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Original article

Elemental concentration of heavy metals in oyster mushrooms grown on mine polluted soils in Pretoria, South Africa

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A B S T R A C T

Issues of food security remains a major subject in ensuring sustainable global development and thus the hazardous effects of heavy metals on food substances call for concern due to the threat on human health and food security at large. *Pleurotus ostreatus* is an edible mushroom species with a promising nutritional and medicinal values. However, *P. ostreatus* is quite susceptible to heavy metal contamination from either polluted soil, mining or other anthropogenic activities. Aim at elucidating on the level of contamination and risk associated with the consumption of *P. ostreatus* from a polluted source, this study examined the amount of heavy metals in the caps and stalks of *P. ostreatus* grown in a soil sample collected from a mined site. Soil samples were obtained from three different mining areas and *P. ostreatus* spawns were grown in triplicates on these soils and on unpolluted soil. At maturity, the harvested parts (cap and stalks) were analyzed for heavy metals using Inductively Coupled Plasma Mass Spectrometry (ICP–MS). We found that mean concentration of chromium, manganese, cobalt, nickel, zinc, cadmium, mercury and lead were significantly different ($p < 0.05$) across the sites. Among the heavy metals investigated, Zn, Cd and Cr topped the permissible values allow for consumption. Though *P. ostreatus* stalk had higher concentrations of heavy metals than the caps, there was a positive correlation of the metal contents between the two components. The values obtained for the transfer factor pointed to the ability of *P. ostreatus* to accumulate cobalt, copper, zinc, arsenic, cadmium and lead. Based on hazard quotient (HQ) values obtained for both adults and children, we suggest that there are no possible human carcinogenic risks associated with the consumption of the Oyster mushroom. However, the continuous consumption may result into a serious health hazard owing to the levels of some heavy metals that were above the permissible limit considered safe for human consumption. It can be concluded from the study that *P. ostreatus* possess the potential to bio-accumulate toxic metals from polluted soils hence we recommend that caution must be taken not to harvest mushroom on polluted soils.

1. Introduction

Mining is one of the major sectors that supports different developmental projects and the economy of South Africa (Davies and Mundalamo, 2010). It contributes to the country's gross rate by providing jobs, generating coal for the energy sectors, as well as contributing to the inflow of capital into the economy (Davies and Mundalamo, 2010). However, several heavy metals including arsenic, iron and zinc are emitted during mining operation. These heavy metals unfortunately get into the food chain and become a potential health hazard to consumers (Cheng et al., 2018; Lu et al., 2019). Previous investigations have reported heavy metals accumulation in consumed plants; medicinal plants, leafy vegetables and ornamental plants (Aina et al., 2018). Similarly, fungi such as mushroom are extremely susceptible to metal contamination (Guerra et al., 2012).

Generally, mushrooms are full of different classes of nutrients and as such recognized as food, medicine and even cultivated on

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a large scale for commercial purposes (Elkhateeb et al., 2019). In South Africa, most people consume mushrooms as source of vegetable soup and has great health benefit.

Despite their reported nutritional and medicinal values, earlier report has pointed out the deposition of toxic metals in mushroom with their utmost concentration abundant in the spore forming part and likewise distributed unevenly in the fruiting body (Soylak et al., 2005). Indeed, mushrooms possess a special system that aids the absorption of metals from the substrate through their mycelium and this makes them more useful and reliable compared to green plants in bio-remediation of contaminated soils. They bioaccumulate more heavy metals in their fruiting bodies; due to the mycelium structures they possess (Demirbas, 2001).

Heavy metal pollutants remain major source of concern due to their negative impacts on human's health. Some of these metals like cadmium and arsenic are unstable in nature. They can be easily circulated in the environment by wind during a rise in temperature and further increase several worse health conditions (Beccaloni et al., 2013). Yet, vast number of mushrooms species including the edible ones possessed capacity to assimilate heavy metals into their tissues (Malinowska et al., 2004). Mercury for instance often attach to the sulfhydryl groups of the substrates thus aiding its movement from the mycelium to the cap and stalk of the mushroom. Such mechanism is also applicable to other heavy metals including cadmium, lead and nickel (Kojo and Lodenius, 1989).

Efforts are geared towards the evaluation of food safety in consumption of mushrooms most especially those ones that has an efficient system in the translocation of toxic metals in their tissues (Gast et al., 1988). For example, Kalac et al. (2004) report on the concentration of heavy metals in some edible mushrooms. However, only little attention has been paid to the ability of mushrooms particularly *Pleurotus ostreatus* to serve as bio-remediators of heavy metals from polluted soils.

Pleurotus ostreatus is the most popular edible mushroom in South Africa, according to the report of Southern African Development Community (SADC) due to the satisfying taste (Khan et al., 2013). But despite the popularity of oyster mushroom in South Africa, few studies exist on the documentation of mushroom in some polluted sites most especially the mining sites in South Africa except for Sithole et al., (2017) using white button and crimini varieties of *Agaricus bisporus*.

Although, findings have reported abundance of heavy metals in both edible and non-edible species of mushroom (Rasalanavho et al., 2020), however studies on *P. ostreatus* is scanty and little is known about the possible health hazard that could result from the consumption of oyster mushrooms grown in mine polluted soil in South Africa. Hence, this study examined the levels of heavy metals in *P. ostreatus* (oyster mushrooms) planted on soils collected at three mine in Pretoria, South Africa and assess the health risks linked with eating of mushrooms which grow around the mining areas. The findings of this study will also give information on variation of heavy metal concentration in 3 different mine sites.

2. Methodology

2.1. Sampling procedure

Soil samples were collected from Platinum mining site, chromium mining site and iron and chromium mining site and a control site (Sefako Makgatho Health Science University) represented as Sites A, B, C and D respectively. The soil samples were retrieved into 20 pots of 22 cm diameter.

Straw substrates and mushroom spawns were sourced from a store in Pretoria, South Africa.

2.2. P. ostreatus cultivation and sample preparation

P. ostreatus was planted as previously reported by Sithole et al. (2017). Spawn of *P. ostreatus* (Oyster mushroom) was mixed with soils obtained from the three mined sites as casing layer. The samples were transferred into a growth chamber with room temperature regulated to 22.5 ± 0.5 °C and humid condition was set by sprinkling water till the reproductive phase was reached. At maturity (5 months after spawning), harvest was done and detached to parts: caps and stalks. The detached components were placed in a 60 °C regulated oven for 48 h drying. Sieve of mesh size 2.0 mm was used to sieve the ground samples of mushroom before elemental analysis for heavy metal.

2.3. Elemental analysis using ICP-MS

The mushroom and soil samples were subsequently digested and investigated for heavy metal content using the system described by Mustafa et al. (2005). Briefly, mass of 5 g were retrieved from mushroom and soil samples. Solution consisting of 6 ml of Merck supra pure HNO_3, 2 ml Merck supra pure of $HClO_4$, 3 ml of 37% Merck supra pure HCl and 2 ml of 48% Merck supra pure HF were used in the digestion system. Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine the concentration of toxic metals in the digested solution made up to required volume.

2.4. Quality assurance

Quality assurance was ensured by preparing blanks for both mushroom samples and soil separately. The certified reference material used was NCS DC 73,309 which upon analysis for heavy metals using ICP-MS gave a recovery rate ranging from 96 to 99% for all the heavy metals analysed.

2.5. Mushroom Removal factor (RF)

To obtain the Removal factor (RF), method used by Olowoyo et al. (2011) the proportion of metal abundance in mushroom and soil was calculated as previously (Olowoyo et al., 2011).

$$RF = Cmp/Csoil$$

where

The abundance of heavy metals in mushroom and soil prior to planting mushroom are represented by C_{mp} and C_{soil} respectively.

2.6. Health risk potential

The potential health risk of consuming oyster mushroom planted in mining sites was evaluated as hazard quotient. This was estimated using the equation of Nabulo et al. (2010).

$$HQM = ADDM/RfDM$$

where

ADDM and RfDM are the mean daily dose (µg/g) of the element and dosage reference respectively.

ADDM was calculated as:

$$ADDM = DI \times MF_{MUSH}/WB$$

DI is the daily mushrooms intake (0.182 kg/d for adults and 0.118 kg/d for children); MF_{MUSH} is the concentration of heavy metal in the mushrooms and 55.7 kg body weight (WB) for adults and children body weight used was 14.2 kg (WB) based on the previous investigation of Olowoyo and Lion (2013).

Dosage Reference values of 15.0 µg/g, 2.0–3.0 µg/g, 1.4 µg/g and (0.245 µg/g) for zinc, copper, nickel, and lead, respectively were used (WHO, 1993, 1994; USEPA 2010) as RfDM. HQM values >1 signifies possible health risks due to the consumption of the mushroom.

2.7. Statistical analysis

The variations of abundance of heavy metals between the caps and stalks was examined using Student *t*-test. The strength of the relationship among the metals detected from the two parts (caps and stalks) was tested using correlation coefficient. All analysis was performed using the SPSS version 23.0 software.

3. Results and discussion

3.1. Heavy metals concentration in soil

The average concentration of heavy metals in the soil sample before cultivating mushrooms was in the order chromium > manganese > nickel > copper > zinc > copper > arsenic > lead > cadmium (Table 1). The highest mean concentration for all the heavy metals in soil samples before cultivating mushrooms was recorded for chromium from site B. The concentration ranged from 684.45 ± 1584.27 μg/g to 1584.27 ± 16.51 μg/g. Cadmium at the range of 0.01 ± 0.00 μg/g – 0.12 ± 0.00 μg/g had the least values among the heavy metal detected in the soil samples from site prior to cultivating mushrooms. Consistent with the previous reports by Olowoyo et al. (2013) and Chopin and Alloway (2007), all the soil sample used in this study were acidic; thus, favor the mobility of heavy metals in the soil and their subsequent uptake by the mushrooms. Organic matter content is another factor that determines the mobility of heavy metals in soil. In this study, it was evident that the low organic matter content before and after harvesting the mushrooms favored the mobility of heavy metals in the soil and probably enhanced the growth of the mushrooms. Since fungal and bacteria are known to grow well in low organic matter content soils (Tangahu et al., 2013).

Across the investigated mine sites, the concentration of arsenic, cadmium, chromium, cobalt, lead, manganese, nickel and zinc were significantly different, but no significant difference was observed for the copper concentration (Table 1). The high concentrations of heavy metals noted in this study could be attributed to mining activities and atmospheric pollutants caused by vehicular emissions around the mining sites. Movement of trucks and other automobiles coming in and out of the mining industries might have also accounted for heavy metals high levels. There is evidence of gaseous flames from site C during the working hours of the day which could also contribute to atmospheric pollution polluting the soil (Olowoyo et al., 2013).

3.2. Heavy metals in different part of Pleurotus ostreatus

The mean concentration of heavy metals in the caps of *P. ostreatus* decreased in order of zinc > copper > manganese > nickel > cobalt > chromium > arsenic > cadmium > mercury > antimony (Table 2). Oyster mushroom cap had Zn concentration that surpassed the prescribe WHO limit (60 μg/g; WHO, 1989) in food and 40.3–64.4 μg/g and 29.3–158 μg/g reported by Mendil et al. (2004), but below 75.99–94.61 μg/g stated by Sithole et al. (2017). Although, Zinc (Zn) has an intrinsic effect on growth of human but when in excess, it could cause retardation in young children and lead to poisoning (Singh and Taneja, 2010).

Several researchers (Soylak et al., 2005; SESLI, 2006) presented a different reports when compared with our studies. The concentration of Cd in cap of Oyster mushroom grown on mine soil was generally low (Table 2). Nevertheless, the concentration of cadmium in the caps of *P. ostreatus* (oyster) mushrooms grown in soil collected from site C exceed the recommended limit of 0.05 mg/kg in food as set by WHO (WHO, 1996). The implication of Cd concentration higher than recommended limit and possibility of being accumulated in the body can affect kidneys and liver (Food and Agriculture Organization/ World Health Organization, 2000). Previous studies however, have reported that plants grown in soil containing high levels of cadmium showed symptoms of chlorosis, growth inhibition, browning of root tips and finally death (Wójcik and Tukiendorf, 2004).

Chromium concentrations in mined harvested mushroom was above limit set by WHO in food (WHO, 2001). The Cr concentrations was expected between 0.2 and 5.5 μg/g most especially in toodlers as recommended by Hamrick and Counts (2008). In this study, there were significant differences in the mean concentrations of chromium, manganese, cobalt, nickel, zinc, cadmium, mercury and lead using (Table 2). The concentration of arsenic showed no significant difference in all the mushrooms ($p < 0.05$).

In the stalks of *P. ostreatus*, the heavy metals concentration decreased such that manganese > copper > zinc > chromium > nicke l > arsenic > lead > cadmium > lead > antimony respectively. Mean manganese concentration was highest in the stalks harvested from control site and was between 9.50 ± 0.11 μg/g and 40.12 ± 0.53 μg/g. Manganese (Mn), aside being an essential metal in biological system, it is beside tangled in several chemical procedures in the body and when in excess it can lead to mental disorder due to malformations of the nerve cells (Singh and Taneja, 2010). Mn concentration in Oyster mushroom in our study was above the ranged reported in the previous study of Sithole et al. (2017) where 7.6–492 μg/g were measured in Agaricus species.

Antimony had the maximum mean concentration among all the heavy metals analysed in stalks harvested from soil collected from site D which ranged from 0.01 ± 0.00 μg/g–0.02 ± 0.00 μg/g. There

Table 1
Trace metals concentrations (μg/g dry weight) from collected soil samples before cultivating the mushroom.

Trace metals	Before cultivating mushroom			
	Site A	Site B	Site C	Site D
Cr	778.66 ± 9.31[c]	1584.27 ± 16.51[d]	1386.33 ± 9.29[b]	684.45 ± 2.96[a]
Mn	888.45 ± 11.55[a]	727.14 ± 2.16[b]	191.92 ± 2.32[c]	194.94 ± 5.49[c]
Co	23.56 ± 1.93[a]	22.66 ± 0.60[a]	1.30 ± 0.01[b]	1.32 ± 0.06[b]
Ni	95.00 ± 3.29[a]	80.80 ± 3.72[b]	71.68 ± 1.53[c]	70.48 ± 1.23[c]
Cu	22.64 ± 0.90[a]	22.54 ± 1.77[a]	81.76 ± 50.06[a]	16.16 ± 0.44[a]
Zn	32.47 ± 0.81[a]	29.53 ± 2.08[b]	14.84 ± 0.14[c]	12.92 ± 0.07[c]
As	0.82 ± 0.04[a]	0.83 ± 0.02[a]	0.14 ± 0.00[b]	0.20 ± 0.02[b]
Cd	0.12 ± 0.00[a]	0.05 ± 0.00[b]	0.01 ± 0.00[c]	0.01 ± 0.01[c]
Pb	0.53 ± 0.04[a]	0.51 ± 0.01[a]	0.14 ± 0.01[b]	0.08 ± 0.06[b]

Values in the same row with different letter (s) are significantly different ($p < 0.05$) and values in the same row with the same letter (s) are not significantly different ($p < 0.05$).

Table 2
Mean trace metal concentrations (µg/g dry weight) in the caps of *Pleurotus ostreatus* (oyster) mushroom grown on mine soils.

Trace metals												
Sites	Plant Part	Cr	Mn	Co	Ni	Cu	Zn	As	Cd	Sb	Hg	Pb
A	Cap	1.22 ± 0.02^{c}	8.32 ± 0.06^{c}	3.13 ± 0.06^{b}	4.30 ± 0.49^{b}	17.33 ± 0.08^{a}	65.83 ± 0.45^{b}	0.15 ± 0.14^{a}	0.10 ± 0.02^{b}	0.01 ± 0.00^{a}	0.02 ± 0.01^{b}	0.16 ± 0.01^{c}
	Stalk	2.36 ± 0.13^{c}	$\mathbf{15.59 \pm 0.21^{c}}$	2.92 ± 0.09^{b}	9.86 ± 0.24^{b}	29.52 ± 0.51^{b}	29.28 ± 0.53^{b}	0.27 ± 0.09^{a}	0.03 ± 0.00^{b}	0.01 ± 0.00^{b}	ND	$\mathbf{0.24 \pm 0.01^{c}}$
B	Cap	2.87 ± 0.03^{a}	9.10 ± 0.05^{b}	1.51 ± 0.03^{c}	2.65 ± 0.24^{d}	12.9 ± 0.13^{d}	68.1 ± 0.19^{c}	0.23 ± 0.06^{a}	0.13 ± 0.01^{b}	0.01 ± 0.00^{a}	0.11 ± 0.03^{a}	0.13 ± 0.00^{c}
	Stalk	7.85 ± 0.37^{b}	$\mathbf{9.50 \pm 0.11^{d}}$	0.75 ± 0.03^{c}	3.92 ± 0.35^{d}	15.06 ± 0.67^{d}	22.02 ± 0.56^{c}	0.30 ± 0.06^{a}	0.03 ± 0.00^{b}	0.01 ± 0.00^{a}	0.03 ± 0.01	$\mathbf{0.20 \pm 0.01^{c}}$
C	Cap	2.46 ± 0.14^{b}	9.58 ± 0.21^{b}	0.57 ± 0.02^{c}	2.16 ± 0.17^{c}	16.87 ± 0.53^{b}	77.65 ± 1.72^{a}	0.26 ± 0.07^{a}	0.18 ± 0.03^{b}	0.01 ± 0.00^{a}	0.15 ± 0.04^{a}	0.26 ± 0.01^{b}
	Stalk	9.99 ± 0.87^{a}	$\mathbf{17.63 \pm 1.34^{b}}$	0.77 ± 0.05^{c}	5.15 ± 0.29^{c}	36.64 ± 2.09^{a}	36.16 ± 3.54^{a}	0.35 ± 0.08^{a}	0.09 ± 0.02^{a}	0.01 ± 0.00^{b}	0.06 ± 0.03	$\mathbf{0.72 \pm 0.05^{a}}$
D	Cap	1.42 ± 0.02^{c}	10.01 ± 0.12^{a}	3.87 ± 0.08^{a}	4.63 ± 0.07^{a}	14.66 ± 0.36^{c}	66.12 ± 2.66^{c}	0.13 ± 0.06^{a}	0.20 ± 0.02^{a}	0.01 ± 0.00^{b}	0.09 ± 0.01^{a}	$\mathbf{1.18 \pm 0.03^{a}}$
	Stalk	1.84 ± 0.14^{c}	$\mathbf{40.12 \pm 0.53^{a}}$	4.16 ± 0.19^{a}	14.93 ± 0.34^{a}	25.62 ± 0.98^{c}	24.03 ± 0.45^{c}	0.33 ± 0.04^{a}	0.04 ± 0.00^{b}	0.02 ± 0.00^{a}	ND	0.33 ± 0.01^{b}

Values in the same column with different letter (s) are significantly different ($p < 0.05$) and values in the same column with the same letter (s) are not significantly different ($p < 0.05$).

were significant differences in the mean concentrations of chromium, manganese, cobalt, nickel, copper, zinc, antimony, mercury and lead while there was no significant difference in the mean concentration of cadmium and arsenic using Table 2 respectively ($p < 0.05$).

CO_2 assimilation and ATP synthesis are key roles played by Copper though excess Cu in humans can lead to blood and nerve disorders. Generally, the stalk of oyster mushroom had the maximum concentrations of all heavy metals compared to the caps with the highest Cu concentration of 36.64 ± 2.09. WHO set a safe limit 40 µg/g which was exceeded by our observed concentrations (caps and stalks) and those in reported literatures from Isiloglu et al. (2001) and Sivrikaya et al. (2002).

Statistical analysis indicated that the findings obtained for some of the heavy metals in the caps and stalks correlated positively with each other suggesting a common source for the heavy metals. Oyster mushrooms showed strong correlation between the values recorded for nickel, arsenic, uranium, mercury and cadmium ($r = 0.65$, 0.64, 0.87, 0.75 and 0.89) from the caps. Positive correlation was also found between the values recorded for cobalt and manganese, nickel and manganese, nickel and cobalt, copper and chromium, copper and manganese, arsenic and chromium, arsenic and manganese, cadmium and zinc and lead and chromium from the stalk (Table 3). A negative correlation was found between the values recorded for manganese and chromium, cobalt and chromium, nickel and chromium, zinc and chromium, zinc and manganese, arsenic and cobalt, cadmium and chromium and cadmium and manganese.

3.3. Bioaccumulation factors of heavy metals by the stalks and caps of mushrooms

Based on the transfer factor from the present study, *Pleurotus ostreatus* indicated the capability to bio-accumulate cobalt, copper, zinc, arsenic, cadmium and lead from its fruiting bodies because the transfer factors (TF) were greater than 1 for these heavy metals (Table 4).

The findings of Lion and Olowoyo (2013) reported that the risk in consuming vegetables from the mining sites which may be similar to the present study since soil from mining areas were used for cultivation. Branco (2010) also stated the ability of fungi to flourish on media with high heavy metals which support our findings of *Pleurotus ostreatus* flourishing well in a mine polluted soil with possibility of uptake and transfer factors being affected from the interaction of the heavy metals in the soil up to the caps

The TF values measured were above the reported values in other plants found growing on a waste dump site and does not conform to the study of Olowoyo and others (2011). Heavy metals might have been stored in the stalks after assimilating from the soil prior to upward movement to the cap, therefore higher and lower amount of some heavy metals were found in the stalks and caps respectively. However, our results also affirmed that *Pleurotus ostreatus* (oyster) mushrooms were found to accumulate high concentration of metal in caps as compared to the stalks and while compared with earlier report of Sithole et al. (2017). Oyster mushroom stalk having higher concentrations of heavy metals is not an indicative of only health hazard to human consumption however this could probably cause delay or inability of the needed antioxidant production from the mushroom. In similar form, Sarikurkcu et al. (2010) stated that the reducing power and chelating capacity in mushrooms increased with concentration of some heavy metals.

3.4. Hazard quotient of Pleurotus ostreatus (oysters) mushroom from different mining sites and control area

The health risk associated with the consumption of heavy metals through mushrooms was assessed by estimating the hazard

Table 3
Correlation Coefficient of trace metal concentrations (µg/g) in the caps and stalks of *Pleurotus ostreatus* (oysters) mushrooms grown on mine soils. Bold values are transfer factor that are greater than 1.

Metals	Cr	Mn	Co	Ni	Cu	Zn	As	Cd	Sb	Hg	Pb	U
Cr	**1**											
Mn	−0.06	**1**										
Co	−0.68	0.47	**1**									
Ni	−0.21	0.91	0.65	**1**								
Cu	0.45	0.5	0	0.51	**1**							
Zn	−0.48	−0.58	−0.09	−0.66	−0.56	**1**						
As	0.64	0.57	−0.41	0.41	0.64	−0.69	**1**					
Cd	−0.34	−0.45	−0.04	−0.58	−0.45	0.89	−0.59	**1**				
Sb	−0.03	0.78	0.19	0.71	0.08	−0.62	0.6	−0.59	**1**			
Hg	−0.35	−0.09	−0.21	−0.71	−0.21	0.65	−0.01	0.75	0.01	**1**		
Pb	0.08	0	0.29	−0.03	0.14	0.11	−0.25	0.51	−0.38	0.08	**1**	
U	0.35	0.56	−0.05	0.59	0.87	−0.62	0.74	−0.65	0.35	−0.12	−0.26	**1**

Table 4
Transfer factor (TF) values for caps and stalks in Pleurotus ostreatus (oysters) mushroom grown on soils from different mining sites and control area. Bold values are transfer factor that are greater than 1.

Metals	Site A		Site B		Site C		Site D[a]	
	Caps	Stalks	Caps	Stalks	Caps	Stalks	Caps	Stalks
Cr	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Mn	0.01	0.02	0.01	0.01	0.05	0.09	0.05	0.21
Co	0.13	0.12	0.07	0.03	0.44	0.59	**2.94**	**3.15**
Ni	0.05	0.10	0.03	0.05	0.03	0.07	0.07	0.21
Cu	0.77	**1.30**	0.57	0.67	0.21	0.45	0.91	**1.59**
Zn	**2.03**	**0.90**	**2.31**	**0.75**	**5.23**	**2.44**	**5.12**	**1.86**
As	0.19	0.34	0.28	0.37	**1.92**	**2.55**	0.70	**1.70**
Pb	0.32	0.46	0.27	0.40	**1.92**	**5.14**	**14.81**	**4.18**

[a] Transfer Factor (TF) greater than 1 are bolden (TF>1).

Table 5
Hazard Quotient for adults and children consuming *Pleurotus ostreatus* (oyster) mushrooms grown on soils from different mining sites.

Metals	Age Group	Site A		Site B		Site C		Site D	
		Caps	Stalks	Caps	Stalks	Caps	Stalks	Caps	Stalks
Zn	Adults	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01
	Children	0.04	0.02	0.04	0.01	0.04	0.02	0.04	0.01
Cu	Adults	0.02	0.03	0.01	0.02	0.02	0.04	0.02	0.03
	Children	0.05	0.08	0.04	0.04	0.05	0.10	0.04	0.07
Ni	Adults	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.03
	Children	0.03	0.06	0.02	0.02	0.01	0.03	0.03	0.09
Pb	Adults	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00
	Children	0.01	0.01	0.00	0.01	0.01	0.02	0.04	0.01

quotient. The possible human health risks (HQM) calculated for adults and children for mushroom *P. ostreatus* (oyster) harvested from different mining areas and control is presented in Table 5. The calculated hazard quotient (HQM) values for both adults and children were all <1 suggesting that there were no possible human carcinogenic risks in consumption of the studied mushrooms.

Previously, Chary et al. (2008) indicated that the hazard quotient does not provide the quantitative estimation of chances of serious health effects, caused due to heavy metals but it is considered as a reliable tool used to estimate the risk associated with exposure through heavy metals in food. Globally, Cu has been reported by Cherfi et al. (2014) as a major contributor to the total hazard quotient in vegetables and its consumption can lead to serious health hazards. However, the hazard quotient calculated for copper for both children and adults were less than one suggesting that there were no possible human carcinogenic risks in consumption of the oyster mushroom. Similar trend of <1 HQ was observed in children and adults for lead, Zinc and Nickel which indicated that the consumption of the harvested oyster mushroom is safe. The hazard quotient in Oyster mushrooms of this study were not in accordance with the previous studies by Pedrero et al. (2010) and Guerra et al. (2012) in which they reported maximum concentration of copper followed by iron and relatively lesser concentration of lead.

The risk attached to harvesting plants most especially the edibles in high polluted areas including mining has been previously reported by researchers (Olowoyo and Lion 2013; Rasalanavho et al., (2020). The findings from this study was consistent with the study of Rasalanavho et al. (2020) who observed fungi growing and flourish on media with high levels of metals.

4. Conclusion

The study revealed that *P. ostreatus* possess ability to bioaccumulate heavy metals from polluted soils. This indicated that the continuous consumption of the mushrooms obtained from a metal polluted environment may result into metal bioaccumulation in the body tissues with consequences including severe illness and death. It is therefore recommended that caution should be taken not to harvest them on mined soils. From what was reported in this study, it will be advisable to determine the ability and concentrations of other different types of mushroom that are consumed not only in South Africa but also from other parts of the world since it has been shown from this study and other studies that *Pleurotus ostreatus* can translocate and store metals either in their caps or stalks. Further study should also include monitoring of other emerging pollutants in these types of mushrooms as well.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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