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ORIGINAL PAPER

Occurrence, Human Health Risks, and Public Awareness Level of Pharmaceuticals in Tap Water from Putrajaya (Malaysia)

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Abstract

Pharmaceutical residue pollution remains as an underexplored issue, especially in Asian countries. Along with that line, the purpose of this study was to investigate the occurrence of pharmaceutical residues in tap water and its associated potential health risks, involving a total of 80 Putrajaya residents. Besides, this study also aimed to evaluate public awareness (knowledge, attitude, and practice) levels with regards to pharmaceutical handling. The highest pharmaceutical residue occurrence was caffeine (0.38 ng/L) while the lowest was diclofenac (0.14 ng/L). These pharmaceutical residue occurrences in tap water were linked with rapid urbanization and industrialization in river water, poor removal efficiencies in wastewater and drinking water treatment plants as well as improper pharmaceutical waste handling and disposal from the general public. The potential health risks (RQ_T) indicated residents in Putrajaya with ages between 61 and 75 were exposed to the highest health risks caused by the pharmaceutical residues in tap water. In general, low public awareness (knowledge, attitude, and practice) levels were identified with only 44.5% of Putrajaya population having good knowledge, 27.5% having good attitude and 1.6% having good practice related to pharmaceutical handling and its effect to tap water quality. Findings of this study reflected the importance of public awareness program to educate the general public on proper unused/expired handling and disposal to minimize pharmaceutical pollution.

Keywords Pharmaceuticals · Tap water · Potential risks · Public awareness

Introduction

In southeast Asia, the urbanization rate is estimated at 41.8%, and about 245 million people are living in the urban areas (OECD Rights and Translation Unit 2008). Rapid urbanization rate can be associated with elevated anthropogenic pollutants via point and non-point sources. Along this line, occurrence of emerging pollutants such as pharmaceuticals, phthalate esters, pesticides, and steroid hormones have been detected in river water (Huo et al. 2007; Kasprzyk-Hordern et al. 2007; Archana et al. 2017; Praveena et al. 2018), wastewater (Fang et al. 2019) and even in drinking water (Wen et al. 2014; Yang et al. 2014) as a results of urbanization. Currently, occurrence and impacts of emerging pollutants in an environment are not well understood as emerging pollutants are not included in routine monitoring program although these pollutants have been released for a long time (Klumpp et al. 2015). Over the last 15 years, pharmaceuticals have received growing interest due to pharmaceuticals and associated excretion by human and inefficient removal by sewage treatment plants (Kaushik et al. 2016; Kaushik and Thomas 2019). Pharmaceutical residues have been detected in the environment of river water (Chen and Zhou 2014; Matongo et al. 2015), groundwater (Clara et al. 2004; Bottoni et al. 2010) and wastewater (Niazy et al.

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2012; Mohapatra et al. 2014). However, the occurrence of pharmaceutical residues in drinking water is still in the data analysis stage. So far, as part of the Southeast Asia countries, pharmaceutical occurrence has been recorded in river water samples from Malaysia (Al-Qaim et al. 2018; Praveena et al. 2018), Vietnam (Tran et al. 2014) and Singapore as well as in marine water from Singapore (Wu et al. 2008; Bayen et al. 2013).

Globally, there have been studies focused on pharmaceutical residues in tap water associated with human health risks (Schwab et al. 2005; Leung et al. 2013; Houtman et al. 2014; Wen et al. 2014; Gaffney et al. 2015). However, there is limited information about risks to human health associated with pharmaceuticals content in tap water (World Health Organization 2011). Although there were studies which have concluded appreciable health risks associated with pharmaceutical residues in tap water, yet these studies only utilized total concentrations of pharmaceutical residues in health risk assessment (Schwab et al. 2005; Mompelat et al. 2009; Gros et al. 2010; Kumar and Xagoraraki 2010; Valcárcel et al. 2011; Leung et al. 2013; Houtman et al. 2014). Utilization of total concentration in health risk assessment may inadequately estimate the actual health risks (Kumar and Xagoraraki 2010; Praveena et al. 2015a, b; Li et al. 2017; He et al. 2020; Ji et al. 2020). Thus, for accurate health risks estimation, bioavailability concentration is recommended to be included in the health risk assessment. This is because only a fraction of ingested pollutant will reach human systemic circulation and exert toxic actions. This will provide a more accurate and realistic health risks estimation (Praveena et al. 2017). Besides the human health risk assessment, public awareness (knowledge, attitude and practice) is also crucial to be taken into consideration in the assessment to help the public to be more aware and adopt appropriate disposal practices for expired and unwanted pharmaceuticals and its effects to tap water quality (Aini et al. 2007). Understanding of public awareness level will help to increase consumer's education and efforts for proper disposal of expired and unwanted pharmaceuticals which ultimately reduce associated impacts of these residues entering our environment including water sources and drinking water (Chowdhury et al. 2017; Jalan et al. 2009; Parvez et al. 2006; Wang et al. 2018).

In Malaysia, studies about pharmaceutical residues in water environment have been focused on river water (Al-Odaini et al. 2013; Al-Qaim et al. 2014; Praveena et al. 2018). Findings from these studies revealed that pharmaceutical residue is presented in the river water with potential health risks. These studies have also highlighted possibilities of pharmaceutical residues to be present in tap water due to the inability of conventional drinking water treatment plant in removing these residues. Incorporation of awareness level together with quantitative findings of pharmaceutical residues in tap water is important. This will drive more actions in the public education and communication tools and help to revise current drinking water standard and regulations to include emerging pollutants such as pharmaceuticals (Rodriguez-Moza and Weinberg 2010; Strauch 2011).

At present, tap water quality together with public awareness levels studies have not been studied among the public in Malaysia. Tap water studies in Malaysia were more dedicated either in understanding public awareness level (Rajiah 2012), perception (Azlan et al. 2012) or quality (Azrina et al. 2011; Khoo et al. 2011; Qaiyum et al. 2011). Till date, a limited study has been conducted by Ab Razak et al. (2016) in understanding tap water quality together with awareness levels among the public. Therefore, it is highly relevant to bridge the gaps between emerging pollutants as a new threat to tap water with public awareness (knowledge, attitude and practice) in understanding its associated human health risks. This study aims to evaluate the occurrence of pharmaceutical residues in tap water from Putrajaya (Malaysia). Along with this, potential health risks via drinking ingestion were also investigated by involving Putrajaya residents. Corresponding to its tap water quality, public awareness (knowledge, attitude, and practice) levels with regards pharmaceutical handling among the general public in Putrajaya (Malaysia) was assessed.

Materials and Methods

Study Area

Putrajaya (Malaysia) is the new federal administrative hub of Malaysia with the geographical coordinates of 2°53′ 20" N to 2°57′ 55" N for latitude and 101°37′ 50" E and 101°43′ 20" E for longitude (Almdhun et al. 2018). Putrajaya is divided into 20 precincts with a total area of 4,931 hectares and a total population of 67,964 (Borhan et al. 2019). A total of 14.4% of Putrajaya area is allocated to be residential area with emphasis on well-balanced environment, social and economic elements (Fig. 1). The water of Putrajaya is supplied by Sungai Semenyih Water Treatment Plant from the Semenyih river. Sungai Semenyih water treatment plant is located in Prescient 19 (Putrajaya, Malaysia) which is the first water treatment plant to obtain ISO certification to focus on its capability, public safety and action plan related to water treatment process and operation (SelangorKini 2019). The treated water from Sungai Semenyih Treatment Plant is supplied to residential areas through water pipelines. Similarly, in other places in Malaysia, Putrajaya residents are access to tap water (piped drinking water) as the main water supply for various water-related activities, including drinking water.

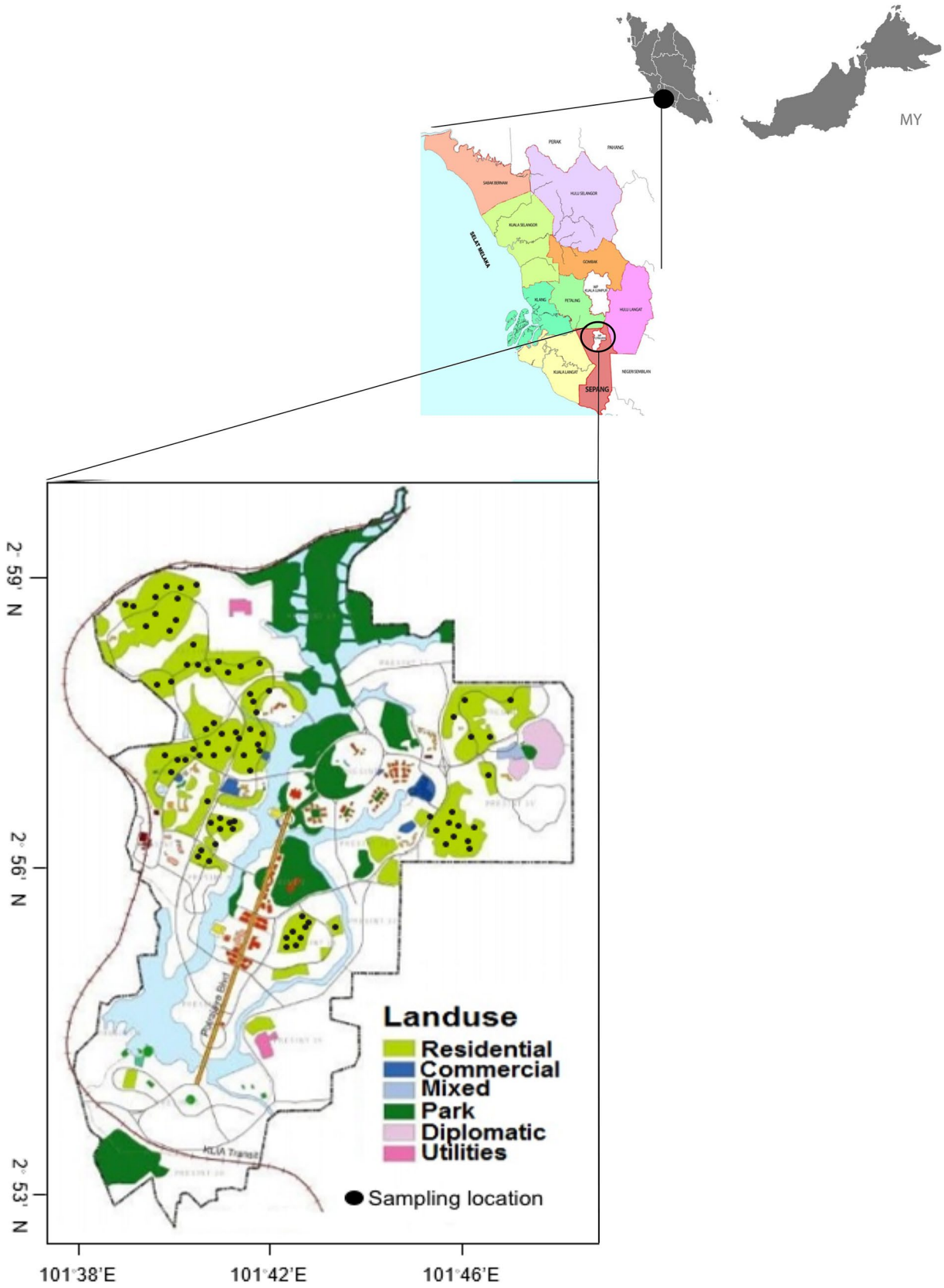

Fig. 1 Tap water sampling locations in residential areas of Putrajaya (Malaysia)

Tap Water Sampling and Questionnaire Survey

A total number of 80 respondents have been calculated using sample size calculation by Daniel (1999) by taking into account 20% of non-response rate. These respondents were selected randomly to participate in this cross-sectional study. In respondents house, 1 L of tap water was collected from tap in duplicates into amber glass bottles. These tap water samples were kept in dark and cool during transport to the laboratory to analyze immediately.

After the tap water sampling, these respondents were requested to completed drinking water questionnaire survey. In total, 80 questionnaires were returned with an overall response rate of 100%. In this study, drinking water questionnaire survey consist of two parts namely sociodemographic and public awareness (knowledge, attitude and practice sections) levels of pharmaceutical handling among Putrajaya population. Sociodemographic questions were focused to obtain respondent's age, gender, body height and weight, length of residence in Putrajaya, type of drinking water and daily water intake amount. While in the knowledge section, information of emerging pollutant such pharmaceuticals in tap water, human health effect of pharmaceutical residues in tap water and information were collected. Respondents' attitudes towards preference on conventional medicines, attitude on finishing the prescribed medicine, proper ways to manage expired medicines were assessed. Lastly, the respondents practices were assessed on ways they disposed their expired and unused medicines.

Pharmaceutical Residues Analysis in Tap Water

In laboratory, 100 mL water was filtered using 0.45 µm Whatman filter paper for each sample. Then, bioavailability form of pharmaceutical residue in tap water was analyzed using in vitro digestion model modified using methods by Versantvoort et al. (2005), Yang et al. (2012) and Minekus et al. (2014) to simulate both stomach and intestine conditions in gastric and intestinal phases of a human body. In the gastric phase, a total of 10 mL tap water was mixed in Simulated Gastric Fluid solution with 1.6 mL pepsin solution, calcium chloride and hydrochloric acid to reach pH of 3.0 with ultrapure water. Next, in intestinal phase, a total of 20 mL tap water was mixed in Simulated Intestinal Fluid solution, pancreatin solution, fresh bile, calcium chloride and sodium hydroxide to reach pH of 7 with ultrapure water. Finally, the digested tap water in the human body was filtered using 0.45 µm Whatman filter paper and brought to solid phase extraction step (Praveena et al. 2018). After completing the solid phase extraction step, the pharmaceutical residues in extracted tap water samples were analyzed using the commercial competitive ELISA kits where the procedures can be referred in Praveena et al. (2018). The analyzed pharmaceuticals in extracted tap water samples were amoxicillin, caffeine, chloramphenicol, ciprofloxacin, dexamethasone, diclofenac, nitrofurazone, sulfamethoxazole and triclosan. These pharmaceuticals were selected based on top pharmaceutical utilization in treating acute, non-chronic and chronic conditions in public and private hospitals in Malaysia (Ministry of Health Malaysia 2007).

Quality Assurance/Quality Control

Quality assurance and control steps have been taken during sampling and analysis. During sampling, the tap water samples were collected using pre-cleaned 1 L amber glass bottles. Prior to each sample collection, the glass bottles were washed and rinsed with the tap water samples several times before an actual sample was collected. During analysis, method blanks (ultrapure water), field blanks were carried out in duplicates. Furthermore, method blanks showed no concentration detected above method detection limits. Linearity was studied for each pharmaceutical in the concentration range between 0.025 and 50 ng/mL. The linearity of each pharmaceutical was calculated based on the mean slope, mean intercept and regression coefficients (R^2). The R^2 values were above 0.96 indicates good linearity of calibration curves. Limit of quantitation (LOQ) and limit of detection (LOD) for each pharmaceutical were analyzed based on ten and three times of signal to noise ratio, respectively. Repeatability of low (0.025 ng/L) and high (50 ng/L) concentrations were assessed via recovery percentage values between 68.56% and 112.26% which were found to be acceptable as long as these values are within the working range of the ELISA kits (European Community 2015) as shown in Supplementary 1. Standard addition method was utilized for determination of pharmaceutical residue concentrations in tap water. Standards were spiked directly to the samples to produce signal relative to pharmaceutical residue which was present in ultra-trace concentrations (ng/L) and eliminate matrix effects. All the tap water and blanks samples were analyzed in two duplicates. All the glasswares utilized in this study were cleaned through soaking in nitric acid overnight with a final rinse with distilled water and oven drying. The questionnaire survey was pre-tested before distributed in Putrajaya (Malaysia) to ensure the effectiveness and identify misinterpretations (Perneger et al. 2015). A Cronbach alpha value of 0.78 was obtained and indicating that this questionnaire survey is reliable to be used (Perneger et al. 2015).

Data Analysis and Potential Health Risk Assessment

Descriptive statistics (mean, maximum, minimum and standard deviation) were performed using Statistical Package for

the Social Sciences (SPSS, Version 23.0) to present pharmaceutical residue concentrations in tap water.

Potential health risk assessment was estimated based on risk quotients (RQs) for adults based on respondents involved in the questionnaire survey. Risk quotients (RQs) values were estimated using pharmaceutical residue concentrations in tap water and Drinking Water Equivalent Level (DWEL) (Eq. 1). Equation 2 and Supplementary 2 shows the estimation of DWEL by taking account the acceptable daily intake (ADI), body weight (BW), hazard quotient, drinking water intake (DWI), gastrointestinal absorption rate (AB) and frequency of exposure (FOE). Total Risk quotient (RQ_T) is expressed as the sum of the RQ from each pharmaceutical (Eq. 3). Total Risk quotient (RQ_T) values greater than 1 indicates the possibilities of health risks caused by exposing to the pollutants in tap water. While RQ_T values less than 1 indicates low possibilities of health risks due to pollutant exposure in tap water.

$$\mathrm{RQ} = C_s/\mathrm{DWEL}, \tag{1}$$

$$\mathrm{DWEL} = \mathrm{ADI} \times \mathrm{BW} \times \mathrm{HQ}/\mathrm{DWI} \times \mathrm{AB} \times \mathrm{FOE}, \tag{2}$$

$$\begin{aligned} \mathrm{RQ_T} = {} & \mathrm{RQ_{amoxicillin}} + \mathrm{RQ_{caffeine}} + \mathrm{RQ_{chloramphenicol}} + \mathrm{RQ_{ciprofloxacin}} + \mathrm{RQ_{dexamethasone}} \\ & + \mathrm{RQ_{diclofenac}} + \mathrm{RQ_{nitrofurazone}} + \mathrm{RQ_{sulfamethoxazole}} + \mathrm{RQ_{triclosan}} \end{aligned} \tag{3}$$

where C_s is the pharmaceutical residue concentration (ng/L) found in tap water, ADI is the acceptable daily intake (ng/kg/day), BW represents body weight (kg), HQ is a hazard quotient which assumed to be 1, DWI is the drinking water intake (L/day) taken from the questionnaire, AB represents the gastrointestinal absorption rate assumed to be 1, and FOE is the frequency of exposure (365 days/365 days).

The scoring system was applied to assess public awareness (knowledge, attitude and practice) levels involving respondents from Putrajaya (Malaysia). This scoring system has been applied to extract knowledge, attitude and practice information from the questionnaire survey. For knowledge and practice, a score of 1 was given for the correct answer and 0 for other answers. While for attitude, the level was assessed by a score of 1 for a positive attitude and − 1 for negative attitude. Next, the total score of each knowledge, attitude and practice level was calculated and converted to 100 points. Overall knowledge, attitude and practice score levels were assessed and modified based on Bloom's cut-off point. Score level above 70% was considered high while score level lower than 70% is considered low (Abdullahi et al. 2016).

Results and Discussion

Occurrence of Pharmaceutical Residues in Tap Water

Figure 2 shows the pharmaceutical residue concentrations detected in the samples of tap water from Putrajaya (Malaysia) analyzed using in vitro digestion model. All the selected pharmaceutical residues were detected with substantial-varying concentrations in the tap water samples. The detection of these pharmaceutical residues can be linked with the raw water quality from Semenyih river supplied to Sungai Semenyih water treatment plant before supplied to Putrajaya. According to Al-Badaii et al. (2012, 2016), Semenyih river water that supplied raw water to drinking water treatment plants has been affected by vast urbanization and industrialization. Semenyih river has been polluted with untreated sewage, domestic effluents, industrial and commercial activities. All the investigated pharmaceuticals (amoxicillin, caffeine, chloramphenicol, ciprofloxacin, dexamethasone, diclofenac, nitrofurazone, sulfamethoxazole and triclosan) were detected in the tap water. The mean concentrations of bioavailable pharmaceutical detected in the tap water were as follows: 0.38 ng/L for caffeine 0.38 ng/L, 0.36 ng/L for triclosan, 0.32 ng/L for dexamethasone, 0.32 ng/L for ciprofloxacin, 0.31 ng/L for amoxicillin, 0.19 ng/L for nitrofurazone, 0.17 ng/L for chloramphenicol, 0.16 ng/L for sulfamethoxazole and 0.14 ng/L for diclofenac.

The detection of pharmaceutical residues in tap water can be associated with several potential sources. Detection of pharmaceuticals in the raw water supply is associated with inadequate drinking water treatment technology which resulted in inefficient micropollutants removal such as pharmaceutical which may lead to its detection in tap water. Moreover, in Malaysia, most of the conventional treatment processes in drinking water treatment plants were developed to remove pathogen and pollutants such as heavy metal. According to the World Health Organization (2012), the coagulation process in conventional drinking water treatment is incapable to remove pharmaceuticals while free chlorine is only capable to remove 50% of pharmaceuticals. Detection of pharmaceuticals in the raw water supply to drinking water treatment plants is linked with the total utilization of pharmaceutical and insufficient sewage treatment plants to remove pharmaceuticals in wastewater. With increasing pharmaceutical utilization of 31.4% from 433.47 DDD/1000 inhabitants/day in 2011 to 569.55 DDD/1000 inhabitants/day in 2014 also increase pharmaceutical residues which are released by human excreta and urine. A study

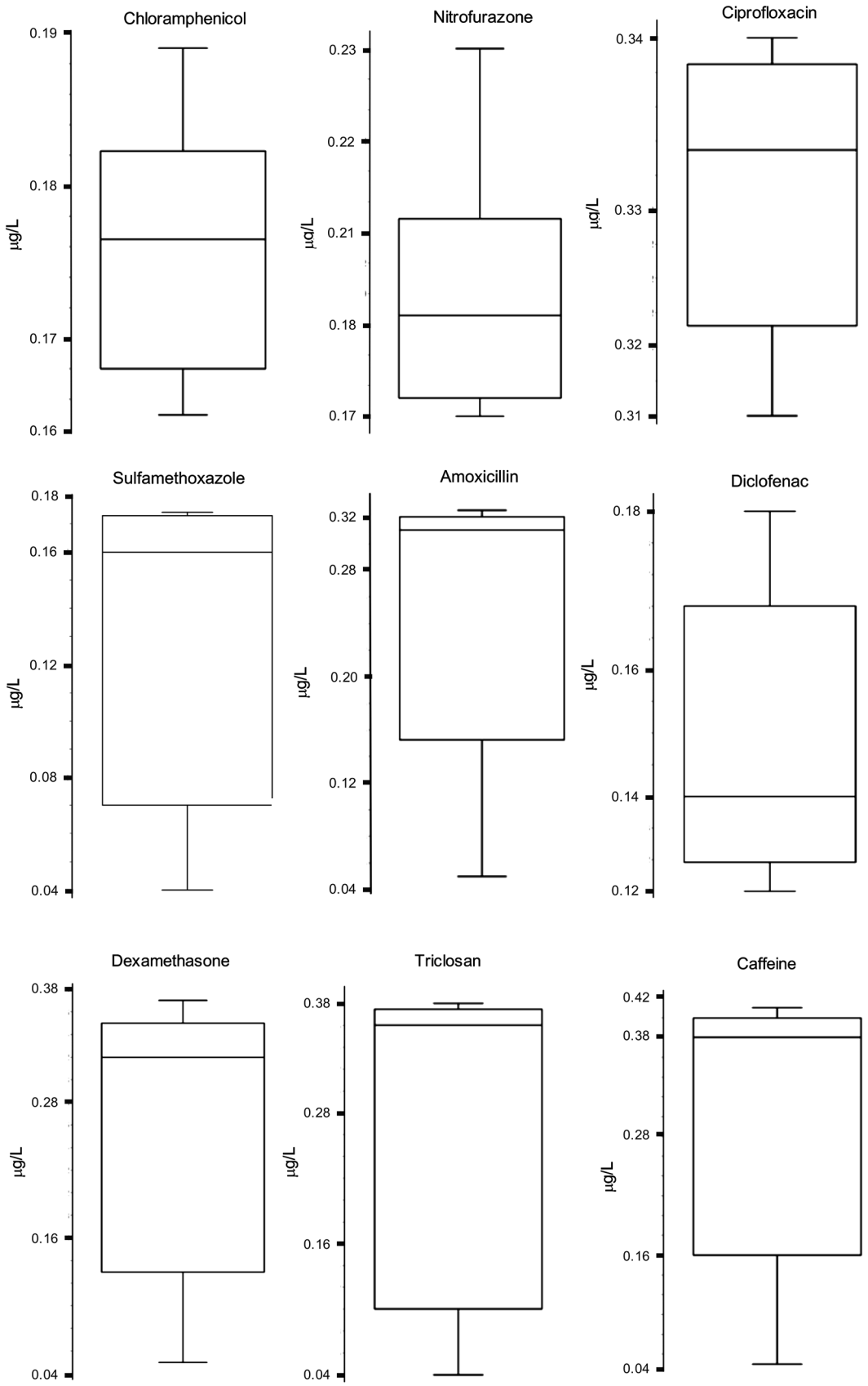

Fig. 2 Concentrations of pharmaceutical residues detected in tap water ($n = 80$) from Putrajaya, Malaysia (boxplots: minimum, first quartile, median, third quartile, maximum)

done by Yacob et al. (2017) showed that sewage treatment plants in Malaysia have shown poor removal efficiencies of pharmaceuticals in sewage ranging from 20 to 90% which resulted in the pharmaceutical residues to be released to the aquatic environment such as river water. Furthermore, improper medicine disposal into trash, sink or toilet is also identified as one of the factors which could lead to pharmaceuticals detection in landfills. Insufficient removal in sewage treatment plant also resulted in pharmaceutical residues being found in the aquatic environment.

Potential Health Risks via Drinking Water Ingestion

Figure 3 shows the calculated RQ_T values using potential health risk assessment based on Putrajaya respondents age groups involved in the questionnaire survey. The RQT values for all age groups exceeded one, which indicated all residents in Putrajaya were exposed to the health risks caused by the bioavailable pharmaceuticals in tap water through drinking water intake. The RQ values of each pharmaceutical for all age groups were ranged from 0.00263 to 1.39. Residents with age between 61 and 75 years old faced the highest RQ_T value. This can be associated with increasing pharmaceutical consumption along with the aging of society. Although these RQ_T values represent individual level yet possible interactions and toxicity mixtures are still unclear. Pharmaceutical residues absorbed by human with non-human target effect above a toxic dose are highly potential to produce allergic response or bioaccumulation capability. Presence of multiple pharmaceutical residues from various different classes in human is also capable to produce combination effects and lead to metabolic disruption. Thus, assessment of specific pharmaceutical classes at individual level is needed to deepen understanding of bioavailable pharmaceutical risks to human health (Schwab et al. 2005; Deo and Halden 2013). Furthermore, these RQ_T values were calculated using values from USEPA (2002) and toxicity data from various organism species. Thus, the final potential health risks are still in progress with the inclusion of other parameters such as pharmaceutical residues in food that forms a human diet, exposure route and toxicity data.

Public Awareness Level of Pharmaceutical Handling Among the General Public in Putrajaya (Malaysia)

Public awareness level information was extracted using scoring system from questionnaire survey filled by Putrajaya (Malaysia) respondents. The scoring system results showed that only 44.5% of Putrajaya population has good knowledge about pharmaceutical handling, occurrence of pharmaceutical residues in tap water and its effect to drinking water quality with mean knowledge scores of 6.84 ± 2.26 (Table 1). A total of 56.3% of the respondents were not aware that tap water may contain pollutants such as pharmaceutical residue in which 55% were not sure about pharmaceutical residues in tap water. This percentage was lower than that in the study by Ab Razak et al. (2016), in which 70% of the respondents knew that tap water may contain pollutants. On the other hand, 60% and 57.5% of the respondents knew the occurrence of pharmaceutical residue in tap water can affect human health and aquatic life, respectively. However, more than 70% of them feel that the boiling process is capable to remove chemical pollutants, including pharmaceutical residue. At the same time, almost more than 90% of them is using water filter unit at home which was believed to remove pollutants (26.3%), reduce odor and color (36.3%) and neutralize tap water (37.4%).

A total of 27.5% of the respondents had a good attitude towards pharmaceutical handling to minimize pharmaceutical exposure in the tap water supply (Table 2). Likewise, about 96% of them feel they need of an additional water filtration unit at their home, 68.8% of them believe that boiling

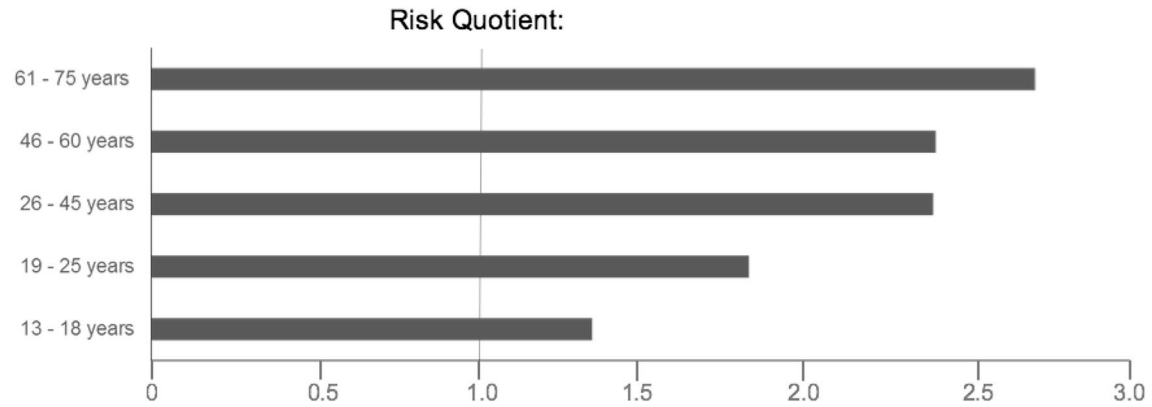

Fig. 3 Total risk quotient (RQT) representing potential human health risks based on age groups of Putrajaya respondents involved in the questionnaire survey

Table 1 Knowledge scores for pharmaceutical handling among the general public in Putrajaya (Malaysia)

Variable	*n*	%	Given score
Knowledge			
Know tap water may contain pollutants such as pharmaceutical residue			
Yes	35	43.7	1
No/not sure	45	56.3	0
Know what is pharmaceutical residue in tap water			
Yes	36	45.0	1
No/not sure	44	55.0	0
Occurrence of pharmaceutical residue in tap water can affect human health			
Yes	48	60.0	1
No/not sure	32	40.0	0
Presence of pharmaceutical residue can affect aquatic life			
Yes	46	57.5	1
No/Not sure	34	42.5	0
Knowledge on boiling can remove pharmaceutical residue in tap water			
Yes	58	72.5	1
No/Not sure	34	27.5	0
Have received education on tap water quality			
Yes	42	52.5	1
No/not sure	38	47.5	0
Use water filter unit to filter tap water at home			
Yes	73	91.3	1
No	7	8.7	0
The role of water filter unit to remove pollutants in tap water			
Remove pollutants	21	26.3	1
Reduce odor and color	29	36.3	1
Neutralize the tap water	30	37.4	0
Not sure			
Total given score			11
Total mean score (SD)			6.84 (2.26)
% Good knowledge (score ≥ 6)			44.5
% Poor knowledge (score ≤ 6)			57.5

can remove chemical pollutants such as heavy metal and pharmaceuticals in water and 91% agreed on routine monitoring and inspection of tap water. While pharmaceuticals handling among Putrajaya respondents showed that 60% will go for conventional medicine with only 36.3% will finish the whole conventional medicine to treat their health problems. Although 91.3% of them aware on the pharmaceutical's expiry date, 51.3% of them feel it is appropriate to throw unused/unfinished/expired medicine into municipal waste bins and flush unused/unfinished/expired into toilet and sink (16.3%).

In relation to practice level, Table 3 shows only 1.6% of respondents were reported to have good practice related with pharmaceutical handling among the general public in Putrajaya (Malaysia). A total of 65% of the respondents have expired/unused medicine in their home where 91.3% of them obtained from clinic/hospital. In terms of pharmaceutical handling and disposal, only 6.3% of the respondents return their expired or unused medicines to the pharmacy while the rest (93.7%) throw into waste bins or flush into sink/toilet. Correspondingly, Yang et al. (2018) and Fatokun (2014) have reported that about 62% of Malaysian medicines dispose into the garbage and low awareness could cause the action of unsafe disposal. Furthermore, Lim and Teh (2012) have concluded that antibiotics are the most consumed pharmaceuticals with low awareness (knowledge, attitude and practice) towards safe disposal practices of expired and unused pharmaceuticals in Putrajaya (Malaysia).

Current study brings out the low public awareness levels related pharmaceutical handling among general public in Putrajaya. Public awareness findings revealed that the respondents have low knowledge related to pharmaceutical handling and its impact to tap water quality. Furthermore, poor attitude and practice were related to pharmaceutical handling among the general public which can be one of the factors for pharmaceutical pollution in raw water supply

Table 2 Attitude scores related pharmaceutical handling among the general public in Putrajaya (Malaysia)

Variable	*n*	%	Given score
Need for additional tap water filtration unit			
Yes	77	96.2	1
No/not sure	3	3.8	0
Believe boiling can remove pollutants such as pharmaceuticals in tap water			
Yes/not sure	55	68.8	0
No	25	31.2	1
Prefer conventional medicine to treat disease			
Yes	48	60	1
No	32	40	0
Will finish whole conventional medicine to treat health problems			
Yes	29	36.3	1
No	51	63.7	0
Realize conventional medicine has an expiry date?			
Yes	73	91.3	1
No	7	8.7	0
Appropriate to throw unused/unfinished/expired medicine into municipal waste bins			
Yes	41	51.3	0
No	39	48.7	1
Appropriate to flush unused/unfinished/expired into toilet and sink			
Yes	13	16.3	0
No	67	83.7	1
Total given score			11
Total mean score (SD)			5.73 (1.4)
% Good attitude (score ≥ 7)			27.5
% Poor attitude (score ≤ 7)			72.5

Table 3 Practice scores related with pharmaceutical handling among the general public in Putrajaya (Malaysia)

Variable	*n*	%	Given score
Do you have expired/unused medicine at your home?			
Yes	52	65	1
No	28	35	0
Do you obtain these medicines from clinic or hospital?			
Yes	73	91.3	1
No	7	8.7	0
What do you do with unfinished medicine?			
Return to pharmacy	5	6.3	1
Discard to waste bin	33	41.3	0
Flash into sink/toilet	42	52.4	0
Total given score			8
Total mean score (SD)			1.89 (0.89)
% Good practice (score ≥ 2)			1.6
% Poor practice (score ≤ 2)			98.4

and tap water. Thus, awareness program play a vital role in spreading information and knowledge on a mass scale. Awareness program design needs to be constructed in a way to develop a holistic understanding of basic tap water quality related with pollutants, emerging issues related to raw water supply pollution sources as well as efforts taken by drinking water surveillance agencies. A special focus by clinics/hospitals involving public participation in health-promotion program could be the first step to change medicine management and measures to dispose of unused/expired

medicines. Unused and expired medicines management handling program with active participation from general public are needed in minimizing pharmaceutical pollution in the environment and raw water supply.

Conclusion

This study has investigated the drinking water quality in Putrajaya (Malaysia) with regards to pharmaceutical residues and its associated human health risks. Besides, this study also has assessed the public awareness (knowledge, attitude and practice) levels of pharmaceutical handling. The main key findings of this study are as follow:

- Mean pharmaceutical residue concentration of caffeine, triclosan, dexamethasone, ciprofloxacin, amoxicillin, nitrofurazone, chloramphenicol, sulfamethoxazole and diclofenac in tap water samples were 0.38 ng/L, 0.36 ng/L, 0.32 ng/L, 0.32 ng/L, 0.31 ng/L, 0.19 ng/L, 0.17 ng/L, 0.16 ng/L and 0.14 ng/L, respectively. Vast urbanization and industrialization along river water, poor removal efficiencies of tap water and wastewater treatment technologies, improper disposal of expired pharmaceutical waste were few of the factors associated with pharmaceutical residues occurrence in tap water.
- Potential health risks involving respondents in Putrajaya (Malaysia) indicated by RQ_T values ranged from 1.35 to 2.71 and the highest group age between 61 to 75 years old with the highest RQ_T value.
- Public awareness levels related to tap water quality and pharmaceutical handling among general public in Putrajaya have indicated low knowledge along with poor attitude and practice.

In the long run, to improve both public awareness related to tap water quality and pharmaceutical handling among the general public, various relevant agencies should draw attention to implement awareness program at the grassroots level. This step is to ensure a proper unused/expired medicine management and reduce these pharmaceutical residues enter environment including water system.

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