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Investigation of Residual Concentration of Organochlorine, Organophosphorus, and Carbamate Pesticides in Urban Drinking Water Networks of Hamadan Province, Iran

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Abstract
Pollution of water resources with pesticides is one of the environmental problems and a serious threat to the communities' health. This study aimed to determine the residual concentration of pesticides in urban drinking water networks of Hamadan province in 2019. In order for investigating the residual concentration of organochlorine (aldrin, dieldrin, lindane, methoxychlor and permethrin), organophosphorus (chlorpyrifos, diazinon and malathion), and carbamate (atrazine and alachlor) pesticides in urban drinking water distribution networks of the province, a total of 46 samples were taken. The samples were analyzed by GC-ECD and the results were analyzed using Excel software (a descriptive cross-sectional study). The residues of aldrin, dieldrin, lindane, diazinon, malathion, atrazine, and alachlor were found in none of the samples. The maximum concentrations of chlorpyrifos and permethrin were 2.20 and 8.03 µg/L, respectively. The methoxychlor residue was observed only in one sample (C=0.35 µg/L) and all other samples were free of methoxychlor. Residues of studied pesticides in all samples are much less than the maximum allowable in the national standard and the World Health Organization (WHO) and Environmental Protection Agency (EPA) guidelines. Therefore, it can be concluded that the studied networks water quality as well as the urban drinking water resources in Hamadan province are at a very desirable level in terms of the pesticide residues. If the consumption of pesticides is not controlled, there is a possibility of increasing the concentration of these pollutants in water resources, which in turn may threaten the human health in the future.
Keywords: Pesticide, Drinking water, Hamadan province, Gas chromatography

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1. Introduction

Pollution of water resources with pesticides is one of the environmental problems that is caused by agricultural development – a by-product of the population growth, leading to an increase in pesticide use. Pesticides used in agriculture can enter water sources through direct washing or irrigation. Rainfall is also sprayed on the fields and before pesticides can be decomposed, it can facilitate their entry into surface waters. In addition, pesticides can enter to groundwater through soil layers as water infiltrates. In some cases, some pesticides can enter the air and, as a result, contaminate surface water and soil through rainfall (1-3).

The entry of pesticides into drinking water sources and networks in terms of severe resistance to environmental factors, water solubility, and toxicity to living organisms can have adverse effects on human health and the environment. The incidence of their adverse effects depends on the type of chemical, duration of use, time of exposure, input concentration, and the degree of toxicity to humans. Important health effects of pesticides entering the body as a whole include short-term side effects such as abdominal pain, dizziness, headache, diplopia, nausea, and ocular and skin problems. Long-term complications include an increased risk of respiratory problems, memory disorders, depression, neurological disorders, cancer, and infertility (3).

Many pesticides with different chemical composition used all over the world are classified into herbicides, insecticides, fungicides, acaricides, nematicide, etc., based on the type of use. The most common of these are herbicides which account for approximately 80% of all pesticide use. Regarding chemical structure, pesticides fall into the categories of organochlorine pesticides, organophosphorus, organonitrogen or carbamate and pyrethroids. Organophosphorus compounds, among the given pesticides, are so diverse that they constitute about 40% of the world's pesticides (4-6). Particular importance is attached to organochlorine pesticides due to their cumulative and carcinogenic properties, to organophosphorus pesticides due to inhibit the activity of acetylcholinesterase (an enzyme required for the function of neural networks), and to carbamate pesticides in terms of their mutagenic effects and their effect on the central nervous system (3,4). Therefore, contamination of water sources by pesticides should be prevented. Given that the measurement of pesticide residues in water is very important in maintaining human health and controlling environmental pollution, the first step in controlling and managing the pesticides residual in water sources is to determine their residual concentration by acceptable accuracy and comparison of obtained values with standards (7). The use of gas chromatography (GC) has been recorded as the world standard method for measuring pesticides. Owing to the low concentration residues of these contaminants in the environment and their complexity in the real samples, the use of the extraction and preconcentration methods seems necessary (4). In order to separate and identify trace amounts of pesticides, various extraction and preconcentration methods have been developed that each of which has specific characteristics. Solid phase extraction, solid phase micro extraction, liquid-liquid extraction, and micro liquid-liquid extraction are the most popular and widely used pesticide extraction methods in aqueous matrices (8).

Many studies have been conducted to investigate the residual concentrations of pesticides in surface and groundwater resources of Iran and other parts of the world. Safari et al conducted a study to assess the prevalence of organophosphate pesticides in the Hablehrood River located in Semnan province through using GC supported by an electron capture detector (ECD) and found out that the concentration of diazinon and malathion in two stations (Bone Kooh and Mahmood Abad) were higher than the standard level (9). In a study by Khalijian et al aiming to determine the residual concentration of diazinon pesticide in groundwater sources of Hamadan-Bahar plain, it was determined that the mean concentration of diazinon residues in samples was 0.23±0.06 µg/mL, being upper than 0.10 µg/mL which is the maximum contaminant levels defined by the World Health Organization (WHO) (10). Khodadadi et al investigated the residual concentrations of organophosphorus pesticides and carbamates in drinking water sources in Hamadan city. The results of the study revealed significant differences among pesticides concentrations in the water samples in different seasons (P<0.05). However, there wasn't a significant difference in pesticides concentrations in surface and ground water samples (P >0.05) (3). In a study by Hasani et al in Shemiranat area to investigate the effect of pesticides on drinking water quality, the residues of organophosphorus pesticides (diazinon, disulfoton, malathion, parathion, ethion, trifluralin) were observed in none of the studied groundwater sources (11). Székács et al identified the chemical toxins atrazine, acetochlor, permethrin and diazinon in 44%, 31%, 18%, and 3% of the samples collected during different monitoring projects in Hungary, respectively. They discovered that the mean concentrations of atrazine and acetochlor in most samples were above standard (12). Lari et al studied the residues of organophosphate and organochlorine pesticides in surface and groundwater resources of agriculture intensive areas in India. After identifying the pesticides of α−HCH, α−endosulphan, chlorpyrifos, and parathion-methyl in the given areas, they determined that the average concentration of pesticides in the samples collected from Bhandara and Yavatmal regions exceeded the EU (European Union) limit of 1.0 µg/L (sum of the pesticide levels in surface water), but were within the WHO guidelines for individual pesticides (13). A study by Kent et al in California on pesticide residues in surface water of Santa Ana Basin found that the majority (92%) of collected samples were contaminated with one or more pesticides (14).

Due to the diversity of agricultural products, suitable climatic and environmental conditions for agriculture, and the expansion of the provincial area under cultivation, there is the possibility of the residue permeation of the pesticides used by farmers and gardeners in drinking water sources. Therefore, a continuous control and monitoring of Hamadan province surface and ground drinking water sources is required regarding the presence of pesticide residues, especially at the point of use.

Given the fact that there has not been a comprehensive study on pesticide residues in water networks of Hamadan province, this study aimed, firstly, to determine the residual concentrations of organochlorine (aldrin, dieldrin, lindane, methoxychlor and permethrin), organophosphorus (chlorpyrifos, diazinon and malathion), and carbamate (atrazine and alachlor) pesticides in drinking water networks of all urban areas of Hamadan province in 2019; and then to determine the water samples contaminated with pesticide residues and to compare the generated results with the maximum allowable values recommended in national and international standards.

The novelty of this study lies in the comprehensiveness and scope of the sampling (including all urban drinking water distribution networks in Hamadan province), as well as in the number of pesticides monitored in it compared to other similar studies.

It is hoped that the results of this study form the basis of an official policy-making strategy towards developing agricultural education and extension programs by Jahad Agriculture Organization as well as Water and Wastewater Company and Health Center of the province active in providing drinking water health, while creating public awareness – especially farmers and gardeners' awareness – about the consequences of excessive or unprincipled use of the pesticides.

2. Materials and Methods

2.1. Study Area

Hamadan province (34.7982°N, 48.5146°E) is located in an area of 19 493 km^2 in the west of Iran. This province is bounded to the north by Zanjan and Qazvin provinces, to the south by Lorestan province, to the east by Markazi province, and to the west by Kermanshah and part of Kurdistan provinces. When conducting this study, the province had nine counties, namely Hamadan, Malayer, Kabudarahang, Razan, Famenin, Tuyserkan, Nahavand, Asadabad, and Bahar (Fig. 1). Hamadan is the most populous county of the province and Hamadan city – the center of the county, is also the capital of the province. Hamadan province, with its abundant rainfall and suitable environmental conditions, has been well-developed in the fields of agriculture and horticulture turning Tuyserkan and Bahar counties into the centers of walnut and potato production in Iran, respectively (15,16).

The province undergoes different climatic variations during the year, and the level of precipitation and the cold varies during the seasons. It is cold in mountainous areas and it snows up to 155–245 mm annually on average, and the cold reaches 30°C below zero. The average annual temperature of the province is 11.3°C. The average annual precipitation is estimated to be 317.7 mm. Surface water and groundwater resources of Hamadan province originate from four main plains and aquifers including the Hamadan–Bahar plain, the Razan–Ghahavand plain, the Kabudarahang plain, and the Kamijan plain that spread across the watershed of the province. Due to the roughness of the rock floor and the existence of feeding areas, these aquifers are not homogeneous and do not have the same status in terms of discharge. The groundwater level varies from 180 to 300 m. Malayer and Tuyserkan plains are erosional in nature, and the rest of the province has dense forest. Geologically, the surface of the plains relative to the heights is composed of permeable formations. The plains, which are composed of alluvial sediments and sedimentary sands, are reservoirs of groundwater and have good permeability. Granite and dense rocks, which have low permeability and, therefore, slow down the movement of groundwater, do not play an important role in feeding groundwater aquifers and are effective in strengthening surface flows. In terms of geographical location, Hamadan province is located under the Salt Lake basins of the Central Iran catchment area, Karkheh in the Persian Gulf catchment area, and Oman and Sefidrood seas of the Caspian Sea catchment area. The three major rivers of Hamadan province, namely Gamasiab, Qarachai, and Talvar flow out of the province and, on their way, move under the Karkheh basins in the southwest, Sefidrood in the northwest, and the Salt Lake in the east. Ekbatan and Abshineh reservoir dams are the most important dams in the province, which have been built on the Abshineh River – the largest branch of the

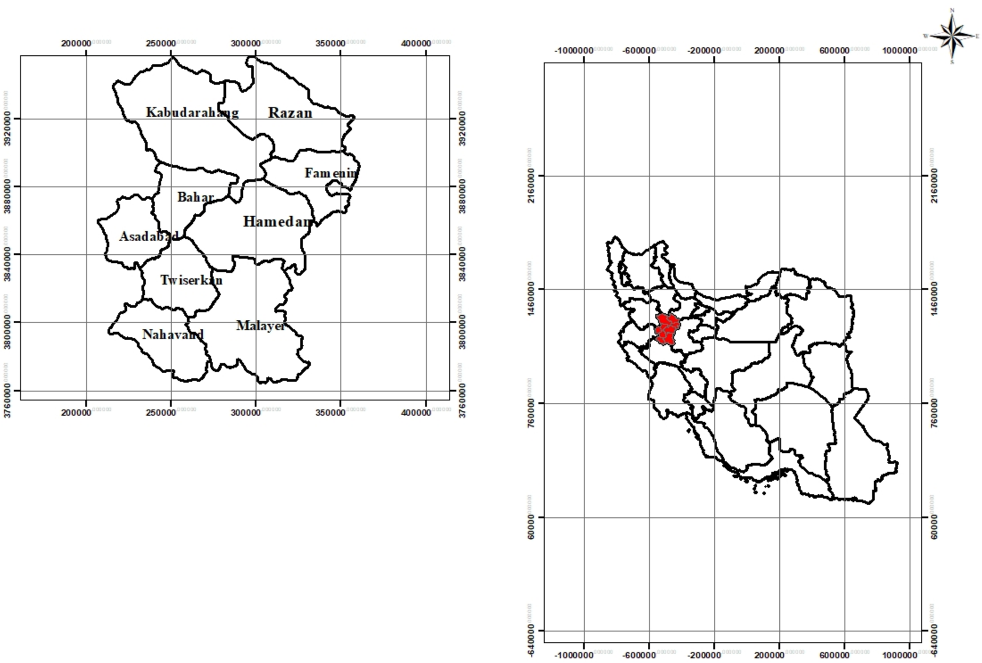

Fig. 1. The Geographical Position of Hamadan Province and its Counties

Qarachai River. The purposes of constructing these dams were to provide drinking water for residents of Hamadan city, and to ensure water supply to the cultivated downstream lands of the mentioned dams (16).

2.2. Chemicals and Standards

All chemicals and solvents were analytical grade and ultrapure. Sodium chloride (EMSURE®), Methanol, dichloromethane, acetone, and n-hexane of HPLC grade were purchased from Merck (Germany).

The individual organochlorine, organophosphorus, and carbamate certified reference standards with certified purity of >99 % were purchased from AccuStandard (USA). Mixed standard solutions were prepared at a concentration of 1.0 µg/mL according to their category, and further stored at −5°C in the dark. Working standards of suitable concentration were made from the mixed standard after appropriate dilution when required.

2.3. Collection and Preparation of Water Samples

This study is a descriptive cross-sectional study and was conducted in 2019. To evaluate the residual concentration of organochlorine (aldrin, dieldrin, lindane, methoxychlor, and permethrin), organophosphorus (chlorpyrifos, diazinon, and malathion), and carbamate (atrazine and alachlor) pesticides in drinking water networks of all urban areas located in Hamadan province, a total of 46 samples of urban water distribution networks were taken according to the instructions in the book of "*Standard Methods for the Examination of Water & Wastewater*" (17).

Sampling method in this study was non-probability sampling method and cluster sampling (18). Based on the number of water resources, storage reservoirs, and the number of urban areas located in each one of the nine counties (i.e. Hamadan, Malayer, Bahar, Nahavand, Asadabad, Tuyserkan, Razan, Famenin, and Kabudarahang) as well as all cities located in each county (a total of 29 urban points when this study was conducted), a total of 46 samples of urban water distribution networks were collected (in 250 mL dark screws cap glass containers) so that all drinking water resources, reservoirs and, consequently, distribution networks of drinking water in all urban areas of the province (all counties) could be covered. Table 1 shows the number of the samples taken from each county along with the names of all urban areas related to the given county.

Following the calculation method of the sample number and sampling place for each urban point, if the city had only a single homogeneous distribution network (water supply sources were the same throughout the network), only one sample was taken for that city; and since there was no parameter affecting the residual concentration of pesticides along the network path, sampling from any possible location along the network length was possible. Samples were taken from, as much as possible, the middle points of the network route and from, if any, the general collection valves of the passages; otherwise they were taken from the special collection valves of the commercial units. However, if the city in question had two or more distribution networks (i.e. water supply sources of each network were different or had different mixing percentages), the water sample was taken according to the number of existing networks. In this case, the sample collection place was the same as the earlier one, but care must have been taken so that each sample was collected from the length of the same selected network. Information on the number of networks in each city and the coverage of each network can be obtained from water experts of each city or the experts working for Water and Wastewater Company of the given city. This information is not fixed and may change periodically.

Spraying of fields and orchards is usually done in May and June. On the other hand, parameters such as time, temperature, ambient pH, half-life of the pesticide and its solubility in water have effects on the residual amount of pesticides in water samples. Fortunately, most pesticides – organophosphorus pesticides in particular, are decomposed over time (3,19-20). Therefore, in order to ensure the completion of the spraying period and

Table 1. Number and Names of Urban Areas, as well as the Number of Collected Samples of Each County

County Name	Number of Urban Areas	Number of Collected Samples	Names of Urban Areas[a]
Asadabad	2	3	Asadabad (2), Ajin (1)
Bahar	4	5	Bahar (1), Lalejin (1), Salehabad (1), Mohajeran (2)
Tuyserkan	3	4	Tuyserkan (2), Serkan (1), Farasfaj (1)
Razan	2	2	Razan (1), Damaq (1)
Famenin	2	2	Famenin (1), Mamahan (1)
Kabudarahang	3	5	Kabudarahang (2), Shirin Soo (2), Gol Tappeh (1)
Malayer	5	6	Malayer (2), Azandarian (1), Jokar (1), Samen (1), Zanganeh (1)
Nahavand	4	5	Nahavand (2), Barzul (1), Gyan (1), Firoozan (1)
Hamadan	4	14	Hamadan (11), Qahavand (1), Joraqan (1), Maryanaj (1)
Total sum	29	46	46

[a] Number of collected samples in parentheses.

decomposition of unstable pesticides, sampling was done in summer and late July 2019.

After sampling, water samples were immediately transferred to the Pesticides and Heavy Metals Analysis Unit of the Western Water and Wastewater Reference Laboratory (affiliated to the Vice-Chancellor for Health, Hamadan University of Medical Sciences) while monitoring the cold chain. Then pre-concentration and extraction of pesticides from water samples were performed in laboratory by a modified micro liquid-liquid extraction method, using minimum solvent and within a maximum of one week. A mixture of 60:40 n-hexane and dichloromethane was used as an extraction solvent, and sodium chloride salt (NaCl) was added in water samples to produce a salt out effect. After extraction, the extracts were transferred to 2 mL amber vials. The pre-concentration coefficient in this extraction method was 50 fold. All samples and extracts were stored in refrigerator at 4°C until the extraction or analysis was performed (21-24).

2.4. Determination of Pesticides Residues

The extracts were analyzed using a Young Lin 6500GC gas chromatograph (Young Lin Co., South Korea) equipped with an electron capture detector (GC-ECD) within 21 days after extraction phase and in accordance with the existing instructions and standards (17,22-24).

The GC conditions used for the analysis were as the below; the capillary column (Agilent Technologies Inc., USA) coated with HP-5 phase (30 m × 0.32 mm internal diameter, 0.25 µm film thickness), the injector and the ECD detector temperature were set at 250 and 300°C, respectively. The oven temperature was programmed as follows: 80°C held for 3 minutes, ramp at 15°C/min to 200°C, held for 1 minute, ramp at 8°C/min to 260°C, held for 0 min, and finally ramp at 30°C/min to 295°C, held for 3 minutes. Helium (99.999%) was used as carrier gas at a flow rate of 1.5 mL/min. The injection volume of the GC was 2.0 µL via a microliter syringe (Hamilton Co., USA). The total run time for a sample was 23.7 minutes.

When analyzing water samples by gas chromatograph, the first phase was to compare retention time (Rt) of each pesticide with its pure standard retention time through using YL-Clarity software (Young Lin Co., South Korea). Then each selected pesticide was qualitatively identified, and the presence or absence of the studied pesticide in the sample was confirmed. Now, the sub-peak areas obtained from software integration was compared with calibration curves resulting from injection of several different concentrations of pure standards, and the residual concentration of each pesticide in the sample was obtained. Finally, the concentrations read from the gas chromatograph software were analyzed using Excel software and the results were compared to Iranian National Standard (No. 1053) and international standards and guidelines (EPA and WHO) (25-27).

2.5. Quality Assurance and Quality Control

All glasswares used for analysis were rigorously washed with detergent, rinsed with enough tap and distilled water, thoroughly rinsed with analytical grade acetone, and dried overnight in an oven at 150°C. The glasswares were then removed and allowed to cool down and stored in dust-free cabinets.

The quality of organochlorine, organophosphorus, and carbamate pesticide residues was guaranteed through the analysis of solvent blanks, procedural matrix blanks, and duplicate samples (24). All reagents used during the analysis were exposed to the same extraction procedures and applied solvents were run to verify for any interfering substances within the run time. As for the solvent blank in each extraction procedure, no values were obtained for the analytes of interest. Recalibration curves were run with each batch of samples to check whether the regression coefficient was kept around $r^2 = 0.990$. A fortification level of 0.05 µg/L of standard mixture was chosen before the analysis in order for evaluating the recovery of the compounds in the water samples analyzed. Fortified samples were determined with good recoveries. The efficiency of the analytical method was determined by recoveries of an internal standard. The mean recoveries of internal standards ranged between 72% and 118 % for all compounds analyzed in the water samples. These recovery values showed that the adopted method was reproducible.

The residue levels of organochlorine, organophosphorus, and carbamate pesticides were quantitatively determined by the external standard method using their peak areas. Measurement was carried out within the linear range of the ECD detector. The peak areas whose retention times coincided with the standards were extrapolated from their corresponding calibration curves to obtain the concentration. The determined limit of the pesticide residue detection was based on the extract of the fortified samples. Any concentration producing a response three times higher than the standard deviation of the least fortified sample was used to estimate the statistical significance of the differences between low level analyte responses and the combined uncertainties in both analyte and background measurements. The limits of detection for the organochlorine, organophosphorus, and carbamate pesticide residues detected in the water samples were 0.02, 0.10, and 0.10 µg/L, respectively.

3. Results and Discussion

According to the results obtained, no residues of the pesticides aldrin, dieldrin, lindane, diazinon, malathion, atrazine, and alachlor were found in any of the samples. The highest concentrations of chlorpyrifos and permethrin were 2.20 and 8.03 µg/L, respectively (Table 2). The maximum allowable concentrations for chlorpyrifos and permethrin pesticides introduced by Iranian National Standard No. 1053, the guidelines of the WHO, and the

Table 2. The Mean and Maximum Values of the Studied Pesticides and Their Allowed Limit in Drinking Water in Micrograms Per Liter (ppb)

Pesticide Group	Pesticide Name	Mean	Maximum	Maximum Allowable	
				National Standard[23]	WHO & EPA Guidelines[24,25]
Organochlorine	Aldrin	N. D.*	N. D.	0.03**	0.03**
	Dieldrin	N. D.	N. D.		
	Lindane	N. D.	N. D.	2	2
	Methoxychlor	0.008	0.35	20	20
	Permethrin	0.777	8.03	300	300
Organophosphorus	Chlorpyrifos	0.248	2.20	30	30
	Diazinon	N. D.	N. D.	-	0.1
	Malathion	N. D.	N. D.	-	0.1
Organonitrogen (carbamate)	Atrazine	N. D.	N. D.	2	2
	Alachlor	N. D.	N. D.	20	20

*Not detected.
**The sum of aldrin and dieldrin.

US Environmental Protection Agency (EPA) are 30 and 300 µg/L, respectively (25-27). Comparing our study results with national and international standards, it was concluded that the residual concentration of chlorpyrifos and permethrin in drinking water samples of Hamadan province was much less than the maximum allowable concentration of these pesticides determined by the standards.

Methoxychlor was observed in only one of the samples with a concentration of 0.35 µg/L, while other samples were found to be free of methoxychlor. The maximum allowable concentration for the methoxychlor pesticide determined in the national standard, guidelines of the WHO, and the US EPA is 20 µg/L (25-27). Comparing the obtained amount (0.35) with national and international standards, it was revealed that the residual concentration of methoxychlor in drinking water samples of Hamadan province was also much less than the maximum allowable concentration of this pesticide determined by the standards.

As mentioned above, only three pesticides out of ten studied pesticides (i.e. permethrin, methoxychlor, and chlorpyrifos) were detected with maximum concentrations of 8.03, 0.35 and 2.20 µg/L, respectively; and the other pesticides remained undetectable. The reason might be due to the greater use of these three toxins compared to other toxins application in Hamadan province farms, as well as the stability of these toxins. In the case of toxins for which no concentration had been detected, it was assumed that they were not consumed by farmers and gardeners, or were decomposed after consumption prior to sampling. Unfortunately, there were no exact information about the kinds of high-consumption pesticides, as well as their exact amount of consumption in Hamadan province.

As for the diazinon and malathion pesticides examined in this study, as well as for many other high-consumption pesticides, the maximum allowable concentration, unfortunately, was not reported by the national standard system. When studying such pesticides, therefore, results of the study are usually compared with other European or American standards. The best and closest international standards to Iran's national standards are WHO guidelines. According to the WHO guidelines – as well as the EPA ones, the maximum allowable concentration for diazinon and malathion is 0.1 µg/L (25-27).

In addition, the European Union has set the maximum allowable concentration for the total pesticide residues in drinking water sources at 0.5 µg/L, and for these pesticides at 0.1 µg/L separately (16, 28). As mentioned earlier, the best and closest international standard to Iran's national standards are the WHO guidelines. Therefore, in order to avoid any further complexity and sensitivity, the results were not compared to the European standard. The results of the studied organochlorine, organophosphorus and carbamate pesticides in urban drinking water networks of Hamadan province, as well as their maximum allowable concentrations in the national standard and WHO and EPA guidelines are summarized in Table 2.

The results showed that the residual concentrations of all studied pesticides in all samples was much less than the maximum allowable concentration introduced by national standard and WHO and EPA guidelines, and no sample was found with a concentration of pesticide residue higher than the allowed limit of the standards. In a study by Khodadadi et al (3) on the residues of organophosphorus and carbamate pesticides in water sources of Hamadan city, none of the pesticides was detected in winter water samples, which is consistent with the results of our study. The finding might be explained by the facts that a long time has passed since the pesticides have been used, and these pesticides have relatively low stability in the environmental conditions. Another study by Safari et al (9) to assess the prevalence of organophosphate pesticides in the Hablehrood River found that the concentration of diazinon and malathion in tow stations (Bone Kooh and Mahmood Abad) were higher than the standard level. Also, Khalijian et al (10) in their study to determine residual concentrations of diazinon pesticide in groundwater sources of Hamadan-Bahar plain sampled in summer revealed that the average residual concentration of this pesticide in the samples exceeded the allowed limit in the WHO guidelines. The results of these two recent studies contradict with those of the present study. In our study, no amount of diazinon and malathion were observed in any of the samples from Bahar, Hamadan, and even from other counties of the province. This discrepancy might be attributed to the difference in the sampling years of the two studies. It seems that the improvement of precipitation in recent years has had a significant effect on diluting the concentration of environmental pollutants, especially on pesticides.

One of the advantages of this study was the comprehensiveness or scope of the sampling which included all urban drinking water distribution networks in Hamadan province, as well as the number of the pesticides monitored in it compared to other similar studies. One of the most important limitations of this study was the number of laboratories accepting and analyzing the samples of other drinking water distribution networks in the province – especially rural water supply complexes due to the personnel and logistical limitations, forcing the authors to conduct their study in only one season. After the removal of such limitations, it is hoped that analyzing more samples and other pesticides becomes possible. Regarding several factors such as the lack of maximum concentration allowed for a large number of high-consumption pesticides in national standards, the need for updating the existing standards or developing new standards, as well as the need for preventing the increasing concentration of pesticides in the environment and, subsequently, in water sources, it is suggested that the farmers are educated about the scientific and regulated use of the pesticides, and the pesticides are replaced with biologically-controlled methods.

Serious challenges such as population growth, food shortage, plant pests, resistance of pests against many pesticides, and the cheapness and availability of pesticides have convinced farmers to use different types of pesticide. Many pesticides used in agriculture and orchards can enter the surface and ground water resources through irrigation and rainfall, and pollute these valuable and vital resources (1,2). Therefore, routine monitoring of pesticide residues in study area is necessary for the prevention, control and reduction of environmental pollution, with ultimate aim of minimizing health risks to human.

4. Conclusion

Our study results showed that only three pesticides out of ten examined pesticides (i.e. permethrin, methoxychlor, and chlorpyrifos) were detected with a maximum concentration of 8.03, 0.35 and 2.20 μg/L, respectively; and the rest were undetectable. It was also revealed that the residues of studied pesticides in all samples were much less than the maximum allowable in the national and international (WHO and EPA) standards. Therefore, it was concluded that the examined networks water quality and, therefore, urban drinking water resources of Hamadan province was at a very desirable level regarding the amount of pesticide residues.

If the consumption of pesticides is not controlled, there is a future possibility of increasing the concentration of these pollutants in water, and threatening the health of Hamadan province population. Therefore, a periodic and continuous monitoring of drinking water sources and networks is highly recommended in terms of pesticide contamination.

Conflict of Interests Disclosure

The authors declare that they have no conflict of interests.

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