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Human health risk assessment of metal contamination by consumption of contaminated apples due to growing power projects in Bharmour, district Chamba, India

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ABSTRACT

The environmental exposure to heavy metals is a critical situation of current scenario. We investigated level of nine different heavy metals (Zn, Co, Ni, Mn, Fe, Pb, Cd, Cu and Hg) and three essential metals (Na, K and Mg) in three different varieties (Red, Royal and Golden) of apples of Bharmour, Himachal Pradesh. This research deals with human health risk assessment of metal contamination through the consumption of three variety of apple (red, royal and golden). Hg and As was not detected in all the studied samples. This study will bring awareness to consumers of these fruits about what they are taking and the health implications as well as to assist them and the farmers in taking necessary precautions towards proper care of their fruits before consumption. The study was also done to investigate the bioaccumulation factor. Bioaccumulation factor of Cd was greater than 1 for all the three variety of apple while red apple also shows BCF value greater than 1 for Pb and Cu so these plants could be considered as accumulator for these metals and might be introduced as Cd-hyperaccumulator plants. Our study showed that native plant species growing on contaminated sites may have the potential for phytoremediation. Target Hazard Quotient (THQ) was also calculated to assess the health risk and also to determine carcinogenicity of the samples. The result shows that THQ for Pb and Cd were significantly higher than the other metals which signifies that daily exposure at this level may cause very serious health hazard to human being.

Keywords: Heavy Metals, Atomic absorption spectroscopy, Bioconcentration factor, Hyperaccumulator, Risk Assessment.

1. INTRODUCTION

The consumption of fresh fruits or juices, food pastes, jellies, jams assure the vitamins for a better life. The fruits contain the variable content of sugar, proteins, ascorbic acid, and mineral substances that are the essential part of human diet. Among fruit crops apples are found in the fourth place worldwide with 56 million tons annually. Apple plays an important role in all food diets and its therapeutic value is well known for different illnesses. It determines the absorption of gastric secretions, the elimination of toxins, and diuretic effects etc [1]. Fruits have a very important place in human diet, but unfortunately constitute a group of foods which contributes maximally to nitrate and other anions as well as heavy metal consumption.

It is known that systematic health problems can develop as a result of excessive accumulation of dietary heavy metals. Heavy metals are extremely persistent in the environment. They are non biodegradable and thermo stable and thus readily accumulate to toxic levels. The main sources of heavy metals to crops are their growth media (soil, air, nutrient solutions) from which these are taken up by the roots or foliage [2]. The other sources of heavy metals for fruits are: traffic density, rainfall in atmospheric polluted areas, use of fossil fuels and oil, heating, atmospheric dusts, plant protection agents and fertilizers which could be adsorbed. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soils [3-5].

Recently Himachal Pradesh, has been marked as the 'Power state' with a good potential to produce electric energy. More than 400 projects have been allotted and 43 are already commissioned in the Himachal Pradesh and three main commissioned power projects in Chamba district are Baira suil (198 MW), Chamera-I (540 MW) and Chamera-II (300 MW). These small hydropower plants also influence the microclimate as well as spatial distribution of macro invertebrate of the project site and vegetables/fruits grown surrounding of hydro power projects [6].

Keeping in view of toxicity, persistent nature and their behavior as well as the consumption of fruits and vegetables, there is necessity to test and analyzed these food items to ensure that the level of these contaminants meet the agreed international requirement. Although, pesticide and heavy metal contamination in food stuffs have been carried out for decades in most developed countries [7-9] but apples of Himachal Pradesh specially Bharmour, Chamba is not much investigated from heavy metal point of view.

Furthermore, several technologies are available to remediate soils that are contaminated by heavy metals. However, many of these technologies are costly (e. g. excavation of contaminated material and chemical/physical treatment) [10]. Phytoremediation can provide a cost-effective, long lasting and aesthetic solution for remediation of contaminated sites [11]. One of the strategies of phytoremediation of metal contaminated soil is phytoextraction i. e. through uptake and accumulation of metals into plant shoots, which can be harvested and removed from the site. Another application of phytoremediation is phytostabilization where plants are used to minimize metal mobility in contaminated soils. There has been a continuing interest in searching for native plants that are tolerant to heavy metals; however, few studies have evaluated the phytoremediation potential plants under field conditions [12, 13].

Moreover, several methods have been proposed for estimation of the potential risks to human health of heavy metals in food stuffs. The risks may be divided into carcinogenic and non-carcinogenic effects [14]. Risk assessment is one of fastest method which is need to evaluate the impact of the hazards on human health and also need to determine the level of treatment which are tend to solve the environmental problem that occur in daily life [15]. Current non-cancer risk assessment methods do not provide quantitative estimation of the probability of experiencing non-cancer effects from contaminant exposure. These method are typically based on the Target Hazard Quotients (THQ) [16].

The study therefore sought to qualitatively and quantitatively determine possible heavy metal contamination in three varieties of apple (Royal, Red and Golden) of Bharmour, Chamba district Himachal Pradesh with a view to compare the results with tolerable limits of WHO/FAO recommendations. Results concerning the relationships soil-plant in these areas and absorption of heavy metals in edible part of fruits are also given in the paper. The next objective of this research is to assess the feasibility to use these plants for phytoremediation purpose and to calculate THQ to assess the hazard to human health by consumption of these fruits.

2. MATERIAL AND METHODS

2.1. Sample Collection

This study was carried out at the Bharmour sub-tehsil of Chamba, Himachal Pradesh, India. Bharmour is one of the places which are famous for Red, Royal and Golden variety of apple. Bharmour, situated at an altitude of 7000 feet in the Budhil Valley (32.26 ^{0}N and 76.32 ^{0}E), forty miles to the south-east of Chamba. In Bharmour, four sub sites namely, Badhogli, Khadli, Banni and Patti, cited as Site 1, 2 and 3 throughout the paper, are choosed for the study. Fresh apple samples of three different varieties (Red, Royal and Golden) were collected from the orchids of the selected sub stations. In each farm, four sampling points were systematically choosed along crop planted rows at specified intervals of 20 cm from each other. At each sample location, apple samples of each variety were collected from four different locations to provide replicate samples of each plant. Soil samples from the rooting zone (0-10 cm) were taken from each sample location.

2.2. Sample preparation and treatment

2.2.1. Sample preparation of fruit sample

The fruit samples were rinsed with distilled water, peeled, sliced to obtain the edible portion for analysis. The samples were washed following the same procedures as for food preparation to remove any surface deposits[17]. Immediately after slicing samples were oven dried at 150 ^{0}C for 28 hours. The dried samples were then grounded to fine powder and passed through 2 mm sieve which further kept in polythene bags for acid digestion.

1.0 g of the samples were weighed and digested with the help of a mixture of 5 ml of HCl, 2 ml of conc. H_2SO_4 and 20 ml of conc. HNO_3 in a conical flask under a fume hood. The content was mixed and heated gently at 180-220 °C for about 30 min on a hot plate. The content was continuously heated till dense white fumes appear. The sample was then finally heated strongly for 30 min and then allowed to cool before making up to the mark in 50 ml volumetric flask. All reagents used were of analytical grade.

2.2.2. Sample preparation of soil sample

The collected soil samples were air-dried and sieved into fine powder. Well-mixed samples of 2 g each were taken in 250 ml glass beakers and digested with 8 ml of aqua regia for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 ml of 2% nitric acid, filtered and then diluted to 50 ml with distilled water.

2.3. Atomic absorption spetrophotometer

Analysis of heavy metals of interest was performed using a Atomic Absorption Spectrophotometer, fitted with a specific lamp of particular metal using appropriate drift blanks, of thermo spectronic-vision 32 software V1.25. All calculations have been performed to double precision as defined by ANSI/IEEE STD 754-1985.

2.4. Calculation of Hazard Quotient for benefit-risk ratio

Consuming fruits, a person will obtain a dose of heavy metal (DM) (mg/kg/day), which can be defined as:

$$DM = [HM] .c \qquad [1]$$

Where c (mg/kg) is the content of a metal in a studied fruit

Average daily intake (EDI) of metals can be calculated as:

$$EDI = DM/BW \qquad [2]$$

Where, BW is the body weight. The average body weight was taken as 70 kg for adults [17]. Daily apple consumption rate for adult residents was an average of 1.35 kg per year [18].

Risk of assuming a dose of heavy metal may be characterized using a total hazard quotient (THQ) [19], which can be represented as:

$$THQ = \frac{EF\ X\ ED\ X\ FI\ MC}{R_f D\ X\ BW\ X\ AT} X\ 10^{-3} \qquad [3]$$

Where EF is the exposure frequency (365 days/year), ED is the exposure duration (70 years), FI is the food ingestion (g/person/day), [MC] is the metal concentration in fruits (mg/kg), RfD (mg/kg/day) is a reference dose, defined as the maximum tolerable daily intake of specific metal that does not result in any deleterious health effects, BW is the average body weight. AT is average time (365 days/year x number of exposure years, assuming 70 years in this study). The oral reference dose was taken as 0.3, 2.0, 0.02, 1.4, 5.0, 0.04, 0.0005 and 0.004 mg/kg/day for Zn, Co, Ni, Mn, Fe, Cu, Cd and Pb respectively [20].

If the THQ is less than 1, obvious adverse effects are experienced by the exposed population of that particular area. If the THQ is equal to or higher than 1, there is a potential health risk, and related interventions and protective measures should be taken.

To evaluate the potential risk to human health through more than one heavy metals, the hazard index (HI) can be used. [19] The HI is the sum of the hazard quotients, as described in equation 4. It assumes that the magnitude of the adverse effect will be proportional to the sum of the multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organ.

$$HI = \sum HQ = HQ_{Zn} + HQ_{Co} + HQ_{Ni} + HQ_{Mn} + HQ_{Fe} + HQ_{Cu} + HQ_{Cd} + HQ_{Pb} \qquad [4]$$

3. RESULT AND DISCUSSION

3.1 Heavy and essential metal ion concentration in apple

The qualitative and quantitative results of heavy metals in different varieties of apple obtained in the study, is given in table 1.

Zn is an essential element for plants and animals, but only a small increase in its level may cause interference with physiological processes. The Zn concentration was found Higher than the permissible limit in red and royal apple whereas its highest concentration was found in red apple. Among all heavy metals, Zn is the least toxic and is an essential element in the human diet as it is required to maintain the proper functioning of the immune system, normal brain activity and is fundamental in the growth and development of the foetus. However, excessive Zn in the diet is also cause hazard to human health.

Co, a necessary cofactor for making the thyroid hormone thyroxin, and has also been used in anemia treatment as it causes the red blood cells production. The Co is less toxic as compared to that of many other metals[22]. The concentration of Co was found lower the permissible limits in all the samples.

The concentration of Ni and Mn are found very much below the permissible limit set by WHO/FAO, while the concentration of these metals was found highest in red apple in comparison to royal and golden apple. Ni is an abundant element naturally found in soil, water and food [23]. Natural sources of atmospheric nickel are dusts from volcanic emissions and the weathering of rocks and soils, while natural sources of aqueous nickel are derived from

Table - 1: Mean concentration (mg/kg) of heavy metals in different varieties of Apple sample collected from Bharmour, Himachal Pradesh.

Variety of Apple		Zn	Co	Ni	Mn	Fe	Pb	Cd	Cu	Hg	As
Red	Mean ±SD	**2.506 ± 2.099**	1.524 ± 0.773	0.531 ± 0.223	**1.312 ± 1.769**	3.145 ± 1.043	2.204 ± 1.481	0.200 ± 0.253	**2.755 ± 1.755**	ND	ND
	Range	0.615 - 4.832	0.406 - 2.1	0.304 - 0.838	0.200 - 3.954	2.09 - 4.58	0.558 - 4.161	0.070 - 0.58	0.247 - 4.113		
Royal	Mean ± SD	1.751 ± 0.113	1.613 ± 0.541	**0.216± 0.189**	**0.356 ± 0.148**	**1.327 ± 0.527**	**0.649 ± 0.281**	**0.057 ± 0.022**	**1.031 ± 0.688**	ND	ND
	Range	1.582 - 1.824	1.20 - 2.41	0.092 - 0.492	0.228 - 0.487	0.66 - 1.95	0.423 - 1.002	0.04 - 0.09	0.488 - 2.041		
Golden	Mean ± SD	1.035 ± 0.232	1.411 ± 0.725	**0.311 ± 0.137**	**0.367 ± 0.163**	**2.795 ± 0.678**	**1.055 ± 0.719**	**0.075 ± 0.545**	**0.293 ± 0.089**	ND	ND
	Range	0.815 - 1.298	0.565 - 2.02	0.188 - 0.448	0.227 - 0.545	1.85 - 3.46	0.382 - 2.047	0.03 - 0.15	0.208 - 0.418		
Permissible level as per (FAO & WHO)		**1.5**	**2.0**	**0.5**	**5**	**5**	**2**	**0.2**	**0.5**	**0.05**	**0.1**

In each row, mean value with bold font is significantly different from the corresponding WHO/FAO permissible value, 2011[21].
Bold with underlined means are critical values for necessary intervention.

Table - 2: Mean concentration (mg/Kg) of essential metals in different varieties of apple samples collected from Himachal Pradesh.

Variety of Apple		Na	K	Mg
Red	Mean ±SD	16.06 ± 10.11	374.92 ± 299.82	17.94 ± 3.93
	Range	5.3 -28	179.9 - 821.5	14.94 - 23.63
Royal	Mean ±SD	12.71 ± 11.20	388.67 ± 120.51	15.24 ± 0.74
	Range	2.48 -28.31	275.2 – 553.8	14.51 – 16.21
Golden	Mean ±SD	13.19 ± 11.54	276.80 ± 111.07	14.89 ± 1.53
	Range	3.35 - 25.63	150.2 - 410.9	12.81 - 16.40

biological cycles and solubilization of nickel compounds from soils [24, 25].

Cd is highly toxic and responsible for several cases of poisoning. Cd is so much toxic that its small quantity may cause adverse changes in the arteries of human kidney [26]. Pb and Cd toxicity are well documented and are recognized as a major environmental health risk throughout the world [27, 28]. Because of their high toxicity, Pb, and Cd need to be quantified in food and beverages [29]. The analysis of Pb and Cd content reveals the fact that the concentration of these two heavy metals was found much below the WHO permissible limits in royal and golden apple sample while their concentration is in the range of permissible limits in red apple sample.

It is also important to note that accumulation of different metals depends on the crop physiological properties. The low concentration of Cd in all samples may be due to the presence of sufficient amount of Zn which neutralizes the Cd contents [30]. Hence, low values are recorded in most of the samples.

Fe is an essential element for all forms of life. It takes part in photosynthesis, respiration, DNA synthesis, and hormone structure and action. The concentration of Fe was found very much lower than the maximum permissible limits in all the studies samples. Whereas, the concentration of Cu was found above the maximum permissible limits set by WHO/FAO in red and royal apple while its concentration was found much below the permissible limit in golden apple.

It is important to note here that Hg and as were not detected in all the samples. These are highly toxic heavy metals, their presence in food stuffs should be very negligible or in trace amount.

The mean concentrations of essential metals (Na, K and Mg) are given in table 2. It is clear from the table that the concentration of K was found very much higher as compared to Na and Mg in all the samples. The concentration of essential metals varies as K> Mg > Na in all the three types of apple.

Diuretic nature of K shows it's importance and Na is essential in the transport of metabolites. The ratio of K/Na in any food is an important factor as it prevents many diseases like hypertension arteriosclerosis[31]. Magnesium (Mg) improves insulin sensitivity, reduce blood pressure and protect against diabetes and its complications.

3.2 Heavy and Essential metal ion concentration in soil samples

Table 3 shows the mean concentration of heavy metals of the 0-10 cm subsoil of the selected areas of Bharmour. The investigation of the total content of the heavy metals in the soils was restricted to the sub surface soil since sub surface soil are better indicators of plant available metal uptake and not a major indicator of metallic burdens.

The concentration of all the heavy metals in soil (mg/Kg) in selected orchids of the study area are found much below than the permissible limit set by WHO [32]. The comparatively low soil trace levels might suggest that, perhaps, plant uptake some of these metals under irrigation has been high to the extent that their levels in the soils has been significantly lowered.

It is important to note here that Fe shows remarkable changes among all the four study centers. Fe concentration was found the highest (240 mg/Kg) at Khadli area whereas its minimum concentration was found in Banni area (3.85 mg/Kg) showing higher standard deviation. The higher standard deviation shows higher variation in the heavy metal distribution from the point source emission to the adjacent areas. The low standard deviation in Co, Ni, Pb and Cd may be described to its continuous removal by vegetable or fruit grown in studied area.

pH value of soil varies from 5.9 to 6.8. Soil pH had a narrow range between mild acidic (pH 5.90) at Patti to nearly neutral (pH 6.80) at Khadli. Akinola et al.[33] recorded a pH of 6.02 for soil from a non-industrial area and concluded that soils with near neutral pH cause low uptake of heavy metals by vegetables, thereby leaving a higher concentration of the metals in the soil. In our study, it was observed that soil at Patti area is somewhat acidic in caparison to other studied areas and at Patti area concentration of heavy metals is minimum in comparison to other studies areas which is in good agreement with Akinola et al and Lugwisha Esther Hellen [34].

3.3. Accumulation of metals in Plants

Bio concentration factor (BCF) or Plant concentration factor is a parameter used to describe the transfer of trace elements from soil to plant edible parts. In other words, we can say a plant's ability to accumulate metals from soils can be estimated using the BCF, which may be defined as the ratio of metal concentration of plant to the corresponding soil [35,36].

$$\mathbf{BCF = [X]_{plant}/[X]_{soil}}$$

Where, $[X]_{plant}$ and $[X]_{soil}$ represents the heavy metal concentration in extract of plants and soils respectively.

By comparing BCF values, we can compare the ability of different plants in taking metals from soils. Plants exhibiting BCF values less than one are unsuitable for phytoextraction. A few species growing at the site were capable of accumulating heavy metals in the roots, but most of them had low BCF values, which means limited ability of heavy metal accumulation and translocation by plants [36].

For most metals, a BCF value greater than 1 means that bio-accumulation of the metals by organisms occurs that is usually unexpected[37]. As usual, most of the metals have BCF values less than 1, which are considered normal. Cu has the highest values of BCF for all the three varieties of apples. All these values were considered too high when compared with the highest value of 1.00 expected for any metal. An interesting observation is that most of the plants are efficient in taking up Cu from soil. Red apple has BCF value greater than 1 for Pb, Cu and Cd, while royal and golden apple has BCF value greater than 1 only for Cd (Table 4). The high BCF values obtained for Cu, Cd and Pb therefore indicated that the metals were highly bioaccumulated and bio-magnified in the tissues It is important to note here that in our study Pb, Cd, and Cu are the trace elements which are mainly transfer from soil to plants in the different variety of apple at studied stations and Ni, Mn and Fe are showing least absorption in all the samples.

The variation in heavy metal concentrations in fruit and vegetables were due to variation in their absorption and accumulation tendency. Soil properties such as Ph, soil texture,

Table - 3: Heavy, essential metal concentration (mg/Kg) and pH in soil samples collected from studied area of Bharmour, Chamba.			
Metals	**Mean**	**Standard Deviation**	**Range**
Zn	4.810	2.988	0.73 - 7.91
Co	1.873	0.768	1.36 -3.00
Ni	1.620	0.682	0.99 - 2.58
Mn	14.543	5.182	6.86 - 18.22
Fe	116.513	125.132	3.85 - 208.5
Pb	1.258	0.393	0.69 - 1.54
Cd	0.033	0.005	0.03 - 0.04
Cu	2.428	1.118	1.57 -3.92
Hg	ND	ND	ND
As	ND	ND	ND
Na	21.690	8.820	11.59 - 29.75
K	458.400	417.308	60.5 - 862.2
Ca	159.503	72.567	92.41 - 227.6
Mg	121.468	79.120	65.17 - 233.48
pH	6.375	0.377	5.9 - 6.8

Table - 4: Bioconcentration Factor (BCF) of Samples of Heavy as well as essential metals.			
Metals	**Red Apple**	**Royal Apple**	**Golden Apple**
Zn	0.52	0.364	0.215
Co	0.813	0.861	0.753
Ni	0.327	0.133	0.191
Mn	0.09	0.024	0.025
Fe	0.026	0.0113	0.0239
Pb	**1.751**	0.515	0.838
Cd	**6.06**	**1.727**	**2.272**
Cu	**1.134**	0.424	0.12
Hg	ND	ND	ND
As	ND	ND	ND
Na	0.74	0.585	0.686
K	0.817	0.847	0.603
Mg	0.147	0.125	0.122

Values>1 are in bold font

redox botanical, organic matter, cation exchange capacity, and clay content may also affect the heavy metal uptake [38].

Heavy metal-tolerant species with high BCF can be used for phytostabilization of contaminated site. According to our study red apple plant for Pb, Cd abd Cu, royal and golden apple plant for Cu can be used for phytostabilization of these particular sites (Table 4).

Phytostabilization can be used to minimize migration of contaminants in soil[39]. This processes uses the ability of plant roots to exchange the environmental conditions via root edudates. Plants can immobilize heavy metals through absorption onto roots, or precipitation with rhizosphere. The process reduces metal mobility and leaching into ground water, and also reduces metal bio ability for entry into the food chain. By using metal tolerant plant species for stabilizing contaminant in soil, particularly metals, it could also provide improved conditions for natural attenuation or stabilization of contaminants in the soil. However, studies are needed regarding the turnover of nutritive roots and the potential release of metals from decomposing roots [40].

3.4. Human health risk assessment

The THQ which is the ratio between the exposure and the reference dose (or RfD), is used to express the risk of non-carcinogenic effects by consumption of any edible. THQ is less than 1 signifies no risk. Conversely, an exposed population of concern will experience health risk if the dose is equal to or greater than the RfD. THQ is calculated by the method provided in the United States EPA Region III risk-based concentration table [41]. The dose calculations were carried out using standard assumptions from an integrated United States EPA risk analysis. Some assumptions listed in table 5 are taken during this study for the health risk calculations.

Table - 5: Assumption for THQ calculation.

Assumption for THQ calculation	Reference
Ingested dose is equal to the absorbed Pollutant dose	[41]
The average body weight for Adults Assumed to be 70 Kg	[17]
Average lifeline is 70 years	[17]

The target hazard quotients (THQ) of studied metals through consumption of different types of apples for residents were derived and listed in Table 6. Pb and Cd has the highest THQ value and it was very much higher than comparable values for other heavy metals. This research found that Pb was a major risk contributor for general population of Bharmour Himachal Pradesh, accounted for 52.40 % for red apple, 50.32 % for royal apple and 59.44 % for golden apple of the total THQ (Table 7). The next higher risk contributor element was Cd, contributing about 37.00 % for red apple, 35.40 % for royal apple and 34.24 % for golden apple of the total THQ.

The THQ of Pb, Cd and Cu is very much greater than 1 in all the three types of apple whereas THQ of these heavy metals is the highest for red apple. These results indicate that people would experience significant health risk from the consumption of individual metals through contaminated apple from the selected region. However, the health risk associated with red apple is highest among the three varieties of apples.

In addition, there are also other sources of metal exposures, such as consumption of other foodstuffs and dust inhalation, which were not included in this study.

Although, the HQ based risk assessment method provides an indication of the risk level due to exposure of pollutants. However, it does not provide a quantitative estimation for the probability of an exposed population experiencing a reverse health effect [32]. Many researchers consider the risk estimation method reliable and it has been proven to be valid and useful.

Table - 6: Estimation of daily intake of metal (mg/Kg) and target hazard quotient (THQ).

Variety of Apple		Zn	Co	Ni	Mn	Fe	Pb	Cd	Cu	Total
Red Apple	EDI	0.048	0.029	0.010	0.025	0.060	0.043	0.004	0.053	0.271
	THQ	0.160	0.015	0.500	0.018	0.012	**10.625**	**7.600**	**1.325**	20.254
Royal Apple	EDI	0.033	0.031	0.004	0.007	0.026	0.013	0.001	0.020	0.134
	THQ	0.110	0.016	0.208	0.005	0.051	**3.125**	**2.200**	0.495	6.209
Golden Apple	EDI	0.020	0.027	0.006	0.007	0.053	0.020	0.001	0.006	0.140
	THQ	0.066	0.014	0.295	0.005	0.011	**5.000**	**2.880**	0.141	8.411
RfDo (mg/kg/day)		0.3	2	0.02	1.4	5	0.004	0.0005	0.04	8.7645

Table - 7: Showing % of metal contribution to THQ.

Variety of Apple	Zn	Co	Ni	Mn	Fe	Pb	Cd	Cu
Red Apple	0.79	0.07	2.46	0.09	0.06	52.40	37.00	6.54
Royal Apple	1.77	0.25	3.34	0.08	0.82	50.32	35.40	7.97
Golden Apple	0.78	0.16	3.51	0.06	0.13	59.44	34.24	1.61

4. CONCLUSION

The aim of this research was to provide assessment of heavy metal contamination in three varieties of apples found in Bharmour area of Chamba district, Himachal Pradesh. The concentration of all the metals (Co, Ni, Mn, Fe, Cd and Pb) was found much below than the permissible limit of WHO/FAO while Zn and Cu concentration was found above the permissible limits. The concentration of Zn in red apple and Cu concentration in red and royal apple are found in critical situation. Zn concentration in red apple 2 fold higher, Cu concentration in red apple 5 fold and in royal apple 2 fold higher are shown by the result.

The concentration of all the heavy metals are also estimated in soil samples but their concentration in all the soil samples was not exceeding the maximum permissible limits.

The health risks posed by exposure to heavy metals Zn, Co, Ni, Mn, Fe, Cu, Cd and Pb to the local inhabitants through the consumption of contaminated fruits were investigated based on estimated target hazard quotients (THQs). THQ value was found <1 for Pb and Cd in all the three types of apple. Pb is the major risk contributor which account for around 50 % of THQ in all types of apples and Cd is the second major risk contributor, which account around 30 % in all types of apples.

Furthermore, the study was also conducted to screen plants growing on a contaminated site to determine their potential for metal accumulation. Among the three varieties of apple, red variety of apple for Cd, Pb and Cu while royal and golden apple for Cd was found to be most effective in taking up these metals from soil. The phytoremediation potential of these plants species, especially for use in sub-tropical and tropical areas need to be further investigated.

At last, it can be said that the intensive uncontrolled operations of various power plant in Bharmour, district Chamba has resulted in the release of trace metals in the local environment and fruits grown in the nearby sites were contaminated by Pb, Cd and Cu which could be potential health concern to the local residents. Consumption of contaminated apple of this particular area could lead to changes in health of the inhabitants of nearby areas, and can contribute to the emergence of various chronic diseases. The phenomenon has become alarming for people, who systematically eating such fruits growing in polluted areas and an urgent step is taken by relevant agencies to address this issue.

Conflict of Interest

There is no conflict of interest in this Manuscript.

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