Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2022.28219

263 (2022) 145–151
July

Investigations on pharmaceuticals and radioactive elements in wastewater from hospitals in Kuwait

A. Mydlarczyk, A. Al-Haddad*, H. Abdullah, A. Aba, A. Esmaeel, R. Al-Yaseen

Kuwait Institute for Scientific Research, Kuwait City, Kuwait, Tel. +965 97877302; email: ahadad@kisr.edu.kw (A. Al-Haddad)

Received 28 February 2022; Accepted 27 April 2022

ABSTRACT

A research studies were performed to characterize the wastewater generated from four hospitals located in Kuwait. In general, the wastewater generated from hospitals is discharged directly without any pre-treatment to public sewage treatment plants supervised by Ministry of Public Works (MPW). In this study, wastewater samples were collected on weekly basis from four hospitals (Al-Sabah, Al-Razi, Maternity and Chest diseases). Field wastewater measurements were carried out onsite for all sites including temperature, pH, electrical conductivity and oxidation–reduction potential. The collected samples were analyzed for determination of chemical parameters (total suspended solids and total dissolved solids), organic parameters including total organic carbon, chemical oxygen demand, biochemical oxygen demand and five dominate pharmaceutical compounds (four antibiotics sulfamethoxazole, metronidazole, ranitidine and trimethoprim plus paracetamol) and concentrations of radioactive elements in the wastewater (I-131, K-40, Tc-99m). The laboratory results indicated that all wastewaters from hospitals contained high levels of Tc-99m (0.14–14.151 Bq/L), I-131 (13.56–27.1 Bq/L), and low levels of K-40 (0.45–0.86 Bq/L). In addition, the pharmaceutics' concentration results revealed a high concentration of paracetamol (580 μg/L), where the maximum was detected in wastewater from Al-Razi hospital. The study recommends construction of onsite wastewater pre-treatment units.

Keywords: Radioactive isotopes; Hospital wastewater; On-site wastewater pre-treatment; Pharmaceutical compounds

1. Introduction

Wastewater from healthcare institutions usually contains disinfectants, antibiotics, pharmaceuticals and magnetic resonance imaging (MRI) contrast agents. Residues of pharmaceuticals are present in all wastewater treatment plants' effluents. The conventional activated sludge systems are usually not efficient for pharmaceuticals removal [1]. Inefficient removal of pharmaceuticals from wastewater treatment plants was also confirmed by other researchers [2–4]. Pauwels and Verstraete [5] discussed many aspects of chemicals present in wastewater belong to groups like antibiotics, disinfectants, pharmaceuticals and MRI contrast agents. El-Morhit et al. [6] investigated wastewater from hospitals in Morocco and found that mean value for chemical oxygen demand (COD) was 828.4 mg/L, which did not exceed the maximum limit for domestic wastewater. Novo and Manaia [7] studied factors influencing antibiotic resistance in municipal wastewater treatment plants and confirmed that longer hydraulic retention time corresponded to higher bacterial removal rates but still such rates were not efficient enough.

In Kuwait, there is lack of information regarding characterization of wastewater from hospitals. Kuwait Institute

* Corresponding author.

Presented at the 14th Gulf Water Conference: Water in the GCC… Towards Economic Efficiency and Financial Sustainability, 13–15 February 2022, Riyadh, Saudi Arabia

1944-3994/1944-3986

for Scientific Research conducted two projects. The first one is WT013C [8], which presented parameters for wastewater from two hospitals namely, Al-Razi and Al-Sabah Hospital. The reported results were based on only one sampling from both hospitals which cannot represent actual fluctuation in concentrations or even considered averages of parameters. Alajmi [9] studied removal of the pharmaceuticals as metronidazole, trimethoprim, sulfamethoxazole, paracetamol and ranitidine from the wastewater coming to Sulaibiya Wastewater Treatment and Reclamation Plant in Kuwait. He has chosen these pharmaceuticals as the most frequently used in Kuwait and stated that their removal was above 97%. In the second project titled "A Baseline Screening Survey of Human Pharmaceuticals in Wastewater Treatment Plants in Kuwait (EM049C)", samples were collected from inflow and effluent of two wastewater treatment plants. The results indicated that influent concentrations of pharmaceuticals were higher than in final effluents and it was on the level of microgram per liter. The highest concentration was mainly for analgesics and anti-inflammatory drugs Gevao et al. [10] confirmed that pharmaceuticals are not fully removed in wastewater treatment plants during the standard biological process. In this study, the obtained field and lab results are compared with KEPA requirements regarding domestic wastewater effluent discharged to sewage network.

Prayitno et al. [11] investigated wastewater from three hospitals in Malang City in Indonesia and reported that COD ranged between 110, 351 mg/L, and total suspended solids (TSS) between 43 and 83 mg/L, respectively. These wastewater parameters exceeded the Indonesian quality standards. Al-Ajlouni et al. [12] evaluated wastewaters discharged from twelve hospitals in Jordan. High COD values (725–1,356 mg/L) and highly differential values for TSS (45–1,419 mg/L) were obtained. The current study includes collection of wastewater from four hospitals (Fig. 1). The aim of this research is to assess the concentration of antibiotics and radioactive elements in wastewater generated from four hospitals in Kuwait. The wastewater generated from four hospitals represents a combination of domestic and industrial water type. The generated wastewater sent to the public sewage network any treatment.

2. Materials and methods

Full chemical and microbiological characteristics of wastewater from studied hospitals were conducted at KISR and external laboratories. The main part of analyses was carried out at Sulaibiya Research Plant Laboratory, which belongs to Wastewater Treatment and Reclamation Technologies Program. Prior sampling, the following wastewater parameters were examined: temperature, pH, electrical conductivity (EC) and oxy-redox potential. The sampling was carried out on the weekly basis from beginning of August 2019 until 31 March 2021. Due to spread-out of Covid-19, the sampling was suspended from March 2020 until 18 January 2021. Samples were collected manually and all analyses were carried out in accordance to standard methods of APHA [13]. Analyses of radioactive isotopes (I-131, K-40, Tc-99m) presence were carried out by Laboratory of Environmental and Life Sciences Research Center in KISR by application of gamma spectroscopy. 4 L samples were prepared in the geometry of Marinelli Beaker (3,000 mL). Two gamma spectrometry system, equipped with High Purity Germanium Detectors (Ortic Coaxial GMX40-83-LB-C (relative efficiency 40%, FWHM at 1,332 is 1.95 keV), and Ortic Coaxial GEM50-83-LB-C (relative efficiency 50%, FWHM at 1,332 is 1.9 keV)) have been used. Both detectors were shielded with low background lead. The spectrometer was calibrated using a mixed nuclide standardized solutions QCYB41 (Eckert & Ziegler Nuclide GmbH).

The gamma spectrometers used were calibrated using standard reference materials. All analyses were carried out in accordance with APHA standards [13]. Presence of pharmaceuticals (four antibiotics such as metronidazole,

Fig. 1. Location map for Al-Sabah, Al-Razi, Chest and Maternity hospitals in Kuwait.

trimethoprim, sulfamethoxazole and ranitidine plus paracetamol) was determined by external laboratory (Biofocus in Germany).

3. Results and discussion

3.1. Analysis of wastewater pH from studied hospitals

The results of seasonal pH changes for wastewater from all the discussed hospitals are presented in Fig. 2. All statistical values for Al-Sabah hospital wastewater were the highest among all studied hospitals.

3.2. Analysis of wastewater EC from studied hospitals

The changes of electrical conductivity for wastewater from all hospitals is shown in Fig. 3. All presented values are smaller than maximum required by KEPA (2,000 µS/cm) for wastewater discharged to sewage network in Kuwait.

3.3. Analysis of wastewater oxy-redox potential for studied hospitals

The results of oxidation–reduction potential (ORP) are presented in Fig. 4. The minimum and maximum values of ORP were observed for Al-Razi hospital. Moreover, the mean value was also the highest.

3.4. Radioactivity in wastewater of all studied hospitals

The efficiency calibration curve of the Marneli Beake counting geometry used (3,000 mL) is shown in Fig. 5.

The collected gamma spectra were analyzed by Canberra Genie-2000 gamma acquisition and analyses software. Fig. 6 shows a gamma spectrum generated by the Genie-2000 software using the HPGe detector.

The activity concentration was calculated using the calibration parameters and the created radionuclide library that including the radiopharmaceuticals nuclide.

It should be noted that the concentration of the radionuclides was decay corrected, as most of the radiopharmaceuticals are short-lived radioisotopes. The obtained results were compared with maximum limits established by Environment Public Authority in Kuwait for materials discharged to environment (2017).

^{99m}Tc radio-pharmaceutical, which is extensively used for diagnosis has been found as a common radionuclide used in the four discharging points; while ^{131}I was found only in Al-Razi and Al-Sabah hospitals. The natural radionuclide ^{40}K was found in all samples within the natural

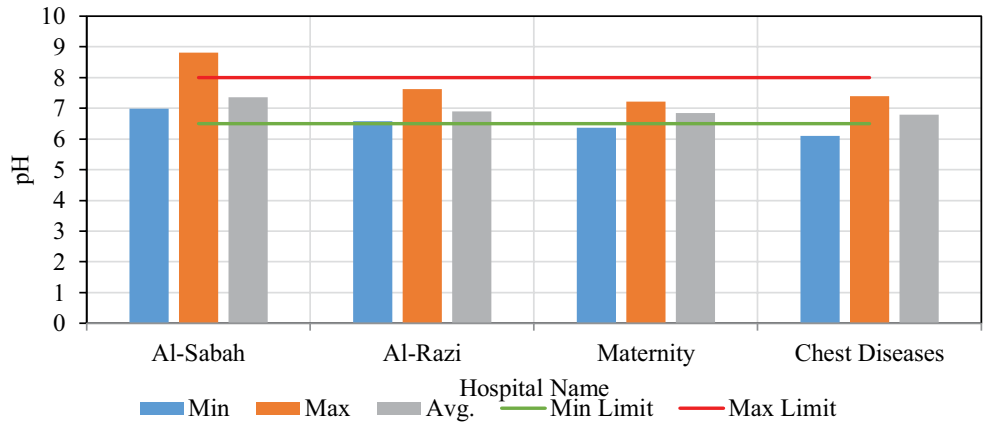

Fig. 2. pH variation for hospital wastewater in Kuwait.

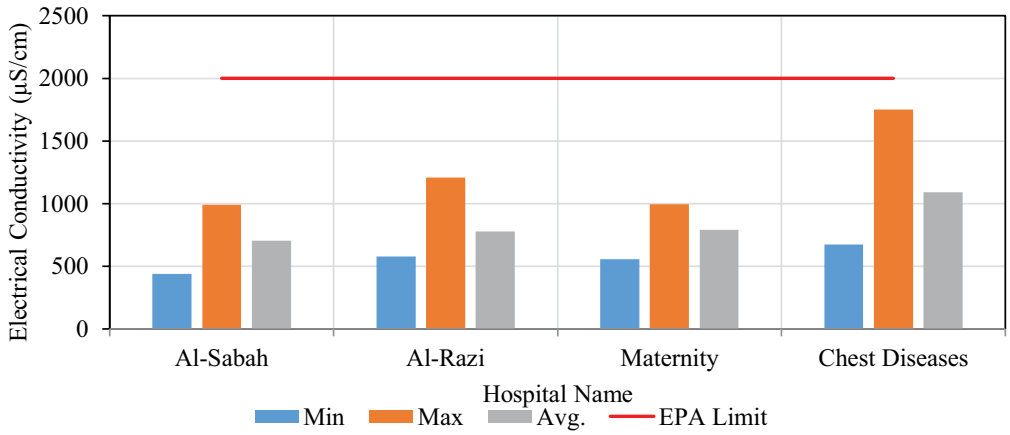

Fig. 3. Electrical conductivity variation for hospital wastewater in Kuwait.

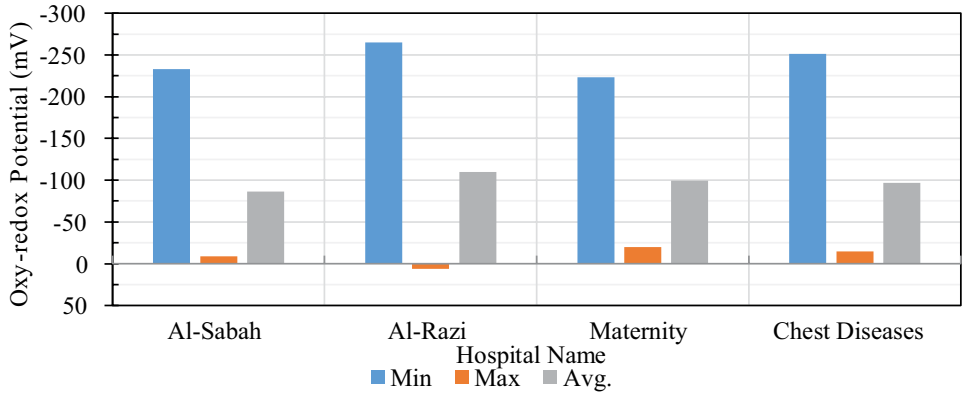

Fig. 4. Oxidation–reduction potential (ORP) variation for hospital wastewater in Kuwait.

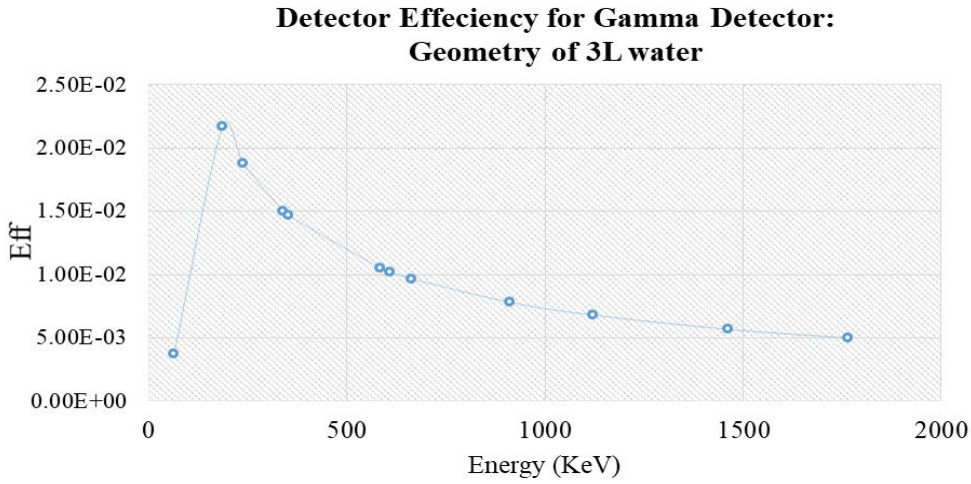

Fig. 5. Detector efficiency curve of the Marinelli Beaker counting geometry.

background level. According to the activity concentration observed in all healthcare centers, the ^{131}I varied from 0.03 to 27.1 Bq/L with an average of 5.48 Bq/L. Fig. 7 showed that ^{131}I was detected only on the discharge point of Al-Sabah healthcare center in frequent dates. The highest activity value belongs to the sample collected in 19 Sep 2019, which reached 27 Bq/L (Fig. 7).

On the other hand, ^{99m}Tc activity concentration varied from 0.14 to 14,151 Bq/L with an average value 717 Bq/L. The highest concentration was found in the sample of 25 January 2021 from Chest Diseases hospital (Fig. 8). The daily discharge of ^{99m}Tc from all hospitals exceeded daily maximum limit set by EPA in Kuwait for this radioactive isotope. The concentration of natural radionuclide ^{40}K presented in Fig. 9, which was in the natural background level, however the variation found was due to the amount of suspended particles in the sample.

3.5. Pharmaceutical compounds in wastewater generated by hospitals in Kuwait

The obtained mean concentrations of the five most common pharmaceuticals in wastewater generated from the four hospitals in Kuwait are presented in Table 1.

The highest value for all five studied pharmaceuticals was found in wastewater from Al-Razi hospital and it was equal 580 μg per liter. The lowest values of antibiotic concentration in studied wastewater were found for metronidazole and trimethoprim, which were below 0.01 μg/L.

4. Conclusion

Five pharmaceuticals including metronidazole, trimethoprim, sulfamethoxazole, paracetamol and ranitidine were analyzed and it was found that the maximum concentration among them appeared for paracetamol, which was equal 130 μg/L for the sample from Chest diseases hospital when for Al-Sabah and Al-Razi, the concentration reached 370 and 580 μg/L. Other antibiotics were frequently present in wastewater from all studied hospitals. Several researches indicated that advanced oxidation methods through using ozone and hydrogen peroxide gases were suggested to treat the wastewater antibiotics generated from the hospitals [14]. Therefore, the obtained low concentrations of pharmaceutical compounds might be treated through advanced oxidation techniques and not through the biological treatment (resistant to antibiotics) in municipal wastewater treatment plants.

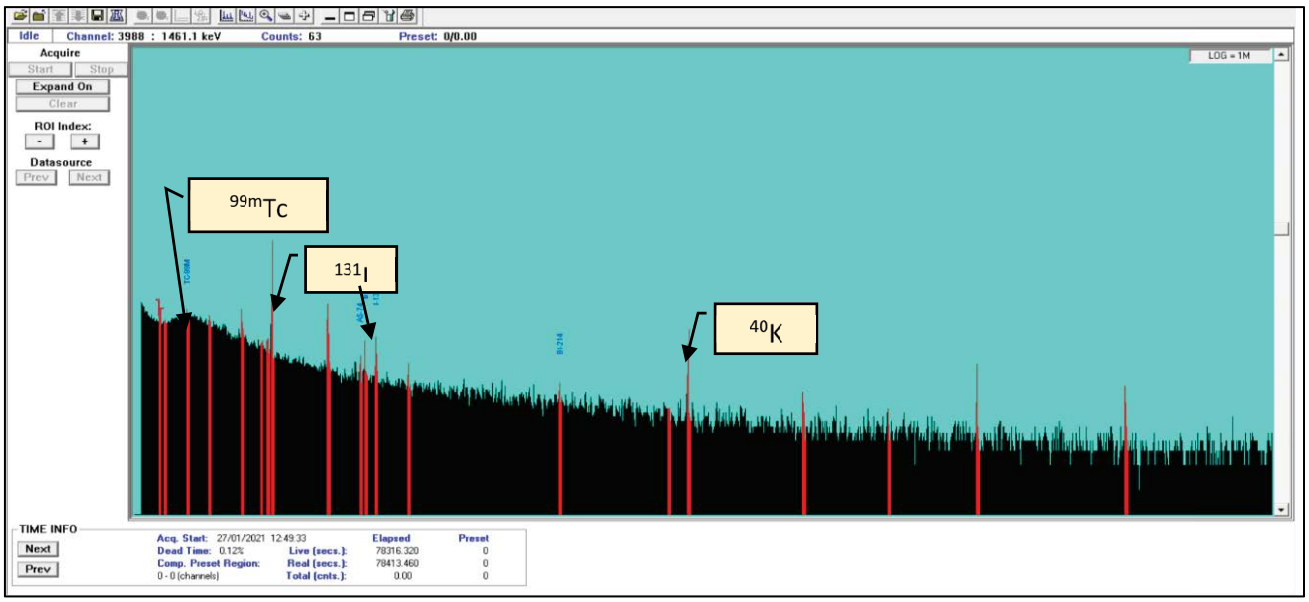

Fig. 6. Gamma spectrum generated by the Genie 2000 Software using the HPGe detector.

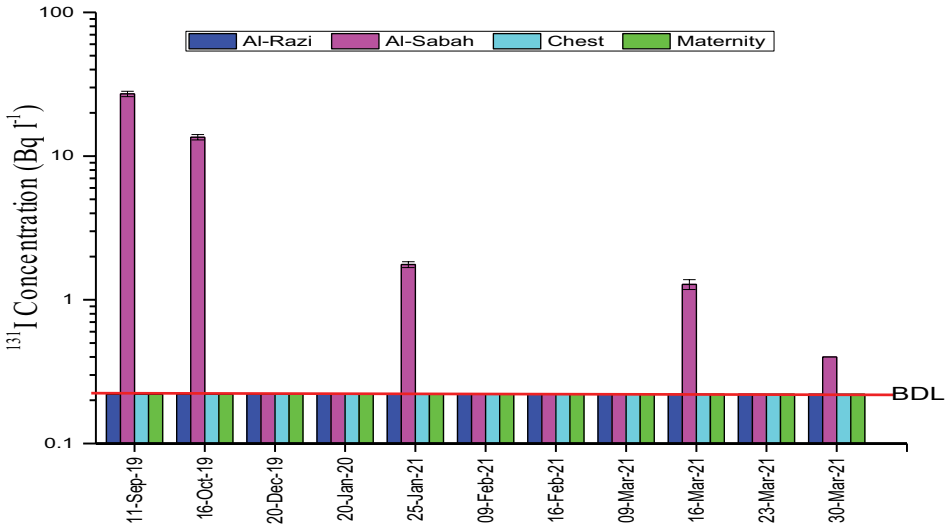

Fig. 7. ^{131}I activity concentration in wastewater from all studied hospitals in Kuwait.

5. Recommendation

- Yearly wastewater monitoring program should be established for all hospitals. The wastewater sampling campaign should cover full analysis of physical, chemical, organics, microbial, radioactive isotopes, toxicity, human hormones and pharmaceutical compounds. In addition, onsite field measurements should be conducted prior to sampling. Automatic online sampling equipment should be implemented to obtain fully representative samples.
- Onsite treatment units should be constructed within each hospital premises to treat and if possible reuse of generated wastewater. The capacity of treatment units should be designed based on the volume of wastewater generated by each hospital daily.
- The suggested onsite treatment unit should consist of the following stages: preliminary treatment, extended aeration, membrane bioreactor, and adsorption by activated granulated carbon, ozone oxidation for permeate disinfection by UV and excess sludge utilization.

Acknowledgment

The authors would like to extend their appreciation to the Kuwait Foundation for the Advancement of Science (KFAS) for its generous financial support. The overall support from the management of the Kuwait Institute for Scientific Research (KISR) is also gratefully acknowledged. Special thanks are extended to the staff of Technical Division

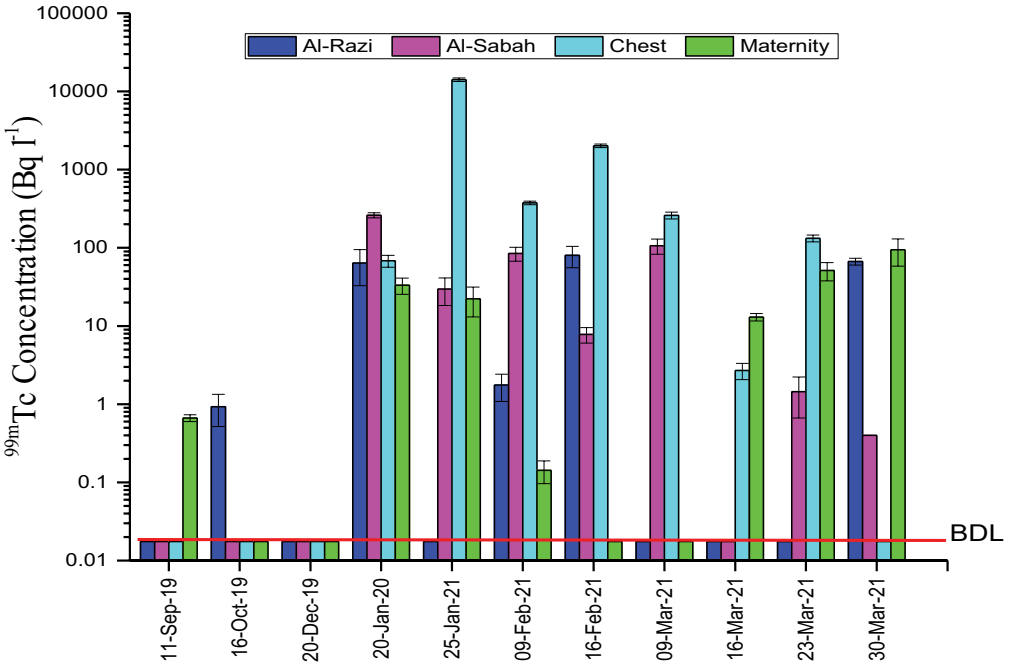

Fig. 8. ^{99m}Tc activity concentration in wastewater from all studied hospitals in Kuwait.

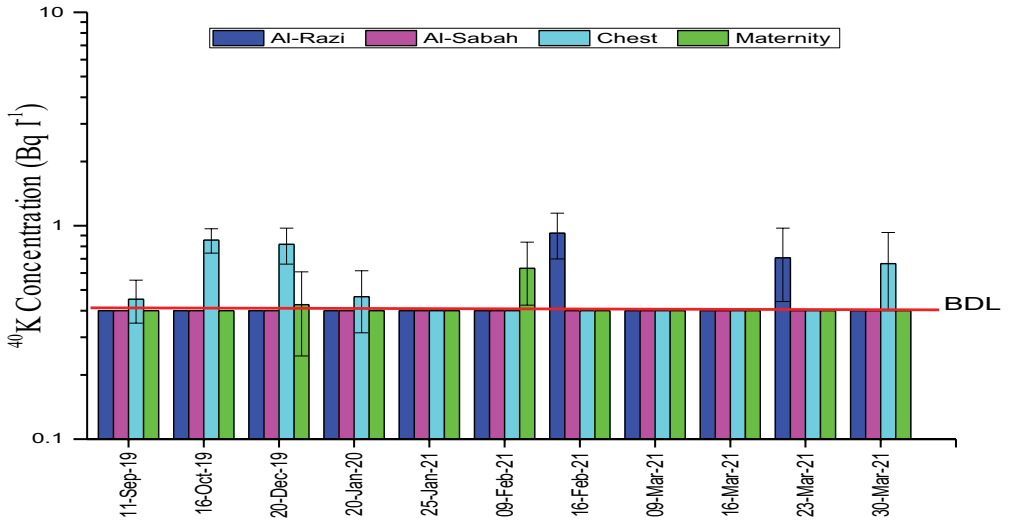

Fig. 9. ^{40}K activity concentration in wastewater from all studied hospitals in Kuwait.

Table 1
Mean concentrations of pharmaceutics in wastewater from four hospitals in Kuwait

S. No.	Name of pharmaceuticals	Names of hospitals			
		Al-Sabah	Al-Razi	Maternity	Chest
1	Metronidazole (μg/L)	10.12	0.403	45.8	0.159
2	Paracetamol (μg/L)	141.6	179.2	66.55	49.04
3	Ranitidine (μg/L)	0.26	0.05	0.07	0.10
4	Sulfamethoxazole (μg/L)	0.42	0.71	0.06	0.03
5	Trimethoprim (μg/L)	0.08	0.11	0.02	0.01

of Ministry of Health for assistance in weekly sampling. The authors also acknowledge the efforts of the staff from the Water Research Center (WRC) and the Environmental and Life Science Research Center (ELSRC) at KISR who were contributing in evaluation of radioactivity in analysis of wastewater.

References

[1] K. Kümmerer, Drugs in the environment: emission of drugs, diagnostic aids and disinfectants into wastewater by hospitals in relation to other sources – a review, Chemosphere, 45 (2001) 957–969.
[2] S.A. Snyder, P. Westerhoff, Y. Yoon, D.L. Sedlak, Pharmaceuticals, personal care products, and endocrine disruptors in water: implications for the water industry, Environ. Eng. Sci., 20 (2004) 449–469.
[3] M. Petrović, S. Gonzalez, D. Barceló, Analysis and removal of emerging contaminants in wastewater and drinking water, TrAC, Trends Anal. Chem., 22 (2003) 685–696.
[4] M. Carballa, F. Omil, J.M. Lema, M. Llompart, C. García-Jares, I. Rodríguez, M. Gómez, T. Ternes, Behaviour of pharmaceuticals, cosmetics and hormones in a sewage treatment plant, Water Res., 38 (2004) 2918–2926.
[5] B. Pauwels, W. Verstraete, The treatment of hospital wastewater: an appraisal, J. Water Health, 4 (2006) 405–416.
[6] M. El-Morhit, M. Yagoubi, A. Belmakki, M. Zouhdi, Monthly physicochemical characterization of a hospital effluent according to technical and care activities (Avicenna Rabat-Morocco), World J. Pharm. Pharm. Sci., 4 (2015) 247–267.
[7] A. Novo, C.M. Manaia, Factors influencing antibiotic resistance burden in municipal wastewater treatment plant, Appl. Microbiol. Biotechnol., 87 (2010) 1157–1166.
[8] A.M. Shahalam, A. Al-Haddad, A. Abusam, S. Al-Shammari, H. Al-Naser, H. Safar, Development of a Wastewater Quality Database and Assessment of Effluent Quality for Potential Reuse in Kuwait, Final Report, KISR9652, 2009.
[9] H.M. Alajmi, Effect of Physical, Chemical and Biological Treatment on the Removal of Five Pharmaceuticals from Domestic Wastewater in Laboratory-Scale Reactors and Full-Scale Plant, Civil Engineering and Geosciences, Newcastle University, 2014, pp. 1–245.
[10] B. Gevao, M. Porcelli, Al-Bahloul, Abaseline Screening Survey of Human Pharmaceuticals in Wastewater Treatment Plants in Kuwait, Final Report KISR 12451, 2014.
[11] Prayitno, Z. Kusuma, B. Yanuwiadi, R.W. Laksmono, Study of hospital wastewater characteristic in Malang City, Int. J. Eng. Sci., 2 (2013) 13–16.
[12] K. Al-Ajlouni, S. Shakhatreh, N. Al-Ibraheem, M. Jawarneh, Evaluation of wastewater discharge from hospitals in Amman JORDAN, Int. J. Basic Appl. Sci., 13 (2012) 44–50.
[13] APHA, Standard Methods for Examination of Water and Wastewater, American Public Health Association (APHA), The American Water Works Association (AWWA), and The Water Environment Federation (WEF), 2017.
[14] G. Frascaroli, D. Reid, C. Hunter, J. Roberts, K. Helwig, J. Spencer, A. Escudero, Pharmaceuticals in wastewater treatment plants: a systematic review on the substances of greatest concern responsible for the development of antimicrobial resistance, Appl. Sci., 11 (2020) 6670, doi: 10.3390/app11156670.