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Research article

Heavy metals in unrecorded Albanian rakia: A pilot study on a potential public health risk

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ABSTRACT

Unrecorded alcohol has been linked to illness above and beyond that caused by ethanol alone because of the presence of toxic contaminants. While it can be found in all countries, consumption is high in Albania, where it is frequently consumed as a fruit brandy known as rakia. Among the contaminants identified previously in such products, metals including lead have been detected at levels posing a risk to health but there is little information on their presence in rakia. To fill this gap, we measured the level of ethanol and 24 elements among them toxic metals in 30 Albanian rakia samples. We found that 63.3% of rakia samples had ethanol concentration above 40% v/v. We also showed that there was a significant difference between the measured [mean: 46.7% v/v, interquartile range (IQR): 43.4–52.1% v/v] and reported (mean: 18.9% v/v, IQR: 17.0–20.0% v/v) concentrations of ethanol in rakia. Among the metals detected, aluminium, copper, iron, manganese, lead, and zinc were present in rakia samples at concentrations ranging between 0.013 and 0.866 mg/l of pure alcohol (pa), 0.025–31.629 mg/l of pa, 0.004–1.173 mg/l of pa, 0.185–45.244 mg/l of pa, 0.044–1.337 mg/l of pa, and 0.004–10.156 mg/l of pa, respectively. Copper and lead were found to be the greatest concern posing a potential public health risk. Although the estimated daily intake of these heavy metals from unrecorded rakia was below their toxicological threshold, the concentrations of lead and copper exceeded their limit value of 0.2 and 2.0 mg/l of pa specified for spirits in 33% and 90% of samples, respectively. Therefore, the possibility of adverse health effects cannot be excluded completely. Our findings highlight the need for action by policymakers against the risks posed by these products in Albania.

1. Introduction

Excessive alcohol consumption is one of the leading risk factors contributing to the global burden of communicable and non-

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communicable diseases [1]. The World Health Organization (WHO) estimates that the loss of 3 million lives and more than 130 million life years worldwide in 2016 could be attributed to harmful use of alcohol [2]. Among WHO's regions, the share of disability-adjusted life years (10.8%) and mortality (10.1%) attributable to alcohol consumption is the highest in Europe [2]. Most of this can be attributed to the large volume of alcohol consumed and way it is drunk in this region [3–6]. However, several studies have suggested that the intake of unrecorded alcohol of dubious quality can also make a contribution to alcohol attributable disease in the WHO European Region, especially in the countries of Central and Eastern Europe [2,7–9]. WHO defines unrecorded alcohol as "all alcoholic beverages that are not accounted for in official statistics on alcohol taxation or sales in the country where are consumed because usually are produced, distributed and sold outside the formal channels under government control" [2]. This comprises alcoholic beverages that can be purchased through cross-border shopping, made at home, produced informally, or smuggled and products containing ethanol originally intended for industrial or medical use [2,10,11]. According to the latest data available, on average, 18.4% of total per capita alcohol intake was consumed in the form of unrecorded alcohol in the WHO European region [2]. However, this varies widely within the region [2]. As a share of total per capita alcohol intake it is much higher in some Western Balkan countries including Albania (33.3%), Bosnia and Herzegovina (28.1%), North Macedonia (44.4%), and Montenegro (21.2%) [2]. In these countries, a large proportion of alcohol is consumed as home-made fruit spirits [2,12]. Among them, rakia is one of the most widely consumed fruit spirits, particularly in Albania, where it is commonly distilled from the mash of grapes, plums, apples, and pears [13,14].

Although previous investigations have described that humans can be exposed to metals from a variety of sources including soil, wastewater and food, limited attention has been paid to their intake from home-made fruit spirits [15–17]. The studies available have found that, among the contaminants detected in unrecorded fruit spirits, metals can be often present at levels posing a public health concern [18,19]. They can arise from raw materials of home-made fruit spirits or equipment used during distillation, bottling, storage, and aging [20,21]. Although unrecorded spirits rarely contain metals at levels that can cause acute toxicity, chronic exposure presents a health risk since many metals including cadmium (Cd), and lead (Pb) have been linked to kidney diseases, neurological disorders, and cancers of the skin, lung, bladder, pancreas, colon and liver [22–27]. Despite the widespread consumption of rakia in Albania, no systematic measurements have been carried out to determine the types and levels of metals that may be present in it and we are only aware of the analysis of one sample of unrecorded Albanian spirits in the published literature [13]. To fill this gap, we have measured the level of ethanol and the concentration of 24 elements among them many toxic metals [Cd, chromium (Cr), cobalt (Co), copper (Cu), nickel (Ni), Pb], metalloids [arsenic (As), boron (B)], alkali metals [potassium (K), sodium (Na)], and alkaline earths metals [calcium (Ca), magnesium (Mg)] in 30 rakia samples collected in Albania. All elements analyzed in our study are listed in Section 2.3.3. In addition, we aimed to compare the levels of the elements detected in rakia with toxicological threshold values defined by the Alcohol Measures for Public Health Research Alliance (AMPHORA) project [28]. This is the first research to show that Albanian alcohol consumers can be exposed to high levels of ethanol, Cu and Pb when drinking unrecorded rakia.

2. Materials and methods

2.1. Sample collection

We used the methodology from the AMPHORA project to collect a sample of unrecorded spirits [28]. Thirty samples of rakia were purchased from individual small-scale and sustenance producers and from bars and restaurants, none bearing the tax stamp required in Albania where the law mirrors European Union Directive No. 2008/118 on excise duties [29]. Following collection of samples, each was decanted into a glass bottle and labelled with an identification number to prevent mismatches. Information on the origin, raw materials, reported ethanol content (measured by producers/sellers using hydrometers), and date of sampling were documented. The unrecorded rakia samples were reported, variously, to have been distilled from fermented grapes, mulberries, cornelian cherries, juniper, plums, and blackberries. All spirit samples were kept in the dark at 4 °C until gas chromatographic mass spectrometric (GC/MS) and inductively coupled plasma optical emission spectrometric (ICP-OES) analyses were performed.

2.2. Gas chromatographic mass spectrometric analysis

2.2.1. Materials

Ethanol and acetonitrile were purchased from Merck (Darmstadt, Germany) and used as standard for the qualitative analysis of spirit samples and internal standard (ISTD), respectively. All chemicals were of high performance liquid chromatography grade.

2.2.2. Determination of ethanol concentration in spirit samples

Analysis of rakia samples was carried out using a Hewlett-Packard (HP) GC/MS system (Palo Alto, CA, USA) consisting of a HP 6890 GC, a HP 5973 mass selective detector (MSD) and an Agilent 7683 automatic liquid sampler (Agilent Technologies, Palo Alto, CA, USA). A Hewlett-Packard Free Fatty Acid Phase (length: 50 m, internal diameter: 0.2 mm, film thickness: 0.33 μm) cross-linked capillary column (Hewlett-Packard, Palo Alto, CA, USA) was employed for the separation of ethanol using helium as carrier gas at 3.0 bar constant pressure [7,30]. Spirit samples with a volume of 1.0 μl were injected into the system in split mode (split ratio of 80:1) at an inlet temperature of 200 °C. The oven ramp for ethanol was set as follows: 4.0 min at 60 °C, 60–110 °C, 5 °C/min. The temperature of GC/MS interface, MSD ion source, and MSD quadrupole was 280 °C, 230 °C, and 150 °C, respectively. The ionization energy was 70 eV. Prior to quantitative analysis, the calibration of the GC/MS system was carried out. The calibration curve for ethanol was obtained by injections of 1.0 μl mixtures containing ethanol at concentrations of 237.0, 276.2, 315.6, 355.1, 394.5, 394.5, 433.1, 473.4, and 512.1 g/l. Acetonitrile was used as ISTD for quantification of ethanol at a final concentration of 118 g/l. The final volume of standard mixtures was 1.0 ml. The concentration of ethanol in rakia was determined by mixing 150 μl ISTD with 850 μl of samples. Then, 1.0 μl of this mixture was injected into the GC/MS system. System control, data acquisition and analysis were performed with HP G1701BA MSD Productivity Chemstation software (Hewlett-Packard, Palo Alto, CA, USA). The concentration of ethanol was calculated by the data analysis software according to the calibration curves.

2.3. Inductively coupled plasma optical emission spectrometric analysis

2.3.1. Materials

Nitric acid and mono element spectroscopic standards were purchased from Scharlab (Debrecen, Hungary). Multi element spectroscopic standard solution and hydrogen-peroxide were acquired from Merck (Darmstadt, Germany). Ultrapure water was prepared by a Synergy UV Water Purification System (Merck Millipore, Darmstadt, Germany). All chemicals were of spectroscopic or reagent grade.

2.3.2. Sample preparation

Prior to ICP-OES measurements, samples were prepared according to the method described by Baranyai and co-authors [31]. Briefly, 5.0 ml of each spirit sample was measured into glass beakers and completely dried using a laboratory heating plate. Subsequently, the sample matrices were chemically degraded by adding a mixture containing 5.0 ml of 65% nitric acid (HNO_3, reagent grade) and 1.0 ml of 30% hydrogen-peroxide (reagent grade) to the dried samples. Then, the samples were dried again. Next, ultrapure water was added to the chemically degraded samples which were transferred into volume calibrated plastic centrifuge tubes and diluted to 10.0 ml. Prior to elemental analysis the diluted samples were kept in the dark at 4 °C.

2.3.3. Determination of levels of elements in rakia samples

Concentrations of 24 elements were determined by an Agilent ICP OES system (5100 SVDV model, Agilent Technologies, Santa Clara, USA) as described previously [31,32]. An auto sampler (Agilent SPS4), a Meinhard type nebulizer and a double pass spray chamber was employed to introduce the sample solutions. Argon gas was used to supply the plasma and nitrogen gas was used for sample introduction and optical purge. Standard solutions of As and tin (Sn) were prepared from mono element spectroscopic standards with a concentration of 1000 mg/l. Calibration series of other elements including silver (Ag), aluminum (Al), B, bismuth (Bi), Ca, Cd, Co, Cr, Cu, iron (Fe), gallium (Ga), indium (In), K, lithium (Li), Mg, manganese (Mn), Na, Ni, Pb, strontium (Sr), thallium (Tl), and zinc (Zn) were prepared from a multi element spectroscopic standard solution with element concentrations of 1000 mg/l. In both cases, a 5-point calibration curve was used. The standard solutions were diluted with 0.1 M HNO_3 prepared in ultrapure water. Blank samples were used to check the purity of water and glassware applied. Three parallel measurements were performed for each sample. Operating conditions of the ICP-OES are shown in Supplement 1.

2.4. Compliance of metal concentrations with threshold values

The concentrations of metals detected in our rakia samples were compared with the threshold values established by the AMPHORA project [28]. To enable comparability with other studies, given the range of ethanol content in products, we expressed the levels of metals in mg/l of pure alcohol (p.a.). The results of this comparison are shown in Table 1.

2.5. Statistical comparison of ethanol concentrations in rakia samples

The concentrations of ethanol reported by sample providers (reported ethanol concentration) were compared to those of determined by GC/MS analyses (measured ethanol concentration). Mean differences between the reported and measured ethanol concentrations were compared using the Wilcoxon signed-rank test. Statistical analysis was performed using IBM SPSS version 25.0 (IBM Inc, Armonk, New York, USA). Values of $p < 0.05$ were considered statistically significant. Median concentration of ethanol, its interquartile ranges (IQR), and 1.5 times the interquartile ranges (as whiskers) are shown in Fig. 1.

3. Results

Table 2 shows that out of the 30 unrecorded rakia samples analyzed 22 (73.3%), 1 (3.3%), 1 (3.3%), 4 (13.3%), 1 (3.3%), and 1 (3.3%) were distilled from fermented grapes, mulberries, cornelian cherries, plums, juniper and blackberries, respectively. Twenty-seven spirit samples were distilled between 2017 and 2019 while 3 were produced earlier, in 2010, 2014, and 2015 (Table 2). Sample providers reported the ethanol content of only 50% (n = 15) of samples, which varied between 16.0 and 22.0% vol/vol (v/v) [Table 2].

The measured ethanol concentrations were between 28.6 and 57.6% v/v. Ethanol levels (mean: 46.7% v/v, IQR: 43.4–52.1% v/v) were significantly higher than reported ones (mean: 18.9% v/v, IQR: 17.0–20.0% v/v) (Fig. 1, $p < 0.001$).

The elements detected in rakia samples by ICP-OES analyses are shown in Table 1. Al was detected in 97% (n = 29) at concentrations ranging from 0.013 to 0.866 mg/l of p.a. but none exceeded the AMPHORA threshold value of 2.0 mg/l of p.a. Cu was present in all of the samples at levels varying from 0.025 to 31.629 mg/l of p.a. and exceeded the recommended limit of 2.0 mg/l of p.a. in 90% (n = 27). Although, Fe was detected in 93.3% (n = 28) of rakia samples, none contained Fe at concentrations above the AMPHORA threshold of 2.0 mg/l of p.a. All samples contained Mg at levels varying between 0.185 and 45.244 mg/l of p. a. but in only one did the

Table 1
Concentration of metals detected in Albanian rakia samples

	concentration of detected metals[a]					
	Al [mg/l]	Cu [mg/l]	Fe [mg/l]	Mn [mg/l]	Pb [mg/l]	Zn [mg/l]
AMPHORA threshold values of metals	**2.0**	**2.0**	**2.0**	**0.5**	**0.2**	**5.0**
sample 1	0.054	**4.729**[c]	0.071	0.004	<LOD[b]	1.415
sample 2	0.037	1.416	0.060	0.009	<LOD	0.092
sample 3	0.013	**9.216**	0.021	0.013	<LOD	0.004
sample 4	0.427	**8.039**	<LOD	0.010	0.066	1.493
sample 5	0.038	**25.498**	0.117	**0.520**	0.134	<LOD
sample 6	0.805	**21.917**	0.076	0.012	<LOD	<LOD
sample 7	0.082	**23.386**	0.073	0.004	0.052	0.219
sample 8	0.212	**4.831**	0.141	0.009	0.044	<LOD
sample 9	0.042	**3.446**	0.028	0.005	<LOD	0.084
sample 10	0.017	**2.134**	0.004	0.004	<LOD	<LOD
sample 11	0.053	**10.824**	0.030	0.011	**1.337**	1.524
sample 12	0.223	**25.721**	0.092	0.012	**1.010**	1.255
sample 13	0.047	0.025	0.018	<LOD	<LOD	0.018
sample 14	0.135	**20.405**	0.284	0.005	0.135	0.317
sample 15	0.058	0.043	0.070	<LOD	<LOD	<LOD
sample 16	0.044	**6.415**	0.225	<LOD	<LOD	<LOD
sample 17	0.065	**25.555**	0.125	0.011	0.065	0.610
sample 18	0.060	**5.078**	0.068	0.004	0.124	<LOD
sample 19	0.171	**13.090**	0.593	0.005	0.083	0.273
sample 20	0.027	**5.481**	0.031	<LOD	**0.351**	0.982
sample 21	<LOD	**15.411**	<LOD	0.004	**0.599**	0.717
sample 22	0.018	**19.736**	0.677	0.006	**0.236**	0.036
sample 23	0.104	**9.233**	0.024	0.009	**0.217**	1.948
sample 24	0.106	**17.050**	0.097	<LOD	<LOD	0.097
sample 25	0.056	**19.511**	0.068	<LOD	**0.261**	0.298
sample 26	0.091	**26.451**	0.085	0.006	<LOD	0.582
sample 27	0.287	**10.932**	0.126	<LOD	<LOD	<LOD
sample 28	0.108	**31.629**	1.173	0.014	**0.468**	**10.156**
sample 29	0.703	**13.941**	0.027	<LOD	**0.527**	<LOD
sample 30	0.866	**14.422**	0.144	<LOD	**0.543**	0.137

[a] Concentrations of metals were determined by inductively coupled plasma optical emission spectrometric analysis (ICP-OES) and expressed in mg/liter (mg/l) of pure alcohol.
[b] <LOD: The concentration of metals was below the limit of detection (LOD) of the ICP-OES.
[c] Bold values indicate spirit samples that contained metals at levels above the AMPHORA threshold values. The concentrations of other elements detected in rakia samples are in the Supplement 1.

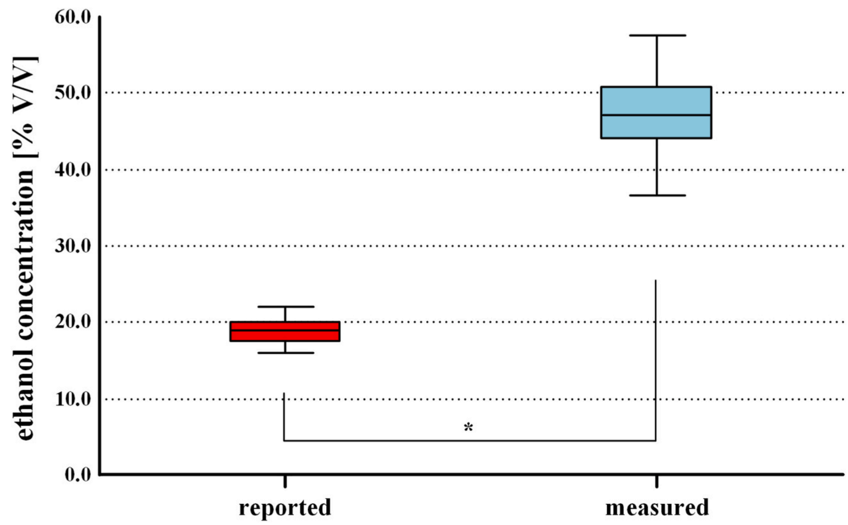

Fig. 1. Differences between reported and measured ethanol concentrations of the rakia samples
Ethanol concentrations were reported by the sample providers who used hydrometers to determine the ethanol levels. The alcohol concentrations were also measured by gas chromatographic/mass spectrometric analysis. *$p < 0.001$.

Table 2
Characteristics of rakia samples analyzed

sample number	place of sample collection	raw material	year of distillation	reported ethanol concentration (% v/v)[a]	measured ethanol concentration (% v/v)[b]	difference between measured and reported ethanol concentration (% v/v)
sample 1	producer's home	grape	2017	20.0	53.4	33.4
sample 2	producer's home	grape	2017	20.0	43.4	23.4
sample 3	producer's home	grape	2010	20.0	47.1	27.1
sample 4	producer's home	mulberry	2014	22.0	57.6	37.6
sample 5	producer's home	grape	2015	21.0	47.7	26.7
sample 6	producer's home	grape	2018	19.0	49.7	30.7
sample 7	producer's home	grape	2018	19.0	46.5	27.5
sample 8	restaurant	grape	2018	17.0	45.3	28.3
sample 9	restaurant	grape	2018	18.0	47.8	29.8
sample 10	producer's home	cornelian cherry	2017	19.0	52.1	33.1
sample 11	producer's home	plum	2017	20.0	52.5	32.5
sample 12	bar	grape	2019	unknown	52.1	not applicable[c]
sample 13	bar	juniper	2018	unknown	34.2	not applicable[c]
sample 14	bar	grape	2019	unknown	41.6	not applicable[c]
sample 15	bar	plum	2018	unknown	34.4	not applicable[c]
sample 16	bar	grape	2019	unknown	32.0	not applicable[c]
sample 17	bar	grape	2019	17.0	36.7	19.7
sample 18	bar	grape	2018	unknown	46.8	not applicable[c]
sample 19	bar	grape	2018	17.0	43.2	26.2
sample 20	bar	grape	2019	19.0	45.0	26.0
sample 21	bar	grape	2019	unknown	47.4	not applicable[c]
sample 22	bar	blackberry	2017	unknown	33.1	not applicable[c]
sample 23	bar	plum	2018	unknown	42.4	not applicable[c]
sample 24	bar	grape	2019	unknown	41.4	not applicable[c]
sample 25	bar	grape	2019	16.0	32.2	16.2
sample 26	bar	grape	2019	unknown	33.0	not applicable[c]
sample 27	bar	grape	2019	unknown	28.6	not applicable[c]
sample 28	bar	grape	2019	unknown	29.5	not applicable[c]
sample 29	bar	plum	2018	unknown	29.6	not applicable[c]
sample 30	bar	grape	2018	unknown	29.1	not applicable[c]

[a] Information on ethanol concentration were reported by the producer/seller of the rakia sample. All sample providers used hydrometer to determine the alcohol content of their spirit.
[b] The concentration of ethanol was determined by gas chromatographic mass spectrometric analysis.
[c] The difference between the measured and reported ethanol concentration can not be calculated.

concentration exceed the AMPHORA threshold value of 0.5 mg/l of p.a. Pb was detected in 60% (n = 18) of the samples of which ten (33%) contained concentrations above the AMPHORA limit of 0.2 mg/l of p.a. Apart from a single spirit sample in which the concentration of Zn was twice the threshold value (10.156 mg/l of p.a.), all Zn levels were below the threshold limit of 5.0 mg/l of p.a. Our main findings are summarized in Supplementary Fig. 1.

Supplement 1

4. Discussion

Although there have been previous published analyses of the concentrations of metals in unrecorded alcohol samples from several Western and Central European countries, little attention has been paid to their levels in unrecorded fruit spirits in the Western Balkan countries [12,13,19,33,34]. Moreover, we are unaware of any study on levels of ethanol and metals in rakia, the most widely consumed traditional fruit spirit in Albania [2,14]. Thus, by determining the alcohol strength and metal levels in these alcoholic beverages and comparing them to toxicological threshold values we have extended previous research. We found that 63.3% (n = 19) of rakia samples had ethanol concentration above 40% v/v, the typical alcohol content of recorded spirits [35,36]. This is in agreement with previous findings showing that unrecorded spirits often contain ethanol at concentrations higher than their recorded counterparts [13,37,38]. Importantly, when ethanol content was reported, this significantly underestimated the value determined by GC/MS analyses. A similar result was obtained by Lachenmeier and his co-authors who reported a significant difference between the reported (20% v/v) and measured (44% v/v) alcohol strength of a single rakia sample from Albania [13]. This discrepancy may arise because providers used hydrometers to measure ethanol concentrations. Although, this simple tool is widely used to determine the alcohol strength of spirits based on their specific gravity, it is suitable only for semi-quantitative measurement [39,40]. In addition, lack of expertise with hydrometers or failing to correct for temperature (they are typically calibrated for use at 20 °C) can give rise to inaccurate results [40]. As a consequence, those consuming unrecorded rakia will often be misinformed about the level of ethanol in their drink, with attendant risks of overconsumption and subsequent harm.

We also identified several metals at concentrations above the accepted thresholds in our rakia samples, consistent with previous research on unrecorded fruit spirits elsewhere [33,34,41–43]. Among them, Cu and Pb are the greatest concern [19,33,34,44,45]. The average concentration of Cu in rakia samples was 13.1 ± 9.09 mg/l of p.a., similar to that reported by Pál et al. (5.51 ± 8.06 mg/l of p.a.) and Torović et al. (8.18 ± 8.37 mg/l of p.a.) in unrecorded spirits in Hungary and Serbia, respectively [19,34]. In addition, the concentration of Pb in unrecorded spirits was found to be between 0.0 and 0.581 mg/l of p.a. and 0.0–1.87 mg/l of p.a. by Tatarková and Torović et al., respectively [33,34]. These results are consistent with our findings (0.0–1.337 mg/l of p.a.).

The concentration of Cu and Pb exceeded the AMPHORA threshold values in 90% and 33% of rakia samples, respectively. To assess the importance of these findings it is necessary to estimate daily intake of these heavy metals attributable to rakia consumption and compare it with oral reference doses. We can illustrate the potential risk by assuming average annual per capita consumption of unrecorded alcohol, at 2.5 l for both sexes in Albania, containing mean levels of Cu (13.1 mg/l of p.a.) and Pb (0.2 mg/l of p.a.) as measured in our samples [2]. We also assume an average body weight of 73.9 kg and duration of exposure of 365 days [46]. The daily intake is calculated from the per capita alcohol consumption multiplied by the mean concentration of Cu and Pb, divided by average body weight and duration of exposure. This implies a daily intake of Cu and Pb by an average Albanian alcohol consumer of 0.001 mg/kg body weight/day and 0.02 μg/kg body weight/day, respectively. Thus, daily intake of Cu (0.001 mg/kg body weight/day) is significantly lower than its reference dose of 0.04 mg/kg body weight/day so it is unlikely that exposure from rakia can pose any health risk to average alcohol consumers [47]. There is no published reference dose for Pb, but the lower one-sided confidence limit of the benchmark dose (BMDL) in humans was reported to be 1.5 μg/kg body weight/day [27]. Since the estimated daily intake of lead (0.02 μg/kg body weight/day) was substantially lower than the BMDL, the consumption of rakia is, again, not likely to pose any health risk to average drinkers. However, as reported by Lachenmeier, Tatarková and Torović et al., exposure to Pb from unrecorded spirits may be an additional health risk in chronic heavy drinkers [33,34,48].

5. Strengths and limitations

Our study is the first that systematically measured the concentrations of metals in traditional Albanian rakia. By comparing their levels with AMPHORA threshold values we demonstrated that a large proportion rakia samples contained Cu and Pb above these limits. This is also the first research in which the reported and measured ethanol concentrations in rakia samples were compared statistically. The results of our research can raise awareness among public health professionals working in the Western Balkan countries that the health risks associated with the consumption of unrecorded spirits containing toxic metals is an under-researched topic that requires more attention in the future. The limitations include the relatively low number of samples and inclusion only of unrecorded rakia.

6. Conclusions

Consistent with previous investigations, our study confirms that, apart from the high ethanol concentration in these unrecorded spirits, lead contamination may also be a public health concern. The discrepancy between the reported and measured concentrations of ethanol is a clear breach of product safety principles. Our results showed that Cu, Mn, Pb, and Zn can be present in unrecorded rakia at concentrations exceeding AMPHORA threshold values. Among the toxic metals detected in our samples, Cu and Pb were found to be the greatest concern posing a potential public health risk. Although the estimated daily intake of Pb from unrecorded rakia was below the BMDL, the concentration of this heavy metal exceeded the AMPHORA limit in 33% of samples analyzed so, given how Pb accumulates in the body over the long term, the possibility of adverse health effects cannot be excluded completely [22]. There is a clear need for Albanian food safety authorities to bring these products within their existing consumer safety procedures and our findings point to the concerns that should be addressed as part of a comprehensive strategy to decrease the alcohol-related disease burden in Albania. To estimate the health risks arising from the consumption of unrecorded Albanian rakia more precisely, further studies using greater number of samples are required.

Author contribution statement

Teuta Muhollari: conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; wrote the paper.

Sándor Szűcs: conceived and designed the experiments; contributed reagents, materials, analysis tools or data; analyzed and interpreted the data; wrote the paper.

Zsófi Sajtos: contributed reagents, materials, analysis tools or data; wrote the paper.

Martin McKee: analyzed and interpreted the data; wrote the paper.

Edina Baranyai: contributed reagents, materials, analysis tools or data; wrote the paper.

Róza Ádány: analyzed and interpreted the data; wrote the paper.

László Pál: conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e13717.

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