Evaluation of heavy metal contamination in indigenous fruits and associated human health risk: evidence from Fuzzy-TOPSIS approach

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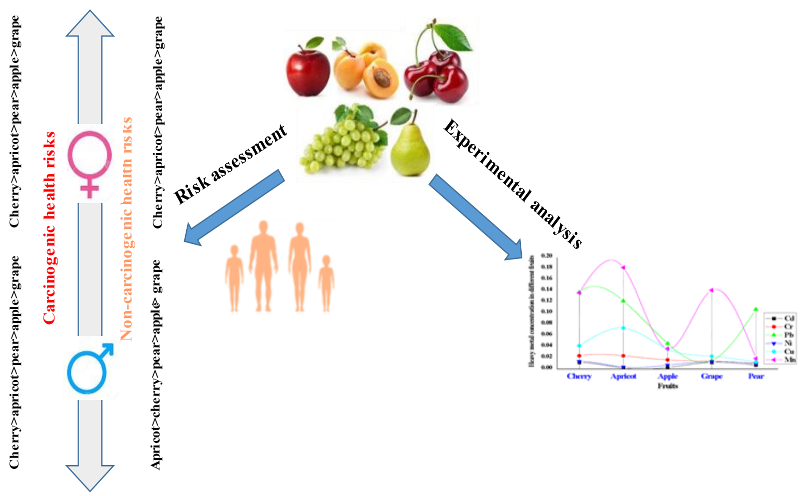
Graphical Abstract



ABSTRACT

In Gilgit-Baltistan, urbanization, transportation, unplanned small-scale industry, kitchen waste, inorganic fertilizers, pesticides, insecticides, and weedicides contribute to agricultural field contamination, creating severe health risks. This study aims to determine the health risks caused by heavy metals found in various indigenous fresh fruits. To this end, we first assessed heavy metals concentration using well-established experimental procedures. In addition, a survey of male and female respondents in the Gilgit District of Pakistan was conducted to determine the daily intake pattern, finally we used the Fuzzy-TOPSIS technique to calculate each indigenous fresh fruit's health risk and synergetic performance score. Results show the concentration order of heavy metals in indigenous fresh fruits, such as, Mn >Pb>Cu>Cr>Ni>Cd. For both males and females, the order of estimated daily intake (EDI) was Mn>Pb>Cu>Cr>Ni>Cd. Males estimated daily intake of Mn was highest in apricots, whereas female's EDI of Cd was lowest in apples. The Content of heavy metals consumed by males and females via fruits, for females, the sequence was cherry>apricot>pear>apple>grape, while for males it was apricot>cherry>pear>apple>grape. Individual cancer risks varied from 1.513E-03 to 1.066E-01, with cherries posing the highest risk for males and grapes posing the lowest risk for females. Non-carcinogenic risks in fruits were cherry>apricot>pear>apple>grape for females and apricot>cherry>pear>apple>grape for males, whereas carcinogenic risks exhibited cherry>apricot>pear>apple>grape for both males and females. Although the estimated daily consumption of Mn and Pb exceeded the WHO standards, the heavy metals were below permissible levels. The Health Index (HI) revealed a ranking of cherry>apricot>pear>apple>grape for females and apricot>cherry>pear>apple>grape for males. According to the ranking, the cumulative cancer risk for both males and females followed the order of cherry>apricot>pear>apple>grape. The fuzzy-TOPSIS results were consistent with the experiment, and it was established that a regular intake could synergistically cause cancer. The study's findings can support policymakers and administrators in improving food safety standards to ensure fruit quality.

Keywords: Heavy metals; indigenous fruit; fuzzy-TOPSIS; health risks

1. Introduction

Fruits are one of the most important components of the human diet, and it is widely recognised that consuming these foods on a regular basis is one of the best ways to improve one's health. Furthermore, people all over the world have recently become concerned about the benefits of nutrition more fresh fruits rather than red meat for good health because they significantly reduce the incidence of chronic diseases like diabetes, cancer, cardiovascular disease, and other age-related diseases (Prakash et al,, 2012).

Heavy metal contamination, which is induced by a variety of anthropogenic activities, poses a serious threat to food safety (Cui et al., 2004). Agricultural foods are frequently contaminated with contaminants, particularly heavy metals, as a result of direct and indirect industrial operations, automotive pollution, excessive metal-based fertilisation, and pesticide use. Some heavy metals, such as Cd and Pb, on the other hand, have no known positive role in human metabolism and are regarded chemical carcinogens even at extremely low levels of exposure (Jarup, 2003).

Heavy metals that are present in very small amounts in the environment are biomagnified and become part of various food chains, where their concentration rises to levels that are dangerous to humans and other living things. However, eating is the main route of human exposure to heavy metals, which constitute one of the potential risks linked with foodstuffs (Mart-Cid et al., 2008). The dietary intake of lead, copper, and chromium through food has been observed to be higher than allowed limits in urban areas, owing to plant origin fruits and vegetables (Yebpella et al., 2011).

Many factors contribute to heavy metal pollution in fruits, including irrigation water, industrial pollutants, the harvesting process, storage, and/or at the point of sale (Huang et al. 2014). Furthermore, food security is a key concern throughout the globe. During the previous eras, the growing response for food security has stimulated explorations concerning risks related to the ingestion of food stuffs adulterated by pesticides, heavy metals, and toxins. The expanding patterns in food contamination are to a countless extent while farming, poor handling and taking care of food at the market, and utilization of polluted wastewater for water systems (Guerra *et al.,* 2012).

Consumption of heavy metal-polluted foods may result in the accumulation of these pollutants in various tissues, resulting in both chronic and acute health effects (Jarup 2003). As a result, it is plausible to believe that eating fruits containing heavy metals poses a health risk to consumers.

Therefore, determination of toxic metals, exposure assessment, and the risk characterization of the contaminated food material are all the decisive components in the estimation of health risks.

To the best of authors' knowledge, for the first time, this paper incorporated the determination of heavy metal concentrations, daily consumption levels of fresh fruits in addition to cancer and non-cancer risks via interviewing enough male and female respondents. For this purpose, experimental, theoretical, and numerical approaches have been employed to get insight into the emerging environmental concern. Standard experimental procedures were used for heavy metal analysis. Besides, the fuzzy TOPSIS, multi-criteria decision-making techniques were used to determine the best appropriate options concerning the concentrations of heavy metals, daily intake, and related health risk from selected fruits. Thus, this study results will pave the way towards understanding and insights of the current fruit quality status and risk associated with selected fruits posed to buyers in supporting the necessity of food safety initiation by the administration.

2. Materials and methods

2.1 Samples collection and preparation

A total of fifty samples of five fresh fruits (apricot, apple, pear, peach, and grape), ten for each fruit were acquired in their respective season from different selling points of the local market of Gilgit city (Figure 1). Two grams of each fruit sample were digested with HNO_3, and $HClO_4$, in 10:2 ratios until a clear solution was gained as defined by (Commission and others, 2001; FAO/WHO, 2001). The fruit abstracts were filtered and diluted with 25ml with deionized water. The heavy metals in the acid extracts of fruit samples were investigated with Flame Atomic absorption spectrophotometer in laboratories of Fatima Jinnah Women University Rawalpindi and Soil fertility laboratory National Agriculture Research Center NARC Islamabad by following the methods used by researchers (Huang *et al.*, 2014; Ikechukwu *et al.*, 2019).

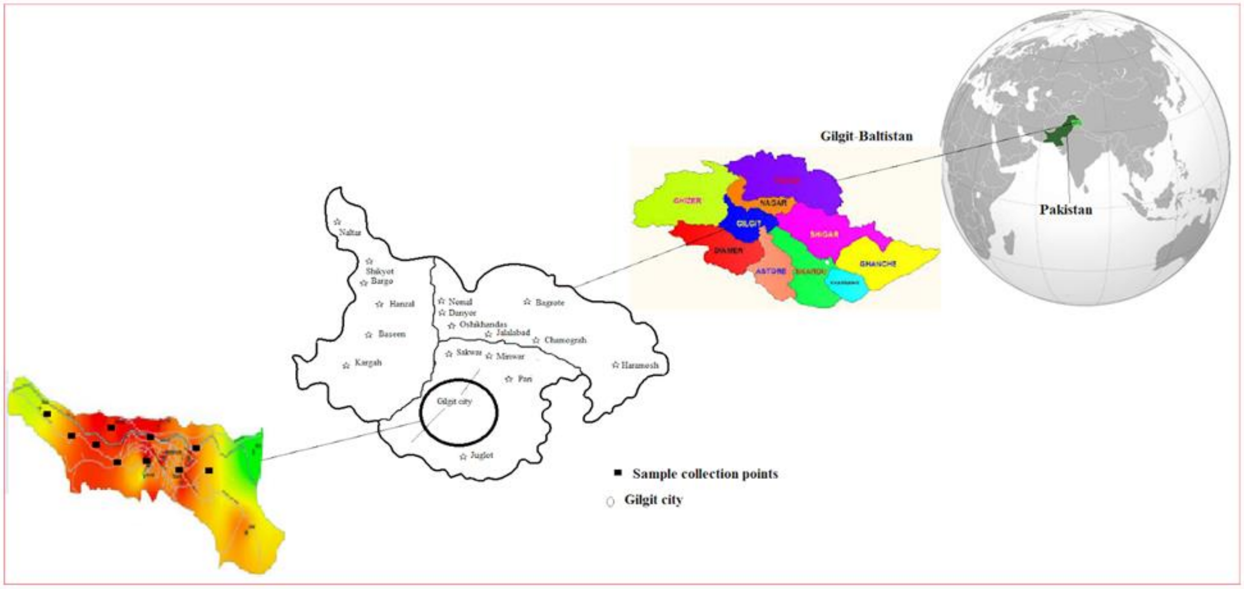


Figure 1. Study area map

2.2 Determination of Heavy Metal

The level of heavy metals was examined using a Flame Atomic Absorption spectrophotometer, (FAAS). A double beam and deuterium hollow cathode lamps of Pb, Cd, Cr, Cu, Ni, and Mn were used at specific wavelengths, where samples were run in triplicates (Ikechukwu *et al.*, 2019; Sultana *et al.*, 2017).

2.3 Determination of Estimated Daily Intake of Heavy Metals (EDI)

The Estimated Daily Intake was measured by expanding the methods (Ikechukwu *et al.,* 2019; Jan *et al.,* 2015; Sultana *et al.*, 2017). EDI was designed using the following equation.

$$\text{EDI} = \frac{C_{metal} \times D_{fruit\ intake}}{BW_{average}} \quad (1)$$

Where: C stands for metal concentration in fruit in mg/kg, D daily intake of fruit in grams, and BW the average body weight in kg. For this purpose, total 600 questionnaires were distributed across Gilgit city and its vicinity to gather the required data on daily fruit intake and body average weight of males and females.

2.4 Target hazard quotient (THQ)

Non-carcinogenic risks for single heavy metals were assessed by calculating the target hazard quotient (THQ) using the following equation (Nordberg *et al.*, 2014; Sultana *et al.*, 2017).

$$\mathrm{THQ} = \frac{\mathrm{EDI}}{\mathrm{R}f\mathrm{D}} \quad (2)$$

Where EDI is the estimated daily heavy metal intake and RfD is the oral reference dose (mg/kg/day) where, EPA mentioned RDf standards for Cr, Cu, Mn, Ni, Cd, and Pb were used in the above equation (Dee *et al.*, 2019; Di *et al.*, 2014; Wei and Yang, 2010; Zhuang *et al.*, 2009). If the THQ value is equal to or >1, there is a possible health risk, and <1, the exposed residents are suspect of any adverse health hazard (Wang *et al.*, 2005).

2.5 Hazard index (HI)

To calculate cumulative health risk through more than one heavy metal, a chronic hazard index (HI) was acquired from the addition of all-hazard quotients (THQ) (NFPCSP Nutrition Fact Sheet, 2011). It was measured as follows:(Ikechukwu *et al.*, 2019; Sultana *et al.*, 2017).

$$\mathrm{HI} = \mathrm{THQ_{Cd}} + \mathrm{THQ_{Cr}} + \mathrm{THQ_{Pb}} + \mathrm{THQ_{Mn}} + \mathrm{THQ_{Ni}} + \mathrm{THQ_{Cu}} \quad (3)$$

Where: HI = Hazard Index THQ = Target Hazard Quotient. The calculated HI is related to standard levels: the inhabitant is predicted safe when HI < 1 and in a level of anxiety when 1 < HI < 5 (Guerra *et al.*, 2012).

2.6 Determination of Cancer Risk (CR) Index

CR specifies the individual cancer risk over a lifetime due to exposure. Cancer risk over a lifetime exposure to Cd, Cr, Cd, and Pb were developed by equation using cancer slope factor CSF (Cherfi *et al.*, 2014; Ikechukwu *et al.*, 2019).

$$\text{Cancer Risk CR} = \mathrm{CSF} \times \mathrm{EDI} \quad (4)$$

Where: CSF is the oral carcinogenic slope factor of 0.0085, 0.38, 0.5, and 1.7 (mg/kg/day) for Pb, Cd, Cr, and Ni, respectively, and 1.5 (mg/kg/day) for asset by USEPA (2010). Acceptable risk levels for carcinogens range from 10−4 to 10−6 (risk of developing cancer over a human lifetime is 1 in 1,000,000 (US EPA, 2011).

2.7 Determination of Total Cancer Risk

The cumulative cancer risk due to contact with numerous sources of carcinogenic heavy metals through ingesting of a specific variety of fruits was measured, and the sum of each heavy metal increment risk was determined by the following equation (Liu *et al.*, 2013).

$$\text{Total Cancer Risk TCR} = \sum CR \ or \ \mathrm{CR_{Cd}} + \mathrm{CR_{Cr}} + \mathrm{CR_{Pb}} + + \mathrm{CR_{Ni}} \quad (5)$$

Where CR is the cancer risk.

2.8 Fuzzy-TOPSIS method

The “Technique for Ordering Preference by Similarity to Ideal Solution (TOPSIS)” is one of the classical decision-making methods for solving multi-criteria decision-making (MCDM) problems with crisp numbers, which has a simple computation process, systematic procedure, and sound logic that represent the rationale of human choice. Decision-making is the process of selecting the best option from a set of options. Fuzzy-TOPSIS has achieved considerable success in several fields of practical life due to its potentiality in handling hesitation and vagueness, such as aggregations, information measures, remote sensing, data processing, identification of patterns, and multivariate data analysis and decision making etc. This method has been widely used in different decision-making evaluations, including health risk assessment. The best handling methods or postharvest technologies that can be used to maintain the quality of citrus fruit in Selayar, South Sulawesi, Indonesia by using fuzzy TOPSIS (Dirpan, 2018). Organic agriculture is expected to play a major role in a healthy world in the future. Organic agriculture is healthier than inorganic agriculture and treatments are evaluated using Fuzzy TOPSIS (Suder and Kahraman, 2018). The products produced using Apple Ber powder need to be evaluated for their quality. Sensory evaluation plays a significant role in assessing the quality of the product. This opinion is evaluated and ranked using Fuzzy TOPSIS a nine-point scale. It can be used to assess the product's safety and reliability (Mathangi and Prakash Maran, 2021).

In this paper, we applied the TOPSIS method to deal effectively with the MCDM problems including Fuzzy sets (FSs). The main contributions of this paper are summarized as follows;

Step 1: Construct the decision Matrix D_{ij} .

Step 2: Construct normalized decision matrix. The normalize decision matrix values D_{ij}^{*} where, $i = 1,2, \dots, m$ (criteria), $j = 1,2, \dots, n$ (alternative) is calculated as:

$$D_{ij}^{*} = \frac{D_{ij}}{\sqrt{\sum_{j=1}^{n} D_{ij}}} \tag{6}$$

Step 3: Calculate the criterion weights of the normalized decision matrix by using eq. (7) with the performance values of the normalized decision matrix.

$$\omega_i = \frac{\omega_i^{*}}{\sum_{i=1}^{n} \omega_i^{*}} \text{ , Where } \sum_{k=1}^{s} \omega_i = 1, \ \omega_{\hat{k}} \in [0,1]. \tag{7}$$

Step 4: Calculated the weighted normalized matrix is estimated by using Eq. (8) with the help of performance values of normalized decision matrix and criterion weights.

$$D_{ij} = D_{ij} \times \omega_i \tag{8}$$

Step 5: Calculate the ideal best and ideal worst values from weighted normalized decision matrix, respectively, as follows:

$M^{+} = Max(x_{ij})$ for beneficial criteria and, $M^{+} = \min(x_{ij})$ for cost criteria Where $j = 1,2, \dots, n$

$M^{-} = \min(x_{ij})$ for beneficial criteria and, $M^{-} = \max(x_{ij})$ for cost criteria Where $j = 1,2, \dots, n$

Step 6: Calculate the Euclidean distance from each alternative to the ideal best solution and ideal worst solution is given under, respectively.

$$d_i^{+} = \sqrt{\sum_{i=1}^{n} \left\{ (\hat{\mu}(x_i) - \hat{\mu}(x_i))^2 \right\}} \ , \qquad i = 1,2, \dots, n \tag{9}$$

$$d_i^- = \sqrt{\sum_{i=1}^{n}\left\{(\underset{\smile}{\mu}(x_i) - \underset{\smile}{\mu}(x_i))^2\right\}} \quad , \qquad i = 1,2,\ldots,n \tag{10}$$

Step 7: Calculated the performance Score

$$P_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{11}$$

Where p_i is performance score value and values of p_i lies between zero and one.

3. Step 8: Finally, the Ranking of each alternative is done on the basis of performance score values.

Results and discussion

3.1 Heavy metals concentration

In the current study, the lowest detected concentration of heavy metal was for Cd while the highest determined Mn concentration was in all the fruits as shown in Table 1 and

Table 2. All the heavy metals were within the recommended limits than the previously conducted studies from a variety of soil and crops (Di *et al.*, 2014) in China, (Roba *et al.*, 2016) in Romania and (Khan *et al.*, 2013) in Pakistan. Excessive variation was recorded in heavy metal quantity between samples due to climate variability in the studied location, the growth phase of plants having the ability to accumulate the heavy metals depend upon the pollution of the area (Roba *et al.*, 2016).

Table 1. Mean concentration of heavy metals in studied fruits as mg/kg

Fruits	Cd	Cr	Pb	Ni	Cu	Mn
Permissible Limits	0.20	0.10	0.18	0.20	0.20	0.30
Cherry	0.0121±0.00003^{A}	0.0240±0.00009^{A}	0.1376±0.00007^{A}	0.0140±0.00006^{A}	0.0420±0.00007^{A}	0.1367±0.00008^{A}
Apricot	0.0020±0.00004^{B}	0.0240±0.00008^{A}	0.1223±0.00005^{B}	0.0039±0.0001^{B}	0.0737±0.00004^{B}	0.1819±0.0001^{B}
Apple	0.0030±0.0001^{C}	0.0166±0.00007^{B}	0.0459±0.0001^{C}	0.0072±0.00009^{C}	0.0363±0.0001^{C}	0.0365±0.0002^{C}
Grape	0.0121±0.00007^{A}	0.0143±0.0001^{C}	0.0153±0.0001^{D}	0.0136±0.0002^{D}	0.0231±0.0001^{D}	0.1413±0.0001^{D}
Pear	0.0072±0.00008^{D}	0.0107±0.00008^{D}	0.1070±0.0001^{E}	0.0101±0.00004^{E}	0.0128±0.0001^{E}	0.0190±0.0001^{E}

Note: Letters show significant differences among the fruits at $P < 0.05$.

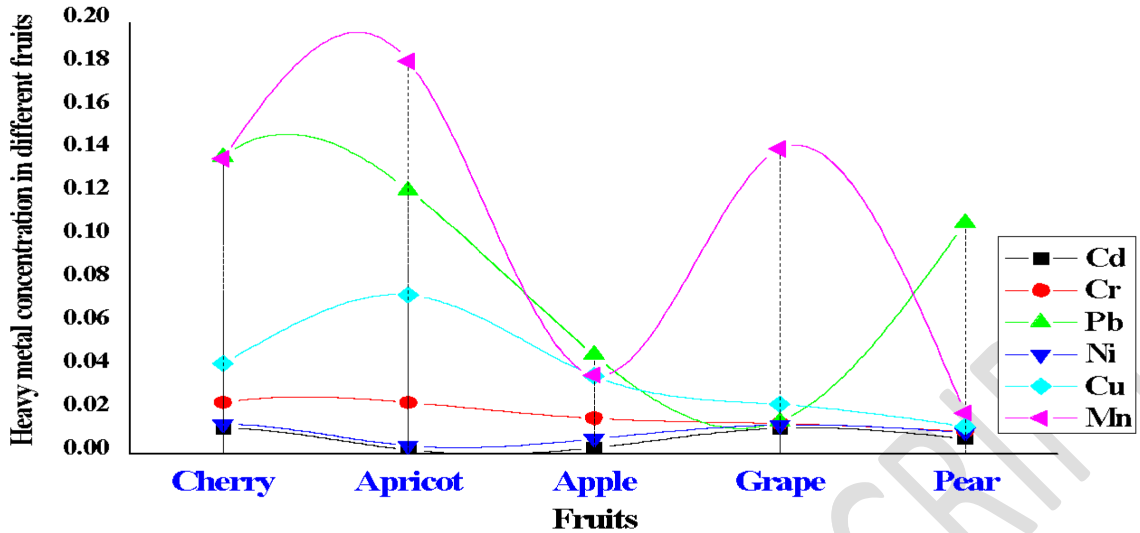
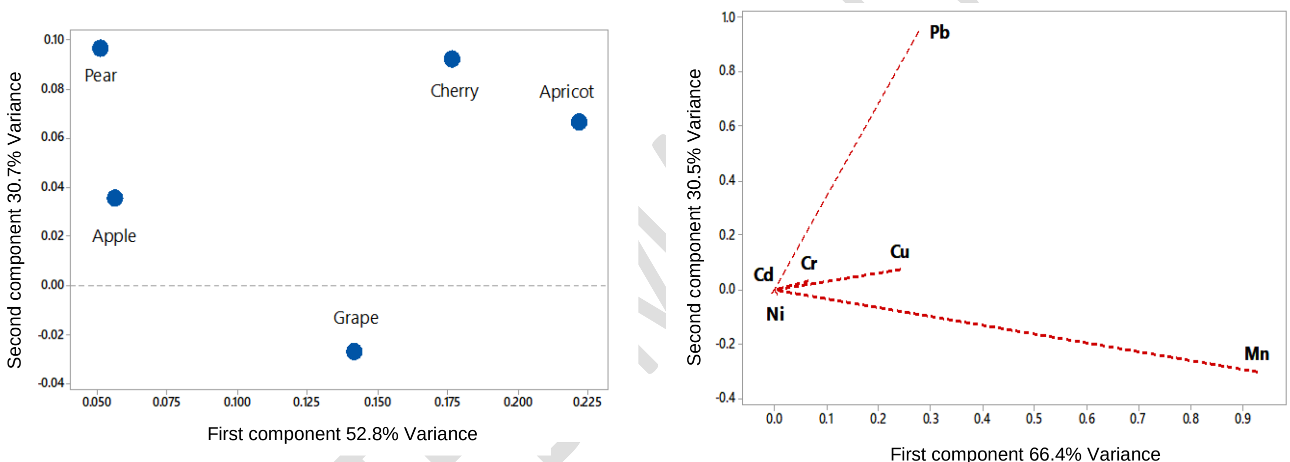


Figure 2. Mean concentration of heavy metals in different fruits samples collected from Gilgit city

Figure 3. Principal component analysis of heavy metal concentration in different fruits collected



in Gilgit City

Maximum of the heavy metals are the natural elements of earth's crust and from there they are taken by plants and thus transported to the food chain. Researchers consider that the major anthropogenic sources of heavy metals in cultivated soils vegetables and fruits mostly arise from chemical fertilizers and the use of pesticides (Semnani *et al.*, 2010; Wei and Yang, 2010). Heavy metal concentration in different fruits collected in Gilgit City was analyzed using principal component analysis Figure 3. The PCA study found two significant components horizontal and vertical axis represents the variance. Both components in vertical and horizontal were responsible 52.8%+30.7% =83.5% for fruits and 66.4%+30.5% =96.9% of the overall variance for heavy metals respectively. Component 1 was related to grape and accounts for 52.8% of the overall variance. Component 2 was associated with apple, pear, cherry, and apricot and accounted for 30.7% of the overall variance. The results showed that grapes had a negative relationship with other fruits due to higher concentration of all the heavy metals and increasing trend in grapes as compare to other fruits. For heavy metals, PCA analysis showed that component 1 is correlated to Ni and Mn which was 66.4% of the total variance. Component 2 accounted for 30.5% of the overall variance and has high Pb loading. The association of metals in the PCA study was verified the correlation results, which revealed that Ni and Mn were negatively correlated with all other metals except.

3.2 Fuzzy TOPSIS method

The fuzzy-TOPSIS multi-criteria decision-making method was applied to find the best alternative (metal) for heavy metal concentrations in different fruits. For this purpose, alternatives $\boldsymbol{A} = \{\mathbf{Cd}, \mathbf{Cr}, \mathbf{Pb}, \mathbf{Ni}, \mathbf{Cu}, \mathbf{Mn}\}$ analyzed based on the five criteria; these are Cherry, Apricot, Apple, Grape and Pear. Where all are beneficial criteria and calculated the criterion weights of estimated daily intake of heavy metals of different fruits $\boldsymbol{\omega_i}$ = 0.2771, 0.0349, 0.2071, 0.2693, 0.2118 respectively, and ideal best and ideal worst values are presented in (

Table **2**). It was observed the performance score values in terms of Fuzzy ideal solutions to each alternative. From the table $\boldsymbol{Mn > Pb > Cu > Cr > Ni > Cd}$ order of ranking was established. $\boldsymbol{Mn}$ Was closest from the positive ideal solution and furthest from the ideal worst and $\boldsymbol{Cd}$ explicit was furthest from the positive ideal solution and closest from the ideal worst. It showed that *Mn* and $\boldsymbol{Pb}$ had the highest concentration while *Cd* had the lowest heavy metal concentrations in different fruits of the study area.

Table 2. Overall performance score values of heavy metal concentrations in different fruits

Metals	$\boldsymbol{d_i^+}$	$\boldsymbol{d_i^-}$	$\boldsymbol{P_i}$	**Rank**
Cd	0.0245	0	0	6
Cr	0.0231	0.0021	0.0834	4
Pb	0.0153	0.0188	0.5514	2
Ni	0.0241	0.0006	0.0243	5
Cu	0.0207	0.0052	0.2008	3
Mn	0.0084	0.0224	0.7273	1

Note: $\boldsymbol{d_i^+}, \boldsymbol{d_i^-}$ are Euclidean distance from each alternative to the ideal best solution and ideal worst solution, respectively. And p_i is performance score value and values of p_i lies between zero and one. These have further explained in above material and methods section 2.8 steps 6 and 7.

3.3 Estimated daily intake of heavy metal

The results of daily intake of heavy metal in different fruits are presented in Table 3. According to the study, Cd exhibited the highest EDI levels in Grape 0.0257 mg/day from males as compared to other fruits which were within the limits of 0.06 mg/kg (WHO, 2021). Cd is harmful to our health even intake in lesser amount. Food is the main source of Cd exposure, besides cigarette smoking (Hussain *et al.*, 2021a). Regular Cd intake damage the respiratory system, lung cancer, Parkinson's and Wilson's diseases, and breast cancer in postmenopausal women (Hussain *et al.*, 2021a, 2021b; Nordberg and Nordberg, 2016), In Japan, ingestion of Cd polluted rice causes bone disease and kidney failure to the local inhabitants (Wuana and Okieimen, 2011). The highest daily intake of Cr metal based on average concentration level was 0.0448 mg/day from Apricot in males of this study. This level was within the recommended standard of 0.2 mg/day (WHO, 2021). This EDI value indicated that consumers in Gilgit town were not at health risk due to the uptake of Cr levels in fruits. It was reported that Cr was a heavy metal of concern in food crops as it is the most bio-available element in soil uptake and subsequent deposition to plant parts including fruits (Chamannejadian *et al.*, 2013; Kumar and Chopra, 2015).

The highest daily intake value of Pb 0.2552 mg/day from cherry in Females has exceeded the recommended level 0.18 mg/day (WHO, 2021). Consumers in Gilgit town are at health risk due to elevated levels of Pb in terms of concentration levels in the fresh fruits under study. (NG, 2000) reported that the level of Pb in fruits ranged from 0.63 to 8.71 mg/ kg in mango. In the top 20 most lethal heavy metals, Pb is the number second after As. It is very detrimental even in slight quantity (Assi *et al.*, 2016; Jaishankar *et al.*, 2014). There are several ways of Pb exposures, but inhalation and ingestion through an adulterated diet are found to be the most common route (Jan *et al.*, 2015). Extreme Pb uptake damage to the intelligence of children such as mental and behavioral issues (Canfield *et al.*, 2005; Wani *et al.*, 2015). This is because the brain development and central nervous system of children are vulnerable to destruction (Wani *et al.,* 2015; WHO, 2019). Continuously intake of Pb through polluted diet can stored metal in bones, leading to kidney, liver, cardiovascular, cancer, and reproductive system weakness (Assi *et al.*, 2016).

Ni exhibits a maximum concentration of 0.0289 mg/kg from Grapes in males. This level was within the recommended standard of 0.2 mg/day (WHO, 2021). Consumers in Gilgit town are not at health risk due to low concentration levels in the fresh fruits under study. Mahmood and Malik (2014) reported contradicted results and observed high Ni concentrations in carrot irrigated with groundwater and wastewater. (Sobukola *et al.,* 2010) studied watermelon and orange recorded range 0.083 to 0.119 mg/kg and orange level between 0.039 to 0.043 mg/kg they observed that all the levels recorded lower the level in Sudan. The highest daily intake of the Cu level was 0.1376 mg/day from Apricot in males of this study. This level was within the recommended standard of 0.2 mg/day (WHO, 2021). This EDI value indicated that consumers in Gilgit town were not at health risk due to the uptake of Cu in fruits. Cu is a vital metal for living organisms which initiate enzyme to function accurately and supports enzymes to transfer energy into the cells in humans (Chitturi *et al.,* 2015). The shellfish is the best source of Cu for human necessity (Olmedo *et al.,* 2013). But, intake of Cu higher than needed level can lead to adverse effects (Tvrda *et al.,* 2015). The effects comprised headache, vomiting, liver and kidney failure, and Wilson's disease (Hussain *et al.,* 2021a; Jaishankar *et al.,* 2014). (Sobukola *et al.,* 2010) reported that Cu content in watermelon, orange, and banana was in the range of 0.002-0.006mg/kg, 0.001-0.003 mg/kg in orange 0.007-0.35 mg/kg respectively.

The highest daily intake of Mn (0.3396mg/day) from apricot in males has exceeded the recommended level of 0.30 mg/day (WHO, 2021). Consumers in Gilgit town are at health risk due to elevated levels of Mn in terms of concentration levels in the fresh fruits under study. Mn is a crucial metal for living organisms. Little quantity of Mn is essential to form strong bones, control the blood sugar level, sustain, and boost digestion, and increase vitamin absorption (Horning et al., 2015). Exceeded Intake of Mn from nutrition sources is common (Mitchell *et al.*, 2021). When Mn intake exceeds the recommended limits, it has adverse effects on the human body comprising weakness, muscle pain, and clumsy movement of the limbs, and neurological diseases (Guilarte and Gonzales, 2015; WHO, 2019).

Table 3. Estimated daily Intake of heavy metal of different fruits of Gilgit Market in mg/kg

Fruits	Genders	Cd	Cr	Pb	Ni	Cu	Mn
Cherry	**Male**	0.0175	0.0347	0.1987	0.0202	0.0607	0.1974
	Female	0.0224	0.0445	0.2552	0.0260	0.0779	0.2535
Apricot	**Male**	0.0037	0.0448	0.2283	0.0073	0.1376	0.3396
	Female	0.0036	0.0437	0.2225	0.0071	0.1341	0.3309
Apple	**Male**	0.0055	0.0304	0.0841	0.0132	0.0665	0.0669
	Female	0.0058	0.0321	0.0888	0.0139	0.0702	0.0706
Grape	**Male**	0.0257	0.0304	0.0325	0.0289	0.0491	0.3006
	Female	0.0228	0.0270	0.0289	0.0257	0.0436	0.2666
Pear	**Male**	0.0106	0.0158	0.1583	0.0149	0.0189	0.0281
	Female	0.0127	0.0189	0.1889	0.0178	0.0226	0.0335

3.4 Fuzzy TOPSIS method for estimated daily intake of heavy metal of different fruits of Gilgit market in mg/kg

In this section, the fuzzy TOPSIS multi-criteria decision-making method was employed to select the best alternative (metal) estimated daily Intake of heavy metal of different fruits of Gilgit market in mg/kg. For this, alternatives $A = \{Cd, Cr, Pb, Ni, Cu, Mn\}$, and analyzed based on the five criteria i.e. cherry, apricot, apple, grape and pear called them all beneficial criteria. The criterion weights of estimated daily intake of heavy metals of different fruits $\boldsymbol{\omega_i}$ = 0.2771, 0.0349, 0.2071, 0.2693, 0.2118 were calculated respectively.

It was found the performance score values in terms of Fuzzy ideal solutions to each alternative, and finally, ranked each alternative for the purpose of the relative nearest degree.

Table 4. Overall performance score values of daily intake of heavy metal concentration of different fruits of Gilgit district in mg/kg

Metals	d^+	d^-	P_i	Rank
Cd	0.0442	0	0	6
Cr	0.0419	0.0036	0.0792	4
Pb	0.0306	0.0311	0.5041	2
Ni	0.0435	0.0011	0.0247	5
Cu	0.0377	0.0092	0.1962	3
Mn	0.0137	0.0411	0.75	1

The order ranking of Mn>Pb>Cu>Cr>Ni>Cd was found Table 4 and was obvious that Mn closest to the positive ideal solution and forest from the ideal worst and Cd was farthest away from the positive ideal solution and closest from the ideal worst. Thus, the Mn had the highest concentration while Cd had the lowest level in daily intake of heavy metals of different fruits.

3.5 Non-carcinogenic health risks

THQ via intake of fruits and vegetables is an actual degree of chemical pollutants. It cannot calculate the exact risk but specifies a level of an alarm condition (Bhatti *et al.*, 2020; Wang *et al.*, 2005) described that the maximum THQ value poses a higher possible health risk to humans. In the current study, there is no THQ of heavy metals of fruits vended at the Gilgit market. Cd, Cr, Pb, Ni, Cu, and Mn perceived THQ in all fruits which were <1 Table 35. The maximum values of THQ were observed in Pb 0.1823 from the cherry in females and 0.1631 from apricot in males. (Dee *et al.*, 2019) reported THQ of all the heavy metals were less than 1 as recommended THQ, depicted no hazard. (Sultana et al., 2017) observed THQ > 1 for Pb, As, Mn, and Fe in vegetables, for adults and children. It specifies that the intake of these heavy metals through the ingestion of vegetables poses a considerable non-cancer risk. On the other hand, the intake of single heavy metal Cr, Co, Cd, Cu, Zn, and Ni via intake of vegetables and fruits in this area is harmless THQ < 1 for the citizens, and similar results were also described in other researches (Khan *et al.*, 2010; WHO, 2021). HI of heavy metals of fruits vended at the Gilgit market. It was perceived that no fruits had HI ≥ 1. All fruits had HI <1, which varies from 0.0567-0.2246. The HI of all fruits specifies no harmful effect to health because the HI is <1. (Dee *et al.*, 2019) so, the calculated HI was 0.61, less than 1. This suggested that there was no risk to human health-related with the intake of heavy metals via diet. But, health risks end users depend on the quantity of estimated weekly intake of heavy metals. A contradictory study was reported by Sultana et al. (2017) in vegetables and fruits indicated the risk level HI > 1 with the maximum 15.89 where all the vegetables and fruits showed a non-cancer risk HI > 1. Ikechukwu *et al.* (2019) studied the evaluation heavy metals and associated health risk to human from slected fruits of Nigeria, all the fruit indicated that the HI < 1 showed there is no any non carcinogenic health risk via consumption of selected fruits. Gupta et al, (2022) invistigated a study on accumulation of heavy metals and related health risk via intake of vegetables, HI shows that coriander, onion, and tomato consumption in the research area is risk-free.

Table 5. Non-carcinogenic human health risks posed by heavy metals in different fruits

		Target Hazard Quotient (THQ)						Health Index (HI)
Fruits	**Genders**	**Cd**	**Cr**	**Pb**	**Ni**	**Cu**	**Mn**	
Cherry	**Male**	0.0175	0.0116	0.1419	0.0010	0.0015	0.0014	0.1749
	Female	0.0224	0.0148	0.1823	0.0013	0.0019	0.0018	0.2246
Apricot	**Male**	0.0037	0.0149	0.1631	0.0004	0.0034	0.0024	0.1880
	Female	0.0036	0.0146	0.1589	0.0004	0.0034	0.0024	0.1832
Apple	**Male**	0.0055	0.0101	0.0601	0.0007	0.0017	0.0005	0.0786
	Female	0.0058	0.0107	0.0634	0.0007	0.0018	0.0005	0.0829
Grape	**Male**	0.0257	0.0101	0.0232	0.0014	0.0012	0.0021	0.0640
	Female	0.0228	0.0090	0.0206	0.0013	0.0011	0.0019	0.0567
Pear	**Male**	0.0106	0.0053	0.1130	0.0007	0.0005	0.0002	0.1304
	Female	0.0127	0.0063	0.1349	0.0009	0.0006	0.0002	0.1556

3.6 Fuzzy TOPSIS method for non-carcinogenic human health risks posed by heavy metals in different fruits.

For this section, the fuzzy TOPSIS multi-criteria decision-making method was used to choose the best alternative (Fruits) for non-carcinogenic human health risks posed by heavy metals in different fruits. So, the four alternatives such as cherry, apricot, apple, grape, and pear and further analyzed based on the above criteria. It was found that the performance score result in terms of Fuzzy ideal solutions to each alternative Table 6. Then, ranked each alternative A_i to the relative nearest degree. The order cherry>apricot>pear>apple>grape for females and apricot>cherry>pear>apple>grape for males clarified the maximum non-carcinogenic human health risks posed by heavy metals in different fruits that observed in cherry while the lowest was in grapes for females and the maximum was detected in apricot while the lowest was examined in grapes for males respectively.

Table 6. Overall performance score and ranking of non-carcinogenic human health risks

Gender	**Fruits**	d^+	d^-	P_i	Rank

Male	**Cherry**	0.0076	0.0342	0.8182	2
	Apricot	0.0056	0.0409	0.8796	1
	Apple	0.0298	0.012	0.2871	4
	Grape	0.0395	0.0083	0.1737	5
	Pear	0.0189	0.0251	0.5705	3
Female	**Cherry**	0.0004	0.0466	0.9915	1
	Apricot	0.0082	0.04	0.8299	2
	Apple	0.0339	0.0132	0.2803	4
	Grape	0.0457	0.006	0.1161	5
	Pear	0.0172	0.032	0.6505	3

3.7 Carcinogenic health risks

USEPA, (1989) states that 10-6 to 10-4 signify a range of permitted projected lifetime risks for carcinogens. The substance which the risk factor recorded under 10-6 may be eradicated from more consideration. The current study depicts that the intake of Cd for all analyzed samples fruits fluctuated from 6.496E-05 to1.066E-01, all were within recommended limits except intake of cherry for males recorded as 1.066E-01 has exceeded the permissible limits. This finding indicated that Cd might be a cancer-causing agent owing to the daily lifetime intake of Cd by cherry. Whereas the intake of Pb exhibited a variation from 2.454E-04 to 1.345E-03 in all the samples. These values exceed the projected allowable lifetime risks excluding pear and apricot for both males and females. These results may purpose that Pb may also cause cancer due to lethal daily lifetime intake of Pb from all the fruits that excluding pear and apricot. Long-term exposure to little amounts of Cd and Pb might outcome in several kinds of cancers (Jarup., 2003; Mohammadi *et al.*, 2019). Chukwuemeka and Hephzibah, (2018) investigated a study on leafy vegetables in Nigeria Cr exhibits higher than the permissible limits. This may specify that Cr might be a concern that could result in cancer due to the ingestion of Cr. In a current study Cr vacillated from 6.488E-04 to 1.106E-03 in all the samples were above the predicted lifetime risks excluding pear which was within the limits, this result purposed that Cr could cause cancer due to chronic daily lifetime intake of Cr from all fruits excluding Pear. Similarly, in current research the ingestion of Ni fluctuated from 5.960E-06 to 1.109E-05 in all the samples were within the projected acceptable lifetime risks, the results suggest that Ni may not leads to cancer due to the intake of fruits while heavy metals Pb, Cr Cd, and Ni can possibly increase the risk of cancer in humans (Tani and Barrington., 2005; Cao *et al.*, 2014). Total cancer risk was ranged from 1.513E-03 to 1.097E-01. The cumulative risk of all the heavy metals in all fruits was exceeded the permissible limits Table 7. Thus, all the heavy metals could lead to cancer due to the consumption of fruits (Ikechukwu *et al.,* 2019) described that ingesting *Gongronema latifolium* might pose a cancer risk to human health based on the exceeded level of Cu, Ni, Cr, Cd, and Mn. Among the calculated heavy metals, Cr has the maximum chance of cancer risks of 6.54E-03 and Ni has the minimum chance of cancer risk of 9.16E-05 (Mohammadi *et al.*, 2019). A contradicted study was reported by (Dee *et al.*, 2019) showed that the ingesting of *C. D fluminea* in the studied area, at the amount of 75 g/day/person with the rate of three times per week most possibly does not pose cancer to citizens. Chukwuemeka and Hephzibah, (2018) showed 1.35E-03 the highest value of Cr in leafy vegetables, exceeded the predicted permissible lifetime risks, and significant carcinogenic health risks related to the intake of vegetables.

Table 7. Carcinogenic human health risks posed by heavy metals in different fruits

		Cancer Risk (CR)				**TCR**
Fruits	**Gender**	**Cd**	**Cr**	**Pb**	**Ni**	
Cherry	**Male**	1.066E-01	1.421E-03	1.689E-03	1.698E-05	1.097E-01
	Female	1.369E-04	1.825E-03	2.169E-03	2.181E-05	4.153E-03
Apricot	**Male**	2.278E-05	1.837E-03	1.941E-03	6.116E-06	3.807E-03
	Female	2.220E-05	1.790E-03	1.891E-03	5.960E-06	3.710E-03
Apple	**Male**	3.355E-05	1.248E-03	7.153E-04	1.109E-05	2.008E-03
	Female	3.539E-05	1.316E-03	7.545E-04	1.170E-05	2.118E-03
Grape	**Male**	1.570E-04	1.247E-03	2.767E-04	2.430E-05	1.705E-03
	Female	1.393E-04	1.106E-03	2.454E-04	2.156E-05	1.513E-03
Pear	**Male**	6.496E-05	6.488E-04	1.345E-03	1.255E-05	2.071E-03
	Female	7.753E-05	7.744E-04	1.605E-03	1.498E-05	2.472E-03

Note: TCR is Total Cancer Risk

3.8 Fuzzy TOPSIS method for carcinogenic human health risks posed by heavy metals in different fruits.

The Fuzzy-TOPSIS, four alternatives A_i cherry, apricot, apple, grape, and pear including the five criteria as beneficial criteria were analyzed. Where the performance score values in terms of Fuzzy ideal solutions to each alternative is shown in Table-8 and ranking for each alternative Ai to the relative nearest degree.

Table 8. Overall performance score and ranking of carcinogenic human health risks in different fruits

Fruits	d^{+}	d^{-}	P_i	Rank
Cherry	0.0003	0.0334	0.9911	1
Apricot	0.0333	0.0019	0.054	2
Apple	0.0334	0.0008	0.0234	4
Grape	0.0333	0.0006	0.0177	5
Pear	0.0334	0.0008	0.0234	3

The ranking order showed a cumulative or total cancer risk in decline pattern cherry>apricot>pear>apple>grape. It elucidated the maximum carcinogenic human health risks posed by heavy metals in different fruits found in cherry while the lowest was perceived in grapes for male and females respectively.

4. Conclusion

The results of the present study revealed that the level of all heavy metals was within recommended limits, whereas the estimated daily intake of heavy metals was within the suggested concentrations except Pb and Mn. Furthermore, cherry and apricot showed higher levels of Pb, although Mn exceeded in Apricot. Thus, there were no promising non-carcinogenic health risk concerns for all analyzed heavy metals owing to the estimated daily intake of metal values from the consumption fruits. Nevertheless, the results further confirmed the potential carcinogenic health risk a profound connection with the intake of fruits. In this regard, more research is required to examine the soil where fruits grow to further designing a robust bio-monitoring mechanism as developed countries undertake for ultimate food safety assurance.

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