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*Original Research Article*

# Evaluation of Metal Composition of Cast Iron Disc Used in Local Grinding Machine

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## ABSTRACT

The need to prevent metal-related sickness is the driving force for this research. The research evaluates the composition and concentration of metals present in cast iron grinding disc used for local grinding. Different acidic mixtures were used to digest the pulverized cast-iron disc, and atomic absorption spectrophotometric analysis revealed the presence of essential minerals such as iron, copper, zinc, manganese, and toxic metals like metals cadmium, chromium, lead, and nickel. The concentration of the metals varies in different ranges cadmium 0.73 to 3.44, chromium 0.88 to 6.80, lead 0.55 to 1.58, nickel 0.40 to 7.17, manganese 3.12 to 21.00, zinc 2.03 to 40.50, iron 1.93 to 49.16 and copper 3.00 to 26.92 all in mg/kg. The presence of heavy metals in the grinding disc could be a source of food contamination and possible potential health risks.

## GRAPHICAL ABSTRACT


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## 1. INTRODUCTION

Food, no doubt, is essential to human well-being; however, its processing method can cause it to affect human health negatively. In many African countries, grinding machines are employed to process food products such as maize, tomatoes, dry yam, and soup condiments to powder and semi-liquid before cooking. The local grinding machine is an invented device with two revolving cast-iron discs having coarse surfaces [1]. Cast iron is a re-melted pig iron alloyed with considerable amounts of scrap iron, scrap steel, limestone, and carbon. Unfortunately, metals such as nickel (Ni), chromium (Cr), copper (Cu), molybdenum (Mo), and silicon (Si) are added during the production of iron (Fe) to improve the mechanical properties [2]. Regrettably, the lack of quality control on the chemical composition of scrap Fe, scrap steel, and other materials used in the production of cast iron probably has produced cast iron with several heavy metals. Not only that, the nonexistence of good standard tests or criteria for produced cast iron, such as allowable level of defects, has led to the market of all categories of cast irons. Contrariwise, abrasive effects during grinding combined with cast-iron disc defects will lead to iron wearing and metallic inclusions in processed food.

The presence of different heavy metal particles in food products has been established in the literature [3]. Normanyo et al. reported the presence of iron in food products and confirmed that the grinding iron disc was the source of the iron particles [4]. In a study done on heavy metals concentration in food materials due to milling machines, lead (Pb), cadmium (Cd), zinc (Zn), Cu, Fe, and Cr were found to be present in different concentrations, with iron having the highest value, followed by lead and chromium [5]. The presence of Fe, Zn, Pb, manganese (Mn), Cr, and Ni in food materials due to the use of grinding disc has been confirmed, and the study revealed that lead content was above the recommended standard in food [6]. Various metals such as mercury (Hg), Mn, Cobalt (Co), Cr, Fe, Pb, Zn, and Ni have been reported to have contaminated foodstuff in varying concentrations when evaluating various grinding equipment [7]. Although, metals such as Ni, Fe, Mn, Cu, and Zn are pivotal to human development and health when not above the permitted limit. Fe is vital for procreation, growth, immunity, and chemical metabolism [8]. At the same time, Zn assists in hormone activities, immune development, and blood vitamins promotion, and Cu promotions iron metabolism and manganese help in food metabolism. However, frequent in-take of heavy metal could cause metal accumulation above recommended values, leading to various degenerative diseases such as neurological sickness, internal organ diseases, and headaches [9]. For example, excess of Fe has been linked to health challenges such as liver and tissue damages, brain disorder, and heart problems [10]. Cd can cause all forms of cancer and osteoporosis [11], while Pb retards an infant's cerebral and intelligent development, raises blood pressure, and promotes adult cardiac disease [12]. Excessive chromium intake could be responsible for respiratory issues, skin cancer, and oral infection [13]. Cu has been implicated as the cause of Wilson disease and non-Wilson diseases such as cancer [14]. Ni initiates the development of cancer, respiratory and reproductive sicknesses [15]. Mn excess can affect the central nervous system causing degenerative brain-related disease, sexual, respiratory and dementia problems [16]. Zn's continuous ingestion can cause various intestinal discomforts, exhaustion, anemia, and dizziness [17]. Heavy metal-induced diseases and sicknesses are becoming a critical health challenge; thus, there is a need to unravel the source of heavy metal in-road into food materials. Therefore, this study evaluates metals' chemical composition and concentration in the cast iron grinding disc using different digestion chemical mixtures.

## 2. Materials and method

### *2.1 Materials*

The cast iron grinding disc sample was obtained from Disc grinding workshop, Akure, Ondo State, Nigeria. Hydrochloric acid (37 %), Nitric acid (68%), Sulphuric acid (98%), and Hydrogen peroxide (70%) used are Sigma Aldrich products. The metal analysis was carried out using atomic absorption spectrophotometer (Buck Scientific, Model: 210 VGP).

### *2.2 Methods*

2.2.1 Sample Preparation

The sample was cleaned and smoothened with sandpaper, pulverized, and stored in a container.

*2.2.2 Digestion of Sample*

For the digestion of the metals, 5 g of the sample was digested for 4 hours using four different acid mixtures as follows; the first experiment was done with $HNO_3$, $H_2O_2$ (30 % v/v), and HCl in ratio 3:1:1 and was coded as D1, the second with $HNO_3$, and HCl in ratio 3:1, denoted as D2, third carried out with $H_2SO_4$, $H_2O_2$ and HCl in ratio 3:1:1, coded as D3 and fourth $H_2SO_4$ and HCl in ratio 3:1 coded as D4. After the heating process, 20 ml of distilled water was added to D2 and D4, and the filtrate was obtained into a 50 mL standard flask and made up to mark with deionized water.

5 mL of 0.5M $HNO_3$ and 0.5M H2SO4 was added to D1 and D3 respectively, and the solution was warmed slightly. 20 ml of distilled water was added, and the filtrate was obtained into a 50 mL standard flask and made up to mark with deionized water. Two different controls were also prepared to account for the acid's background effects and correct for changes resulting from digestion procedures. The elemental analysis was done using the Atomic Absorption Spectrophotometer Buck Scientific 210 VGP model.

## 3.0 Results and Discussion

### *3.1 Results*

The results (Figure 1 and 2) of the metal composition analysis of the cast iron grinding disc revealed the presence of different heavy metals such as Cd, Mn, Pb, Ni, Cr, Cu, and other less harmful metal like Zn, and Fe, in various concentrations. Though, Odusote et al. [18] stated that Fe, carbon, and silicon are the components of cast iron grinding disc, Fe being in higher percentage and other very small. Thus, the results obtained in this study agreed with the summation of Johnson [2], which stated that heavy metals such as Ni, Cr, Cu, and Mo are added during the production of iron. The lack of quality control on the types of iron and other metals that should be used for food processing, such as cast-iron grinding disc, is one of the many reasons for various heavy metals in the grinding disc. Nevertheless, the result agreed with many other studies that have revealed that Fe is the significant component. The highest average value (34.72 mg/kg) recorded for Fe could probably be the basis for high Fe content in foodstuff, as reported by Oniya et al., [5]. The high average value of Fe, Cu (17.87 mg/kg), and Zn (19.53 mg/kg) may be linked to their availability as the most familiar waste metals around; they can be easily gathered and recycled with iron during cast iron production.

The results also revealed that the digesting chemical mixtures of $HNO_3$, $H_2O_2$, and HCl (D1) and $H_2SO_4$, $H_2O_2$, and HCl (D3) gave a higher metal composition than the $HNO_3$ and HCl mixture (D2) and $H_2SO_4$ and HCl (D4), probably due to the inclusion of hydrogen peroxide. It has been established that the addition of hydrogen peroxide in metal analysis enhances metal digestion and can sometimes increase the solubilizing power of mineral acids [19]. Human biological development uses valuable heavy metals such as Cu, Fe, Co, and Zn. For example, iron is a need in proper hemoglobin functioning, and cobalt is a co-chemical in Vitamin B12 [20].

While Zn is a catalyst to most human enzymatic processes and copper, chromium and manganese are vital in human nutrition [21]. However, a high concentration of these metals could cause harmful health effects. Thus, the results of this study could be used to predict the likelihood of heavy metal inclusion in food materials during processing using cast iron grinding and the possible measures to prevent this occurrence.

Manganese is an essential metal for upholding human well-being and can be obtained from various food sources [22]. Conversely, high intake and accumulation of Mn could threaten human health such as causing neurological disorders [23]. Mn daily intake for an adult is expected to be between 2-6 mg/day, according to the National Academic of Sciences [24]. The amount recorded from this study is 21.00 mg/kg (D1), 3.67 mg/kg (D2), 3.38 mg/kg (D3), 3.12 mg/kg (D4), which are on the high side for people that are constantly using cast iron grinding disc for food preparation. There is the possibility of Mn accumulation that can cause health problems.

The importance of Zn in human health cannot be over-emphasized. Inadequacy of Zn in humans touches 17 % of the world populace [25] and has resulted in 4 % of infant death [26]. Daily intake of Zn according to the US Institute of Medicine/Food and Nutrition board is 11 mg/day (male), 8 mg/day (female), and 40 mg/day for adult's tolerable upper limit [27], 2-3 mg/day (infants) and 5-9 mg/day (children) (Trumbo et al., 2001). The concentration of Zn in this study are 3.00 mg/kg (D1), 2.03mg/kg (D20), 40 mg/kg (D3) and 32 mg/kg (D4). When the 3.00 mg/kg and 2.03 mg/kg are within the range stipulated for infants and children, all the concentrations are allowable for an adult. However, depending on the acidic and moisture effect during grinding, both of which can increase the concentration of metal particles in food materials, children and infants could be at the risk of Zn poisoning.

Cast iron grinding disc no doubt cannot be produced without Fe; nevertheless, the problem of food contamination through the wearing of its particle needs to be addressed. Elekofehinti et al., [7] and Oniya et al., [5] in their various study have reported high Fe content in food materials. In this study, Fe has the three highest values of 41.70 mg/kg (D1), 49.16 mg/kg (D3), 46.10 mg/kg (D4) out of four used digesting chemical mixtures, and the highest average value of 34.72 mg/kg, linked to its high content in the cast-iron disc. Fe, no doubt, can help human development, but its leaching propensity and high concentration in food processed by grinding disc are harmful to human health. Metals are known to wear with usage; the action can be accelerated by oxidation and acidic effect of food materials, the reason for high metal content in food material. The need to reduce metal in the food chain has called for replacing the cast iron grinding disc with a stable material with no leaching during food processing.

Cu, though it is a micro mineral, its high intake if accumulated above the tolerated body quantity could be a probable health hazard. Cu daily intake according to WHO is 50 µg/kg for an adult, but a case of a healthy man becoming sick of liver disease after taking 30 mg Cu per day for two years and the intake was raised to 60 mg the third year [28,29]. Cu was recorded to be present at 26.92 mg/kg (D1), 3.00 mg/kg (D2), 23.55 mg/kg (D3), and 18.00 mg/kg (D4) in the disc. These values are high, which could be a potential threat to the constant usage of grinding discs for food condiments.

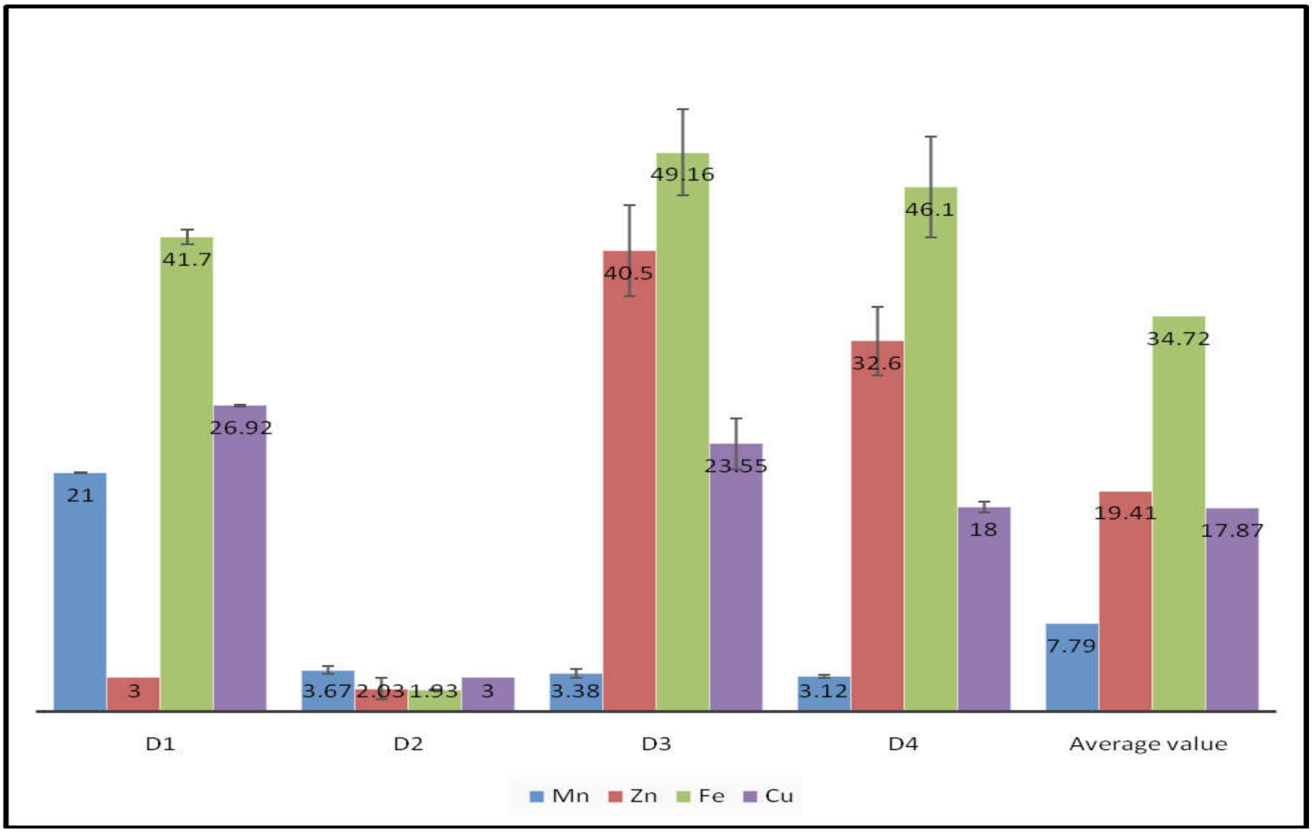


**Fig. 1.** Essential Heavy Metal (mg/kg) detected in cast iron grinding disc (Values are means triplicate determinations)

Cadmium is neither mineral nor macro-mineral needed by the human body; however, it can get into human food through soil or fish intake. Nevertheless, there is a need to prevent its daily intake increment. From the result, the lowest Cd value was 0.73 mg/kg (D1), the highest 3.44 mg/kg (D3), and the average value 2.10 mg/kg. Various regulatory bodies have given a standard recommendation for permissible Cd concentration in the body, 0.007 mg/kg [30] and 0.003 mg/L [31]. Since Cd is not expected in food materials, intake of minute concentration every day could lead to its accumulation which may eventually be the root of Cd-related sickness.

The interconvertibility of chromium ions made it a toxic metal. However, Cr (vi) is the most toxic, with its DNA damaging effect. Cr (iii), the reduced form of Cr (vi), is accountable for cellular impairment [32]. The dangerous nature of Cr ions has made its daily intake lower than those of some other heavy metals. Cr (iii) daily intake is between 2–8 µg, corresponding to 0.03 to 0.13 µg Cr (iii) per kg of body weight per day for a 60 kg human adult. At the same time, Cr (vi) is 0.02 µg/L [13], Though these daily intake values are for water, one will not expect the food to be higher, and all the Cr concentration values reported in this study are far higher than those values. Cr concentrations in this study are 08 mg/kg (D1), 0.88 mg/kg (D2), 0.99 mg/kg (D3), and 0.54 mg/kg (D4). The grinding process is known for particle size reduction. This means that frequent grinding using cast iron discs may produce metal particles with reduced sizes that can easily penetrate different organs in the body. This means that Cr in the cast-iron disc projects a very grievous health implication.

The values for Pb, 1.37 mg/kg (D1), 0.55 mg/kg (D2), 1.24 mg/kg (D3), and 1.58 mg/kg (D4) are higher than 0.24 mg/day acceptable everyday intake according to FAO for 70 kg individual [33]. Pb concentration in food material could increase, especially when grinding in a wet state, because moisture and acidic pH (the pH of most food materials) have been reported to aid metals leaching into food materials [34]. Food processing material should be Pb-free because Pb at a low concentration has been reported to be very toxic to humans [35]. To reduce Pb related sicknesses that are perhaps caused by grinding discs, there is a need for strict measures to control the production of cast iron.

Nickel is naturally found in the environment and living cells, and it is essential to living organism development. However, a high quantity of Ni has negatively affected plant metabolism [36]. Chen et al. [37] have submitted that Ni can cause the development of various human sicknesses liable on the dosage and duration of contact. Having Ni concentration ranges from 0.40 mg/kg, 0.53 mg/kg, 1.35 mg/kg, and 7.17 mg/kg could signify a future danger if no drastic action is taken to regulate the elemental composition of cast iron grinding disc.

## Conclusion

The study has revealed that cast iron grinding disc is produced from various metallic materials that contain heavy metals. Also, most of the heavy metals' obtained concentration is above the permissible daily allowable human intake, which may be the root of health challenges in the future. Although some essential heavy metals such as Fe, Mn, Zn and Cu exist, their frequent intake could lead to various health challenges.

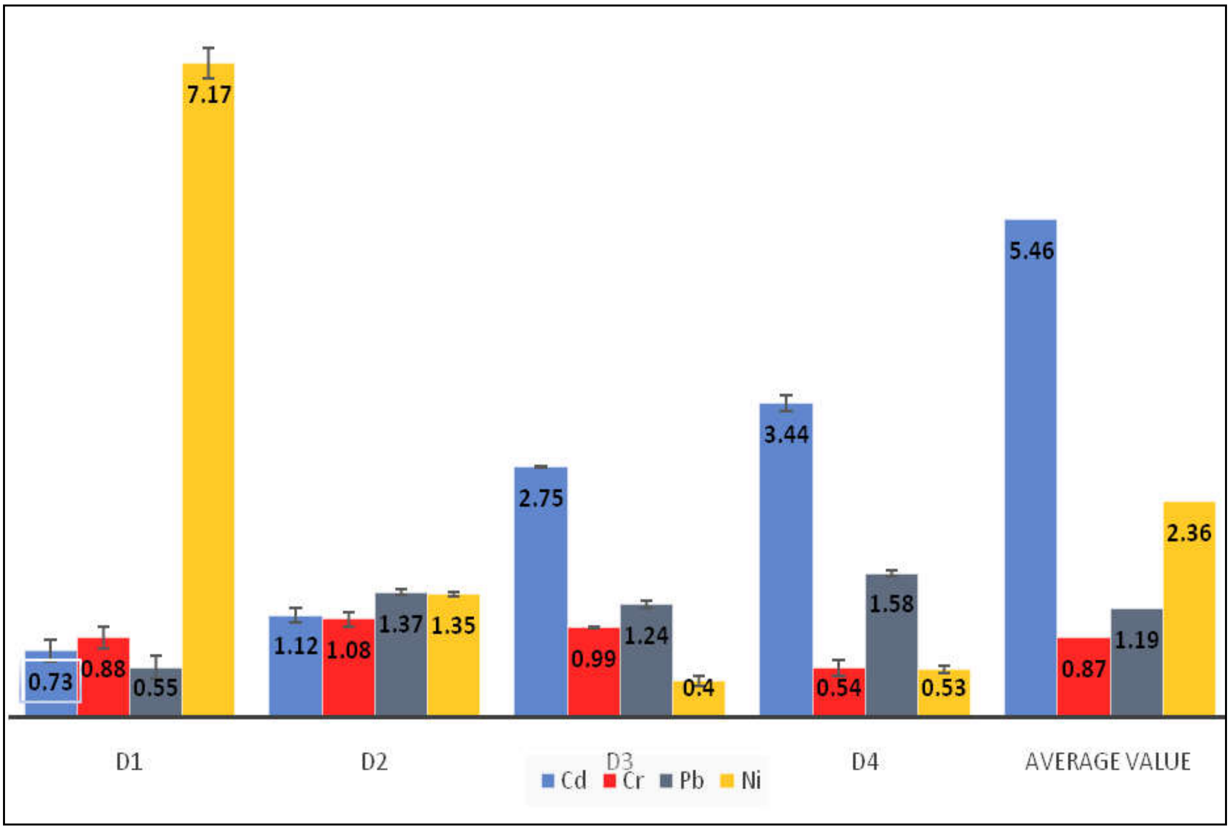


**Fig. 2.** Non-essential Heavy Metal (mg/kg) detected in cast iron grinding disc (Values are means triplicates determinations)

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