

Elemental Analysis of One Rupee Indian Coins by Using EDXRF Technique

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ABSTRACT

Elemental analysis of some Indian coins of one rupee has been carried out by Energy Dispersive X-ray Fluorescence (EDXRF) technique which is non destructive, rapid and multi elemental in nature. The present investigation has been made for coins of different years for their elemental compositions with EDX-720 spectrometer equipped with Si(Li) detector having energy resolution 165 eV at 5.9 keV Mn K X-rays. This study observed the presence of Cu, Ni, Fe and Cr as the major elements.

Keywords: Si(Li) Detector, X-ray Tube, EDX-720 spectrometer, Indian Coins, Elemental Analysis

INTRODUCTION

Coins are the mirror of any nation's economy and culture. They provide fruitful information including life, politics and present environment of the nation. Relative to different aspects of country, different coins are issued from time to time. The form and structure of coins with different elemental compositions and mint has been released by the issuing authority of coins. Now a day in India, coins are generally fabricated by materials like Fe, Cu, Mn, Cr, Al, Ag, Ni etc. Various nuclear techniques like neutron activation analysis (NAA), Proton Induced X-ray Emission (PIXE), Atomic Absorption Spectrometry (AAS), Inductively-Coupled Plasma Mass spectrometry (ICP-MS), Energy Dispersive X-ray fluorescence etc.¹⁻⁶ are available for elemental analysis of coins. Among these techniques, EDXRF is of special interest because of non-destructive nature, fast, sensitive and capable of simultaneous multielemental analysis. Lot of work has been done for elemental analysis by using EDXRF technique⁷⁻¹⁰. Also EDXRF is economic and require less effort to run the setup.

In the present work, Indian one rupee coin of different years has been analyzed for their elemental compositions by EDXRF technique.

EXPERIMENTAL TECHNIQUE

In the present study total 8 Indian one rupee coins are dipped in Acetone for 24 hours and then washed with distilled water and also cleaned with soft brush. Finally coins are dried in fresh air and then subjected to EDXRF analysis. The EDXRF system EDX-720 provided with EDX software version 1.00, release 017 at Physics Division, Forensic Science Laboratory, Madhuban (Karnal, Haryana) India has been used for analysis of the elements present in these coins. The systematic diagram of EDXRF setup is shown in figure 1. X-ray spectrometer is provided with X-ray tube (*Rh* target) having tube voltage 5-50 KV and tube current lie in range between 1 to 1000 μ A. The instrument is equipped with Si(Li) solid state detector having energy resolution of 165 eV at 5.96 KeV K_{α} Mn line with liquid nitrogen (LN2) cooled. The sample was irradiated with 3mm² spot size under vacuum of $\sim 10^{-6}$ torr. The sample chamber is under observation with CCD camera which gives exact location of sample placement where X-rays are irradiated. The elemental compositions were determined by using the formula

$$m_{ij} = \frac{N_{ij}}{I_o G \epsilon \sigma_{ij} \beta_i}$$

Where m_j is the concentration of j^{th} element present in the sample, N_{ij} is the net counts per unit time for the i^{th} group of X-rays of j^{th} element, $I_o G$ is the intensity of the exciting radiation incident on the sample visible to the detector, ϵ is

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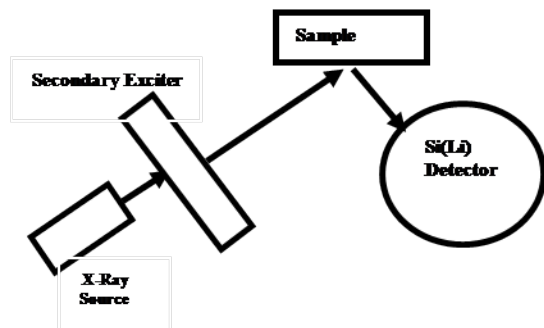


Figure 1. Systematic Diagram of EDXRF Setup

the detector efficiency for the j^{th} element, σ_{ij} is the theoretical X-ray fluorescence cross section at 20.21KeV excitation energy and β_i is the self absorption correlation factor that accounts for absorption of incident and emitted X-rays in the sample.



Figure 2. Obverse and Reverse sides of One Rupee Coins

RESULT AND DISCUSSION

The elemental composition of different coins is depicted in table 1. From table 1 it is apparent that Indian coins are fabricated with different elemental compositions that change from time to time. In years 1962 and 1970, the coins are generally made with pure Ni metal. In the year 1983, 1985 and 1986, coins have major concentration of elements i.e. Cu and Ni. The percentage composition of Cu varies from 66.654 to 72.10 % and Ni concentration varies from 27.411 to 32.709 % respectively. Some traces of Mn and Ca are also observed whose percentage is below 1%. Due to less productivity of Ni, cupro-nickel coins are issued in these years. Comparison of present study with RBI data¹¹⁻¹³ and other freely available data¹⁴⁻¹⁸ of various numismatists, we found that coin of this period have slight variation in concentration of major elements Cu(2.9-8.346%) and Ni (2.411-7.709%). A typical mix for cupro-nickel coin is 75% copper and 25% nickel and trace amount of manganese. Manganese (Mn) is usually added as the strengthening element. The thorough information of different coins with years, weight, and size has been taken from RBI (Reserve Bank of India)¹¹⁻¹³ illustrated in table 2. The photograph of both reverse and obverse sides of these coins is shown in figure 2.

Table 1. Elemental Concentration (in mass %) of Indian One Rupee Coins.

Coin No.	Year	Element %	Element %	Element %
		(Present study)	Ref.11-13 (RBI)	Other Ref. (14-18)
#1	1983	Cu 72.100%	Cu 75%	Cu 75%
		Ni 27.411%	Ni 25%	Ni 25%
		Mn 0.287%		
		Ca 0.202%		
#2	1985	Cu 66.654%	Cu 75%	Cu 75%
		Ni 32.709%	Ni 25%	Ni 25%
		Mn 0.267%		
		Ca 0.370%		
#3	1986	Cu 67.644%	Cu 75%	Cu 75%
		Ni 31.983 %	Ni 25%	Ni 25%
		Mn 0.176%		
		Ca 0.197%		
#4	2000	Fe 82.698%	Fe 82%	Fe (83%
		Cr 17.123%	Cr 18%	/82%/80.5%)
		Cu 0.032%		Cr
		Ni 0.147%		(18%/17%)
#5	2001	Fe 83.231%	Fe 82%	Fe (83%/
		Cr 16.590%	Cr 18%	82%/80.5%)
		Cu 0.070%		Cr
		Ni 0.108%		(18%/17%)
#6	2008	Fe 83.573%	Fe 82%	Fe (83%
		Cr 16.089%	Cr 18%	/82%/80.5%)
		Cu 0.121%		Cr
		Ni 0.217%		(18%/17%)
#7	2009	Fe 84.027%	Fe 82%	Fe (83%
		Cr 15.973%	Cr 18%	/82%/80.5%)
				Cr
				(18%/17%)
#8	2011	Fe 82.918%	Fe 82%	Fe (83%
		Cr 16.371%	Cr 18%	/82%/80.5%)
		Ni 0.094%		Cr
				(18%/17%)

Table 2. Size and Weight of the Coins

Coin No.	Year	Size	Weight
#1	1983	26mm	6gm
#2	1985	26mm	6gm
#3	1986	26mm	4.85gm
#4	2000	25mm	4.85gm
#5	2001	25mm	4.85gm
#6	2008	25mm	4.85gm
#7	2009	25mm	4.85gm
#8	2011	24mm	3.75gm

During decades 2000-2011, there is drastic change in alloy composition of the coins. Major element Cu and Ni have been replaced with Fe and Cr. Basically ferrite-stainless steel is preferred to cupro-nickel alloy during this decades due to high and cheap availability of steel. During the years 2000,2001,2008,2009 and 2011, Fe is the major element in the coins with percentage that vary in the range 82.918-84.027%. A small variation in percentage composition of Cr has been found that changes from range of 15.973 to 17.123%. Traces of Cu and Ni are also observed with concentration less than 1%. With comparison to RBI data¹¹⁻¹³ we have observed variation of Fe (0.698-2.027%) and Cr (0.877-2.027%). It is also observed that during 1980's, Mn and Ca are found as traces and during time 2000-2008, above said traces are replaced with Cu and Ni.

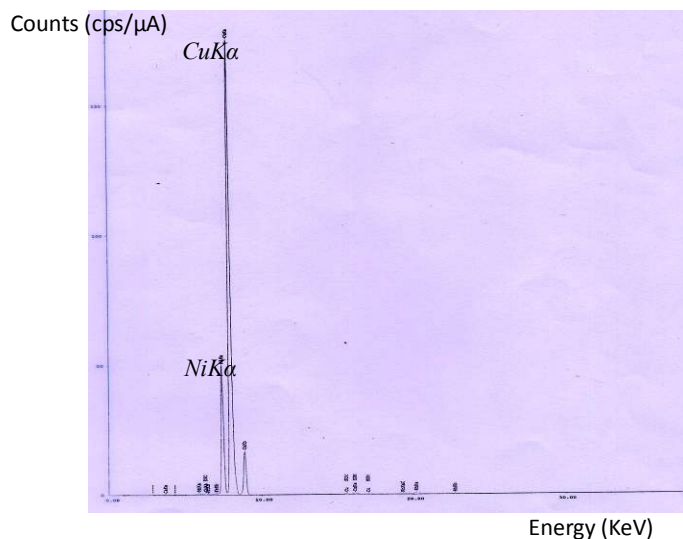


Figure 3(a). EDXRF Spectra of Coin #1

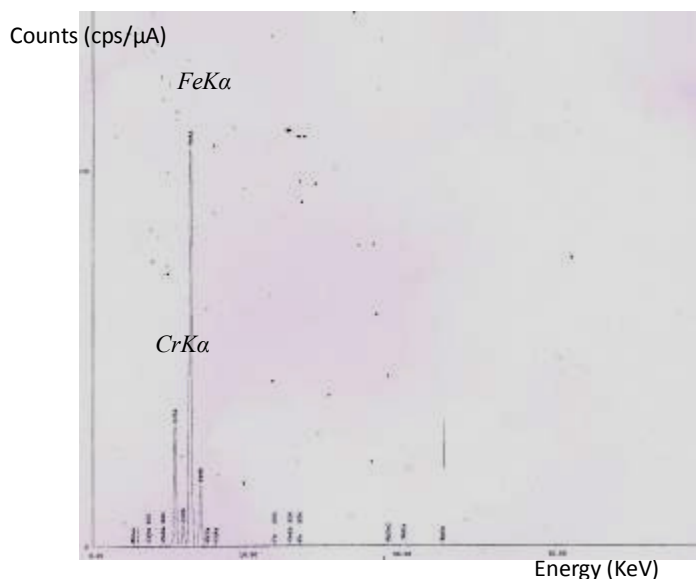


Figure 3(b). EDXRF Spectra of Coin #6

These traces are added in the metal alloy to improve corrosion resistance, to increase strength and to produce high toughness. Since 2009 till now, alloy of Fe and Cr are preferred for coin manufacturing. With comparison to other numismatist's data¹⁴⁻¹⁶ we are in close proximity of metal composition. EDXRF spectrum of coin 1 and coin 6 shown in figure 3(a) and 3(b) which shows dominance of Cu, Ni and Fe, Cr over all other elements present in the coins respectively.

CONCLUSIONS

In the Ancient (up to 1295AD) and Medieval (1295-1724 AD) era, the coins were fabricated mainly with Au, Ag and Cu and in British Rule (1904-1933) coins were made of silver (Ag) as major constituent as reported by T.R. Rautray et al. (2004)⁶ and B.B. Tripathy et al.(2009)⁷. Up to 1970, Ag is completely removed from the coin's composition in Modern era. All investigations related to one rupee Indian coins of two decades (1980 and 2000) have been done by Energy Dispersive X-ray Fluorescence (EDXRF) technique. It has been found that Fe and Cr are the major ingredients of Modern Indian coins that replaced with Cu and Ni in 1980's coins. Coins of Earlier era (1970) of pure Ni metal now a days are completely removed from usages. This study shows significant change in the composition of alloy from one to next decades. At present all Modern era coins are fabricated with Ferrite stainless steel with lesser weight. The EDXRF study reveals that such type of investigations can be effectively done with this technique for elemental analysis of coins. Due to gradual rise in the price of copper and nickel, the native value of the cupro – nickel coins surpassed its value. To check the large scale diversion of these cupro – nickel coins from circulations for melting purposes by fraudulent traders, the one rupee coin of ferrite-stainless steel were issued from 1992.

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