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Traditional vegetarian food products in villages of Syunik, Armenia: Technogenic contamination risks assessment

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ABSTRACT

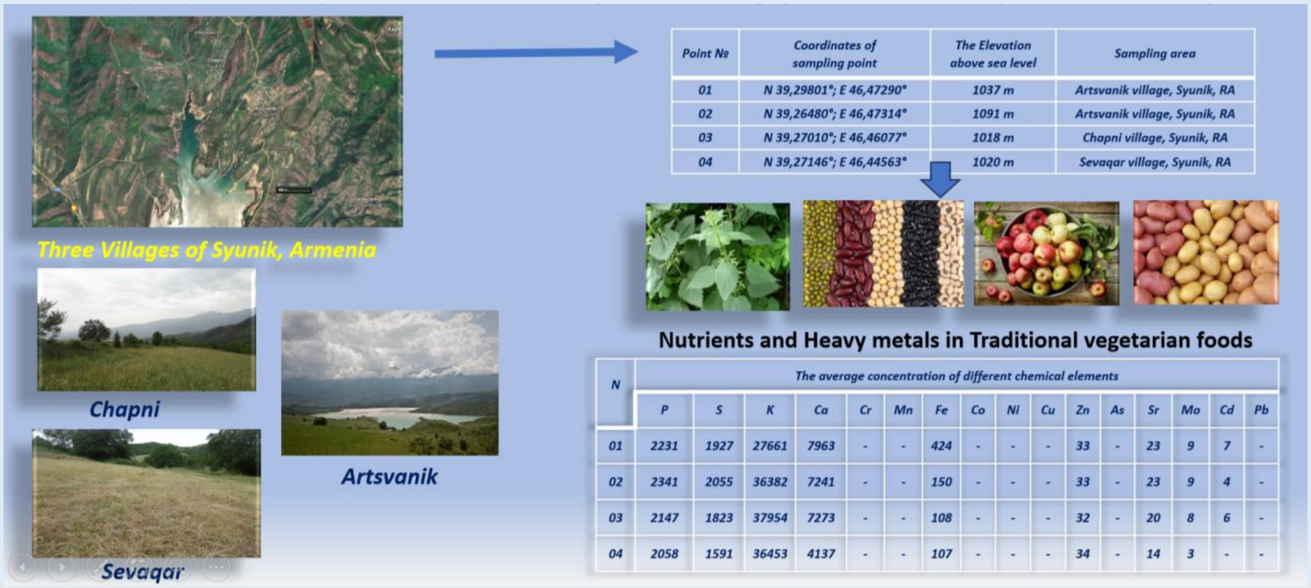
Background: For generations, vegetarian food products have been fundamental to the diets of rural Armenian communities. However, villages situated near territories near mines face severe chemical contamination of soil, air and water. This poses a significant problem in Syunik Region, Republic of Armenia (RA), where metal mines have operated for over 50 years. Notably, this region is one of Armenia's most important agrarian areas ensuring food production for the entire country. Therefore, assessing potential chemical contamination risks in food products from this region is crucial.

Objectives: This article assesses the risks associated with chemical contamination of traditional vegetarian food products commonly consumed in the villages of Artsvanik, Sevaqar, and Chapni in Syunik region of Republic of Armenia (RA). Specifically, this region has hosted both a thriving mining industry and agriculture for over 50 years.

Results: According to the results obtained, there was no significant increase in the concentrations of most studied metals in the plant samples.

Conclusions: Concentrations of most studied metals remained unchanged. However, copper (Cu) and molybdenum (Mo) levels were elevated in nettle samples. Long-term consumption of nettle-based foods, from this region may pose health risks. In contrast, consuming other plants is considered lower risk. Nevertheless, to minimize health risks ongoing monitoring of Cu and Mo concentration in this area is essential.

Keywords: heavy metals, vegetarian food, *Phaseolus vulgaris*, *Urtica dioica*, *Malus domestica*, *Solanum tuberosum*.



Graphical Abstract: Traditional vegetarian food products in villages of Syunik, Armenia: Technogenic contamination risks assessment

INTRODUCTION

Vegetarian cuisine, sourced from plants, is a common dietary choice internationally, encompassing vegetables, crops, fruits, and other botanical products [1-2]. Recently, vegetarian and vegan diets have gained popularity due to various reasons including potential health benefits, religious and ethical considerations, ecological activism, and animal rights protections [3-7]. In many Asian countries, plant-derived food products are staple components of daily diet [8-9]. Functional foods are also based on vegetables and fruits [10-11]. Common vegetarian products worldwide include beans (*Phaseolus vulgaris* L.), rice (*Oryza sativa* L.), almonds (*Prunus amygdalus* Batsch), apples (*Malus domestica* (Suckow) Borkh.), and potatoes (*Solanum tuberosum* L.).

In Armenia, there is a rich tradition of plant-based foods and beverages [12]. Edible herbs like nettle (*Urtica dioica* L.), Armenian dock (*Rumex confertus* Willd.), Common mallow (*Malva neglecta* Wallr.), Purslane (*Portulaca oleracea* L.), Sickleweed (*Falcaria vulgaris* Bernh), Whitetop (*Lepidium draba* L), Okra (*Abelmoschus esculentus* (L.) Moench), and others are used in various regions. These plants are used in salads, soups, appetizers, and canned foods (cucumbers, paprika, cabbage, okra, etc.). Wild and cultivated plants are used in traditional Armenian herbal teas such as Rose Hip (*Rosa cinnamomea* L.), Thyme (*Thymus serpyllum* L.), and Mint (*Mentha spicata* L., *M. × piperita* L). Aromatic herbs like allspice (*Pimenta dioica L.*), pepper, paprika

(*Capsicum annuum subsp. grossum*), Ocimum (*Ocimum basilicum* L.), Tarragon (Artemísia dracúnculus L.), parsley (*Petroselinum crispum* (Mill.) Fuss), Rosmarinus (*Rosmarinus officinalis* L.), coriander (*Coriandrum sativum* L.), and oregano (*Origanum vulgare L*), are prominent in traditional in Armenian cuisine.

One portion of the mentioned herbs is used in cooking Zhengyal, a traditional dish common in Artsakh (also known as Nagorno-Karabakh) [12-17]. Additionally, some of these herbs are utilized in traditional medicine due to their high concentration of bioactive compounds, making them valuable for medicinal and chemical plant-derived preparations [18-19].

The Syunik region of Armenia, a vital agrarian hub in the Republic, is characterized by high metal content in its soil and rocks. Consequently, metal mines are present in this area, posing significant risks of technogenic pollution [20]. In this context, the primary factor contributing to technogenic contamination of air, water, and soil is the increased concentration of heavy metals [21]. This is particularly concerning, as certain plants are not only sensitive to heavy metals but also capable of accumulating significant amounts in their tissues [22].

Heavy metals are among the most hazardous agents of environmental anthropogenic pollution. They exhibit a dualistic influence on plants, animals, and fungi, dependent on concentration. High concentrations can significantly impair cellular function, detrimental to all living organisms, due to their ability to irreversibly inhibit key enzymes in metabolic pathways. Conversely, low concentrations of certain heavy metals (Cu, Zn, Fe etc.) can promote growth [23-26]. Heavy metals and their compounds (salts, oxides, hydroxides, colloids, etc.) occur naturally in the environment and can accumulate through both natural disasters (forest fires, volcanic eruptions, tectonic activity, etc.) and anthropogenic activities. Anthropogenic factors, primarily industrial processes, like mining, agriculture, waste disposal, and smelting, emit and accumulate heavy metals [27].

Active mining, manufacturing, waste Incineration, and agricultural practices (metal-containing classical fertilizers, pesticides, and irrigation water) contribute to environmental contamination. Additional sources include atmospheric deposition, sewage sludge application, and improper waste disposal [28-29]. Heavy metals persist in soil due to their stability low degradation rates, and strong binding to soil particles. Once in the soil, heavy metals accumulate over time, leading to increased concentrations and potential bioaccumulation in plants, animals, and microorganisms [30]. This process poses risks to organisms higher up the food chain, including humans [31]. Therefore, monitoring heavy metals and developing innovative soil and water remediation methods after contamination are critical research directions [32-33].

This study investigates the content of micronutrients (metals and non-metals) content and heavy metals in commonly consumed edible plants used in traditional foods in Armenia's Syunik region.

MATERIALS AND METHODS:

Samples collection: Four plant species were selected for research: two vegetables, beans (*Phaseolus vulgaris L.*) and potato (*Solanum tuberosum L.*) one fruit, apple (*Malus domestica* (Suckow) Borkh.); and one commonly used edible herb (nettle (*Urtica dioica L.*) representing wild plants. The edible parts of all the studied plants were collected [34-35].

Plant sampling was conducted in three villages of the Syunik region of RA: Arstvanik, Chapni, and Sevaqar. Considering the geographic location and land use peculiarities in these communities, four sampling points were selected for effective sample collection (Table 1, Fig. 1.).

Table 1. The Plant sampling points**.**

Point №	Coordinates of sampling point	The Elevation above sea level (in m)	Sampling area
01	N 39,29801°; E 46,47290°	1037	Arstvanik village, Syunik, RA
02	N 39,26480°; E 46,47314°	1091	Arstvanik village, Syunik, RA
03	N 39,27010°; E 46,46077°	1018	Chapni village, Syunik, RA
04	N 39,27146°; E 46,44563°	1020	Sevaqar village, Syunik, RA

Figure 1. The map of the studied area of Syunik Region

Element consistence assessment: The concentration of micronutrients (including metals and some non-metals) in prepared plant samples was determined using induction-coupled plasma-mass spectrophotometry (ICP-MS) with an ELAN 9000 (PerkinElmer). The analysis results for some elements in edible parts of sampled plants (dry mass) are presented [36-38]. The following elements were measured in studied plant samples: phosphorus (P), sulfur (S), potassium (K), calcium (Ca), chromium (in both Cr (VI) and Cr (III) forms), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), strontium (Sr), molybdenum (Mo), cadmium (Cd) and lead (Pb)

Statistical analyses: The statistical assessment of experimental reliability followed generally accepted protocols and methodologies [39]. The research consisted of eleven independent series, each with three replicates per collected sample. Data analysis utilized MS Excel, estimating the Standard Error of the Means (SEM) as ± 0.23–0.37. Significance was tested using Student t-test, yielding a mean p-value < 0.05.

RESULTS: The obtained results revealed variations in the concentrations of metals, non-metals, heavy metals, toxic non-metal elements, and nutrients across different sampling points (Tables 2-5).

Table 2. The element analyses of green bean pods by sampling points (dry mass, mg/kg).

N	The average concentration of different chemical elements															
	P	S	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Mo	Cd	Pb
01	2231	1927	27661	7963	-	-	424	-	-	-	33	-	23	9	7	-
02	2341	2055	36382	7241	-	-	150	-	-	-	33	-	23	9	4	-
03	2147	1823	37954	7273	-	-	108	-	-	-	32	-	20	8	6	-
04	2058	1591	36453	4137	-	-	107	-	-	-	34	-	14	3	-	-

N – sampling point number in correspondence to areas of analyses: 01 and 02 – Artsvanik village, 03 – Chapni village, 04 – Sevaqar village; “- “– absence.

Table 3. The element analyses of potato tubers by sampling points (dry mass, mg/kg).

N	The average concentration of different chemical elements															
	P	S	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Mo	Cd	Pb
04	1813	1490	31747	1268	-	-	316	-	-	-	8	-	5	-	10	-
05	1755	1835	30831	945	-	-	112	-	-	-	14	-	3	-	7	-
06	1917	1820	31217	1237	-	-	122	-	-	-	19	-	7	-	7	-
07	2808	2159	34232	1034	-	-	85	-	-	-	19	-	5	-	11	-

N – sampling point number in correspondence to areas of analyses: 01 and 02 – Artsvanik village, 03 – Chapni village, 04 – Sevaqar village; “-“– absence.

Table 4. The Element analyses of apple fruits by sampling points (dry mass, mg/kg).

N	The average concentration of different chemical elements															
	P	S	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Mo	Cd	Pb
01	**574**	**790**	**15985**	**1508**	-	-	**895**	-	-	-	-	-	**10**	-	**7**	-
02	**519**	**821**	**11988**	**1464**	-	-	**159**	-	-	-	-	-	**9**	-	**9**	-
03	**414**	**682**	**11753**	**1275**	-	-	**142**	-	-	-	-	-	**7**	-	**8**	-
04	**418**	**788**	**12309**	**1327**	-	-	**21**	-	-	-	-	-	**8**	-	**17**	-

N – sampling point number in correspondence to areas of analyses: 01 and 02 – Artsvanik village, 03 – Chapni village, 04 – Sevaqar village; “-“– absence.

Table 5. The element analyses in Nettle edible parts by sampling points (dry mass, mg/kg).

N	The average concentration of different chemical elements															
	P	S	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Mo	Cd	Pb
01	1466	4924	23330	59617	-	108	4099	-	-	3	31	-	133	-	3	-
02	2140	3885	40646	38041	-	5	1214	-	-	-	39	-	240	-	-	-
03	3177	6427	32832	43755	-	-	534	-	-	-	31	-	173	-	-	-
04	1361	5297	20132	39545	-	-	552	-	-	7	23	-	160	-	-	-

N – sampling point number in correspondence to areas of analyses: 01 and 02 – Artsvanik village, 03 – Chapni village, 04 – Sevaqar village; “-“ – absence.

According to the obtained data, the Cd levels in nearly all samples exceed the Maximum Permissible Concentration (MPC) mean value. Some samples also showed significantly higher Fe concentrations than the MPC recommended by the WHO (World Health Organization) and FAO (Food and Agriculture Organization of the United Nations) [40-42].

Among cultivated plants, bean pods had the highest average content of P, S K, Ca, Zn, and Sr. Nettle generally absorbed more of the considered elements than other plants, accumulating exceptionally high levels of S, Ca, Fe, Zn, and Sr. Notably, Cr (III) and Cr (VI) were not detected in any of the studied samples.

DISCUSSION

This study examined micronutrient and heavy metal content in four plants from Armenia's Syunik region. Green bean pods showed no presence of Cr, Mn, Co, Ni, Cu, As, or Pb, indicating no significant risks associated with these elements. However, Cd was detected in significantly increased concentrations, exceeding MPC values, in Artsvanik and Chapni samples. Conversely, Sevaqar samples showed no Cd presence. Nettle exhibited lower Cd concentrations compared to the other crops, whereas apple fruits had higher concentrations. Considering the collected data, the contamination situation with heavy metals is alarming, potentially posing serious negative consequences for human health. Elevated Cd concentrations have multiple adverse effects on various organ systems, including increased oncological pathology risks [43-45]."

Studying micronutrient concentrations revealed the highest levels of Ca, Ka, P, and S in nettle samples across all observation points. Manganese (Mn) was detected only in some nettle samples, highlighting this plant's unique ability to accumulate Mn, Mo, and other metals in its tissues [46-47]. Notably, the maximum Mn content was observed in samples from Artsvanik village. Manganese is an environmentally common essential metal required for normal enzymatic activity in various metabolic processes in animals and human cells. It functions as a cofactor of holoenzyme complexes. Decreased Mn concentrations can lead to immune dysfunctions, energetic metabolism pathologies, and other issues. Mn also regulates growth processes, blood coagulation, and hemostasis as part of the antioxidant system. However, excessive concentrations can provoke neurodegenerative processes (e.g., Parkinson's disease.), cardiotoxicity, and hepatotoxicity [48].

According to our data, Mo accumulated primarily in bean pods and nettle, with higher levels observed in communities near mining sites. Molybdenum is a component of coenzymes necessary for xanthine oxidase, sulfite oxidase, and aldehyde oxidase activity. Molybdenum poisoning is rare, with symptoms including uric acid metabolism disorders, gastrointestinal tract issues, and liver and kidney disorders [49]. Copper analysis revealed increased concentrations only in nettle samples. This confirms that elevated Mo and Cu levels are linked to mining activity in the area. The increased Cd levels are also attributed to the mining industry, as Cd is a primary byproduct. Interestingly, Cd measurements in Sevaqae Village samples were significantly lower than in the other two villages, likely due to the distance between the measurement area and mining zones [50-51]. Copper is an essential micronutrient vital for plant and animal cells, including human cells. However, exposure to high concentrations through contaminated food and water can be harmful. Cu intoxication symptoms include diarrhea, headaches, and severe liver and kidney failure [52].

Measurements of various heavy metals revealed differences between elements and plant types, attributed to specific plant tolerance and accumulation abilities. Certain plants, such as hyacinth, azolla, duckweed, cattail, and poplar, are utilized for soil remediation [53]. In the Syunik region, where agriculture is well developed, cultivating these plants for soil remediation could decrease heavy concentrations in crops, vegetables, and fruits.

CONCLUSION

Considering the data on non-metals (sulfur, phosphorus) and essential metals (potassium, calcium, zinc, iron, and strontium), this study concludes that micronutrient levels showed no significant changes. However, toxic heavy metals like As, Pb, Co, and Ni were undetectable, instead concentrations in Cd, Mo, and Fe were excessively high and hazardous.

Chronic consumption of plant-derived foods from these areas may lead to various health issues. Therefore, regular monitoring of Cd, Cu, Mo, and other heavy metals concentrations in these areas is crucial. This issue holds significant importance for both ecology and healthcare, particularly in preventing cancer, arthrosis, cardiovascular, digestive, reproductive, mental, and neurodegenerative diseases. Moreover, chronic exposure to heavy metal-contaminated foods, including animal products from regionally farmed animals, may have devastating consequences for human genetics and epigenetic regulation of metabolic processes. Further research on this problem is planned.

Abbreviations: FAO, Food and Agriculture Organization of the United Nations; ICP-MS, inductively coupled plasma-mass spectrophotometry; MPC, Maximum Permissible Concentration; WHO, World Health Organization.

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