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Health Risk Assessment of Metals in African Aphrodisiacs: A Case Study of Aqueous Concoctions from Johannesburg and Durban Herbal Markets, South Africa

Siphesihle Dube [1], Nkosinathi Makhubela [1], Lawrence Mzukisi Madikizela [2], Nkoana Ishmael Mongalo [3], Vusumzi Emmanuel Pakade [4], Bethusile Rejoice Maseko [1] and Somandla Ncube [5,*]

1 Department of Chemistry, Sefako Makgatho Health Sciences University, Medunsa 0204, South Africa
2 Institute for Nanotechnology and Water Sustainability, College of Science, Engineering and Technology, University of South Africa, Florida Science Campus, Roodepoort 1710, South Africa
3 CAES Laboratories, Department of Agricultural Sciences, College of Environmental Science and Agriculture, Engineering and Technology, University of South Africa, Florida Science Campus, Roodepoort 1710, South Africa
4 Department of Biotechnology and Chemistry, Vaal University of Technology, Private Bag X 021, Vanderbijlpark 1911, South Africa
5 Department of Chemistry, Durban University of Technology, Durban 4000, South Africa
* Correspondence: somandlan@dut.ac.za

Abstract: Consumption of aphrodisiacs is a common practice in South Africa. Hence, determining the levels of trace metals as potential pollutants is necessary to protect consumers' health. The current study reports a health risk assessment due to metals in aphrodisiacs collected from herbal markets in Johannesburg and Durban, South Africa. Samples were digested using microwave-assisted digestion followed by inductively coupled plasma-optical emission spectrometry analysis. The results showed that the concentrations of common metals (Na, K, Mg, and Ca) were within the guideline limits for human consumption, while the trace metals (Ni, Cr, Co, As, Cd, and Pb) were above the limits, recording values of 0.132–0.268, 0.209–0.308, 0.224–0.405, 0.0884–0.230, 0.0402–1.11, and 0.146–0.207 mg L^{-1}, respectively. The source of the trace metals was traced to the tap water probably collected from dilapidated buildings where the water systems are ailing. A strong correlation for metals with similar sources was observed, notably for Pb and Cd that leach from water pipes. The aphrodisiacs had low consumption rates, and the health risk assessment gave a hazard quotient of 0.225 as a total for all studied metals. The group of aphrodisiacs investigated in the current study therefore poses minimal health risks and can be consumed without fear of metal contamination. More inclusive studies are, however, needed to have a better understanding of aphrodisiacs with the aim of potentially commercializing them like the other commercialized herbal concoctions currently distributed in South African markets and pharmacies.

Keywords: aphrodisiac; herbal concoction; health risk assessment; metal analysis; lead

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1. Introduction

The use of stimulants or enhancers dates back to ancient times when cultures sought natural remedies that could help men father more children or improve their sexual performance. These became known as aphrodisiacs, a name derived from Aphrodite, the Greek goddess of love and patron of prostitution. An aphrodisiac is, therefore, a substance that is said to enhance sexual drive and desires, resulting in a greater sexual experience and performance [1,2]. It can be seen as a remedy for treating sexual dysfunction or just sexual satisfaction [3,4]. There are different kinds of aphrodisiacs that come in many forms, but a simple classification puts them as either herbal or synthetic. Unlike in medicine where synthetic pharmaceuticals have replaced natural products, with aphrodisiacs this is not the case, with most men still preferring natural products. The consumption of natural aphrodisiacs in Africa has remained strong throughout the ages despite repeated attempts to introduce synthetic pills and inhalants as alternatives. There are different perspectives concerning the consumption of aphrodisiacs. Some view them as a remedy for treating sexual dysfunction [3,4], while others consume them without prior knowledge of a sexual problem. In some tribes, men use aphrodisiacs to cement masculinity and male sexual virility [5].

Most herbal remedies for medicinal purposes or health promotion in western countries are regulated and commercialized, but regulating their quality and safety in developing countries is still a challenge [1,6–9]. While research on the pharmacology and efficacy of packaged concoctions has increased [2,10], the efficacy and safety for most of the traditional herbal aphrodisiacs are less understood, mainly because research is still limited [1–4,11]. In Africa, knowledge of the plants and the preparation processes is sacred to the traditional practitioners, even though recent efforts by various researchers have tried to break these boundaries by profiling common medicinal herbs [4,12–21]. The unwillingness of traditional practitioners to share indigenous knowledge systems has hindered research on African products. Currently, the effectiveness of African aphrodisiacs is mainly based on anecdotal evidence from the users and the suppliers. Importantly, a recent review by Ajao et al. identified 75 species of herbs used for the preparation of aphrodisiacs in South Africa [4]. Generally, research on various aphrodisiacs has attributed performance to both psychological and physiological effects [1]. At the same time, evidence on potential side effects is also limited [17], while anecdotal evidence points out that some side effects are as serious and confusing as erectile problems in males. Mild side effects include nausea, diarrhea, vomiting, headache, and temporary memory loss [17]. Hence, there is a need for studies to better understand the efficacy and potential side effects of aphrodisiacs.

In South Africa, the cult of consumption of aphrodisiacs has been passed from generation to generation with many cultures using them. The Zulu and VhaVenda tribes are known to pride themselves on using aphrodisiacs derived from various plant species. For the Zulu tribe, it is all about having many wives and a large family, while among the VhaVenda, focus is mainly on masculinity and sexual satisfaction. Most South African men are promiscuous, and among the Zulu tribe, polygamy is a common practice [22]. The men, therefore, use these concoctions to ensure every woman in their circle is sexually satisfied. While this may actually enhance one's performance, it is the potential health side effects that should be of concern, especially in places where these concoctions are sold in street markets without any scientific tests being conducted on them. For example, health-based products are regulated in South Africa by the South African Health Products Regulatory Authority, yet aphrodisiacs marketed by street vendors and markets are not regulated. Metal pollution and associated human health effects have been reported in herbal medicines [23–25], but data on aphrodisiacs are still limited. In the current study, we have done an assessment of the metal composition in aqueous concoctions collected from traditional markets in two important cities in South Africa (Johannesburg and Durban) and used the measured concentrations to do a health risk assessment based on the permissible limits for metals in aqueous food sources recommended by various international organizations.

2. Materials and Methods

2.1. Chemicals and Reagents

Analytical grade hydrochloric acid (32%, *v*/*v*) and nitric acid (70%, *v*/*v*) were purchased from Sigma-Aldrich (Johannesburg, South Africa). Certified reference standards for elements used for preparing calibration standards were purchased from Supelco (Belefonte, PA, USA). Ultra-high purity water was generated from a Milli-QRO4 system 117 (Millipore, Bedford, MA, USA) that was set at 18.2 MΩ cm^{-1}.

2.2. Sample Collection and Preparation

A total of 20 samples were collected from different traditional practitioners in Durban and Johannesburg. In each city, all the traditional practitioners were located in the same market. The Faraday *muthi* market in Johannesburg is considered the biggest traditional market in South Africa [26], with the city of Johannesburg being considered as the South African economic hub. Therefore, Johannesburg is one of the most highly populated South African cities with its residents coming from all of the South African tribes, while Durban's traditional practitioners have customers mostly from the Zulu tribe. Importantly, a minimum of three samples were collected from each traditional healer. Knowledge of the plants used and of the preparation process is sacred to the traditional practitioners, but all of them pointed out that they use different herbs and boil the herbs to create a concoction. The concoctions are then decanted and poured into empty containers, usually empty whiskey and vodka glass bottles, as well as plastic water bottles (Figure 1). The volumes are, therefore, dependent on the capacity of the container. The most common containers are the 225 mL whiskey and vodka empties, the 500 mL plastic water bottles, and the 2 L plastic soft drink containers (Figure 1). Concoctions had different colors, which is believed to be influenced by the herbs themselves.

Figure 1. Samples of the aphrodisiac concoctions.

2.3. Microwav-Assisted Digestion and Metal Analysis

The instrument used for the microwave digestion of the aqueous concoctions was a Multiwave 5000 version (Anton Paar Southern Africa (Pty) Ltd., Midrand, South Africa) with a 20SVT50 rotor system. The instrument equipped with a carrying capacity of 20 bomb vials has a power and temperature limit of 1800 W and 220 °C, respectively. A U.S. EPA SW-846 Method 3015A[5] recommended by the supplier (Anton Paar) for digestion of plant material was adopted with a slight modification for the digestion of the aqueous concoctions. In the current study, a 20 mL volume of a well-shaken concoction was digested using a mixture of 4 mL HNO_3 and 1 mL HCl. The method involved increasing the temperature to 200 °C in 20 min and maintaining it for a further 10 min. The temperature was then allowed to drop down to 70 °C, resulting in a total runtime of 52 min. The microwave bomb vials were then removed from the system and further vented in a fume hood to minimize the potential rush of acid vapor during uncapping. The digestate was quantitatively transferred to 50 mL vials. About 5 mL of each digested sample was filtered into ICP vials for analysis using an Agilent ICP-OES 700 Series instrument (Agilent Technologies, Santa Clara, CA, USA). The instrument parameters, emission wavelengths, and validation approaches for the target metal ions were adopted from our previous study [27].

Importantly, each sample was digested in triplicate. Ultra-pure and tap water were also digested simultaneously with the concoctions. Acid-digested ultra-pure water was used as a control, and its measured metal concentrations were subtracted from the total metal concentrations in the digested tap water and concoctions. Furthermore, the concentrations recorded for tap water were also subtracted from the total concentrations to determine the true concentrations due to the components of the concoctions. However, the total metal composition of the concoctions (tap water + concoction components) was used for health risk assessment predictions.

2.4. Principal Component Analysis and Analysis of Variance

An analysis of variance (ANOVA) coupled with Tukey pairwise comparisons, all at a 95% confidence interval, was performed on Minitab 18.1 to assess any variances in the mean metal ion concentrations among samples. ANOVA and the Tukey method were also essential in doing a metal source apportionment. In this regard, the source of the metals found in the concoctions could be separated based on the components used in preparing the concoctions with some being related to steaming pots. A principal component analysis was done on RStudio version 3.5.0 by Posit (PBC, Boston, MA, USA). Firstly, the metal ion concentrations were partitioned such that 80% of the data was used for training the software and the remaining 20% for testing the data. The principal components were then created via the built-in prcomp function in R-Studio to counteract multicollinearity problems associated with correlograms, and the results were visualized using biplots. A typical program used for this is given in the supplementary information (Table S1). Importantly, a principal component analysis was done for Johannesburg samples and Durban samples separately and also as a combined set to have a better understanding of correlational behaviors between concoctions from the two cities and the metal compositions within the samples.

2.5. Health Risk Assessment

For the health risk assessment, the metal daily intake due to drinking concoctions was estimated based on the recorded concentrations and the worst-case concoction consumption rate (*CIR*) using Equation (1). According to the traders, for optimum performance, a man can consume about 2 cups (2 × 250 mL) at least 4 h before sexual activity. However, some passers-by are content with a single cup in the afternoon before the night. For those in long-term polygamous relationships, a 2 L concoction is recommended every fortnight, which should be taken prescription-style, that is, a cup (~250 mL) 3 times a day until the concoction is finished.

$$EDI = (C_m \times CIR)/BW \quad (1)$$

where EDI is the estimated daily intake (mg L^{-1} day^{-1}), C_m is the average concentration of the metal in the concoction (mg L^{-1}), CIR is the concoction intake rate (0.143 L day^{-1} for an extrema-case scenario; see Section 2.2), and BW is average body weight of a man in South Africa (71.9 kg).

The recommended consumption of 2 L of the concoction per fortnight equates to a CIR value of 143 mL per day. To assess any potential for health risk, two important assessment parameters were calculated. The first parameter was the Target Hazard Quotient (*THQ*) which served as a prediction of noncarcinogenic effects for each element. The *THQ* was calculated as a ratio of the estimated daily intake (*EDI*) value to the acceptable reference daily intake (Rf_D), while at the same time taking into consideration the exposure duration (*ED*) and the life expectancy of a man in South Africa using Equation (2) [28,29]. The *EDI* was estimated for 45 years, which represents an age range from 20 to 65 years. This age range represents a worst-case scenario and caters to a man who was promiscuous at the age of sexual maturity and then became polygamous in later years. The average weight of a man in South Africa is 71.9 kg (https://www.worlddata.info/average-bodyheight.php, last accessed on 4 February 2022).

$$THQ = \sum(EDI \times EF \times ED)/(Rf_D \times AT)) \quad (2)$$

where THQ is the target hazard quotient as a total for the studied elements, EDI is the estimated daily intake (mg L^{-1} day^{-1}), Rf_D is the reference daily oral intake (mg kg^{-1} day^{-1}) of an element according to the WHO/FAO, EF is the exposure frequency (365 days yr^{-1}), ED is the exposure duration (45 yr), and AT is the average time (365 days yr^{-1} × 65 yr = 23,725 days).

Secondly, the Target Cancer Risk (TCR) values for metals with known carcinogenic effects were predicted as the potential of the measured concentrations to pose cancerous risks. This was achieved by calculating the TCR based on the EDI values and Cancer Slope Factor (CSF) values using Equation (3) [28,29]. Metals with known carcinogenic effects are Pb, Cr, As, and Cd, and their CSF values have been set at 0.0085, 0.5, 1.5, and 6.3 kg-day mg^{-1}, respectively. In addition to the risk assessment parameters, the study also predicted a maximum permissible amount of the concoction per day that would not result in potential health risks over a 45-year period of sexual activity for a man using Equation (4).

$$TCR = \sum((EDI \times EF \times ED)/(CSF \times AT)) \quad (3)$$

where TCR is the target cancer risk due to a carcinogenic metal, EDI is the estimated daily intake (mg L^{-1} day^{-1}), EF is the exposure frequency (365 days yr^{-1}), ED is the exposure duration (45 yr), AT is the average time (365 days yr^{-1} × 65 yr = 23 725 days), and CSF is the cancer slope factor for that metal (kg-day mg^{-1})

$$ER_{lim} = (Rf_D \times BW \times EF)/C_m \quad (4)$$

where ER_{lim} is the maximum permissible concoction consumption limit (L day^{-1}), Rf_D is the reference daily oral intake (mg kg^{-1} day^{-1}) of an element according to the WHO/FAO, BW is the average body weight of a man in South Africa (71.9 kg), EF is the exposure frequency (365 days yr^{-1}), and C_m is the average concentration of the metal in the concoction (mg L^{-1}).

3. Results and Discussion

3.1. Metal Concentrations in Aqueous Samples

The concentrations of the selected studied elements in tap water and concoctions and the comparisons with drinking water quality guidelines are summarized in Table 1. The results show that most of the metal concentrations were within the acceptable limits for human consumption, except for Ni, Cr, As, Cd, and Pb. The consumption rates for these five metals should be controlled because of their known adverse effects on human health. The two alkali metals (Na and K) had concentrations significantly higher in the concoctions than in tap water in all samples, while the alkaline earth metals (Ca and Mg) were significantly higher in 47 and 76% of the samples, respectively. These samples are listed in Table S2 in the Supplementary. The samples with concentrations that were significantly higher in the concoctions than in tap water for Fe (76%), Al (59%), and Zn (29%) are listed in Table S2. The concentrations of Ca, Mg, Na, and K were similar to those reported in other herbal concoctions within South Africa [30], with one recent study recording maximum values between 10 and 30 mg L^{-1} for Ca and Mg and 50–60 mg L^{-1} for Na and K [21]. The concentrations of Fe and Zn were similar to those reported for potable water in Nigeria, where the concentrations were as high as 0.3 and 3 mg L^{-1}, respectively [29]. This was an indication that the presence of these metals in concoctions was due to other components of the concoctions in addition to the tap water.

Table 1. Concentrations of metals in the aphrodisiac concoction samples.

Element	Drinking Water Guideline Limits (mg L^{-1})		Method Detection Limits (mg L^{-1})	Tap Water Concentration (mg L^{-1} ± %RSD)	Concentration Range (mg L^{-1}) %RSD = 4.31–20.4	
	WHO	South Africa			Johannesburg	Durban
Na	-	200	0.179	8.55 ± 0.44	13.3–160	15.0–170
K	-	50	0.195	2.99 ± 0.61	5.26–163	7.14–59.7
Mg	-	70	2.15×10^{-3}	5.63 ± 0.80	9.40–73.5	10.1–36.5
Ca	-	150	4.53×10^{-4}	19.9 ± 1.1	18.2–31.2	16.2–32.3
Cu	2	2	0.0145	0.146 ± 1.7	0.132–0.294	0.116–2.78
Zn	3	5	0.0102	nd	0.0904–1.58	0.0683–0.714
Mn	0.4	0.4	2.31×10^{-3}	0.336 ± 1.2	0.065–7.05	0.0729–0.587
Mo	0.07		9.20×10^{-3}	0.0260 ± 1.2	0.0310–0.0916	0.0301–0.0327
Al	0.9	0.3	0.0590	0.0939	0.0837–20.1	0.901–7.91
Fe	-	2	4.69×10^{-3}	nd	nd–16.1	nd–6.57
Ni	0.070	0.07	0.0101	0.207 ± 0.59	0.132–0.268	0.180–0.265
Cr	0.050	0.050	0.0196	0.219 ± 1.7	0.212–0.308	0.209–0.282
Co	-	0.5	6.28×10^{-3}	0.159 ± 0.29	0.324–0.404	0.401–0.405
As	0.010	0.010	0.0621	0.112 ± 2.8	0.0884–0.230	0.122–0.196
Cd	0.003	0.003	0.0142	0.0402 ± 0.21	0.0402–1.11	0.0403–0.0404
Pb	0.010	0.010	0.0801	0.131 ± 11.9	0.142–0.207	0.163–0.191

E—scientific notation; Source of Drinking water guideline limits [31,32].

The trace metals (Ni, Cr, Co, As, Cd, and Pb) were found in concentrations higher than the permissible limit, which raises some health concerns. While this is generally higher than the concentrations reported in most aqueous herbal mixtures, some of the metals have also been reported to have concentrations above permissible limits [8,29]. For example, in a recent study in Nigeria, the concentration of Pb in aqueous herbal samples was as high as 3.01 mg L^{-1}, while the concentration of Co (0.266 mg L^{-1}) was similar to the current study [29].

3.2. Metal Source Apportionment

The earth metals were present in significantly higher amounts in the concoctions than in water, and it was a similar case with some essential elements, including Al, Fe, and Zn (Table S2). The earth metals exist abundantly in the earth's crust, and their existence in the concoctions was probably from the plant material used in preparing the concoctions. Additionally, Street and Rice in 2013 observed that the addition of salts, including $CaSO_4$, NaCl and $KMnO_4$, to herbal concoctions is common among traditional practitioners, which could have contributed to the high concentrations observed in the concoctions compared to the tap water [33]. Traditional practitioners are reported to use $KMnO_4$ to treat some sexually transmitted infections [34]. For Al, Fe, and Zn, more research is needed to identify the true source between the steaming pots and the plants used in the preparation of the concoctions. Interestingly, Zn was not detected in tap water but existed in the concoctions albeit within the drinking water guideline limits. Currently, we suspect that these metals may have leached from the pots as most practitioners either used cheap Al pots or homemade Zn pots.

On the other hand, the concentrations of trace metals (Ni, Cr, Co, As, Cd, and Pb) were not significantly different from those of tap water, implying that their existence in concoctions was entirely due to the tap water. Previous studies on tap water have identified leaching from water pipes as a main contributor of metals such as As, Cd, Cr, Pb, Cu, Fe, and Zn [35–37]. However, in their studies, the metals remained within the permissible limits, which is in contrast with the results of As, Cd, Co, Cr, Ni, and Pb in the current study. Concentrations within the WHO guideline limits for drinking water have also been reported in Egypt [38], Turkey [39], Kenya [40], and Iran [41]. Importantly, Pb has always been associated with service connections and plumbing in buildings and the period in which the water has been in contact with the lead-containing materials. In this regard, the WHO recognizes that Pb concentrations may be higher but not more than 0.050 mg L^{-1} in piped water [32], which is true for most studies in the literature. However, in the current study, its average concentration was 0.131 mg L^{-1}. A study in Thailand also reported concentrations of Pb that were higher than guideline limits, but their reported value of 0.0250 mg L^{-1} was still less than 0.050 mg L^{-1} [42]. For Ni, its existence has also been blamed on the chemicals used in water purification [32]. The elevated concentrations of the trace metals in the current study, therefore, raise the issue of leaching from potentially corroded pipes, which could be a sign of ailing plumbing systems in the two important cities of South Africa. For example, the area in downtown Johannesburg where the traditional practitioners operate is characterized by old buildings, some of them in a dilapidated state. The occurrence of trace metals in the drinking water should be of serious concern since drinking water is a component of many food sources. Trace metals have been detected at elevated levels in other aqueous herbal concoctions in South Africa [43], while in solid herbal concoctions, they have been reported within limits with only a few exceptions [44].

3.3. Correlational Interactions

Most pollutants in the environment and food sources with similar point sources have the tendency to correlate in terms of observed concentrations [35]. Metal pollutants also tend to show collinearity, especially if the source is due to anthropogenic activities. The PCA diagram in Figure 2A shows that there were various strong correlations between certain metals. The PCA and the correlogram show that there was a strong correlation between the presence of Pb and the presence of Cd, implying that their existence in the tap water is probably due to the plumbing material. These correlational observations have been presented elsewhere [35,45]. The elements with a chance of leaching from cookware (Zn, Al, and Fe) were also strongly correlated, as were K, Ca, and Mg. The association of Zn, Al, and Fe with K, Ca, and Mg could not be explained, but there is a possibility of solid salt accumulation in the brewing pots that eventually degrades during the prolonged brewing of the concoction. The metal correlations that existed for samples from each town are presented in the supplementary materials as Figure S1, while the sample correlations are given in Figure S2. The PCA in Figure 2B also shows that 70% of the Durban samples were correlated with tap water concentrations, while only 20% of the Johannesburg samples had a strong correlation with tap water samples. The grouped information using the Tukey method in relation to ANOVA ($p \leq 0.05$) showed that samples collected from Johannesburg had metal concentrations significantly higher than in samples from Durban, except for Na (Table 1). The maximum concentration recorded (170 mg L^{-1}) was still within the South African guideline limits. The variation in samples based on the city where the samples were collected is essential in understanding the potential sources of the metals in the concoctions. Regarding the metals with concentrations that were significantly higher in the concoctions than in the tap water, there is a chance that the metals in the Johannesburg samples entered during the preparation process or due to the origins of the herbs. More studies are required to have a better understanding of the higher concentrations observed in the Johannesburg samples.

3.4. Health Risk Assessment

A health risk assessment based on extreme consumption behaviors (Table 2) showed that the common aphrodisiacs from Johannesburg and Durban have minimal chances of causing any health side effects due to metals in the concoctions, with a value of 0.2 for both the THQ and TCR. A health risk assessment of most herbal concoctions revealed that their consumption was safe. A study first done in 2006 on other South African medicinal remedies showed that metal concentrations in those remedies posed no risk, something is still observed 20 years later [30]. This is an important observation because with more pharmacokinetic studies, this could mark a dawn for aphrodisiacs with a potential for commercialization. The metal concentrations in the current study may have been higher than permissible limits, but the risks are low based on consumption habits, as observed in the current study. This dose-dependent trend has been observed for other herbal medicines where the levels were above permissible limits but the risks were low [8,29,43,46].

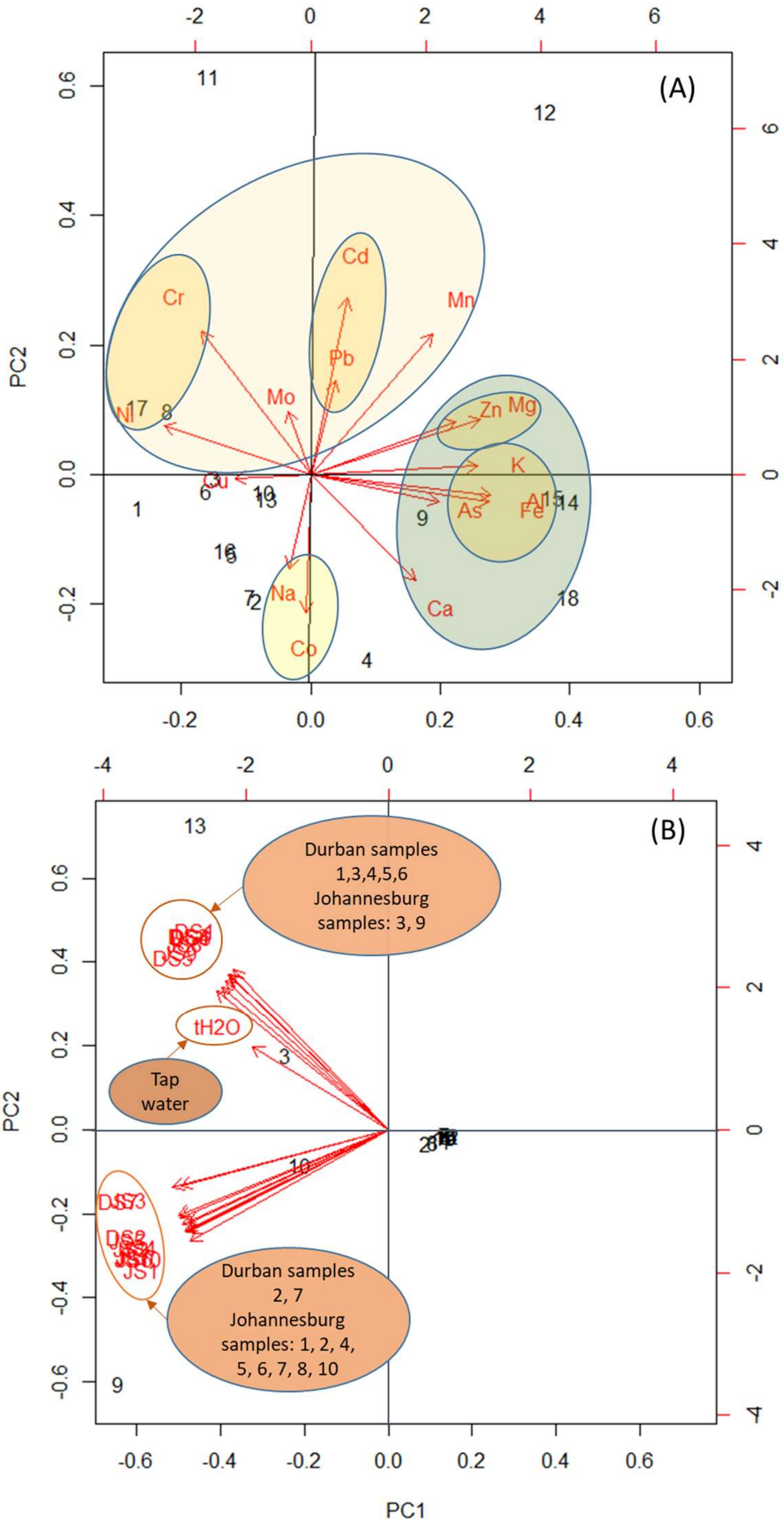

Figure 2. Principal component analysis representing correlational behaviors between (**A**) metals and (**B**) samples. PC1 and PC2 refer to principal components 1 and 2, respectively.

Table 2. Aphrodisiac metal ion consumption rates and health risk assessment.

Element	Reference Dose (µg kg^{-1}(bw) Day^{-1})	Estimated Daily Intake (µg kg^{-1}(bw) Day^{-1}) Johannesburg	Durban	Target Hazard Quotient	Target Cancer Risk
Na	1500	0.0264–0.317	0.0298–0.339	1.22×10^{-6}–1.56×10^{-4}	
K	4700	0.0105–0.325	0.0142–0.119	1.54×10^{-6}–4.79×10^{-5}	
Mg	420	0.0187–0.146	0.0201–0.0342	3.08×10^{-5}–2.41×10^{-4}	
Ca	1000	0.0361–0.0620	0.0322–0.0643	2.23×10^{-5}–4.45×10^{-5}	
Cu	0.9	2.64×10^{-4}–5.85×10^{-4}	2.03×10^{-4}–4.50×10^{-4}	$<4.27 \times 10^{-4}$	
Zn	11	1.80×10^{-4}–3.14×10^{-3}	1.36×10^{-4}–1.32×10^{-3}	8.55×10^{-6}–1.97×10^{-4}	
Mn	2	1.29×10^{-4}–0.0140	1.45×10^{-4}–7.96×10^{-4}	4.48×10^{-5}–4.86×10^{-3}	
Mo	0.045	6.16×10^{-5}–1.82×10^{-4}	6.07×10^{-5}–7.52×10^{-5}	9.34×10^{-4}–2.80×10^{-3}	
Al	-	1.66×10^{-4}–0.0401	1.79×10^{-3}–6.01×10^{-3}	-	
Fe	18	≤0.0321	$<6.16 \times 10^{-3}$	≤0.00123	
Ni	0.02	2.62×10^{-4}–5.34×10^{-4}	3.58×10^{-4}–5.26×10^{-4}	9.07×10^{-3}–0.0185	
Cr	0.035	4.22×10^{-4}–6.12×10^{-4}	4.85×10^{-4}–5.60×10^{-4}	0.00834–0.0121	1.46×10^{-4}–2.12×10^{-4}
Co	-	6.44×10^{-4}–8.04×10^{-4}	7.99×10^{-4}–8.04×10^{-4}	-	
As	0.003	1.76×10^{-4}–4.58×10^{-4}	2.43×10^{-4}–3.89×10^{-4}	0.0406–0.106	2.53×10^{-4}–0.239
Cd	0.025	7.99×10^{-5}–2.21×10^{-3}	8.01×10^{-5}–8.04×10^{-3}	0.00221–0.0613	3.49×10^{-4}–9.66×10^{-3}
Pb	0.015	2.83×10^{-4}–4.12×10^{-4}	3.24×10^{-4}–3.80×10^{-4}	0.0130–0.0190	1.66×10^{-6}–2.42×10^{-6}
				Total = 0.225	Total = 0.249

E—scientific notation.

4. Implications for Aphrodisiacs

An understanding of aphrodisiacs, starting with metal contamination, is a step forward towards addressing some issues with aphrodisiacs. Importantly, the current study observed that the metal contribution by the herbal constituents of the concoctions was very low and the health risk assessment pointed out that health risks due to the presence of metals were limited. Regardless of these observations, there are still various issues that need to be addressed to fully protect the consumers of aphrodisiacs in South Africa. A good example from the current study was the realization that important trace metals (Ni, Cr, Co, As, Cd, and Pb) were all above permissible limits, but their potential to cause cancer throughout one's lifetime was minimal. The dose dependence of metals in herbal medicines has been observed in other herbal mi×tures where the concentrations were high but the risks were low [8,29,43]. It is therefore important to emphasize the need to strongly monitor aphrodisiac consumption behaviors. In light of this, it might be important to have permissible limits specific to aphrodisiacs to protect communities where aphrodisiacs are part of their culture, something that requires more research before it can be done. On the other hand, the e×istence of trace metals with known health effects in concentrations above permissible levels should be a cause for concern. Consumption of herbal concoctions is not through a prescription, and ingestion rates are dependent on individual and cultural perceptions. It is therefore advised that more studies on herbal side effects be done.

It was also obvious that quite a large number of metals detected in the concoctions came from the tap water and the pots used for preparing the concoctions. Knowledge of the metal concentrations and their sources could be essential in communicating ways that could reduce associated health risks. Since most of the heavy metals were from tap water, the potential health risks can be greatly reduced if, for e×ample, deionized water is used instead of tap water. In addition, those elements linked with leaching from the pots, such as Al, can be controlled by choosing the right utensils for preparing the concoctions. Finally, the presence of metals in tap water, especially those with known health effects, should be of serious concern to the municipalities. Further intensive studies are needed to identify the origins of these metals, whether they are from processing or the ailing water systems. This could be essential for taking proper action to protect the public from potential lifelong health effects.

5. Conclusions

The current study performed a health risk assessment based on the presence of metals in aqueous aphrodisiac concoctions from common markets in Durban and Johannesburg herbal markets. The results showed elevated levels of trace metals in the concoctions; however, based on the consumption rates, the metals were found to pose minimal health side effects. This study also observed the contribution of tap water to increasing the metal concentrations. This is a serious concern as it may point to ailing water systems where important trace metals, such as Pb and Cd, leach from dilapidated pipes. The study recommends the need for a more inclusive study to look at the real problem contributing to elevated levels of important trace metals. Currently, the South African consumers can continue the cult of consumption of aphrodisiacs.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13042148/s1, Figure S1: Metal correlations for Johannesburg samples (A) and Durban samples (B); Figure S2: Correlations for Johannesburg samples (C) and Durban samples (D); Table S1: Typical RStudio Program; Table S2: List of samples whose metal concentrations were higher than in tap water.

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