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Speciation study of the heavy metals in commercially available recharge cards coatings in Nigeria and the health implication

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ABSTRACT

This work assessed levels of heavy metals exposure from silver coatings of mobile phones recharge cards of three major companies (designated as A, B and C) with price denominations ₦ 100, ₦ 200 and ₦ 400 from companies A, B and C respectively, which were carefully scratched using a plastic scraper into a glass tube. The coatings were acid digested for total metal concentration, while speciation experiment for Mn, Cu, Cd and Pb was carried out. Total metals and speciation analysis were done using AAS and XRF techniques. The total metal concentration from XRF analysis was in the range: Ca (70–2140 μg/g), K (20–4930 μg/g), Sc (80–270 μg/g), Ti (1530–12,580 μg/g), Fe (50–6660 μg/g), Ni (20–2040 μg/g), Cu (20–850 μg/g) and Zn (40–460 μg/g). Cr had the lowest concentration (10 μg/g) in A (₦ 400) while Ti had the highest concentration (12,580 μg/g) in C (₦ 500) for all the coatings analyzed. AAS and XRF results agreed closely except for Fe with higher concentration. A (₦ 100) contained high concentration of the metals compared with others. Speciation study identified Mn as the most mobile element when present in the environment.

1. Introduction

Heavy metals have been shown to abound in several environmental matrices including water [18], plants [17], soil [24], air particulates [12], cosmetics [15] and even biological tissues and organs [33] to mention a few. Some of these heavy metals are essential elements for human growth and development, but could pose serious health problems at very high concentration in the body. For example, zinc (Zn) is important for the physiological functions of living tissue and regulates many biochemical processes but too much Zn can cause imminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anemia [25]. Copper (Cu) does essential work in animal metabolism but excessive ingestion of copper brings about serious toxicological concerns, such as vomiting, cramps, convulsions, or even death [27]. Nickel (Ni) exceeding its critical level might bring about serious lung and kidney problems aside from gastrointestinal distress, pulmonary fibrosis and skin dermatitis; Ni is also known as a human carcinogen [2]. High concentrations of mercury (Hg) cause impairment of pulmonary and kidney function, chest pain and dyspnea [20], while chronic

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exposure of cadmium (Cd) results in kidney dysfunction and high levels of exposure will result in death. Lead (Pb) can damage the kidney, liver, reproductive system, basic cellular processes and brain functions. The toxic symptoms are anemia, insomnia, headache, dizziness, and irritability, weakness of muscles, hallucination and renal damages.

Although several adverse health effects of heavy metals have been known for a long time, the exposure to these elements continues and is even increasing in the less developed countries where several people still remain ignorant of how to curb the menace of heavy metal exposure. One of the present day exposure routes to heavy metals is through the use of mobile phone recharge cards which are becoming increasingly popular among the young and the old [23]. Hence, the associated health risk of the heavy metal content of these recharged cards based on their species motivated the present study. To the best of our knowledge, the present speciation study represents the first of its kind with respect to recharge cards usage.

Chemical speciation of heavy metals describes their composition, forms of association, ionic types and concentration in a given matrix. The significance of chemical speciation for the environmental sciences lies in its usefulness as a tool for the interpretation of chemodynamics, properties and toxicity of chemical compounds. Chemical speciation depends, amongst other factors, on the composition of the system, pH, temperature, ionic strength and time. Many studies dealing with particulate metals in natural water systems (i.e. metal associated with suspended matter or bottom sediments) including roadside deposits are usually concerned with total metal concentration [26,14,16,19,13]. Relatively few attempts have been made to evaluate the speciation of particulate metals in sub-urban center particularly among the various forms in which they might exist even in other matrices including recharge cards silver coatings.

Use of total metal concentration as a criterion to assess their potential effects in the environment is important but it implies that all terms of a given metal have an equal impact on the environment; such an assumption is clearly unacceptable. However, a comprehensive knowledge of interaction between the different species of the metal and environmental media is important in predicting their environmental impacts and consequent health risk.

Since the advent of recharge cards in the world especially for commercial consumption by the regular cell phone users, little or very scarce reports on its heavy metals speciation have been reported. For example, Okunola et al. [23] reported the presence of total iron, nickel, chromium, manganese, copper, zinc, lead, and cadmium in commercially available recharge cards but not the species of the metals. Assessing the health risk associated with this metals is important since it is a common habit among people using recharged cards especially in Nigeria to use their finger nails to scratch the recharge card coating without proper washing of the nails thereby contributing a direct dermal contact with the heavy metal content of the coating films. Also in the course of removing the coating or scratching, the scratched particles are carelessly dispersed in the environment. Some of the particles contaminate the air around, while in most cases, larger percentage are returned into the ground where they are subjected to a number of processes that influences their mobility in the soil as well as their potential to contaminate ground water. Further transformations may lead to contamination of farm products and fresh water plants and animals, and finally get into the food chain. Thus, the human health implication of these heavy metals in the recharge card coatings, either in their total, free or bonded form cannot be over emphasized.

This study was aimed at determining the levels of heavy metals and their species in silver coating films of commercially available recharged cards in Nigeria and assessing the health implications of such practices on humans. It also attempted to evaluate their long term stability tendency when present in the environment.

2. Materials and methods

2.1. Sample collection and preparation

Mobile phone recharge cards from three major recharge cards producing companies in Nigeria were used for this study. The companies are denoted as A, B and C, respectively. The recharge cards commonly and commercially available are in the price denominations of ₦ 100, ₦ 200, ₦ 400, ₦ 500, ₦ 750, and ₦ 1500, respectively, with the ₦ 100 denomination most purchased by a greater percentage of the population. More than hundred (100) samples of each denomination were obtained from the recharge cards sellers and retail shops in Ile-Ife, Osun-State, Nigeria. The denominations obtained and studied for each company were: A (₦ 100, ₦ 200, ₦ 400); B (₦ 200, ₦ 500); and C (₦ 200, ₦ 500), respectively. The silver coatings were carefully scratched off using a plastic scraper into a glass tube. Adequate care was taken during sample collection to avoid cross contamination. The samples were later analyzed for their metal composition using both X-ray fluorescence (XRF) and Atomic Absorption Spectroscopic (AAS) techniques.

2.2. Reagents used and treatment of containers

Reagents used were of analytical grade (Sigma, Merck and BDH chemicals) and include ammonium acetate (NH_4COOCH_3), sodium acetate (CH_3COONa), hydroxylamine hydrochloride ($NH_2OH{\cdot}HCl$), acetic acid (CH_3COOH), nitric acid (HNO_3) and hydrogen peroxide (H_2O_2). Solutions were prepared using doubly distilled-deionised water. All glassware used were washed in detergent solution, rinsed several times with distilled-deionised water and then soaked for 48 h in 10% HNO_3, after which they were rinsed further with distilled-deionised water and dried overnight in an oven at a temperature of 120 °C before used [37]. Plastic bottles (60 mL) needed for AAS sample preparation were cleaned using (1:1) HCl–water solution. The syrup bottles were fully filled with the 1:1 HCl solution and left for 24 h, after which they were rinsed thoroughly with distilled-deionised water and dried.