. Fluoroquinolones (ciprofloxacin and levofloxacin) were frequently detected in all water samples. Ciprofloxacin was detected in 11 out of 36 water samples, with maximum concentration at W1 (1.270 $\mu g\ L^{-1}$); nine samples confirmed the presence of levofloxacin, with a maximum concentration of 0.177 $\mu g\ L^{-1}$ at W1. Amoxicillin was found only in one sample in R1 at the concentration of 1.50 $\mu g\ L^{-1}$. Ciprofloxacin was the most frequently detected in both water treatment plants (Table 2 and Figure 2). Interestingly, the average BOD removal rate of Al-Wihda plant was zero, whereas in Al-Rasheed plant the average BOD removal rate was about 11.8509, thus indicating the efficient water treatment strategy in the former plant; this result was noticed by [41]. The occurrence of antibiotics in environments particularly in aquatic environment is under consideration due to the probable emergence of drug-resistant bacteria [40]. In such case, many studies reported that the development of drug-resistance bacteria is due not only to the presence of drugs in the aquatic environment, but also to the density of resistance bacteria, antibiotic exposure time, and nutrient enriched environment [14, 42]. Long exposure time to subtherapeutic dose of antibiotics potentially leads to creating suitable conditions for resistance gene transfer [42]. The presence of high concentrations of ciprofloxacin in the drinking water used for human consumption indicates the influence of wastewater discharge. Thus, the possibility and extent of pollution from animal sources should not be underestimated. For example, enrofloxacin is used only for animal treatments, but can be metabolized to ciprofloxacin under certain conditions [43, 44]. In this study, amoxicillin was detected in only one sample; this is because that *B*-lactam drug has chemically unstable rings that readily undergo hydrolysis and may not be detected easily in the finished water [10, 26]. Furthermore, many studies documented the prevalence of amoxicillin and ciprofloxacin resistant bacteria in river water, waste water, and drinking water [16, 45, 46].

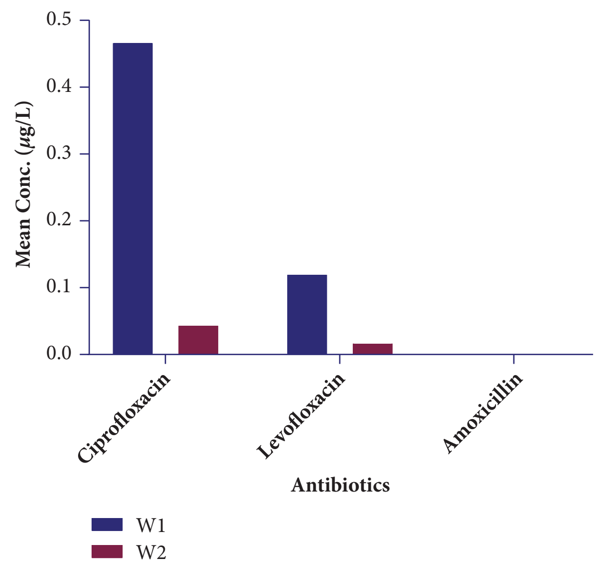


Figure 2: Presence of antibiotics in the raw and finished water at the Al-Wihda plant. The mean value of antibiotics (ciprofloxacin, levofloxacin, and amoxicillin) in the raw and finished water in Al-Wihda plant was illustrated, where the blue columns refer to the concentration of antibiotics in the raw water (W1) and red columns refer to the levels in the finished water (W3). There is no detectable amoxicillin seen, which is indicated by black arrow.

Limit of detection either is defined as the characterization of the general chemical ingredients at very low concentration or recognizes only one chemical measurements process [40]. In the present study the LOD was calculated for detected drugs in all samples, combined with chemical formula and molecular weight, which are listed in Table 3.

Table 2 illustrates the concentration of antibiotics detected from all samples of raw and finished water of Al-Whida plant. Statistical analysis revealed significant differences ($*P<0.05$) between antibiotics and the sites

Table 2: Antibiotics in raw and finished water in the Al-Wihda treatment plant. Mean ± SD values for the three antibiotics between the raw and finished water ($\mu g\ L^{-1}$) are listed. Statistical analyses were done with $*P< 0.05$, between W1 and W3. The asterisk represents the significant differences. NS refers to no significant differences.

Antibiotics	Concentrations in water samples ($\mu g\ L^{-1}$)		LSD value
	W1	W3	
Ciprofloxacin	0.47± 0.005774	0.146± 0.0003333	0.0912∗
Levofloxacin	0.123± 0.0005774	0.020± 0.0006173	0.0415∗
Amoxicillin	0 ± 0	0 ± 0	0.00 NS

Table 3: Qualitative detection (LOD) of residual drugs by HPLC method.

Antibiotics	Samples	LOD	Formula	Mol.Wt (g mol^{-1})	Antibiotic class
Levofloxacin	W1, W3, R1, R3	detected	$C_{18}H_{20}FN_3O_4$,	361.37	Fluoroquinolone
Ciprofloxacin	W1, W3, R1, R3	detected	$C_{17}H_{18}FN_3O_3$	331.34	Fluoroquinolone
Amoxicillin	R1	detected	$C_{16}H_{19}N_3O_5S$	365.40	B-lactam

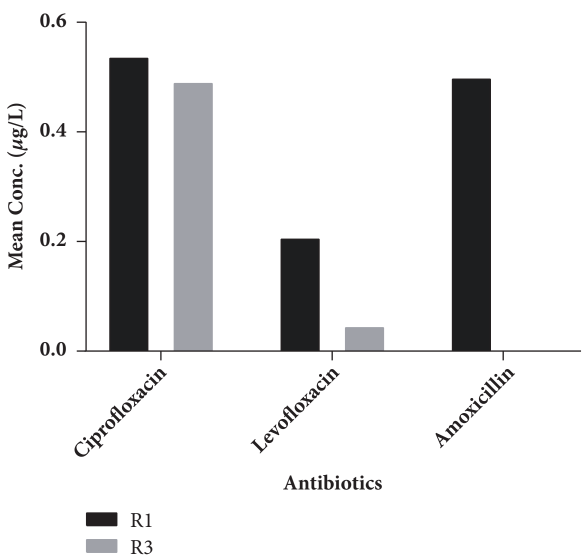


Figure 3: Concentration of antibiotics in water samples at the Al-Rasheed plant. The mean value of antibiotics (ciprofloxacin, levofloxacin, and amoxicillin) in the raw and finished water in Al-Rasheed plant was illustrated where black columns refer to the concentration of antibiotics that were present in raw water (R1) and the gray columns refer to levels in the finished water (R3). The black arrow represents the undetectable amoxicillin in the finished water (R3).

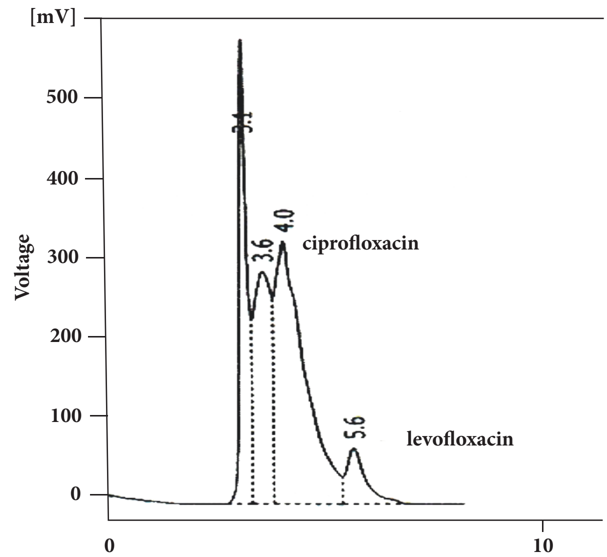
of Al-Wihda plant (W1, W3) for all antibiotics except amoxicillin.

Samples from the Al-Rasheed plant sites R1 and R3 showed higher levels of antibiotics than W1 and W3 of the Al-Wihda plant. Some antibiotics like ciprofloxacin, levofloxacin, and amoxicillin are not completely removed and can become a major health hazard if they persist in the finished water even at low levels (ng L^{-1}), due to the possible development of antibiotic-resistant bacteria in potable water (Figure 3) [29, 47]. The statistical analysis showed significant differences at ($*P<0.05$) between antibiotics and sites of Al-Rasheed plant (R1, R3) for all antibiotics except ciprofloxacin, as seen in Table 4.

The study of [48] showed that nine commonly used antibiotics (like ciprofloxacin and amoxicillin) were tested for fate in wastewater and reclaimed water from two regions in US. They find that the concentration of detected antibiotics in influent samples is more than that of effluent samples. Moreover, the concentrations of these drugs did not change through passing from treatment plant to irrigation site, so antibiotics persist in treated municipal water at low concentration.

Unlike Al-Wihda plant, amoxicillin is detected in higher concentrations compared the levofloxacin and ciprofloxacin in raw and finished water in Al-Rasheed plants (Table 4). It was reported that the concentration of beta-lactam drugs in inlet pond is significantly higher than that of UV-treatment samples (p-value = 0.0006). This increase is might be due to the aeration of these ponds [48]. The degradability of antibiotics may be varied and relies on different treatment technologies as well as storage conditions, where some antibiotics like ciprofloxacin and ofloxacin are shown to be genotoxic [33].

The occurrence and existence of medically active drugs in raw and finished water in this study is consistent with other studies. Most of the active drugs are not fully degraded or consumed, may remain in drinking water in tiny amounts, and can lead to water contamination. In UK, it was reported that clofibric acid was indicated in the river and surface water [49], whereas it was detected in wastewater, ground, and drinking water at a maximum concentration of 70, 165, and 270 ng L^{-1}, respectively, in Germany [15–17]. Another study showed that macrolide antibiotics like tylosin were found in drinking water in UK, Germany, and Italy, at a variable concentration of 10, 6, and 1.7 ng L^{-1} [15, 50, 51]. Furthermore, carbapenem was also detected in the sewage system in Italy at 3.5 ng L^{-1} [50]. Moreover, the persistence of diclofenac and diazepam in wastewater, surface water, irrigation water, and drinking water has been recorded, where they were detected



No.	Retention Time (min)	Area (mV.s)	Height (mV)	Area (%)	Height (%)	WO5 (min)	Compound
1	4.048	15944.144	329.323617	47.8	25.8	0.74	Ciprofloxacin
2	5.632	2208.802	70.309	6.6	5.5	0.48	Levofloxacin

Figure 4: Chromatogram (HPLC-RF) of target antibiotics ciprofloxacin and levofloxacin at the Al-Wihda plant. Ciprofloxacin is represented by the third peak (3.6) and levofloxacin by the fourth peak (5.6) during 10 min.

Table 4: Detection of antibiotics in the raw and finished water at the Al-Rasheed treatment plant.Mean ± SD values of the detected antibiotics between the raw and finished water (μg L^{-1}) at the Al-Rasheed plant are listed. Statistical analyses were conducted with $*P< 0.05$, between R1 and R3, and significant values are indicated by an asterisk. NS refers to no significant differences.

Antibiotics	**Concentrations in water samples (μg L^{-1})**		**LSD value**
	R1	**R3**	
Ciprofloxacin	0.539± 0.0003333	0.492± 0.0005774	0.195 NS
Levofloxacin	0.209± 0.0005774	0.0474± 3.333e-005	0.077 *
Amoxicillin	0.501± 0.0003333	0± 0	0.203 *

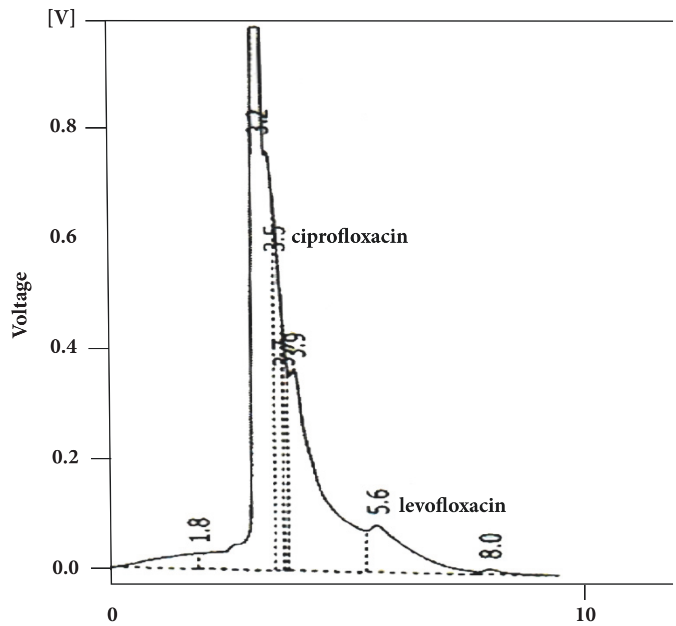
at a maximum level of 258 and 24 ng L^{-1} in USA and Canada, respectively [18, 19].

HPLC is a widely selective separation method for the isolation of pure compounds from crude mixtures and was used successfully to detect antibiotics in low concentrations [52]. Twenty positive water samples were subjected to HPLC for quantitative analysis to investigate the presence of antibiotics in samples acquired from both plants. The chromatogram of raw water samples at the Al-Wihda plant (6 samples out of 18) confirmed the presence of ciprofloxacin and levofloxacin (Figure 4). Ciprofloxacin peaked at about 4.0 min retention time whereas levofloxacin exhibited peak at 5.6 min in comparison to the standard solution peak.

At the Al- Rasheed water treatment facility, the chromatogram showed that the raw water (12 samples out of 18) was contaminated by both ciprofloxacin and levofloxacin with sharp peak of ciprofloxacin at 3.9 min and peak of levofloxacin at 5.6 min (Figure 5). Notably, amoxicillin was found only in one raw water sample at the Al-Rasheed plant with peak at 4.5 min retention time (Figure 6).

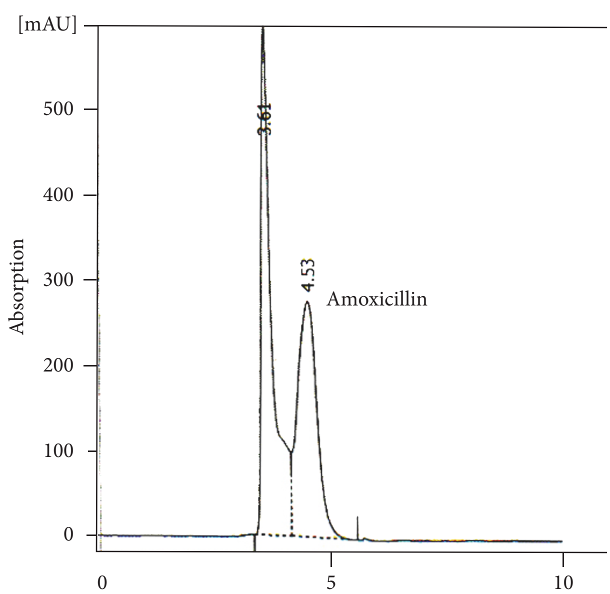
Detection of ciprofloxacin by HPLC using spectroscopic detector resulted in high yield recovery of 75-84% within 13.8 and 15 min [53, 54]; however, ELISA and TLC techniques could be used to detect ciprofloxacin from different samples [55]. The majority of wastewater treatment systems worldwide are not fully equipped to eliminate antibiotics and disinfectants which are not biodegradable, though friendly environment, low cost, and efficient techniques should be assessed to remove antibiotics from wastewater and consequently drinking water [56].

This research signals the need for surveying multiple antibiotics in the raw and finished water of water treatment plants in Iraq. Future studies should concentrate on the presence and transportation of these compounds during the treatment of drinking water. Therefore, the persistence of a wide spectrum of antibiotics in some water sources suggests



No.	Retention Time (min)	Area (mV.s)	Height (mV)	Area (%)	Height (%)	WO5 (min)	Compound
1	3.900	16740.633	367.323	27.9	14.2	0.55	Ciprofloxacin
2	5.620	5162.953	86.240	8.6	3.3	0.87	Levofloxacin

FIGURE 5: HPLC-RF analysis of target antibiotics ciprofloxacin and levofloxacin at the Al-Rasheed plant. Ciprofloxacin is represented by the first peak (3.9) and levofloxacin by the second peak (5.6) during 10 min of the procedure.



No.	Retention Time (min)	Area (mAU.s)	Height (mAU)	Area (%)	Height (%)	WO5 (min)	Compound
1	4.530	8135.560	276.290	45.4	31.6	0.47	Amoxicillin

FIGURE 6: Chromatogram for amoxicillin of Al-Rasheed plant. HPLC-UV analysis showed the presence of amoxicillin in Al-Rasheed water treatment plant, referred by second peak (4.5) during 10 min of aqueous solution.

that the overall impact of antibiotics as a pollutant group should not be ignored.

4. Conclusion

The results of the present study revealed that ciprofloxacin, levofloxacin, and amoxicillin were detected in the raw water, while ciprofloxacin and levofloxacin were detected in the finished water as well. This has serious implications as it can contribute to the development of antibiotic-resistant bacteria. The possible persistence of ciprofloxacin and other antibiotics in potable water sources is a serious problem due to the health impacts of chronic exposure over a lifetime, even at low levels. Besides, the drugs emit unpleasant odors and can cause skin-disorders [57]. Antibiotic pollution of potable water has to be addressed with urgency as some diseases caused by pathogenic resistant bacteria cannot be treated by conventional antibiotics [58]. Thus, this study highlights the need for a comprehensive approach to the presence of antibiotic composites in rivers and potable water in Iraq.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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References

[1] J.-L. Liu and M.-H. Wong, "Pharmaceuticals and personal care products (PPCPs): A review on environmental contamination in China," *Environment International*, vol. 59, pp. 208–224, 2013.

[2] M. Walczak and W. Donderski, "Antibiotic sensitivity of neustonic bacteria in Lake Jeziorak Mały," *Polish Journal of Environmental Studies*, vol. 13, no. 4, pp. 429–434, 2004.

[3] S. Manzetti and R. Ghisi, "The environmental release and fate of antibiotics," *Marine Pollution Bulletin*, vol. 79, no. 1-2, pp. 7–15, 2014.

[4] A. Swiecilo and I. Zych-Wezyk, "Bacterial Stress response as an adaptative to life in a soil environment," *Polish Journal of Environmental Studies*, vol. 22, no. 6, p. 157, 2013.

[5] S. T. Glassmeyer, E. K. Hinchey, S. E. Boehme et al., "Disposal practices for unwanted residential medications in the United States," *Environment International*, vol. 35, no. 3, pp. 566–572, 2009.

[6] D. K. Brown, *Pharmaceutically active compounds in residential and hospital effluent, municipal wastewater, and the Rio Grande in Albuquerque, New Mexico*, The University of New Mexico, New Mexico, 2009.

[7] S. Hussain, M. Naeem, and M. N. Chaudhry, "Estimation of residual antibiotics in pharmaceutical effluents and their fate in affected areas," *Polish Journal of Environmental Studies*, vol. 25, no. 2, pp. 607–614, 2016.

[8] J. P. Bound, K. Kitsou, and N. Voulvoulis, "Household disposal of pharmaceuticals and perception of risk to the environment," *Environmental Toxicology and Pharmacology*, vol. 21, no. 3, pp. 301–307, 2006.

[9] S. Abuin, R. Codony, R. Compañó, M. Granados, and M. D. Prat, "Analysis of macrolide antibiotics in river water by solid-phase extraction and liquid chromatography-mass spectrometry," *Journal of Chromatography A*, vol. 1114, no. 1, pp. 73–81, 2006.

[10] M. Seifrtová, L. Nováková, C. Lino, A. Pena, and P. Solich, "An overview of analytical methodologies for the determination of antibiotics in environmental waters," *Analytica Chimica Acta*, vol. 649, no. 2, pp. 158–179, 2009.

[11] S. Grujić, T. Vasiljević, and M. Laušević, "Determination of multiple pharmaceutical classes in surface and ground waters by liquid chromatography–ion trap–tandem mass spectrometry," *Journal of Chromatography A*, vol. 1216, no. 25, pp. 4989–5000, 2009.

[12] D. G. J. Larsson, C. de Pedro, and N. Paxeus, "Effluent from drug manufactures contains extremely high levels of pharmaceuticals," *Journal of Hazardous Materials*, vol. 148, no. 3, pp. 751–755, 2007.

[13] D. Vishal, J. T. Ashok, and K. K. Rakesh, "Antibiotic and antibiotic-resistant bacteria in waters associated with a hospital in Ujjain," *BMC Pub Hlth*, vol. 10, pp. 414–418, 2010.

[14] K. Kümmerer, "Antibiotics in the aquatic environment—a review—part I," *Chemosphere*, vol. 75, no. 4, pp. 417–434, 2009.

[15] I. A. Sultan, "Detection of Enrofloxacin Residue in Livers of Livestock Animals Obtained from a Slaughterhouse in Mosul City," *Journal of Veterinary Science & Technology*, vol. 05, no. 02, 2014.

[16] M. Stump, T. A Ternes, K. Habrer, P. Seel, and W. Baumann, "Determination of drugs in sewage treatment plants and river water," *Vom Wasser*, vol. 86, pp. 291–303, 1996 (German).

[17] J. H. Stan, M. Linkerhager, and V. Vorkommen, "Occurrence of clofibric acid in the aquatic system-does the medical application case contamination of surface, ground and drinking water," *Vom Wasser*, vol. 83, pp. 57–68, 1994 (German).

[18] T. Heberer, U. Dunnbier, C. Reilich, and J. H. Stan, "Detection of drugs and drug metabolites in ground water samples of a drinking water treatment plant," *Fresenius Environ. Bull*, vol. 6, pp. 438–443, 1997.

[19] R. Tauber, "Quantitative Analysis of pharmaceuticals," in *in Drinking Water from ten Canadian Cities , Environ-Test laboratories, Xenos Division*, Canada, Ontario, 2003.

[20] P. E. Stackelberg, E. T. Furlong, M. T. Meyer, S. D. Zaugg, A. K. Henderson, and D. B. Reissman, "Persistence of pharmaceutical compounds and other organic wastewater contaminants in a conventional drinking-water-treatment plant," *Science of the Total Environment*, vol. 329, no. 1-3, pp. 99–113, 2004.

[21] A. K. Morris and R. G. Masterton, "Antibiotic resistance surveillance: Action for international studies," *Journal of Antimicrobial Chemotherapy*, vol. 49, no. 1, pp. 7–10, 2002.

[22] K. Kummerer, "Significance of antibiotics in the environment," *Journal of Antimicrobial Chemotherapy*, vol. 52, no. 2, pp. 317-317, 2003.

[23] A. L. Batt, D. D. Snow, and D. S. Aga, "Occurrence of sulfonamide antimicrobials in private water wells in Washington County, Idaho, USA," *Chemosphere*, vol. 64, no. 11, pp. 1963–1971, 2006.

[24] V. Voolaid, A. Jõers, V. Kisand, and T. Tenson, "Co-occurrence of resistance to different antibiotics among aquatic bacteria," *BMC Microbiology*, vol. 12, no. 1, p. 225, 2012.

[25] P. Gao, Y. J. Ding, H. Li, and I. Xagoraraki, "Occurrence of pharmaceuticals in a municipal wastewater treatment plant: mass balance and removal processes," *Chemosphere*, vol. 88, no. 1, pp. 17–24, 2012.

[26] D. R. Baker and B. Kasprzyk-Hordern, "Multi-residue analysis of drugs of abuse in wastewater and surface water by solid-phase extraction and liquid chromatography-positive electrospray ionisation tandem mass spectrometry," *Journal of Chromatography A*, vol. 1218, no. 12, pp. 1620–1631, 2011.

[27] M. Heidari, M. Kazemipour, B. Bina et al., "A Qualitative Survey of Five Antibiotics in a Water Treatment Plant in Central Plateau of Iran," *Journal of Environmental and Public Health*, vol. 2013, Article ID 351528, 9 pages, 2013.

[28] WHO, "Pharmaceutical in drinking water", WHO/HSE/WSH/11.05, WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland, 2011. Pp. 1-49.

[29] R. Koczura, J. Mokracka, L. Jabłońska, E. Gozdecka, M. Kubek, and A. Kaznowski, "Antimicrobial resistance of integron-harboring Escherichia coli isolates from clinical samples, wastewater treatment plant and river water," *Science of the Total Environment*, vol. 414, pp. 680–685, 2012.

[30] E. M. Golet, A. C. Alder, A. Hartmann, T. A. Temes, and W. Giger, "Trace determination of fluoroquinolone antibacterial agents in urban wastewater by solid-phase extraction and liquid chromatography with fluorescence detection," *Analytical Chemistry*, vol. 73, no. 15, pp. 3632–3638, 2001.

[31] C. Xi, Y. Zhang, C. F. Marrs et al., "Prevalence of antibiotic resistance in drinking water treatment and distribution systems," *Applied and Environmental Microbiology*, vol. 75, no. 17, pp. 5714–5718, 2009.

[32] S. Mölstad, C. S. Lundborg, A.-K. Karlsson, and O. Cars, "Antibiotic prescription rates vary markedly between 13 European countries," *Infectious Diseases*, vol. 34, no. 5, pp. 366–371, 2002.

[33] K. Kümmerer, A. Al-Ahmad, and V. Mersch-Sundermann, "Biodegradability of some antibiotics, elimination of the genotoxicity and affection of wastewater bacteria in a simple test," *Chemosphere*, vol. 40, no. 7, pp. 701–710, 2000.

[34] V. J. F. Narvaes and C. C. Jimenez, "Pharmaceutical products in the environment: sources, effects and risks," *Vitae*, vol. 19, pp. 93–108, 2009.

[35] I. A. J. Ibrahim and A. S. I. Al-Khayat, "The relation between bacterial and heavy metal water pollution and blood micronuclei as biomarkers in the tigris river fish," *Baghdad Science Journal*, vol. 14, no. 1, pp. 126–134, 2017.

[36] A. Białk-Bielińska, J. Kumirska, M. Borecka et al., "Selected analytical challenges in the determination of pharmaceuticals in drinking/marine waters and soil/sediment samples," *Journal of Pharmaceutical and Biomedical Analysis*, vol. 121, pp. 271–296, 2016.

[37] I. Taverniers, M. De Loose, and E. Van Bockstaele, "Trends in quality in the analytical laboratory. II. Analytical method validation and quality assurance," *TrAC Trends in Analytical Chemistry*, vol. 23, no. 8, pp. 535–552, 2004.

[38] M. Gros, M. Petrović, and D. Barceló, "Development of a multi-residue analytical methodology based on liquid chromatography–tandem mass spectrometry (LC–MS/MS) for screening and trace level determination of pharmaceuticals in surface and wastewaters," *Talanta*, vol. 70, no. 4, pp. 678–690, 2006.

[39] G. Hamscher, S. Sczesny, H. Höper, and H. Nau, "Determination of persistent tetracycline residues in soil fertilized with liquid manure by high-performance liquid chromatography with electrospray ionization tandem mass spectrometry," *Analytical Chemistry*, vol. 74, no. 7, pp. 1509–1518, 2002.

[40] R. Lagishetty and P. Nagrajan, "Qualitative analysis of antibiotic residues in hospital effluents from south India," *Int J Pharm Sci Rev Res*, vol. 32, pp. 315–320, 2015.

[41] F. M. Hassan and A. R. Mahmood, "Evaluation the efficiency of drinking water treatment plants in Baghdad city-Iraq," *J Appl Environ Microbio*, vol. 6, pp. 1–9, 2018.

[42] P. Jarnheimer, J. Ottoson, R. Lindberg et al., "Fluoroquinolone Antibiotics in a Hospital Sewage Line; Occurrence, Distribution and Impact on Bacterial Resistance," *Infectious Diseases*, vol. 36, no. 10, pp. 752–755, 2012.

[43] USP. Veterinary Pharmaceutical Information Monographs-Antibiotics. Journal of Veterinary Pharmacology and Therapeutics, vol. 26, supplement, 2003.

[44] Y. Zhengqi, S. H. Weinberg, and T. M. Meyer, "Occurrence of Antibiotics in Drinking Water," in *U.S. Geological Survey*, pp. 138–142, The University of North Carolina at Chapel Hill, Kansas, 2004.

[45] G. B. Gholikandi, E. Dehghanifrad, M. N. Sepehr et al., "performance evaluation of different filter media in turbidity removal from water by application of modified qualitative index," *Ir J Pub Hlth*, vol. 41, pp. 87–93, 2012.

[46] D. Ašperger, D. Mutavdžić, S. Babić, A. Horvat, and M. Kaštelan-Macan, "Solid-phase extraction and TLC quantification of enrofloxacin, oxytetracycline, and trimethoprim in wastewater," *Journal of Planar Chromatography – Modern TLC*, vol. 19, no. 108, pp. 129–134, 2006.

[47] S. Alpay-Karaoglu, O. B. Ozgumus, E. Sevim, F. Kolayli, A. Sevim, and P. Yesilgil, "Investigation of antibiotic resistance profile and TEM-type β-lactamase gene carriage of ampicillin-resistant Escherichia coli strains isolated from drinking water," *Annals of Microbiology*, vol. 57, no. 2, pp. 281–288, 2007.

[48] P. Kulkarni, N. Olson, G. Raspanti et al., "Antibiotic Concentrations Decrease during Wastewater Treatment but Persist at Low Levels in Reclaimed Water," *International Journal of Environmental Research and Public Health*, vol. 14, no. 6, p. 668, 2017.

[49] M. Fielding, M. T. Gibson, and H. James, *Organic Micropollutants in Drinking water (TR159)*, Water Research Council, 1981.

[50] E. Zuccato, D. Calamari, M. Natangelo, and R. Fanelli, "Presence of therapeutic drugs in the environment," *The Lancet*, vol. 355, no. 9217, pp. 1789-1790, 2000.

[51] A. Waggot, "Trace organic substances in the river Lee (Great Britain)," in *Chemistry in Water Reuse*, W. J. Cooper, Ed., vol. 2, pp. 55–99, Ann Arbour Science, Ann Arbor, USA, 1st edition, 1981.

[52] T. Ramatla, L. Ngoma, M. Adetunji, and M. Mwanza, "Evaluation of antibiotic residues in raw meat using different analytical methods," *Antibiotics*, vol. 6, no. 4, 2017.

[53] A. Kirbiš, J. Marinšek, and V. C. Flajs, "Introduction of the HPLC method for the determination of quinolone residues in

various muscle tissues," *Biomedical Chromatography*, vol. 19, no. 4, pp. 259–265, 2005.

[54] H. Yu, H. Mu, and Y.-M. Hu, "Determination of fluoroquinolones, sulfonamides, and tetracyclines multiresidues simultaneously in porcine tissue by MSPD and HPLC-DAD," *Journal of Pharmaceutical Analysis*, vol. 2, no. 1, pp. 76–81, 2012.

[55] A. Shareef, Z. Jamel, and K. Younis, "Detection of antibiotic residues in stored poultry products," *Iraqi J Vet Sci*, vol. 23, pp. 45–48, 2009.

[56] B. Kasprzyk-Hordern, R. M. Dinsdale, and A. J. Guwy, "The effect of signal suppression and mobile phase composition on the simultaneous analysis of multiple classes of acidic/neutral pharmaceuticals and personal care products in surface water by solid-phase extraction and ultra performance liquid chromatography-negative electrospray tandem mass spectrometry," *Talanta*, vol. 74, no. 5, pp. 1299–1312, 2008.

[57] D. I. Andersson, "Persistence of antibiotic resistant bacteria," *Current Opinion in Microbiology*, vol. 6, no. 5, pp. 452–456, 2003.

[58] S. Budyanto, S. Soedjono, W. Irwati, and N. Indraswati, "Studies the adsorption equilibria and kinetic of amoxicillin from stimulated wastewater using activated carbon and natural bentonite," *Journal of Environmental Protection Science*, vol. 2, pp. 72–80, 2008.