ORIGINALNI NAUČNI RAD

CONSUMER AWARENESS OF ANTIMICROBIAL RESIDUES IN DRINKING WATER

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Abstract: *This study was conducted to assess the awareness among water consumers in urban and rural areas. In Serbia, Croatia, Bosnia and Herzegovina, North Macedonia, and Montenegro, 505 consumers*

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were surveyed using a structured questionnaire and checklist regarding their awareness of water quality and safety issues. A total of 18.4% of the consumers were not aware of the adverse effects of antimicrobial residues in water, while 8.1% of them were buying antibiotics without a medical prescription. The awareness was significantly influenced (P<0.05) by the consumer's educational level and topographical location. The findings revealed that the majority of the respondents are consuming tap water (52.3%), followed by bottled water (43%) and water from natural sources (4.8%), respectively. The results also revealed that the sources of information regarding antibiotics' effects come mostly from medical doctors (43%) and pharmacologists (10.5%), while around 41% of all information regarding antibiotics comes from scientific literature and social media. Around 50% of the respondents have revealed that in their own country it is very easy to get the antibiotics and other drugs without a medical prescription, even if 47.5% of the respondents indicated that during the COVID-19 pandemic a doctor was available to prescribe therapy to a patient.

Keywords: *consumer awareness / tap water / bottled water / AMR / antibiotics.*

INTRODUCTION

Recent years have seen an increase in public health and food safety issues concerning antibiotic residues in food. Because antimicrobials are used indiscriminately in the animal production for a variety of reasons, such as to treat and prevent diseases, as well as to promote the growth, nowadays we can find these residues in milk, eggs and meat (Puvača & de Llanos Frutos, 2021). In addition, plant-derived foods grown in soil and water contaminated with animal waste may act as a second source of exposure to veterinary antimicrobials, resulting in the development of antibiotic resistance (Gothwal & Shashidhar, 2015; Vapa Tankosić et al., 2022). Approximately 40% of antimicrobial drugs are not metabolized in the body and are thereby expelled into the soil either in their original form or as active metabolites (Tiwari et al., 2017). Plants are more likely to absorb waste if they are used as manure for agricultural production. Food products containing edible animal products have been found to contain antimicrobial residues that are above the acceptable levels in developing countries (Puvača et al., 2020). The most frequently used antimicrobials are tetracyclines, followed by beta-lactam antibiotics, such as penicillin (Nag et al., 2020).

Across the globe, antimicrobial residues are associated with the development and spread of antimicrobial resistance (AMR) (Pelić et al., 2023). Antimicrobial resistance compromises many aspects of life, including health care, food security, sanitation and safe drinking water (Chammem et al., 2018). It is estimated that by 2050, the number of deaths caused by antibiotic-resistant diseases will increase from 700,000 in 2014 to 10 million (Temkin et al., 2018), resulting in billions of dollars in healthcare expenditures and trillions of dollars in economic costs. As a result of antimicrobial resistance, up to 24 million people will enter extreme poverty around the world by 2030 (Jasovský et al., 2016). Healthcare expenses, as well as the morbidity and mortality rates, are higher as the result of AMR, which calls for collaboration between all sectors and stakeholders (Bloom & Cadarette, 2019).

Drinking water contaminated with residual antibiotics may pose adverse health risks to humans and animals (Puvača et al., 2022). In the recent years, people have generally used boiled tap water for drinking due to chlorine disinfection in tap water. There has been a gradual shift toward drinking filtered tap water and bottled water by more and more people. Antibiotic residue levels may vary depending on the type of water consumed (Premjit et al., 2022). Human exposure to antibiotics through drinking water has, however, been the subject of only a few studies. There will likely be antibiotic residues in drinking water because 120 different antibiotics are used in daily human and animal health care worldwide (Larsson & Flach, 2022).

Human health and social development significantly depend on the quality of drinking water (Horvat et al., 2021; Ober et al., 2022). Therefore, it is the imperative to gain a comprehensive understanding of the potential health risks associated with drinking water contaminated with antibiotic residues.

MATERIALS AND METHODS

An online Google Forms survey was used to collect the data on consumer awareness. Pre-testing of the questionnaires was conducted on 5% of the sample size to ensure reliability and validity. The researchers closely supervised the collection of obtained data by trained data collectors.

All collected data were analyzed using TIBCO Statistica® 13.4.0 softer for Windows (Tibco Software Inc., Palo Alto, CA, USA). The study used descriptive statistics like frequency and percentage, as well as the inferential statistics. The scores were calculated based on awareness responses from each participant. The adjusted odds ratio and 95% confidence interval for the level of awareness were assessed utilizing binary logistic regression analysis.

The University Ethical Review Committee reviewed and approved the survey proposal. The written consent in the form of a confirmation statement "The results of the research will be used for scientific research purposes, and by filling out this questionnaire, you give your consent to their use for the stated purposes. The anonymity of your answers is guaranteed", after explaining the study objectives, procedures, and confidentiality of the data, was obtained from all the study participants over 18 years of age.

RESULTS AND DISCUSSION

From the results given in Table 1, it can be seen that the majority of the total 505 participants were from Serbia (87.5%), with a total of 81.2% of the participants located in the urban areas. In this survey, the female participants were dominant with 69.3%, while the predominant age group (55.8%) was between 18-35 years of age. A high proportion of the participants (43.4%) had completed bachelor's studies and 70.9% have been employed. A significant proportion of the students (23%) also took part in an online questionnaire. Regarding the number of the household members, from the total of 505 respondents, 80.8% indicated a small household (1-4 members), while only 2% had a big household with more than 7 members, respectively. Based on the provided demographic information, the dullest household has a total average income between 1000 and 2000 EUR, which represents 35.5% of the participants, respectively.

**Table 1.** *The demographic information of the respondents*

| Variable	Frequency, *n*	Proportion, %	95% CI
Country			
Serbia	442	87.5	85.2-90.3
Croatia	14	12.8	9.8-13.4
Bosnia and Herzegovina	21	4.2	2.9-4.8
North Macedonia	6	1.2	0.5-1.7
Montenegro	22	4.4	2.9-5.3
Type			
Urban	410	81.2	76.3-82.8
Rural	95	18.8	17.5-19.1
Gender			
Male	155	30.7	28.4-31.6
Female	350	69.3	67.4-71.7
Age group			
18 – 35 years of age	282	55.8	52.1-57.9
35 – 65 years of age	216	42.8	39.3-44.0
> 65 years of age	7	1.4	0.4-2.1
Education			
Secondary school	105	20.8	17.5-22.3
Faculty (BSc)	219	43.4	40.0-44.9
Master of Science (MSc)	73	14.5	12.3-15.6
Specialization (Spec)	8	1.6	0.8-2.2
Doctor of Science (PhD)	100	19.8	18.1-21.4
Occupation			
Student	116	23	21.2-24.7
Employed	358	70.9	68.9-72.5
Unemployed	27	5.3	4.4-6.7
Retired	4	0.8	0.4-1.6
Number of household members			
1 – 4	408	80.8	78.4-83.1
5 – 6	87	17.2	16.8-18.4
> 7	10	2	1.1-3.5
Total average income of household, €			
< 200	5	1	0.7-1.3
200 - 500	69	13.7	11.2-14.9
500 - 1000	151	29.9	27.8-32.0
1000 – 2000	179	35.5	33.3-36.4
> 2000	101	20	18.6-22.4

CI - 95% confidence interval

Approximately two-thirds of the weight of our bodies are composed of water. Water composes 83% of the blood, 75% of the tissues of the muscles, 74% of the structure of the brain, and 22% of the structure of bones (Heymsfield et al., 1997). Whether you drink bottled or tap water, the body depends on the water for its proper functioning, which is why human beings cannot survive without it. The majority of skin cells are made of water, just like the rest of the body's cells. The organs in the human body cannot function properly without water, and the skin is the biggest organ (Kolarsick et al., 2011). The consumer preferences obtained through a series of questions from the online survey are given in Figure 1. From the obtained results it can be noticed that the respondents most often use the tap water (52.3%), followed by bottled water (43%), while even 4.8% of them use water from the natural sources, such as wells. The most represented brand of bottled water was Rosa (36.6%), with a significant share of two other Serbian bottled water brands - Prolom (21.1%) and Aqua Viva (14.4%). The reasons for buying the chosen brands of bottled water were mainly mineral content of the water (47.7%), while price, brand, and origin of bottled water had the same influence in decision making. Interestingly, the majority of the respondents buy the bottled water because of its taste (24.5%). Also, not a large share of the respondents has indicated that regular quality of water control (10.9%) influences the decision to buy bottled water.
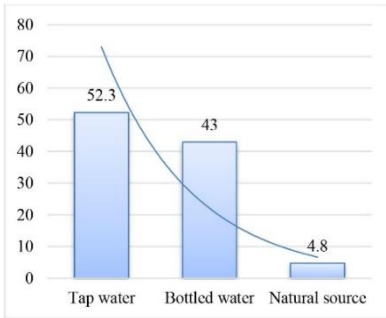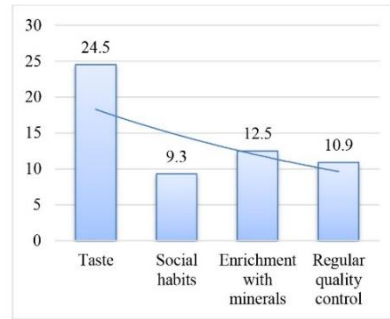
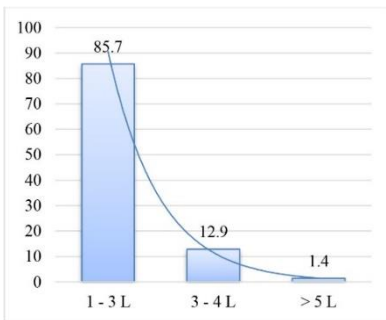(A) What kind of water do you consume most often?
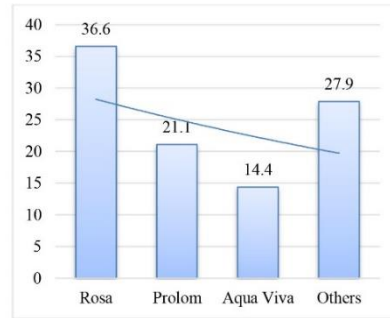
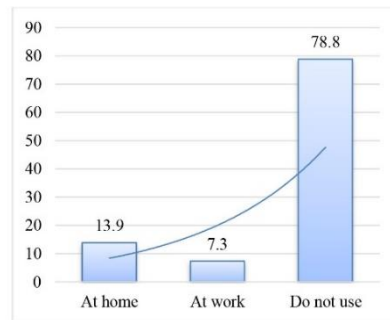(B) Which brand of bottled water do you buy most often?
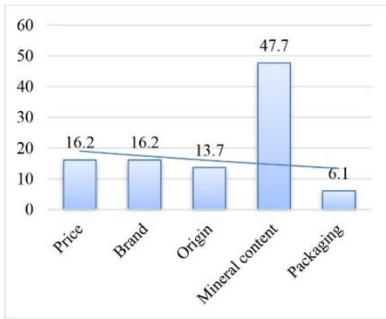
(C) What is the reason for buying the chosen brand of bottled water?

(D) For what reasons do you drink bottled water more often than tap water?

(E) How many liters of water do you drink on average per day?

(F) Do you use water purifiers or filters?

Figure 1: *Consumer preferences obtained using the online questionnaire*

From a total of 505 respondents involved in our research, 85.7% daily drink between 1 and 3 liters of water, respectively. According to the Mayo Clinic (Rochester, Minnesota, USA), the daily intake of water should be a minimum of 1.9 liters (Wolf et al., 2010). To keep your body hydrated, if you exercise, or if you are exposed to hot weather, or work in an office surrounded by central heating, air conditioning, or electrical equipment, you may need even more. Drinking water intake rates between 2 and 4 liters per day are generally used in the risk assessments, but there is insufficient evidence to support this value (Ohno et al., 2018). As a result of the same research, almost the entire population would need to consume at least 2.5 liters of tap water each day to meet their needs. The obtained results have shown that the respondents in any of participating countries of western Balkan are not interested in using water purifiers or filters (78.8%), while a small percentage of respondents are using them in the households (13.9%) and at work (7.3%). A study investigating the effects of different types of water filters was conducted after collecting the baseline information on rural household water quality, diarrheal disease, and other factors related to water use in the rural households (Loomis et al., 2008). There was a significant decrease in diarrheal disease among households using either filter compared with the controls without the filters (Loomis et al., 2008). In the Middle Eastern countries, the use of household water purifiers for the filtration of drinking water has increased more than in western Balkan countries, but their effect on microbiological safety has hardly ever been investigated. A study found that household purified water still poses microbial health risks (Lin et al., 2020).

Table 2 describes the consumer awareness and the attitudes regarding the use of antibiotics and other medicines. Overall, 91.9% of the consumers get antibiotics on their own, without any medical advice and prescription even though 81.6% of the surveyed participants are informed about good or bad antibiotics' effects on humans and the environment. When it comes to buying antibiotics without a medical doctor's prescription, our results have shown that in 51.1% of the cases the antibiotics are easy-to-get in such a way, while 48.9% of them say otherwise. Although problematic, the antibiotics are still being dispensed in some Spanish pharmacies without a prescription despite the problem. A lack of continuing education, indifference, and acquiescence are all the factors contributing to this practice. Following the persisting problem, the patient, physician, dental, and government responsibility for resistance were attributed (Vazquez-Lago et al., 2017). Following the

previous question, a total of 87.9% of the respondents are aware that buying antibiotics without a prescription is not good for public health in general. The students at universities are found to be irrationally prone to using antibiotics. In addition to limiting antibiotics without prescriptions, the national education programs should focus on the dangers of irrational antibiotic use. Several studies have shown that antimicrobial knowledge does not always correlate with the behavior, according to Buke et al. (2005). Based on the study results by Llor and Cots (2009), the pharmacists explained the number of times per day the antibiotic should be taken in 84.3% of the pharmacies, explained the duration of treatment in 68.7% of the pharmacies, and only 16.9% asked about allergies before selling the antibiotics. It was reported that only 57 out of 108 pharmacies (52.8%) did not sell the antibiotics due to health care reasons or the antibiotic resistance concerns (Llor & Cots, 2009).

Table 2: *Awareness and attitudes of consumers about the use of antibiotics and other medicines*

Variable	Positive answer (yes)		Negative answer (no)	
	n	%	*n*	%
Do you get antibiotics on your own, in a pharmacy, without a medical prescription?	41	8.1	464	91.9
Are you informed about the good and bad effects of antibiotics?	412	81.6	93	18.4
Is it easy to buy an antibiotic without a medical doctor's prescription in your country?	258	51.1	247	48.9
If the answer to the above question is yes, do you think this is good for consumers and public health in general?	61	12.1	444	87.9
If you don't think it's good, do you think there should be more control over the purchase of over-the-counter drugs?	404	80.0	101	20.0
Do you think you are sufficiently informed about the improper use of antibiotics and other drugs?*	242	47.9	100	19.8
Are you sufficiently informed about the possibility of antimicrobial resistance due to improper use of antibiotics?**	247	48.9	120	23.8

* - A total of 163 respondents (32.3%) answered that they do not know or that they are not sure; ** - A total of 138 respondents (27.3%) answered that they do not know for sure what exactly "antimicrobial resistance" means.

Nevertheless, a significant number of the participants (47.9%) think that they are sufficiently informed about the improper use of antibiotics, while 80% of the respondents agree that there is a necessity for stronger control of the purchase of over-the-counter drugs. Interestingly, 48.9% of the respondents are sufficiently informed about the possibility of antimicrobial resistance due to improper use of antibiotics, while 27.3% of the respondents do not know for sure what exactly "antimicrobial resistance" means. Education and raising awareness about AMR are of greater importance today than they have ever been because today's challenges related to antibiotic resistance are different from those in the past since the new bacterial pathogens are present and continue to evolve. In recent years, multiple antibiotic-resistant strains have emerged that no new antibiotic has been able to combat. In addition to mortality and morbidity consistently rising, the antibiotic resistance has serious life-threatening consequences (Puvača & de Llanos Frutos, 2021).
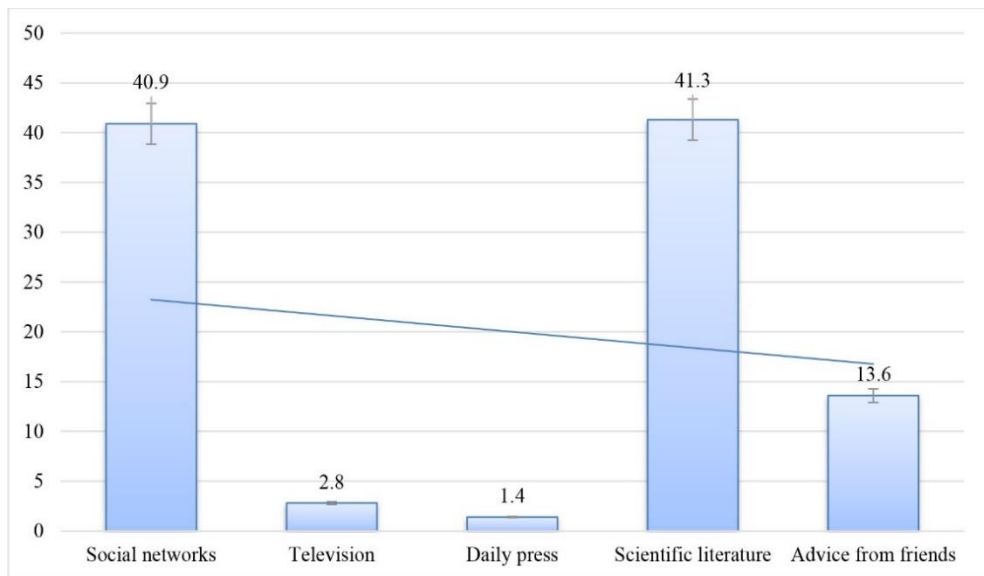
Figure 2: *Sources of information on the beneficial and harmful effects of the antibiotic use*

It is encouraging to know that this goal may be more easily met since people have started to use the scientific literature as their source of information on the beneficial and harmful effects of antibiotic use (41.3%).

On the other hand, it's a bit worrying that people, in high percentage, use social networks as their source of information (40.9%), the place where information most often is not confirmed, accurate, nor filtered. From Figure 3 it can be seen that television (2.8%) and daily press (1.4%) have a significantly low influence as a source of information for people.

The obtained results on consumer attitudes toward antibiotic availability and health care during the COVID-19 pandemic are shown in Table 3. It can be noticed that 48.7% of the respondents did not have information about the availability of antibiotics in sufficient quantities in the pharmacies during the COVID-19 pandemic, compared to 36.2% who stated that during the pandemic the antibiotics were available. According to Yu et al. (2022), to prevent COVID-19 from spreading, drug factories were shut down, disrupting the supply chain and leading to shortages. Our results have shown that a medical doctor was available to prescribe therapy to patients during the pandemic in 47.5% of the cases, while 33.7% of the respondents stated that the introduction of necessary antibiotics in their therapy was not delayed during the COVID-19 pandemic compared to the time before the pandemic, respectively. Some countries changed their antibiotic consumption patterns due to the COVID-19 pandemic, reducing their use of amoxicillin and cefalexin and increasing their use of azithromycin (Del Fiol et al., 2022). Our results have revealed the disturbing fact that 11.7% (59 people) took antibiotics on their own, as well as the other types of drugs, without first consulting a doctor. In the meantime, Elsayed et al. (2021), reported heavy antibiotic dosages without appropriate clinical indications and for long periods during the pandemic, further supporting the notion of antibiotic misuse.

Table 3: *Consumer attitudes toward antibiotic availability and health care during the COVID-19 pandemic*

Variable	Positive answer (yes)		Negative answer (no)		Do not have information / Didn't use antibiotics and other drugs during the pandemic	
	n	%	*n*	%	*n*	%
Do you think there were enough antibiotics in pharmacies during the COVID-19 pandemic?	183	36.2	76	15	246	48.7
During the COVID-19 pandemic, was a medical doctor available to you to prescribe therapy?	240	47.5	67	13.3	198	39.2
Has the introduction of necessary antibiotics in your therapy been delayed during the COVID-19 pandemic compared to the time before the pandemic?	58	11.5	170	33.7	277	54.9
During the COVID-19 pandemic, did you take antibiotics on your own and other types of drugs, without first consulting a doctor?	59	11.7	274	54.3	172	34.1

During the COVID-19 pandemic, the individuals worldwide are thought to have sought and consumed the antibiotics in an "unjustified" or "inappropriate" manner. As a result of the current health crisis, users' perspectives on antibiotic use and seek have received little attention from researchers.

CONCLUSION

Based on the gained results it can be concluded that 48.9% of the consumers are sufficiently informed about the possibility of antimicrobial resistance due to improper use of antibiotics and their residues in drinking water, while a total of 27.3% of the consumers were not familiar with what exactly "antimicrobial resistance" term means. To combat the antimicrobial resistance, it is an imperative to enforce laws and regulations regarding the antimicrobial use, as well as to educate the consumers about the antimicrobial residues in drinking water in the urban and rural areas. In turn, this will serve as a mitigation strategy for the prevention of health-related effects related to unsafe water.

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SVEST POTROŠAČA O OSTACIMA ANTIBIOTIKA U VODI ZA PIĆE

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Sažetak: *Cilj ovog rada je da se ispita svest među potrošačima vode u urbanim i ruralnim područjima. U Srbiji, Hrvatskoj, Bosni i Hercegovini, Severnoj Makedoniji i Crnoj Gori, ukupno 505 potrošača je ispitano korišćenjem strukturiranog upitnika u vezi sa svešću potrošača o kvalitetu i bezbednosti vode. Ukupno 18,4% potrošača nije bilo svesno štetnih efekata ostataka antibiotika u vodi, dok je 8,1% njih kupovalo antibiotike bez lekarskog recepta. Na njih su značajno (P<0,05) uticali nivo obrazovanja potrošača i topografska lokacija. Dobijeni rezultati su takođe otkrili da većina ispitanika konzumira vodu iz česme (52,3%), zatim flaširanu (43%) kao i vodu iz prirodnih izvora (4,8%). Rezultati su takođe otkrili da izvori informacija o efektima antibiotika dolaze uglavnom od lekara (43%) i farmaceuta (10,5%), dok oko 41% svih informacija u vezi sa antibioticima dolazi iz naučne literature i društvenih medija. Oko 50% ispitanika je otkrilo da je u njihovoj zemlji vrlo lako dobiti antibiotike i druge lekove bez lekarskog recepta, čak i ako je 47,5% ispitanika navelo da je tokom pandemije COVID-19 lekar bio na raspolaganju da pacijentu prepiše terapiju.*

Ključne reči: *svest potrošača / voda iz česme / flaširana voda / AMR / antibiotici.*