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India's Readiness on ROHS Directives: A Strategic Analysis

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Abstract - The materials are essential for critical performance of electronic products. Disposal of some of these materials, however, poses a serious threat to the environment after endof- life of the product. The European Union and other developed countries have already enacted legislative measures as Restriction of Hazardous Substances (RoHS) Directive to restrict the use of certain substances in the manufacturing of the electronic products. India has also notified similar legislation on 12th May 2011 to address this serious issue. Indian electronic manufactures are however facing serious challenges due to this legislative restriction. Industry needs testing and certification of admissible level of hazardous substances in the product for necessary compliance. The testing facilities available with few private laboratories are not adequate. Department of lectronics and Information Technology, Government of India, has therefore created a state-of-art laboratory with modern analytical instruments to address the growing demand of the industry. This article provides an overview of the RoHS and other related legislative measures present in the world and in India. An attempt is also made to study the preparedness of the industry and the immediate impact on the business of electronic sector.

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Strictly as per the compliance and regulations of :

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I. Introduction

Electronic materials are at the core of design and development of components and modules, which are in turn the heart of electronic products. The performance of the electronic products solely depends on the critical properties of the materials present in the products. Modern electronics is driven by innovations in advanced materials. Some of these materials are, however, not environmentally-friendly. The demand for electronics products has been enhanced manifold with massive growth of the electronics and hardware sector. Fast change of features in electronics devices and availability of improved products forces the consumers to dispose of the electronics products rapidly. This has alarmingly increased the generation of electronic waste. European Union (EU) had realized that all hazardous substances from the electronic and electrical equipments cannot be recycled or disposed of in an environmentally sound and safe manner.

The EU had first enacted Restriction on Hazardous Substances (RoHS) directive on August 13, 2004 to control the hazardous substances in electrical and electronic products (*source:http://ec.europa.eu/environment/waste/weee/lgis_en.htm*). Several countries have now introduced similar rules to address the issue. Ministry of Environment and Forests (MoEF), Government of India has also notified first ever exclusive rules as electronic waste (Management and Handling) Rules, 2010 on 12th May 2011 (*source: http://moef.nic.in/downloads/rules-and-regulations/1035e _eng.pdf*). The rule includes restrictions on and reduction of the use of hazardous substances in the manufacture of the electrical and electronic equipments.

The present electronic waste rule will have a significant impact on the business of electronics products in India and the world electronics industry. India is a growing consumer market. Every electronics manufacturing, assembling and trading unit needs to abide by the rules and, therefore, needs to procure and sell components, modules, and products that strictly follow the present rules of the MoEF. In order to honour the present rules, manufacturers need to make products so that materials used in them specifically to comply with the list of prohibited substances. These changes in manufacturing and assembly process would not only affect the electronics industry, but also other industry like electrical, power, telecommunication, automotive etc., where electronic products are used.

The testing of the components and modules used in the electronics products and hardware equipments for RoHS are the initial step towards the compliance of the rules. The compliance would be mandatory for the manufacturing and assembly units. Earlier RoHS compliance was needed for Indian exporters of electronic products to the EU and few other developing countries. In the present scenario, Indian industry would desperately need testing and certification facilities for the RoHS even for domestic market. A few private laboratories have already been established in India to provide such services for the industries. These facilities would be inadequate to meet the growing need for the Indian companies. Department of Electronics and Information Technology has therefore created the, first-ever government-owned National Accreditation Board for Testing and Calibration Laboratories accredited and certification facility at Centre for Materials for Electronics Technology (C-MET), Hyderabad.This article

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discusses the immediate impact of the RoHS clause in the present electronic waste rule on the Indian electronics industry and necessary readiness required for coping up the immediate challenges. An attempt has also been made to describe the testing facilities available in India. The article also discusses the function of the equipment, the test procedure and indicative charges of the equipments available in CMET, Hyderabad.

II. What is RoHS?

The Restriction of Hazardous Substances Directive (RoHS) is a Directive of the European Union on the restriction of the use of certain hazardous substances in electrical and electronic equipment. RoHS is one of a handful of European legislation that intended to eliminate or reduce the use of cadmium, hexavalent chromium, and lead in all products from automobiles to consumer electronics. The directive restricted the use of six hazardous materials including Lead, Mercury, Cadmium, Hexavalent chromium, Polybrominated biphenyls (PBB), and Polybrominated diphenyl ether (PBDE) in the manufacture of various types of electronic and electrical equipment with following permissible limits:

- Lead -1000 PPM
- Cadmium -100 PPM
- Mercury -1000 PPM
- Hexavalent Chromium -1000 PPM
- Poly Brominated Biphenyles -1000 PPM
- Poly Brominated Diphenyles Ether -1000 PPM

a) RoHS in Electrical and Electronics Products

The six banned substances are very critical for design and development and functionality of various electronic products (*Sarah et.al, 2008*). Following are some of the applications:

i. *Lead*

Lead is used in following cases:

- Lead acid batteries contain nearly 58% of lead
- Tin-lead alloys are most widely used as solder in electronics industry. The solder is used in personal computers (PC) and laptop, printer and copier, mobile phone, video games, television sets etc.
- Leaded glass and ceramics use lead oxide as an additive. Crystal glass contains 24-36% of lead oxide to shield radiation, which is used in cathode ray tubes in television sets, fluorescent tubes and electrical glass.
- Another important application of lead compounds is as PVC stabilizers as lead salts are most cost effective stabilizers for PVC, which is commonly used in electrical cable insulation, refrigerator racks, cell phone housing, keyboards and computer, monitor housing, cable sheathing in external or internal electric cables.
- Lead is used occasionally as raw material for the synthesis, in electrolysis and in stabilizers

ii. *Cadmium*

Cadmium or cadmium oxides are used in following cases:

- Cadmium oxide is used in nickel-cadmium batteries, where nearly 72% of cadmium is present. Nickel-cadmium batteries are used in cell phones, toys, clocks, older laptops etc.
- Cadmium oxide or metal is used in PVC to retard degradation on exposure to heat and UV light.
- Cadmium is used for metal plating for protection of iron against corrosion.
- Cadmium is a common metal of various alloys used due to their melting temperatures. Tin-lead-bismuth-cadmium alloy joins heat sensitive metal parts, silver-cadmium-copper-zinc-nickel joins tungsten carbide to steel tools.
- Cadmium is also present in copper-cadmium alloys, solders, solar cells (CdTe and CdS) etc. Cadmium plating or solder is very common in semiconductors in computers, toys, mobile phones.

iii. *Mercury*

Mercury is used in following cases:

- Mercury bottom cells are used in watches and batteries
- Mercury is also used in measuring and control instruments, lighting, fluorescent tubes, older switches in some electrical equipment
- Gold and silver recovery in printed circuit board (PCB) recycling plants

iv. *Chromium VI*

Cr (VI) or chromium VI is used in following cases:

- Chromate coatings are used on various metals to protect metal parts from corrosion.
- Chromium in glass is used to achieve emerald green coloured glass
- Chromium VI pigments are important for coating on electrical contacts and fasteners (screws, nuts, bolts, etc.) in aluminium, in all electrical equipment. The chromium coating is also used in cooling systems of refrigerators.
- Chromium coating on copper foil is needed in lithium ion batteries in laptops, mobile phones and video games etc. This coated copper foil is also used on printed circuit boards of all electronic equipment.

v. *Polybrominated biphenyls (PBB) and polybrominateddiphenyl ethers (PBDEs)*

PBB and PBDE are used in different plastics and textiles, as a flame retardant. The brominated flame-retardants are essential in the following products:

- Deca-BDE housings are used in TV sets, mobile phones, wire and cable, connectors in electrical and electronic equipment

- Octa-BDE housings are in TV sets, PC monitors, mobile phones, in connectors, switches, circuit breakers in most electrical equipment, some types of circuit boards, plastic parts in copiers and lamp socket

III. Global Status of Rohs Legislations

The European Union had first initiated the campaign against the Restriction on Hazardous Substances (RoHS) by enacting its Directive 2002/95/EC, the Restriction of Hazardous Substances (RoHS) Directive-2003, effected from August 13, 2004. This directive controls the manufacturing of electronic and electrical equipments using hazardous substances like lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyles, and polybromonated diphenyl ethers exceeding a certain level. The ROHS directive is also known as "Lead-Free" legislation. This directive had, however, exempted certain items such compact fluorescent lamp (CFLs), cathode ray tube (CRT) etc. for which no suitable alternatives are known or limited due to lack of technology.

RoHS compliant electronics products had started entering the EU market since July 1, 2006. The EU countries took pro-active role in banning a number of products containing RoHS using "precautionary and substitution" principles. The RoHS Directive established a regulatory process of placing bans on lead and cadmium, which are essential to the functionality, safety, and reliability of electrical and electronic products. Review of the effects of the directive is being taken time to time at EU. The EU has agreed that bans must be made based on risk assessments. The EU is working to decide whether there should be additional exemptions listed in the RoHS directive. European Commission (EC) reviewed the terms of the Directive in 2008/2009 based on the experiences during the first few years of operations of the RoHS.

The RoHS Directive of the EU was a front running environmental legislation that triggered several similar initiatives around the world. Major initiatives on RoHS were taken in California, Norway, China, South Korea and Japan. Many countries including Australia, New Zealand, Thailand, Malaysia, Taiwan, Canada and Brazil are also seriously considering the matter. New Zealand describes that the countries that did not implement RoHS run the risk of becoming a dumping ground for non-RoHS compliant products. As more and more countries adopt RoHS, the environmental protection campaign strengthens.

a. USA

California's Electronic Waste Recycling Act law prohibits the sale of electronic devices and imposes an advance recovery fee on the sale of electronic products like television, monitors (4'' or greater), cathode ray tubes displays, and laptops from 1st January 2007. The law ensured the disclosure requirement of the restricted material. The law had, however, narrower scope as it included only cathode ray tubes and liquid crystal displays containing four heavy metals restricted by RoHS. This was extended to all the electronic products since 2010. Fees are collected by retailers, managed by the state, and used to fund the recycling programme. Other US states are also discussing the matter seriously to adopt similar law.

a) Canada

Alberta launched Canada´s first provincial electronics recycling program, where an advanced recycling fee of up to US $45 is charged for all the electronics sold in the province since October 2004.

b) New Zealand

The Government of New Zealand outlined, "Product stewardship and water efficiency labeling", from July 2005 to encourage businesses and consumers accept responsibility for the environmental effects of products.

c) Japan

Japan has no direct legislation on RoHS. Recycling laws, however, ensure that the manufacturers move to a lead-free process as per RoHS guidelines. Japanese industrial standard for the Marking of Specific Chemical Substances ensures that electronic products exceeding a specified amount of the identified toxic substances must carry a warning label since 1st July 2006. Advances of eco-design, e.g. 'design for disassembly' and use of 'automated disassembly using smart materials' are evident in Japan. Incentives were provided for design changes and manufacturing of electronics and electrical equipments linked to recycling installations. (Bio Intelligence Service, 2006)

d) South Korea

South Korea issued legislation similar to RoHS known as "The Act for Resource Recycling of Electrical/Electronic Products and Automobiles" on 2nd April 2007 to ban the same hazardous substances as the EU RoHS and also includes the same exceptions. The law was based on self-declaration system, with no special mark needed and does not apply to parts manufactured before 2008 and samples used in Research & Development.

e) China

In China RoHS has been applied to the list of products, which is a subset of the total scope of Electronic Information Products (EIP) from 12th December 2007. Directives point to phase out of heavy metals such as cadmium, mercury, lead, and hexavalent chromium as well as brominated flame retardants in future electronic products. Phase 1 was based on extensive labelling and reporting. The Phase 2 ensured the removal of banned substances.

f) Norway

"Prohibition on Certain Hazardous Substances in Consumer Products" was being considered since 2007. The scope of the law was broader and more stringent for maximum concentration and included more elements. This law extended beyond the electrical and electronics equipments.

IV. Impact of RoHS Legislations on Electronic Products

The electronics and electrical manufactures are becoming more environmentally conscious after implementation of the RoHS directive in the EU. The effect of the directive has already become visible. Electronic products entering in EU market have reduced hazardous substances. A study in the EU has shown a sharp reduction of certain hazardous substances from the electronic products entering the EU market (*Sarah et.al, 2008*). The graphical representation showing the sharp reduction of the six RoHS substances (Pb, Cd, Hexavalent chromium, Hg, PBB and PBDE) in three products namely PC (Fig. 1), Mobile (Fig. 2) and TV (Fig. 3) are shown.

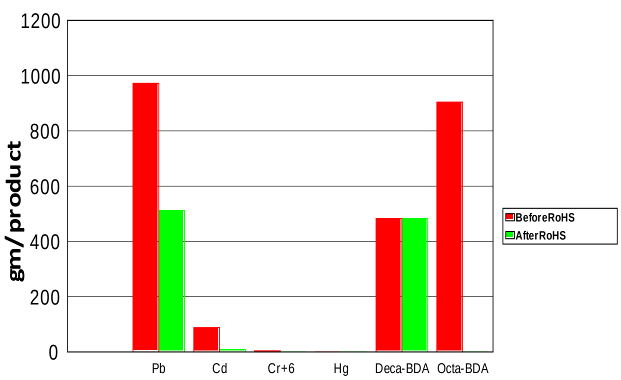

Fig.1: PC: Impact of RoHS Directives in EU

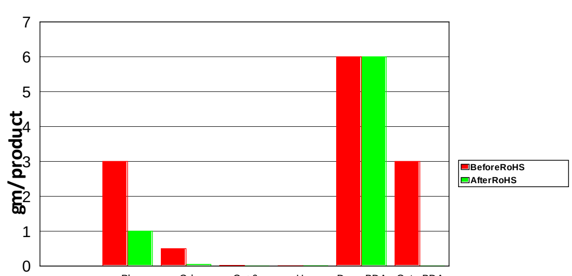

Fig.2: Mobile: Impact of RoHS Directives in EU

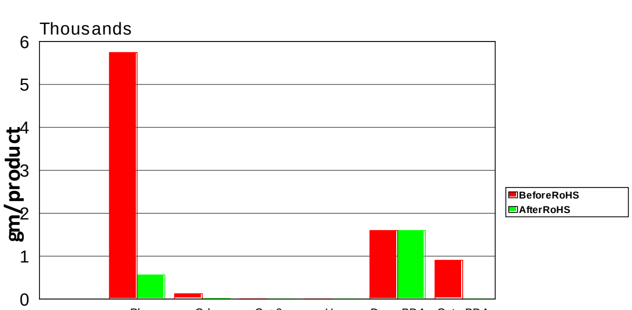

Fig.3: TV: Impact of RoHS Directives in EU

V. RoHS Regulation in India

Ministry of Environment and Forest (MoEF), Government of India is the nodal agency to address the issue related to RoHS and Electronic waste. MoEF has notified (S.O. 1035) the electronic wastes (Management and Handling) Rules, 2010 on 12th May 2011 to address the safe and environmentally friendly handing, transporting, storing, recycling of electronic waste and also to reduce the use of hazardous substances during manufacturing of electrical and electronic equipments (*source:http://moef.nic.in/downloads/rules-and regula - tions/1035e_eng.pdf)*. These are the first ever-exclusive rules on electronic waste in India. The chapter V of the rules has covered the reduction in the use of hazardous substances (RoHS) in the manufacture of the electrical and electronic equipments. These rules have been enacted from 1st May 2012 and rules relating to RoHS will come into effect from 1st May 2014.

The electronic wastes (Management and Handling) Rules, 2010 address reduction in the use of hazardous substances in the manufacture of electrical and electronic equipment. Following are the directives:

- Every producer of electrical and electronic equipment (see Table 1) shall ensure that, new electrical and electronic equipment do not contain lead, mercury, cadmium, hexavalent chromium, polybrominated diphenyls or ethers: Provided that a maximum concentration value of 0.1% by weight in homogeneous materials for lead, mercury,
- hexavalent chromium, by weight in homogenous materials for cadmium shall be permitted.
- The list of applications exempted from provisions of the rule is provided in Schedule-II (*p37 of rule, Source:http://moef.nic.in/downloads/rules-and-regulations/1035e_eng.pdf*).
- The components of electrical and electronic equipment manufactured or placed on the market six years before the date of commencement of these rules are also exempted.
- In the event of a reduction in the hazardous materials used in the electrical and electronic equipment, the detailed information on the constituents of the equipment, need to be provided in the product information booklet.
- Imports or placement in the market for new electrical and electronic equipment, which are compliant to rule, shall only be permitted.
- Manufacture and supply of electrical and electric equipment used for defence and other similar strategic applications shall be excluded from the rule.
- Such reduction in use of hazardous substances in manufactured or imported electrical and electrical equipment shall be achieved within a period of two years from the date of commencement of these rules.

The electronic wastes (Management and Handling) Rules, 2010 cover various electronics and hardware products and telecommunication equipment. These are given in Table1.

Table 1 : Electronics, hardware products and telecommunication equipments covers in electronic waste rule 2010

Categories	Items
Electrical and electronic equipment/ Information technology and telecommunication equipment	• Centralized data processing, • Mainframes, • Minicomputers, • Personal computers, • Laptop, • Notebook, • Notepad, • Printers including cartridges, • Copying equipment, • Electrical and electronic typewriters, • User terminals and systems, • Facsimile, • Telex, • Telephones, • Pay telephones, • Cordless-phones, • Cellphones, and • Answering systems.
Consumer electrical and electronics products	• Television sets, • Liquid crystal display, • Light emitting diode display, • Refrigerator, • Washing machine, and • Air-conditioners.

VI. ROHS Testing Facility in India

a) *Private Initiatives*

Indian electronic and hardware industries had been facing a problem in exporting electronic products to EU countries since the implementation RoHS Directive of the EU in 2004. The problem is getting more pronounced, day-by-day, as the similar legislative measures are being adopted in most of the developed countries. India has limited testing facilities or laboratories. Adequate infrastructures, dedicated to the RoHS test, skilled lab manpower and scientific and technical knowledge base are rarely available. The demand and opportunities were emerging in Indian market for testing facilities and infrastructures and certification for RoHS compliance. Thus, several private laboratories had initiated RoHS testing to avail the timely opportunities as well as to address the needs of the industry. Table 2 provides few such laboratories and their facilities

Table 2 : List of NABL Accredited Private Laboratories involved in RoHS Testing and Certification in India

S.No.	Name & Address of Laboratories	Facilities Available
1	Bangalore Test House (BTH), Marrenahalli, Vijayanagar, 65,20th Main, Bangalore, Karnataka,	UV-VIS, AAS & GC-MS
2	Sargam Labs. Pvt. Ltd., Laboratory Service Division, 2, Ramavaram Road, Manapakkam, Chennai	ICP-MS, AAS, IC, EDXRF, GC-MS & UV-VIS
3	TUV-Rehinland India Pvt. Ltd.,Plot No. 17B, Electronic city, phase-II, Bangalore	ICP-MS, AAS, IC, EDXRF, GC-MS & UV-VIS
4	Hiram Institute For Industrial Research, 14-15, Sadarmangala Industrial Area, Whitefield Road, Bangalore	ICP-MS, AAS, IC, EDXRF, GC-MS & UV-VIS
5	Delhi Test House,A-62/3, G.T.Karnal Road, Opposite Hans Cinema, Delhi	ICP-MS, EDXRF, & UV-VIS
6	Shiva Analyticals (India) Ltd.,Plot No.24 D [P] & 34 D, KIADB, Industrial area, Hoskote, Bangalore	ICP-MS, AAS, IC, & UV-VIS
7	The Automotive Research Association of India, Survey No. 102, Vetal Hill, off Paud Road,Kothrud, Pune	UV-Visible
8	Geo-Chem Laboratories Pvt Ltd.,36, Raja Industrial Estate, Purushottam Kheraj Marg, Mulund (W), Mumbai	ICP-MS
9	Arbro Pharmaceuticals Ltd.,4/9, Kirti Nagar, Industrial Area, New Delhi	ICP-MS
10.	Doctors Analytical Laboratories, Priangut Road, Bhukum, Pune	AAS

The Table 3 provides the charges of the specific test in various private laboratories in India.

Table 3 : RoHS analysis charges at NABL accredited Private Laboratories in India

S. No	Laboratory	Analysis details	Tentative Testing Charge (US$)*
1	Shriram Institute, Bangalore	Pb, Cd, Cr^{6+}, Hg, PBB & PBDE	227
2	Delhi Test House, Delhi	Pb, Cd, Cr^{6+}, Hg, PBB & PBDE	125
3	Bangalore Test House, Bangalore	Pb, Cd, Cr^{6+} & Hg	35
4	Geo-Chem laboratories, Mumbai	Pb, Cd, Cr^{6+} & Hg by ICP-OES	56
5	Lucid Laboratories, Hyderabad	Pb, Cd, Cr^{6+} & Hg by ICP-OES	50
6	SGS, Chennai	Pb, Cd, Cr^{6+} & Hg by ICP-OES	82
7	Arbro, Pune	Pb, Cd, Cr^{6+} by ICP-MS	50
8	Doctors analytical laboratories, Pune	Pb, Cd, Cr^{6+} by AAS	32

NB : Charges mentioned are only indicative, and subject to change from time to time and vary depending on the complicacy of the test above. This is only to give an idea of the cost involved in the RoHS tests.

b) Government Initiatives

Though, private facilities are available, creating a well-equipped government facility was always a demand in India from the manufacturing industries for bringing transparency and neutrality of the test report. It was also felt that RoHS testing requires adequate research base, knowledge and technical skills, which would only be available and sustained by government owned laboratories. It was also stressed that the government can appropriately ensure International Standard like IEC (International Electrotechnical Commission).

Department of Electronics and Information Technology has therefore created a facility of the RoHS at Centre for Materials for Electronics Technology (C-MET), Hyderabad, which is one of the premier R&D institutions in the country under this Department. C-MET is the leading organization for the development of electronics materials, high purity metals, and electro-ceramics. The laboratory has robust R&D infrastructure facilities to carry out high-end research and development projects. This facility is the only government owned laboratory, which has obtained the accreditation from the National Accreditation Board for Testing and Calibration Laboratories. The laboratory is fully equipped with world recognized analytical equipments for RoHS testing. The international standard procedures are followed for the testing. Installed equipments are inductively coupled plasma-mass spectrometer (ICP-MS), ion chromatography (IC), gas chromatograph – Mass spectrometer, energy dispersive x-ray fluorescence spectrometer (EDXRF), atomic absorption spectroscopy (AAS), UV - Vis - spectrophoto meter.

In the following section, working principle and functioning of these equipments are discussed.

i. *Testing equipments for RoHS analysis in CMET, Hyderabad.*

a. *Energy Dispersive X-ray Fluorescence spectrometer (EDXRF)*

The Energy Dispersive X-ray Fluorescence Spectrometer (Model: ARL QUANT "X", Thermo Scientific, Japan) has been installed at CMET, Hyderabad for testing hazardous elements. The EDXRF uses non-destructive technique and multi-elemental analysis with excellent sensitivity. This prerequisite instrument decides the pass or fails RoHS elements like Pb, Cd, Hg, all Cr ions and Br in part per million (ppm) levels. The equipment provides the accurate and fast analysis with mapping facility. The existence of hazardous substances can be confirmed in liquid, solid or film by screening of the samples at EDXRF.

b. *Atomic Absorption Spectrometer (AAS)*

C-MET, Hyderabad has installed the Atomic Absorption Spectrometer (Model: GBC 932 AA, GBC Scientific Equipments P. LTD, Australia) for elemental analysis at ppm level with reasonable accuracy and precision. The principle of AAS is the absorption of light by a free atom in the gaseous state to determine the concentration of a particular element qualitatively and quantitatively. AAS requires standards with known analyte content to establish the relation between the measured absorbent and the analyte concentration using Beer-Lambert Law. The radiation flux with and without a sample in the atomizer is measured to calculate the concentration or mass. The detailed analysis of three elements of RoHS i.e. Pb, Cd & Cr can be made by dissolving the given samples (0.2g) in certain acids by using Microwave Digestion System.

c. *Inductively Coupled Plasma- Mass Spectrometer (ICP-MS)*

Inductively Coupled Plasma- Mass Spectrometer (Model: X Series 2, Thermo Fisher Scientific Wissenschaftliche Gerate GmbH, Austria) has been installed at C-MET, Hyderabad. ICP works on the principle of atomic emission spectrometry. The instrument executes multi- elemental analysis with excellent sensitivity and high sample throughput. ICP-MS employs plasma as the ionization source and a mass spectrometer analyzer to detect the ions produced. It can simultaneously measure most elements in the periodic table and determine the concentration down to the sub monogram-per-liter (nag/l) or part-per trillion (ppt) level. It can perform qualitative, semi-quantitative, and quantitative analysis, since it employs a mass analyzer.

d. *Ion Chromatography (IC)*

The Ion Chromatography (Model: 850 Professional IC, Metrohm AG, Switzerland) has been installed at C-MET, Hyderabad to primarily analyse hexavalent Chromium at lower levels. Ion Chromatography is the only technique that C-MET can provide quantitative analysis of anions/citations at the ppb level. IC determines ions in liquids and ionic contamination on the surfaces of wafers, chips, and packages. Aqueous solutions, required for filtration, dilution, and/or cleaned to remove interferences, are used for analysis. Plastic samples are extracted with water/organic solutions to remove ions from the sample surface. IC analyzes Hexavalent chromium in any plastic sample.

e. *UV-Vis Spectrophotometer*

C-MET, Hyderabad has installed UV-Visible Spectrophotometer (Model: UV 2450, Shimadzu, Japan) to evaluate hexavalent Chromium in RoHS samples. The Cr^{6+} is extracted by using UV-VIS with hot water extraction technique. A beam of light from a visible and/or UV light source (collared red) is separated into its component wavelengths by a prism or diffraction grating. Each monochromatic beam in turn is split into two equal intensity beams by a half-mirrored device. One beam, the sample beam, passes through a small transparent container (curette) containing a solution of the compound being studied in a transparent solvent. The other beam, the reference, passes through an identical curette containing only the solvent.

f. *Gas Chromatography – Mass Spectrometer (GC-MS):*

C-MET, Hyderabad has procured Gas Chromatography – Mass Spectrometer (Model: DSQ II, Thermo Fisher Scientific Wissenschaftliche Gerate GmbH, Austria) to determine the brominated flame retardants. The difference in the chemical properties between different molecules in a mixture will separate the molecules as the sample travels the length of the column. The mono to deca congeners of both PPB and PBDE is analyzed in the given plastic samples by extracting these two components by using a Soxhlet extractor and preconcentrator. The mass spectrometer will quantify the concentrations of PBB and PBDE in plastics.

ii. *Testing Procedure*

During the RoHS testing and investigations of electrical and electronics products, following definitions are considered in choosing the materials.

a. *Unit*

It is the smallest part of electrical or electronic equipment that can be separated from the original products by using ordinary tools, without destroying the function of the part when it is removed.

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b. *Mechanically Disjointed:*

It is the dismantled unit by simple processes such as screwing, disconnecting and/or de-soldering, or using ordinary tools. These materials are free from application of chemicals, cutting, grinding and/or polishing or destroying the function of the unit.

c. *Homogeneous Material :*

A homogeneous material cannot be 'mechanically disjointed' into different materials. 'Mechanically disjointed" means that the materials cannot in principle be separated into other materials by mechanical methods such as unscrewing, cutting, crushing, grinding or abrasive processes

The procedures followed in testing the RoHS samples are very rigorous and requires a lot of training, skill, and research. International standard practices such IEC (*International Electrotechnical Commission*) are followed in choosing materials, preparing the samples and the steps to be followed for particular RoHS test etc. During the RoHS testing and investigations of electrical and electronics products, step-wise procedures are followed by the regular RoHS test, which are shown in the Fig.4.

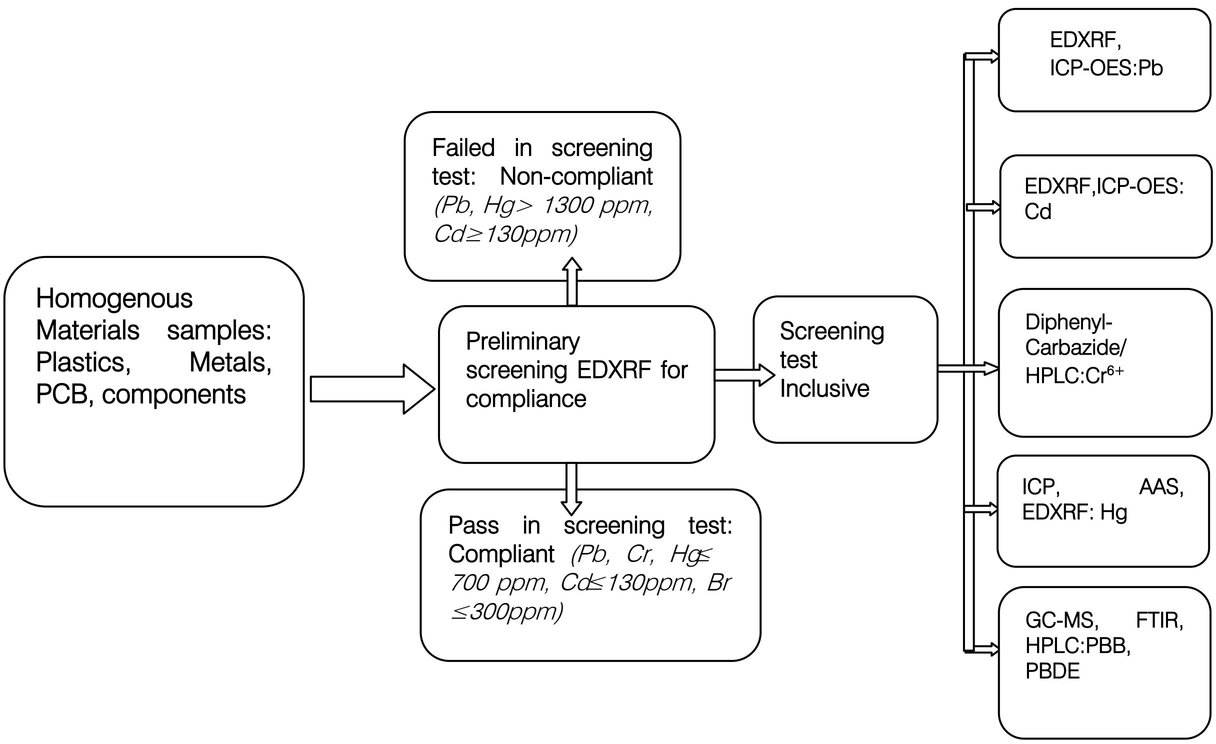

Fig.4 : Steps of RoHS samples test

iii. *Testing charges*

The analyzing of the RoHS samples from the electronic components, modules and electronic products requires specialized skill and expertise. Internationally recognized methods and standard are used to prepare the samples and test procedure.

The choosing of samples, preparation of the appropriate sample, correct analysis using standard methods etc. requires lots of research, study and knowledge base. Considering the consumables, manpower, maintenance of equipment, electricity, and other utilities etc., Centre for Materials for Electronics Technology, Hyderabad has decided test-wise charges, which are shown in Table 4.

Table 4 : Testing charges for RoHS analysis in C-MET, Hyderabad

S.No	Name of the equipment	Analysis details	TentativeTestingCharge (US$)
		Quantitative Analysis	
1	GC-MS	PBB, PBDEs	68
2	ICP-MS / AAS	Pb, Cd, Cr^{6+}, Hg	45
3	IC/UV-Vis	Pb, Cd, Cr^{6+}, Hg	45
		Qualitative Analysis	
4	EDXRF	Scanning for all RoHS elements	34
5.	Test of all six RoHS (Pb, Cd, Cr^{6+}, Hg, PBB and PBDE) in particular sample	Analysis of Pb, Cd, Cr^{6+}, Hg, PBB and PBDE content	34
6.	Scanning charges for all RoHS elements		34

NB : Charges mentioned are only indicative, and subject to change from time to time and vary depending on the complicacy of the test above. These are only to give an idea of cost involved in RoHS tests.

VII. Impact on Electronics Sector

a) *Indian Electronic Industry*

Indian electronics hardware production has been enhanced from US $ 12.4 billion in Financial Year 2005-06 to US $ 26.64 billion in Financial Year 2010-11 (*Source: Annual Report, DIT, Government of India, available at* http://www.mit.gov.in/sites/uploadfiles/dit/files/annualreport2010-11.pdf).

The size of the Indian electronics industry has been estimated to exceed $150 billion by 2015 and US $ 400 billion by 2020. Since the domestic production is less, most of the requirement is being met by imported products. The exports of electronic goods are expected to touch $15 billion by 2013-14. The share of electronics production in India's GDP has increased from 1.6 per cent in 2001-02 to 1.95 per cent in 2009-2010. A year-wise growth path of the Indian electronics industry is shown in Fig. 5.

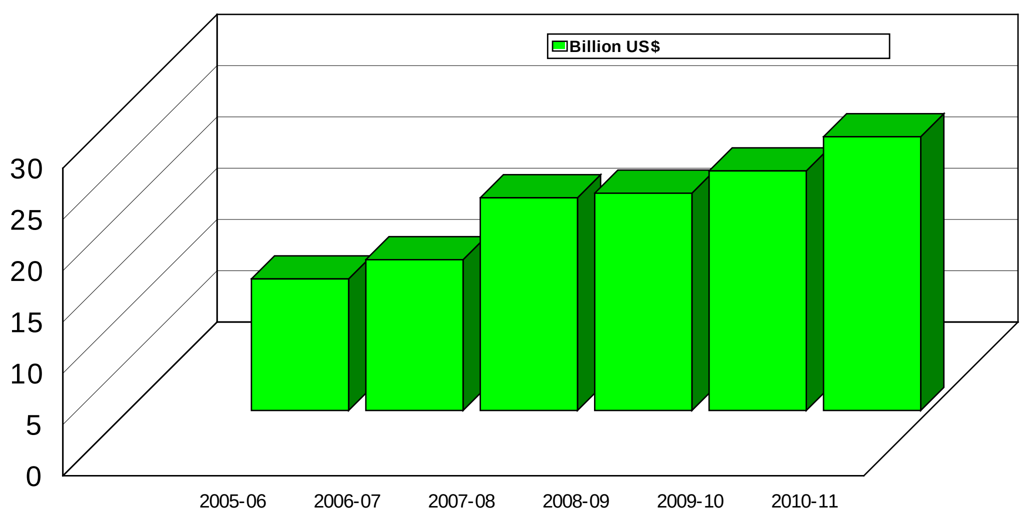

Fig.5: Indian Electronic Hardware Sector

The Indian electronics industry has faced a challenging phase since 2000 due to increasing debt, erosion of net worth, declining profits and low asset utilization. The industry is experiencing a stiffer level of competitions from foreign companies, which has strained the financial health. Though, the domestic demand of the electronic sector is enormously increasing, the Indian electronic manufacturing sector is not growing at that pace. India has substantial resources, capabilities excel the design, manufacturing and services sectors. India has established its presence in engineering, and IT enabled services sectors. India has not yet shown similar strength in manufacturing and design sectors, though, global electronics industries are ready to outsource their design work to Indian companies. The net profit margins for some of the India's largest electronic and consumer companies studied recently shows a very thin net operating level profit margins due to stiff competitions from domestic as well as foreign companies (see in Table 5).

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Table 5 : Profit Margin of Leading Indian Electronic and Consumers Companies

S. No	Name of the companies	Domain Areas	Net Profit Margin (%) (Year 2010)
1.	Videocon Industries	Electronics goods manufacturing	5
2.	Moser Baer India Ltd	Optical storage, solar photo voltaic, consumer products etc.	4
3.	Samtel Group	Color and Black and White cathode ray tube, cathode ray tube glass, deflection yoke, etc.	<1
4.	Solectron	Frequency control products, hybrid micro circuit, etc.	<1
5.	Blue Star	Central air-conditioning	3
6.	Bajaj Electricals Ltd.-	Consumer electrical products	5
7.	Whirlpool India Ltd.	Consumer electrical products	4

Source : http://www.greenworldinvestor.com/2011/04/04/india-consumer-durables-stocks-consumer-discretionary-companies-a-good-play-on-rising-indian-middle-class/

b) *RoHS Compliance: Operating Cost*

Electronic components, modules and products manufacturing companies in China, Taiwan, Korea, Japan, as well as developed countries are incurring significant costs to make their products RoHS compliant. The cost includes administrative, monetary losses, technical and compliance charges etc. A survey finds that the initial RoHS compliance cost of the electronics industry was US $32 billion (*Buonpastore et. al, 2008*). The electronics industry is highly competitive and is reluctant to enhance prices to avoid losing market-share to a competitor. The possible costs on RoHS compliance *(Sarah et.al., 2008)* are briefly given below :

a. *Administrative expenses:* This includes the costs of training and information measures, personnel and resource expenses, costs of the collecting and reviewing information related to exemption procedures. The companies incurred cost for material declarations from suppliers and testing components for compliance etc. Stock management costs would increase as all products are not within the scope of the RoHS and also all markets do not have RoHS-like legislation.
b. *Monetary losses:* This includes a decrease in turnover, temporary discontinuation of non-compliant products, discontinuation (destroying) of non-compliant products, delayed introduction of new products, and obsolete components.
c. *Enhanced manufacturing costs:* In some cases manufacturing cost would increase due to process change with new materials and the low production yield associated with new process.
d. *Technical costs:* This cost would include phasing out capital equipments used for six RoHS materials, operating expenditure, costs of R&D etc.
e. Compliance costs: This includes testing, certification, auditing, for obtaining RoHS compliance certificates etc.

Several studies have been conducted to know the actual economic impact on the electronic sector due to implementation of RoHS. A study has projected that RoHS complying cost including R&D and capital expenditures for the large sector is nearly 1.9% of annual revenues or turnover. Similar costs for small and medium enterprises are considerably higher at 5.2%. The future ongoing costs of complying with RoHS are estimated at 0.4% of annual revenues, whereas, the estimation for the small and medium sectors have a substantially higher future cost (*Wurzman et. al*. 2005).

Few case studies are also made to know the cost impact of technological change. It has been found that lead-free solder costs approximately twice that of earlier cost. RoHS compliant materials contain costly metals like silver and gold and also needs an increased rate of recycling. Manufacturing cost has also increased due to high failure rates of lead-free components during the manufacturing process. The new compound also requires more re-work and repair, and higher energy cost (nearly 19%) due to its high melting point. Thus productivity decreases by 2 to 7%.

c) *RoHS Compliance: Product Cost*

A study on RoHS compliance readiness survey was conducted in China, Taiwan, Hong Kong and South Korea during 2005 by Global Sources. The studyobserved that the price of most of the electronic products have been enhanced between 5-10% in order to comply the RoHS directives. The details are given in Table 6.

Table 6 : Price Rise due to RoHS

Electronic Products	Percentage Rise (%)
Car electronics	5
Batteries	No significant change
Colour TVs	< 5
Computer peripherals	< 5
Computer systems and components	10
Connectors	10
Home a/v products	< 5
LEDs and LED displays	10
Media players and recorders	< 5
Networking products	No significant change
Passive components	< 5
Personal electronic devices	10
Printed circuit boards	< 5
Telecom products	< 5

VIII. Conclusion: India Scenario

India is a growing consumer market. Though, India is not a manufacturing base; mostly products are imported from the countries like China, Taiwan, and Malaysia etc. India has very limited companies involved in manufacturing and core design. The basic needs of these sectors are the capabilities of leading edge technology and availability of local markets. The present situation is conducive in both ways for the growth of India's design and manufacturing sectors. The manufacturing units, however, procure components, semiconductor ICs etc. mostly from neighbouring countries.

The present RoHS rules in India will have a significant impact on the business of electronics products. Indian industry need now to procure the components, modules and other peripheral items, which do not contain restricted chemicals to obey the RoHS rules. The industry would be affected due to the rules, as they would be responsible for dumping of hazardous substances. Presently, India is a major market for the non-compliant products. The electronic and hardware sector in India are mainly assembling and trading units. Every electronics and electrical units now need to abide by the electronic waste rule in India and therefore would force to procure components, modules, products, which are strictly complied with the rule. It would be very difficult for the Indian industry to meet the criteria in the near future as the industry works with very competitive and thin profit margins.

The alternative components, modules and products will be expensive. Extensive R&D is needed to find suitable alternative substances, providing the same functionality and reliability as the banned substances. Elimination of specific substances requires a great deal of research and development of alternative substances, which needs investment of time and resources of electronics manufacturers throughout the supply chain. This effort is technically challenging and sometimes unfeasible due to the complexity of electronic products. The technological know-how on the green electronics of RoHS compliant substances is available with developed countries. The technology cost is substantially high due to the involvement of major fund requirement for research and development. In order to honour the rule, the manufacturers need to make products with RoHS compliant substance, which result in increased costs. The manufacturer will defiantly pass on additional cost to the consumer. These additional costs and technical challenges would make it very difficult for Indian manufacturers to compete globally. This change would not only affect the electronics industry, but also other industry like electrical, power, telecommunication, automotive etc. where electronic products are used.

Similar to the case study of the global electronic sector discussed *at Para VII (b)*, it can be projected that the RoHS compliance cost for Indian electronic companies would also enhance between 1.9% to 5.2% of annual revenues or turnover, depending on the size of the industry (large/medium/or small). Procurement of alternative materials for the components would definitely be costlier. The import cost of the components and modules for most of the Indian companies would be high, being assembly unit. This higher import cost would further strain their operating profit. There will be a substantial rise in bills of materials for meeting the RoHS compliant products. The net profit margin of the local companies (Table 5) would further fall and in some cases would be difficult to sustain.

Indian exporters of electrical and electronic equipments are already experiencing these hurdles due to EU's RoHS directives since 2006. They have already ensured the compliance of the RoHS directive while is exporting their products to European countries. All of reduced to the permitted concentrations from the electrical or electronic products that are being sold to the countries where the law is enacted. Since the product price in the European market is higher than that of the domestic market, absorbing the additional cost for the European market became easier. It would be, however, difficult for the Indian industry to prepare for the domestic market.

If one thinks long term, the environmental sustainability of any product would be ideal. Though, the cost involved in switching over RoHS compliant products is substantially higher, the country without RoHS legislation would, however, face greater risks economically. Most of the major world markets are or will be covered by RoHS like initiatives. Innovative electronics manufacturers would face a barrier to growth when looking at the market, where RoHS compliance is compulsory. Non-compliant imported products would drop in price as the global market for non-compliant products shrunk putting further pressure on locally produced products. Moreover, the loss of exports due to lack of knowledge of RoHS amongst the companies is more prevalent amongst SMEs. Many global manufacturers stress an international standard or centralization to simplify and streamline all the environmental related laws for electronic products.

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