International Journal of Emerging Trends in Health Sciences

Volume 04, Issue 1, (2020) 36-67 www.ij-hs.eu

# Environmental health impact assessment of chrome composite leather-clad rollers used by Indian cotton roller ginning industries and design and development of Eco-friendly alternatives

**Vijayan Gurumurthy Iyer***, Chartered Engineer, A-2/31, Kendhriya Vihar-II, Third floor, Poonamalee-Avadi Main Road, Paruthipattu, Avadi, Chennai 600071, India https://orcid.org/0000-0003-2443-6573

**Suggested Citation:**

Iyer, V. G. (2020). Environmental health impact assessment of chrome composite leather-clad rollers used by Indian cotton roller ginning industries and design and development of Eco-friendly alternatives. *International Journal of Emerging Trends in Health Sciences. 04*(1), 36–67.

Received November 18, 2019; revised February 20, 2020; accepted April 05, 2020.
Selection and peer review under responsibility of Prof. Dr. Nilgun Sarp, Uskudar University, Istanbul.


**Abstract**

This research article realises the hazards of chromium contamination and pollution caused by using chrome composite leather-clad (CCLC) rollers that are commonly used in the cotton roller ginning industries and attempts to eliminate the chromium contamination and pollution during the cotton ginning process. The chromium traces found contain hexavalent chromium being adsorbed from chromium-contaminated lint, yarn, fabrics, seeds, by-products and textile effluent. Chromium acts in three ways on humans, viz. (i) local action explained as dermatitis or absorption through skin, (ii) direct inhalation and (iii) ingestion or absorption into the stomach. Toxic effects are produced by prolonged contact with airborne or solid or liquid chromium compounds even in small quantities because of their properties, viz. carcinogenicity, mutagenicity and corrosiveness. Traces of Cr (VI) are found even in analar grade trivalent compounds, and complications do arise due to reduction in the nature of these traces that affect the organic tissues of the body. These regenerating effects occur rapidly and are dependent on the dose. This research article realises the hazards of chromium contamination and pollution caused by the use of dust-producing grinding of CCLC rollers that are commonly used in the cotton roller ginning industries and attempts to nullify this problem during cotton ginning. This research has been carried out with the following objectives: to identify and study the environmental health effects existing with the present CCLC rollers being used in the Indian cotton roller ginning industries; to conduct an environmental health impact assessment in Indian cotton roller ginning factories during the research years of 1998–2018; to design and develop an eco-friendly chrome-free roller and evaluate its performance with reference to environmental health effects and techno-commercial aspects in the ginning industries. With the author's research background and practical experience in cotton ginning and textile industries, this study is attempted to eliminate the environmental health impacts to a great extent at the source itself, through a suitable design and development of an eco-friendly, pollution-free, chromeless roller for cotton roller gins. An eco-friendly roller ginning process has been designed and developed for replacing the conventional CCLC roller ginning process, to eliminate the chromium contamination and pollution from cotton roller ginning industries and to meet the requirements of World Health Organisation standards, while maintaining high-quality spun yarns and woven fabrics which meet the international standards.

**Keywords:** Assessment, chromium, ginning, health, impact.

* ADDRESS FOR CORRESPONDENCE: **Vijayan Gurumurthy Iyer,** Chartered Engineer, A-2/31, Kendhriya Vihar-II, Third floor, Poonamalee-Avadi Main Road, Paruthipattu, Avadi, Chennai-600071, Tamil Nadu, India.
*E-mail address*: vijayaniyergurumurthy@rediffmail.com

## 1. Introduction

India is one of the leading cotton-growing countries in the world. It has 24% of the world area under cotton cultivation and 11% of the total cotton produced in the world (Krishna Iyer, 2000). India ranks first in area with 11.1 million hectares of land under cotton cultivation and third in production. This is the only country where all the five species, viz. *Gossypium hirsutum*, *Gossypium barbadense*, *Gossypium arboreum*, *Gossypium herbaceum*, and hybrids are cultivated (Vijayan, 1999). Cotton production has been estimated at 2,790 lakh bales (each bale weighs 170 kg of lint cotton) during 2016–2017 in the world. The lint cotton requirement for 2016–2017 AD is projected as 290 lakh *bales*.

Cotton, grown on the plant is seed-cotton (or *kapas*), which consists of 24–40 seeds per boll. This is subjected to the ginning process after being transported from the cotton farm to the ginning mill (Figure 1).

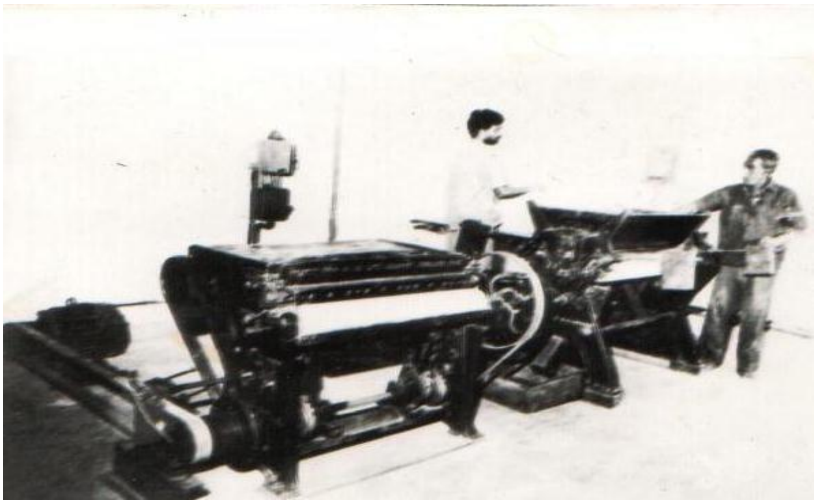

**Figure 1. Environmental health impact assessment (EHIA) being conducted in a cotton ginning plant at a technological laboratory in Matunga, Mumbai, India**

The manufacturing process of cotton textiles consist of two steps, namely (i) fabrication of the cloth and (ii) processing and finishing. There are about 5,500 ginning and pressing units in India. Of these, about 4,700 are exclusively ginning units, 800 are composite units consisting of both ginning and pressing and 100 are exclusively pressing units. There are about 797 pressing factories for pressing the ginned *lint cotton* into *bales*. The bales are transported to either spinning mills or composite mills. There are about 3,200 small and big spinning mills and 400 composite mills containing 33 million of spindles frames (Vijayan, 1999).

Ginning is the first phase of mechanical operation for cotton textile production. Cotton ginning is a method of separating *lint cotton* from the *seed-cotton*. Seed-cotton varieties are classified as per the *staple length of cottons*, namely (a) short staple, (b) medium staple, (c) long staple and (d) extra-long staple cottons (Vijayan, 1999). There are two types of cotton gins (or ginning machines) used in our country, viz. roller gins and saw gins. The roller gins gin all *the staple length* cotton varieties*,* whereas the saw gins gin only *short staple* cotton varieties. About 80% of the seed-cotton produced in India (comprising of nine major cotton-growing states) is ginned on roller gins, which plays an important role in the ginning industry. In the northern zone (comprising of some areas in the states of Punjab, Haryana and Rajasthan), where saw gins are used for ginning, 20% of the seed-cotton produced. The output of the single roller gin is 18–20 kg lint per hour, while that of a double roller (DR) gin is 40–45 kg lint per hour. The output of the saw gin is very much higher, being about 350–700 kg lint per hour (Vijayan, 1995).

The principle of the cotton roller ginning process was invented by McCarthy (Townsend, Walton & Martin, 1940). This process is the mechanical separation of cotton fibres from their seeds by means of one or more rollers to which fibres adhere, while the seeds are impeded and struck off or pulled loose. The principle of cotton roller ginning process is shown in the configuration profile of a cotton ginning process (Figure 2).

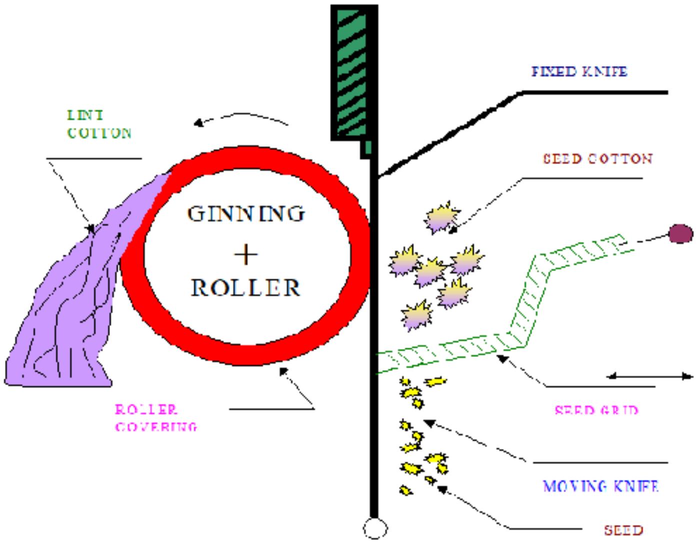


**Figure 2. McCarthy's principle of cotton roller ginning process**

In these gins, spirally grooved leather rollers, pressed against fixed knives, are made to rotate at a definite speed of 100–120 revolutions per minute (rpm). The crank or eccentric shaft close to the leather rollers gives rise to the oscillation action at 960 oscillations per minute (opm) of moving knives (Vijayan & Parthasarathy, 1998). When the seed-cotton is fed to the machine, the fibres adhere to the rough surface of the rollers and are carried in between the fixed knives and the rollers and the fibres are entangled in the process. The moving knives beat the seeds and separate the fibres, which are gripped, from the seed end. This process is repeated a number of times and due to the 'push-and-pull' action, the fibres are separated from the seeds that are carried forward on the rollers to be dropped out of the machine.

The roller constitutes an important element of the roller gins. Until 1940, only Walrus animal hide was used as roller covering material in USA and UK. Later on, due to the non-availability of *Walrus hide*, these countries did not allow this type of hide to be used and obsolete these roller gins. Sheep and Buffalo chrome tanned hides were used as substitutes in the roller ginning machines, although the *interfibrillary action* was not satisfactory compared to the walrus hides. Other roller materials, viz. ordinary leather, newspaper, corkboard and coconut coir, were also tried, but were not been found suitable. Since 1940, chrome composite leather-cladding (CCLC) material has been under use for making rollers of roller gins till now in India, Africa and Egypt. The CCLC rollers have not been used in USA and UK since many years.

Several rollers are required in a year due to wear and tear arising out of grinding action and also resulting in dust production during the process of ginning. The roller of the DR gin is about 1,025 mm long with a diameter varying from 178 to 180 mm. The fully pressed, finished and spirally grooved gin roller is finally used in roller gins (Vijayan & Parthasarathy, 1993). The stationary knife is held tightly against the roller and a moving knife pulls the seeds from fibres, which are held by the stationary knife and roller. Enough pressure ranging from about 5.6 to 7.0 kg/cm$^2$ is kept between the roller and stationary knife (RSK) to gin seed-cotton, with much capacity, without causing excessive heat of roller (Gillum & Marvis, 1964).

In this conventional ginning process, CCLC rollers emit chromium into the environment due to a constant dust-producing grinding action, which contaminates the cotton and its products beyond the safe limits of eco-standards (Figure 3).

**Figure 3. Ginned lint cotton contamination, Phase-I of EHIA: lint pollution by chromium.**

Since the semi-finished chrome leather washers contain 3%–4% of total chromium and are being used by roller ginning industries in India, Africa, Tanzania and Egypt, attention has been drawn to view the pollution and contamination aspects during the cotton ginning process (Vijayan, 2000). This results in *chrome-specific dust* (CSD) production during the process of ginning operation, which is the major environmental chromium contamination and pollution problem in the roller ginning industries in the nine cotton-growing states of India. The CSD contaminates the lint cotton, spun yarns, woven fabrics and cotton seeds during the cotton roller ginning process.

The air pollution due to CSD and cotton dust is responsible for synergistic (augmentative) health complications of chromium-based diseases and byssinosis disease among ginnery and textile mill workers. The CSD pollutes the gin-house air and the cotton-processing workers suffer from chromium-bound diseases and physiological disorders (Figure 4).

**Figure 4. Gin house in a roller ginning industry, Phase-III of EHIA: air pollution**

The chromium adsorbed into lint causes allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septum in cotton-processing workers. Toxic effects are produced by prolonged contact with airborne, solid or liquid chromium contamination and pollution even in small quantities. Cotton seeds get contaminated with chromium from the source (Vijayan, Gurdeep & Saxena, 2001).

The work presented in this article is intended to identify the environmental health-related problems caused by the use of CCLC rollers. Some experimental results of chromium analysis and relevant Indian standards, the concentration of respirable and suspended particulate matter in some samples collected randomly are presented. Health survey observations and cotton technological reports of eco-friendly lint and chrome-contaminated lint are presented for assessing the hazards of chromium contamination of lint, yarn and fabrics, and air pollution problems due to CSD. After realising the hazards of chromium contamination in lint cotton, seed, yarn, fabric and textile effluent and air pollution problems due to CSD in ginning and textile environments, there is a need to eliminate contamination and pollution due to chromium at the source in the cotton ginning process used by roller ginning industries in India, Africa, Tanzania and Egypt. A suitable eco-friendly roller ginning process to eliminate this unsafe chromium contamination and pollution in the environment has been presented in this research review article. An extensive and exhaustive study was undertaken for the design and development of eco-friendly, pollution-free, chromeless, rubberised cotton fabric (RCF) rollers to modify the present conventional CCLC rollers.

## 2. Literature review

### *2.1. History and development of roller ginning process*

The roller gin is an outgrowth of the ancient *Hindu Churka* gin, the first record of which goes back to about 800 BC, although the two gins differ in principle of operation. The ginning of seed-cotton was practiced in a novel way in the home of the world famous *'Decca Muslin'.* The contaminants, like leaves, stalks and capsules, were first removed by hand from seed-cotton and then the fibres were combed by using the *jaw of the bolee fish*, the teeth of which being small, curved and closely set acted as a fibre comb to remove the minute particles of extraneous matter. After combing, the lint cotton was separated from the seed-cotton by placing the combed ends on a smooth board (made of *chaltha* tree) and then rolling a pin backwards and forwards, in such a manner as to separate the fibres without crushing the seeds (Townsend et al., 1940). Several types of primitive roller gins were developed during the nineteenth century, but none of these was found suitable. The mode in use till date was the one patented by McCarthy in 1,840 (Gillum & Marvis, 1964).

### *2.2. Description and performance of CCLC rollers in DR gins*

The roller is the major component of DR gins. The gin roller length varies from 1,025 to 1,148 mm, with a diameter varying from 178 to 180 mm, suitable for operation. The roller consists of 78–80 washer disks. Each washer disk is 180 mm in diameter and 1 mm thick and has 18 CCLC flaps stitched and bonded together (Vijayan, 1999). Figure 5 shows the engineering drawing of the cladding of CCLC washers comprising a roller of a DR gin (Phase-V of EHIA).

Basic chromium sulphate, *Cr (OH) SO4 nH2O*, and impure chromate having 45%–50% basicity are used during the *chrome leather tanning process* for making such CCLC flaps (Vijayan, 1998). The various unit operations involved in making washers to final shape of the roller are as follows: (i) the washers are filled in a steel shaft having a square cross-section of 50 $mm^2$ or hexagonal section of 50 mm E/E to form a roller; (ii) the filled washers are compressed to a pressure of 14 $N/mm^2$ by using a conventional pressing machine. The roller is to be pressed on both sides by adding the required number of washers on each side; (iii) the pressed roller is turned and finished to diameter 180 mm in a centre lathe; and (iv) finally, spiral grooves are made on the surface of the finished rollers. The finished roller is ready for grooving operation by using a band saw, which is initially marked by 'U'-shaped spiral grooves, then fixed in the grooving machine and lastly the spiral grooves are made on the roller surface by a band saw or circular saw cutting machine (Shete & Sundaram, 1993).

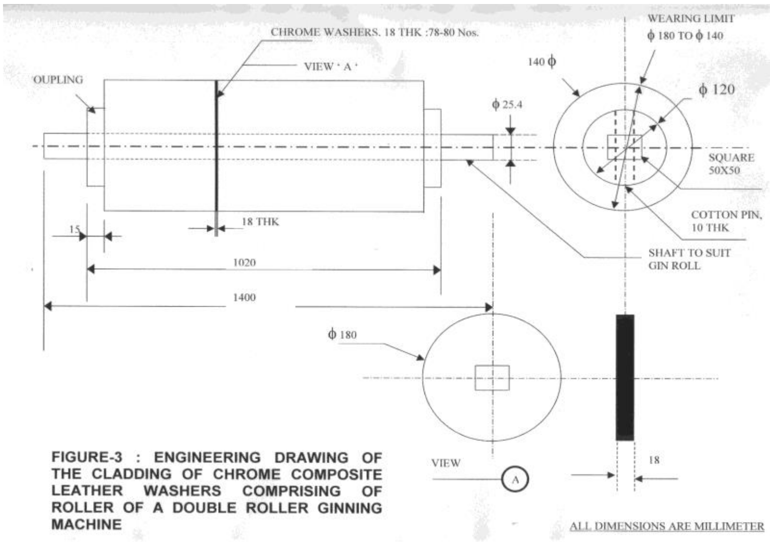


**Figure 5. Engineering drawing of the cladding of CCLC washers comprising a roller of a DR gin (Phase-V of EHIA)**

The ginning efficiency primarily depends upon the surface speed of the roller and the number of working strokes on the moving knife (Shete & Sundaram, 1993). With the operation of these rollers in the ginning machines, the rate of ginning goes on declining when the roller diameter is reduced. By the end of the cotton season, which is 3 months duration, the roller is reduced to 114 mm in diameter and the washers are removed from the shaft. Again, the new washers are recovered and cladded in a shaft. These washers are worn out after a considerable period of usage of about 3 months.

### *2.3. Environmental impacts of CCLC rollers*

The environmental impacts of CCLC rollers are assessed from the pollutants, viz. *cotton dust* and CSD, in the mill atmosphere. Their sources and health effects are briefly described in the following paragraphs.

The *cotton dust* released in the ginning process is a complex and variable mixture of cotton fibres, undeveloped ovules, cotton plant debris, including twigs, bract and *pericarp* particles, left after the ginning process together with soil particles, bacteria, fungi and residues from pesticides. The visible and invisible dust in the mill atmosphere is known as '*Fly*'. The ambient air particles of about 2.5 μm are classified as cotton dust in ginning environment. *Byssinosis* is a disease caused by the inhalation of cotton dust over a long period of time (Shirley Institute, 1982). It is a permanent disabling lung disease. The symptom is chronic cough ending in chronic bronchitis (respiratory disorder). India has many ginning and textile mills employing 48% of all the factory workers (Rao, 1995). About 55% of mill workers suffer from *byssinosis* disease (Rao, 1995). As per the rough estimate during field survey/discussions with ginning industry management, presently, there are about 213,000 CCLC rollers, which comprise 17,040,000 CCLC washers that are used for a cotton season of 3 months in our country. There are about 760,000 people working in roller ginning industries in India.

Due to the persistent rubbing action between CCLC rollers and stationary knives in ginning machines, they is constant and exorbitant wear out contaminating the ginned lint cotton with chromium, which gets permanently coated during the ginning process. CSD production during this process is the major environmental chromium contamination and pollution problem from roller ginning industries. It is mentioned that contamination of cotton by the foreign matter other than field originating trash is the serious problem. Lint cotton and cotton dust are the adsorbents of chromium from CSD emission. Thus, chromium is adsorbed in lint cotton, spun yarns and woven fabrics in a macro level. During the wet textile processing stage, the concentration of chromium in the effluent is precipitated in a micro amount. The chromium concentration is reduced to a micro amount during beating operations, blow room mechanical cleaning and carding process (Gurumurthy, 1997a). It is permanently coated with spun yarns and woven fabrics in considerable amount against the safe limits of 0.1 ppm prescribed by eco-standards. Cotton seeds are an important source of edible oil. The ginned cotton seeds are also contaminated with chromium in huge concentration, thus polluting edible oil. Chromium-contaminated cotton seeds cause chromium poisoning, leadings to skin disorders, liver damage in human and animal liver. Oil cakes consumed by animals were found with chromium poisoning diseases.

Chromium in CSD and contaminated cotton products acts on humans in three ways: (1) local action as dermatitis or absorption through skin, (2) direct inhalation and (3) ingestion or absorption into stomach (Morton, 1991). Toxic effects are produced by prolonged contact with airborne, solid or liquid chromium compounds even in small quantities because of their properties, viz. carcinogenicity, mutagenicity and corrosiveness (Sujana & Rao, 1997). Complications do arise due to the reducing nature of these chromium traces that affect organic tissues of body.

The air pollution caused by CSD and cotton dust is responsible for the synergistic (augmentative) health complications of chromium-based diseases and byssinosis disease on ginning industry workers. Almost most of the mills in India *are not provided* with dust control systems, nor do they provide personal protection devices to the workers. It is mentioned that the ginning industries are located in and around cotton-growing areas and employ women in the age group of 21–40 years for *menial jobs* and male workers in the age group of 18–50 years. The women often come along with their *children* for performing their jobs, like (i) feeding seed-cotton (or *kapas*), (ii) collecting the lint cotton, seed and floor sweeping, (iii) cleaning and grading the seed-cotton and (iv) light activities. The children are exposed directly to CSD. The health effects and reports of the workers have not come out into public because (i) almost all the workers are not in regular employment, (ii) the cotton ginning industry functions seasonally for 6–8 months in semi-arid zones and 8–10 months in rain-fed areas in a year, (iii) the workers are reluctant to go for their medical check-up because of their negligence and fear and (iv) they are economically not sound enough to go for their medical treatments. Based on the environmental impacts of CCLC rollers in roller ginning industries, the first part of this study pertains to assess environmental chromium pollution during the cotton ginning process.

An extensive literature survey was carried out to meet the objectives of design and development of an eco-friendly alternative. Various eco-friendly alternative roller covering materials, viz. vegetable tanned leather, eco-friendly tanned leather, including rubber and rubber-processing technology and modifying the present CCLC roller ginning system, have also been studied.

## 3. Materials and methods

Studies related to size reduction of CCLC rollers were conducted from the two ginning industries situated at Bailhongal (Karnataka) and Sendhwa (Madhya Pradesh). Roller wearing and compaction rate study were conducted in roller ginning industries at Bailhongal for the cotton seasons 1996–1997, 1998–1999, 2000–2001, 2015–2016 (Narasaraopeta Cotton). The roller gins are adjusted using gauges / spacers as per the Central Institute for Research on Cotton Technology (CIRCOT) standards (Vijayan & Parthasarathy, 1993). Gin operation, repairs and maintenance including regular grooving operations were carried out as per CIRCOT standards (Vijayan, 1999).

To study environmental chromium pollution and contamination levels from roller ginning operations, an exhaustive study was made covering four sites each having many ginning industries approximately 300 numbers, namely Guntur (Andhra Pradesh), Sendhwa *(Madhya Pradesh)*, Bailhongal *(Karnataka)* and Surendranagar *(Gujarat)*. Since, all other industries have been following the same trend and method, these were expected to provide fairly a representative data. The experiments, field trials and field survey have been conducted in the chosen sites. Samples have been collected from the study areas to characterise and assess chromium pollution. Atomic absorption spectrophotometers (AAS) (Models-GBC-902 and AAS-3300) were used for analysis of collected and prepared samples as applicable for the total chromium analysis. Samples have been analysed at the Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textiles Laboratory, Mumbai. Some of the samples for environmental analysis were also tested in the Central Pollution Control Board (CPCB), Delhi. Cotton technological tests were carried out in CIRCOT, Mumbai. Laboratory ginning studies on rollers were conducted in CIRCOT, Mumbai. Commercial ginning studies on rollers were carried out at M/S Vijay Cotton Ginning and Pressing Mill, Bailhongal.

To study the heavy metal as total chromium mg/kg (ppm) in cotton lint samples, seed samples, seed-cotton samples, CCLC roller samples and CCLC roller samples were collected during grooving operation; soil samples from the region of investigation were collected from the root of the plant for bio-availability, fibre, yarn, fabric samples and textile effluent samples. The standard American Public Health Association method was followed for chromium (as total and hexavalent) analysis using AAS. Respirable and suspended particulate matter in the gin house air were monitored using high volume air sampler (HVAS) with cascade impactors with appropriate glass fibre filters. (Rao & Rao, 1989). A quantity of pollutants were collected in an HVAS every 8 hours and were analysed for chromium. The worker dose and exposure time were found using the personal sampler. Cotton technological parameters were tested using high volume instrument (HVI) and scanning electron microscope (SEM) for chrome roller ginned lint and eco-friendly roller ginned lint. Some of the chrome tanneries at Chennai, Kanpur and Calcutta were visited for an appraisal of chromium pollution problems. A health study was conducted by the author at Guntur, Bailhongal, Sendwa and Surendranagar, in India, Tanzania and other countries, where the maximum number of ginning factories are situated to survey the health effects and occupational health hazards (Iyer, 2007). Since ginning is a seasonal activity, over a few months of the year, it was not possible to check the health effects. Furthermore, there are no medical records available from nearby hospitals, except in Guntur hospital.

To design and develop eco-friendly RCF rollers, the ginning investigations were carried out at CIRCOT, Mumbai. The laboratory rollers for gin roller experimentation device (GRED) were designed and fabricated at Kolkata at a local manufacturing firm. Figure 6 shows a close-up photograph of pollution-free RCF chromeless washers for laboratory gins (GRED).

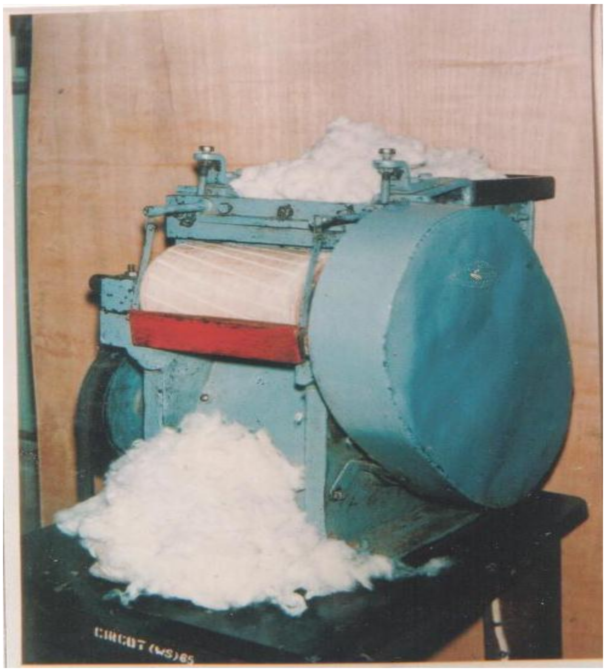

**Figure 6. GRED RCF roller/washer: a close-up photograph**

The close-up photograph of the RCF chromeless washer for pilot model roller is shown in Figure 6 ( Phase-X of EHIA). Such types of washers are used to fill, press and finish one roller in DR gin. Experiments with the designed rollers were conducted at CIRCOT, Mumbai, along with the cotton technological parameters. After the initial tests, pilot model rollers were designed and fabricated, which were tested in Indian ginning factories at Bailhongal and Sendhwa. Environmental analysis was carried out in the Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textile laboratory, Mumbai. Mechanical properties were analysed in various mechanical engineering laboratories. Figure 7 shows photograph of a pilot model roller gin assembled with pollution-free RCF chromeless rollers in operation (Phase-II of EHIA).

**Figure 7. Photograph of a pilot model roller gin assembled with pollution-free RCF chromeless rollers**

To design and develop eco-friendly RCF rollers, the following instruments and methods were used.

| Instruments/equipment used | Specimen/material/test | Methods used |
|---|---|---|
| GRED, CIRCOT Lab. Model Gin, McCarthy Gin and Bajaj DR Gin | Cotton ginning test, roller design and experimentation, outturn test, ginning time, ginning percentage cut seed percentage and redesign of rollers. | As per technological leaflet of CIRCOT |
| HVI, SEM, Baer Sorter (CIRCOT). CIRCOT Uster Evenness Tester, Lea Tester, Twist Analyser (CIRCOT) | Cotton technological fibre tests, namely 2.5% staple length, uniformity ratio, strength, micronaire, grade and fineness. | As per technological leaflets of CIRCOT |
| Compaction meter, Dynamometer, INSTRON-1,122 & Load cell 2511-101, DO Durometer, Rockwell's Hardness Tester and Thermometer. | Cotton technological yarn/ fabric tests, namely yarn strength, count, count strength product, twist/25 mm, hairiness and Uster evenness | As per technological leaflets of CIRCOT |
| | Mechanical properties, namely wearing rate, compaction rate, co-efficient of friction between lint to specimens, hardness, energy consumption, roller-to-stationary knife force and temperature. | Standards methods, CMERI standards. |
| Bruel Kjaer type 2,226 | Noise levels | Standard Method |
| Rubber processing and testing instruments | Fabrication and testing of RCF roller | Rubber Board specifications |

### *3.1. Methodology for construction of roller gin rollers*

- Complete investigations pertaining to RCF covering materials were carried out. The rollers were covered with packing type made from multiple layers of cotton fabric bonded together with a rubber compound. Rollers made from RCF, with different compositions of rubber compounding and multiple cotton fabrics, were tested in GRED and DR gins based on which an existing system was modified.
- Investigations were made in detail, based on the first design of this successful *eco-friendly and pollution-free, chromeless* RCF roller. Similar RCF rollers were fabricated for laboratory and commercial studies. The rollers were assembled in *laboratory model gins* or *GRED* and *commercial DR gins* using appropriate speed-settings. Later on, trial runs in both laboratory and commercial experiments were conducted. Design procedures and engineering drawings, including bill of materials and specifications, were prepared for manufacturing in a local industry.
- In continuation of the first developed RCF roller covering, seven types of trial roller coverings with different rubber-fabric compositions were designed and fabricated to enable further improvements. These were tested for further developments and modifications.
- CCLC roller for GRED and DR gins as well as pollution-*free* RCF rollers for GRED and DR gins were tested for the following tests and performance evaluation was made in both the *'system before and after modifications'*. The performance tests are outlined as follows:

  I. The coefficient of friction was carried out in *INSTRON 1122* load cell *2511-101* full range *10, 20, 30–500 g*. The friction between the roller coverings to the cotton tuft was experimented and the readings of 'effort' to resist frictional force were taken from the graph plotted by the instrument. With the normal load applied for different positions of various materials, the coefficient of friction was calculated.
  II. Hardness of the roller covering was tested in *Rockwell* hardness tester, using the *Rockwell's* 'B' test. The steel ball diameter 4.26 mm equipped with the tester was calibrated for penetrating over the materials. The readings were noted.
  III. Roller indention hardness was measured with DO durometer. The DO durometer has a 2.4 mm diameter spherical indend or protruding 2.56 mm at dial reading. The hardness of roller covering was measured at the ginning surface.
  IV. Characteristic features of chrome washers used for CCLC and RCF rollers were measured. Engineering and ergonomics data were observed for testing and to compare between ordinary and extra-long rollers.
  V. Temperature was measured by using the *thermometer* during the ginning operation.
  VI. GRED was used to experiment the CCLC roller and chrome-free RCF roller. The environmental parameters were lint cotton contamination, Cr (VI), Cr(III), noise level, energy consumption, roller wearing rate, whole seeds %, cut seed %, cotton dust and CSD.
  VII. Cotton technological parameters like ginning time, ginning rate potential, ginning percentage, lint cotton (or *fibre)* parameters and spun yarn parameters were analysed to find out the performance evaluations of RCF roller to its suitability as an alternative in the conventional CCLC roller ginning process.

### *3.2. Cotton technological parameters studied*

- Ginning parameters: Ginning Time, (ii) Cut Seed % and (iii) Ginning %
- Fibre properties: 2.5 S.L, (ii) Uniformity Ratio, (iii) Strength, (iv) Micronaire and (v) Grade
- Yarn properties: (i) Yarn strength, (ii) Count, (iii) CSP, (iv) Twist/25 mm, (v) Hairiness, (vi) Uster evenness %, (vii) Imperfections Thin, Thick and Neps, (viii) the gin speed-settings including roller grooving and shape, roller speeds in GRED and DR gins were followed as per CIRCOT standards for comparative performance and acceptability of the products for commercial purposes. Pilot rollers were experimented in a similar method using the DR gin. (ix) RCF roller

*manufacturing technology* for commercialising the rollers in ginning factories was investigated. Manufacturing technology was also formulated based on relevant technical expertise.
- Equivalent sound levels of DR ginning machine that was assembled with RCF and CCLC rollers were monitored using *integrating sound level monitor.*
- Energy consumption was recorded for the RCF and CCLC roller ginning industries. The energy consumption report was prepared for comparison purposes.
- Ginning outturn was noted for the eco-friendly and CCLC roller ginning industries.
- Cotton technological parameters and engineering data were analysed for commercial studies.

## 4. Results and discussions

An experiment was conducted to find out the wearing and compactness rate of CCLC rollers used by roller ginning industries for a season lasting up to 3 months. At the start of the season, the diameter of rollers are 180 mm. By the end of season, the roller dimensions are noted at left, middle and right positions for all the roller gins in the factory, that is for 18 ginning machines. The results are presented in Table 1. Apart from the wear and tear rate, the table expresses the quantity of pollutants generated during the operation, viz. chromium, chrome tanned leather powder, cotton dust and CSD (Figure 8), Phase-I of EHIA.

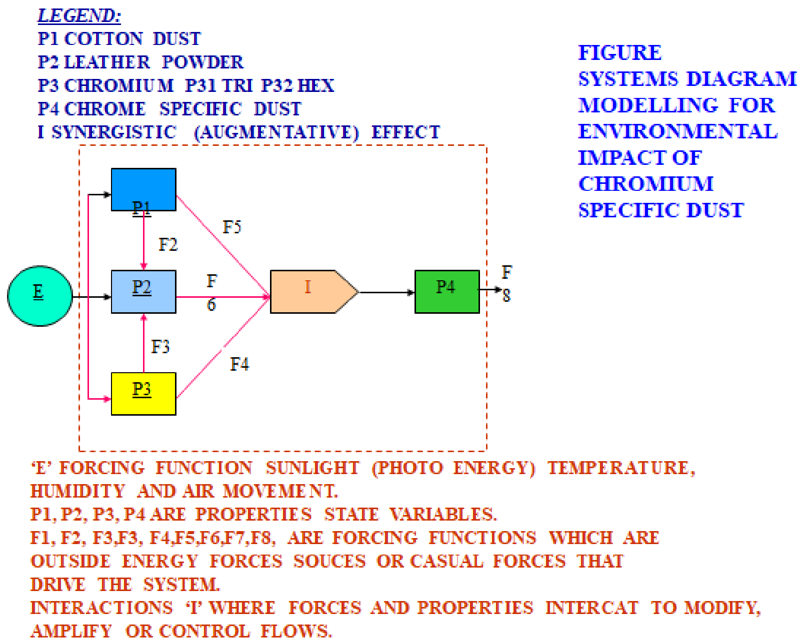


**Figure 8. Systems diagram modelling for environmental impact of CSD**

It is found that the wearing rate is 0.033 mm/hour and the percentage material removed per roller is 43.8%. The final diameter at the end of study is nearly 140 mm. The compaction rate is 0.050 mm/hour. Figure 9 shows a graph of wearing rate of dust-producing grinding of CCLC roller and RCF roller, Phase-IV of EHIA.

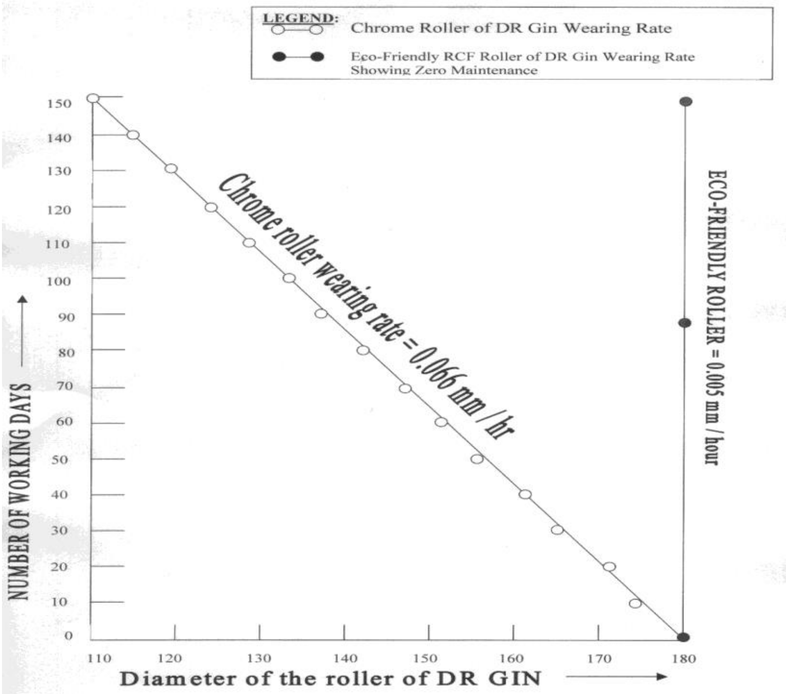


FIGURE 5 : A GRAPH OF WEARING RATE OF DUST – PRODUCING GRINDING OF CHROME ROLLER AND ECO – FRIENDLY ROLLER

**Figure 9. A graph of wearing rate of dust-producing grinding of chrome roller and eco-friendly roller**

**Table 1. Results of roller wear out data**

| M/c No. | Diameter of the rollers after one season in mm | | | | | |
|---|---|---|---|---|---|---|
| | Roller side 'A' | | | Roller side 'B' | | |
| | Left | Middle | Right | Left | Middle | Right |
| 1 | 140 | 140 | 140 | 141 | 143 | 142 |
| 2 | 140 | 140 | 140 | 140 | 142 | 142 |
| 3 | 145 | 146 | 150 | 150 | 145 | 140 |
| 4 | 153 | 153 | 153 | 148 | 148 | 148 |
| 5 | 148 | 147 | 148 | 148 | 148 | 148 |
| 6 | 146 | 147 | 148 | 146 | 146 | 146 |
| 7 | 135 | 135 | 135 | 145 | 142 | 140 |
| 8 | 140 | 140 | 140 | 145 | 142 | 140 |
| 9 | 150 | 150 | 150 | 148 | 148 | 148 |
| 10 | 138 | 136 | 136 | 136 | 136 | 136 |
| 11 | 145 | 145 | 146 | 145 | 145 | 145 |
| 12 | 136 | 136 | 136 | 136 | 136 | 136 |
| 13 | 158 | 158 | 158 | 158 | 157 | 157 |
| 14 | 160 | 160 | 160 | 161 | 160 | 160 |
| 15 | 154 | 154 | 154 | 155 | 156 | 156 |
| 16 | 155 | 155 | 156 | 155 | 154 | 154 |
| 17 | 160 | 160 | 159 | 160 | 160 | 160 |
| 18 | 160 | 160 | 161 | 160 | 161 | 166 |

Initial diameter of the rollers = 180 mm. Chromium roller compactness rate = –0.010 to –0.050 mm, i.e. –10 to –50 μm/hour. Wearing rate = 0.033 mm/hour and the percentage material removed per roller = 43.8%.

### *4.1. Environmental health impact statement*

Characterisation and EHIA studies and checks of chromium pollution existing within the CCLC rollers were conducted. Chromium analysis report of cotton lint samples, seeds and seed linter, seed-cotton samples, fibre, yarn and fabric samples are presented in Tables 2–4. The CCLC roller contains 18,077 mg/kg (ppm) to 30,780 mg/kg (ppm) as total chromium (3%–4% as total chromium). This includes trivalent and hexavalent chromium. During the ginning operation, lint cotton adsorbs chromium particles which contain 143 mg/kg (ppm) to 1,994 mg/kg (ppm). The CCLC roller is grooved at the start of each shift and filing or turning of the roller for levelling in order to get uniform diameter at start of each season. At that time, the wearing of roller is more and the presence of chromium is to the extent of 1,994 mg/kg (ppm) with lint. The total weight of chromium removed during a cotton season of 16 hours per day is 450–600 g per gin roller. The CSD from one ginning machine enters in to environment and is adsorbed in the lint stage, having the level of 143 ppm. The environmental standard for chromium in spun yarn is 2 ppm and Cr (III) for baby clothing and fabric is 0.1 ppm and nil for Cr (VI). The traces found contain hexavalent chromium being adsorbed from contaminated lint, yarn and fabrics, and subsequently cannot be removed in fabrics. There is evidence that the toxic effects are produced on humans due to Cr (III) and Cr (VI) and its carcinogenicity and corrosiveness. The analysis show that traces of Cr (VI) are found in even analar grade trivalent chromium compounds and complications do arise due to the reducibility nature of these traces that affect the organic tissues of the body. This regenerating effect occur rapidly and depends on the worker's dose and exposure time.

Table 2. Chromium contamination levels in cotton and its products

| **Bio-availability for chromium uptake on cotton = 3 ppm** | | | |
|---|---|---|---|
| **Sl.No.** | **Cotton and its Products** | **Total Chromium** | **Environmental Standards [a] MOEF Notification -157 (Indian Standard)** |
| 1. | Lint cotton | 143–1,990 ppm | 0.1 ppm |
| 2. | Spun yarns | 17–250 ppm | 0.1 ppm |
| 3. | Woven fabrics | 17–45 ppm | 0.1 ppm |
| 4. | Cotton seeds | 0–312 ppm | |
| 5. | Edible oil | 0–259 ppm | |
| 6. | Oil cake | 0–190 ppm | |
| 7. | Linter | 0–159 ppm | |
| CCLC roller = 18,077–30,783 mg/kg. | | | |

[a]Adapted from MOEF Notification No.157 (1996).

Table 3 shows the significant findings of chromium in dust samples with relevant eco-standards:

**Table 3. Chromium level in dust samples**

| **Sl. No.** | **Source of dust** | **Total Cr** | **[a]Environmental Standards, LD50** |
|---|---|---|---|
| 1. | Ginning point | 51–173 ppm | 50 ppm |
| 2. | CCLC grooving point | 17–1,994 ppm | 50 ppm |

[a] Adapted from U.S. National Institute of Occupational and Safety Hazard Standards (1992).

**Table 4. Results of total chromium analysis**

| **Sl. No.** | **Description** | **Total chromium, ppm** |
|---|---|---|
| 1. | Lint cotton sample hand ginned weighing 5 g and kept at 550°C for chromium bio-availability (3 samples) | Nil |
| 2. | Lint cotton sample hand ginned weighing 1 g (2 samples) for chromium uptake bio-availability | 2 |
| 3. | CSD from dust-producing, grinding chrome rollers taken in ginning process 5 g each 3 samples | 7,240 |

| | | |
|---|---|---|
| 4. | Bijapur soil sample 1 g each 10 samples | 2 |
| 5. | CCLC roller kept at 800°C and ash samples are taken 5 g each – 3 samples | 30,598 |
| 6. | Dust-producing, grinding CCLC roller powdered samples 10 g each – 3 samples | 30,783 |
| 7. | Dust-producing, grinding CCLC in roller ginnery-I, 3 samples | 18,077 |
| 8. | CCLC sample in roller ginning mill – II, 3 samples each 1 g each | 28,900 |
| 9. | CCLC roller dust-producing, grinding chrome powder taken during grooving operation – 3 samples each 1 g | 18,305 |
| 10 | Chromium settable particulate lint falling from ginning that was point after grooving operation – 5 samples each 5 g | 28,900 |
| 11 | Ginned lint type I cotton using laboratory gin fitted with CCLC roller grooving operation – 3 samples each 1 g | 7,689 |
| 12 | Chromium contaminated ginned lint in SR gin with CCLC roller during regular operation-3 samples, 1 g each | 143<br>1,994 |
| 13 | Root of the plant for chromium uptake for bio-availability from plant – 10 samples 1 g each | Nil |
| 14 | Ginned chromium contaminated lint type – II cotton in laboratory gin with CCLC – 3 samples each 1 g | 21 |
| 15 | LRA 5,166 chromium contaminated sample DR gin with CCLC roller – 3 samples each 5 g | 44 |
| 16 | LRA 5,166 sample ginned in DR gin CCLC roller lint samples–II, 3 samples each 5 g | 143 |
| 17 | Yarn samples from CCLC roller ginning mill | 17–45 |
| 18 | Chromium contaminated yarn samples from CCLC roller ginning mill-II | 25–68 |
| 19 | Chromium contaminated yarn samples made from DCH-32,3 samples each 1 g from grey, mercerised and dyed yarn | 40–250<br>89–159 |
| 20 | Chromium contaminated fabric samples made from DCH-32, 3 samples | 45–250 |
| 21 | Chromium contaminated card frame samples during carding, 3 samples each 1 g | 80–340 |
| 22 | Textile effluent,10 samples | 556 mg/l |
| 23 | Chromium contaminated seed samples – 2 numbers each | 125 |
| 24 | Cotton seed linter – 3 Numbers each | 175 |
| 25. | Cotton seeds collected from seed godown | 141.6 |
| 26 | Lint cotton pala house-gin trash | 173.8 |
| 27 | Lint cotton before beating in pala by a group of women workers | 232.5 |
| 28 | Lint cotton after beating in pala by a group of women workers. | 127.2 |
| 29. | Trash deposited in the machine | 125.6 |
| 30. | When rollers are grooved and deposition in grooving stand | 1,966.4 |
| 31. | Seeds from other chrome rollers | 84.3 |
| 32. | Seeds from RCF cotton | Nil |
| 33. | Cotton seed oil cake | 190 |
| 34. | Chrome roll powder at the time of cutting the rolls | 2,353.4 |
| 35. | Seeds from chrome rollers | 159 |
| 36. | Cotton seed oil | 259 |

**Table 5. Monitoring results of SPM and RSPM in various ranges and chromium concentration in ambient air and mill air. Total chromium analysis in SPM and RSPM dust samples**

| Sl. No. | Particulate matter description | Quantity of dust conc. in ambient air µg/m³ | Chromium content as total Cr in Dust, ppm | Conc. of Cr. in air µg/m³ |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | SPM collected-while HVAS run outside the factory at full swing | 882.6 | 73 | 64.42 |
| 2 | SPM collected-while HVAS monitored when full swing | 2,723 | 90 | 245.07 |
| 3 | SPM collected – while HVAS monitored without factory in operation and rollers were grooved | 2,495 | 1994 | 4,975.03 |
| 4 | SPM collected at open air | 827.6 | 159 | 131 |
| 5 | RSPM below 1 microns-HVAS Monitored and rollers were grooved | 9.5 | 57 | 0.5415 |
| 6 | RSPM 1–3 microns-HVAS monitored and rollers were grooved | 26.3 | 142 | 3.7346 |
| 7 | RSPM 3–5 microns-HVAS monitored and rollers were grooved | 76.5 | 153 | 11.7 |
| 8 | RSPM 5–7 microns – HVAS run when rollers were grooved | 50 | 86 | 4.3 |
| 9 | RSPM 7–10 microns-HVAS monitored, when rollers grooved | 95 | 52 | 4.94 |
| 10 | RSPM below 1 microns-HVAS monitored when rollers grooved | 67 | 173 | 11.591 |
| 11 | RSPM 1–3 microns-HVAS monitored inside factory at full swing | 107.6 | 119 | 12.80 |
| 12 | RSPM 3–5 microns-HVAS monitored inside factory at full swing | 121.1 | 103 | 12.47 |
| 13 | RSPM 5–7 microns-HVAS monitored inside factory at full swing. | 545.3 | 124 | 67.65 |
| 14 | RSPM 7–10 microns-HVAS monitored inside factory at full swing. | 2,141.8 | 123 | 263.44 |
| 15 | RSPM below 1 micron–HVAS monitored inside factory. | 75.7 | 190 | 14.38 |
| 16 | RSPM 1–3 microns-HVAS monitored inside factory | 105 | 132 | 13.86 |
| 17 | RSPM 3–5 microns–HVAS monitored inside factory | 128.3 | 295 | 37.84 |
| 18 | RSPM 5–7 microns–HVAS monitored inside factory | 448.4 | 152 | 68.15 |
| 19 | RSPM 7–10 microns | 4,232.0 | 131 | 554.3 |
| 20 | RSPM below 1 microns-HVAS monitored without factory in operation and rollers were grooved | 16.7 | 51 | 0.8517 |
| 21 | RSPM 3 5 microns-HVAS run without factory in operation and rollers were grooved | 24.6 | 123 | 3.025 |
| 22 | RSPM 3–5 microns-HVAS monitored without factory in operation and rollers were grooved | 25.6 | 68 | 1.74 |
| 23 | RSPM 5–7 microns-HVAS monitored without factory in operation and rollers were grooved | 68.0 | 56 | 3.8 |
| 24 | RSPM 7–10 microns-HVAS monitored without factory in operation and rollers were grooved | 75.1 | 133 | 9.983 |

The following discussion is relevant to Table 5.

Twenty-four samples were analysed in cotton ginning mills situated at Sendhwa, Madhya Pradesh by using HVAS with a cascade impactor. Total chromium analysis was reported as alarmingly, since it was very high and against the *safe limits* for the dust samples below 10 μ. SPM, RSPM and chromium RSPM concentrations were documented. According to national ambient air quality standards (CPCB/NAAQS), the concentration of dust in ambient air should not be more than 150 μg/m$^3$ every 24-hour time weighed average (TWA) for industrial area. The safe limit of chromium concentration in ambient air as TWA for industrial area is 1.5 μg/ m$^3$. Furthermore:

1. SPM at PSD cut-off to about 40–45 μm was 2,495 μg/m$^3$; chromium content in dust collected was 1,994 ppm; and chromium concentration in air was 4,975 μg/m$^3$
2. RSPM was 9–4,232 μg/m$^3$; chromium content in dust collected was 173 ppm; and chromium concentration in air was 554 μg/m$^3$. *PSD < 10 μm.*

#### *4.2. Chromium contamination and pollution levels*

Figures 10 shows chromium adsorption transport of the total contamination and pollution levels due to atmospheric chromium in cotton ginning and textile mill plant, Phase-VI of EHIA.

Figure 10 shows the levels of chromium contamination in the cotton and its products, namely lint cotton, spun yarns, woven fabrics, cotton seeds, edible oil, oil cake and cotton linter along with corresponding safe limits (Phase-IX of EHIA). This study presents chromium pollution levels from the ginning and textile environment as well as SPM, RSPM, and chromium concentration in ambient air, ginnery air and mill air, chromium pollution in textile effluents and their eco-standards. Figure 11 shows the chromium-contaminated cotton seeds containing chromium poisoning.

#### *4.3. Chromium pollution in cotton ginning and textile mills*

There are two investigations that have been carried out for analysing chromium adsorption property into cotton dust, lint cotton, spun yarns, woven fabrics and chromium pollution in cotton ginnery and textile mills. Figure 12 shows the flow chart of chromium transport and adsorption in a ginning and textile mill, Phase-VIII of EHIA.

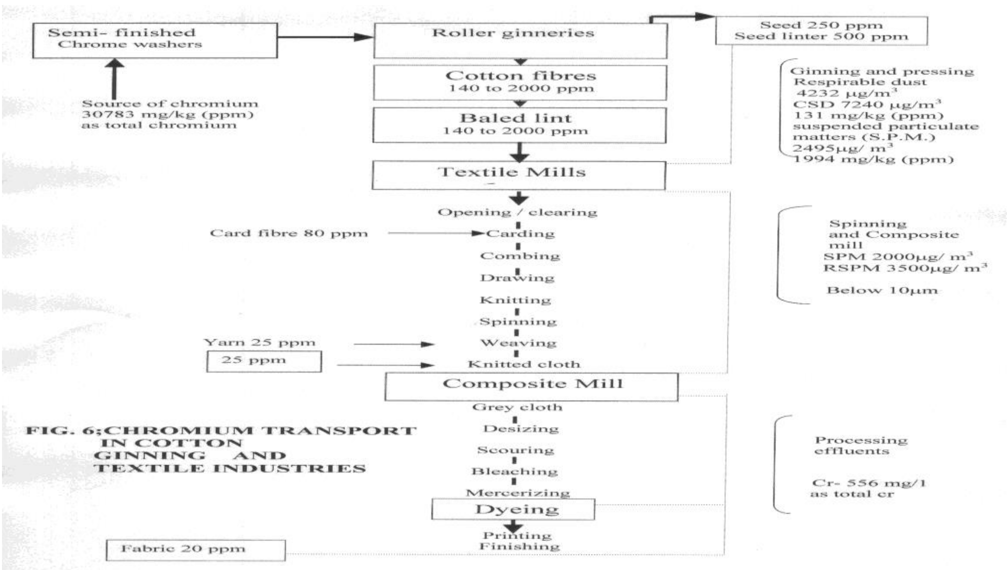


**Figure 10. Chromium transport in cotton ginning and textile industries**

**Figure 11. Chromium-contaminated cotton seeds**

**Chromium Pollution Consolidated ᴗamples' Report and Relevant Eco-Standards for the season-I**

| Sl. No | COTTON TEXTILE PROCESSING | SUBSTANCE | PERMITTED VALUE , ppm | PRESENT ANALYSIS, ppm | NO.OF TIMES INCREASE THAN ECO.STDS |
|---|---|---|---|---|---|
| 1 | COTTON GINNING | CCLC ROLLER<br>RSPM,SPM<br>LINT COTTON<br>SEED,SEED LINTER<br><br>Cr in ambient air | 2 ppm for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI), 20 μg/m³,<br>US OSHA-500μg/m³,<br>ACGIV TLU for Cr(VI):-<br>52 μg/m³<br>1.5 μg/m³ | 30783<br><br>4232μg/m³,1994<br>143 to 300 ppm<br><br>125 ppm<br>450μg/m³ | 15,392<br>212<br>35<br>71<br><br>63<br>300 |
| 2 | CARDING | LINT COTTON | 2ppm for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 80 to 44 ppm | 22 |
| 3 | SPINNING | LINT COTTON | 2ppm for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 80 to 44 ppm | 22 |
| 4 | BLOW ROOM | SPUN YARNS | 2ppm for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 25 ppm | 13 |
| 5 | GREY CLOTH | WOVEN FABRICS | 2ppm for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 17 ppm | 170 |
| 6 | FINISHING | WOVEN FABRICS | 0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 17 ppm | 170 |
| 7 | FINISHING | TEXTILE EFFLUENT | 1 mg/1 for Cr<br>0.1 ppm for Cr(III)<br>Nil for Cr (VI) | 550 mg/1 | 225 |
| 8 | GINNING AND TEXTILE ENVIRONMENT | GIN HOUSE AIR SPM,RSPM CONCENTRATION | 200μg/m³<br>Hex – 0.05 mg/m³<br>TA-Luft 0.1 mg/m³<br>SPM Particle size cut off 45 μm<br>RSPM Particle size below 10μm<br>200μg/ m³<br>National Ambient Air Quality Standards for RSPM not to be more than 100 μg/m³ and chromium in ambient air safe limit is 1.5 μg/m³ | 7240 μg/m³<br>2723<br>μg/m³,1994 ppm<br><br><br><br>2495 μg/m³<br>190 ppm | 362<br><br>135,1000<br><br><br><br>125<br>95 |
| 9. | GINNING AND TEXTILE INDUSTRIES | RSPM in air<br>Cr in air | 150 μg/ m³<br>1.5 μg/ m³ | 527 μg/ m³<br>397 μg/ m³<br>1994 | 4<br>265 |

**Figure 12. Chromium pollution consolidated samples' report and relevant eco-standards for season I**

Figure 12 tabulates the chromium pollution consolidated samples' report and relevant eco-standards for seasons I, Phase-IX of EHIA.

### *4.4. Tannery chromium pollution load analysis*

**Table 6. Tannery chromium pollution load analysis**

| Sl.No. | Description | Indian leather survey | Present analysis |
|---|---|---|---|
| 1. | Total Cr in chrome leather | 13,157–16,142 ppm | 45,333.3 ppm |
| 2. | Total Cr in waste water | 5,250–8,240 | 23,111.1 |
| 3. | Quantity of chromium applied/kg pelt | 21.4 kg/1,000 kg | 68 kg/1,000 kg |
| 4. | In terms of total Cr | 21,400 | 68,000–68,444 |
| 5. | Total chromium in composite waste | 8,000–11,000 | 14,000–20,000 |
| 6. | $Cr^{+6}$ in ppm or mg/l | 2,000–5,000 | 3,500–5,000 |

| | | | |
|---|---|---|---|
| | in waste water coming from chrome tanning process (hexavalent chromium impurity content) | | |
| 7. | Chromium content in roller gin rollers | 13,200–30,000 | 20,000–40,000 |
| $Cr^{+6}$ | impurity content in roller | 6,000–8,000 | 10,000–12,000 |

Chromium compounds like dichromate, sodium chromate and sulphate of *30%–60% basicity* are used in the tanning industries. The impure chromates have hexavalent forms of chromium salts mixed with chromium sulphate for making semi-finished leather. This has been used for making ginning rollers by the locally made indigenous manufacturers in Kanpur, Ahmedabad and Chromepet, Chennai. The chromium percentage contained in the leather was approximately 3%–4% by weight basis. Table 6 shows that about 66% of the total chromium compounds applied during tanning process were absorbed in leather and the remaining was discharged as effluent.

#### *4.5. Basis of design and development of eco-friendly chromeless roller for cotton roller gins*

In conventional ginning process, CCLC rollers emits tremendous chromium in ginning environment due to constant dust-producing, grinding action which contaminates the cotton and its products. This also causes air pollution in the mill environment. An exhaustive study is needed for the development of eco-friendly chromeless roller, which can be an alternative to the existing CCLC rollers.

Exhaustive material studies were carried out for the suitable material's selection of the gin rollers which were made of Walrus skin, spider tuck packing, coir-board, rubber packing, metal cylinder, rubber roll, fabric and rubber packing, leather, cotton, rubber and cork, plastics and fluorinated ethylene propylene. The peculiar gripping action or adherence of the cotton fibres to the roller surface is considered while designing the rollers. The leather surfaces possess *interfibrillary* action, which enables the adherence of fibre on the surface. This particular property is studied extensively for the different materials and combination of different materials to design and fabricate laboratory gin chromeless rollers for GRED and prototype eco-friendly chromeless rollers for existing DR gins.

One of the associated objectives of laboratory studies is to define the physical properties of a roller covering material which contributes to its energy consumption, ginning rate potential, eco-friendly parameters, cotton technological parameters, mechanical engineering analysis, wear resistance properties, heat proof capacity and to search better roller covering materials.

#### *4.6. Rubber processing technology for manufacturing RCF rollers*

Specifications and rubber compounding were followed as per standards from Rubber Board and IS3400 (Rubber Board, 1990). The rubber processing technology for making RCF rollers was studied at the Rubber Technology Centre, at Indian Institute of Technology, Kharagpur, and Rubber Board, Kottayam. The following rubber compound materials were selected in fabricating the RCF roller:

Materials for rubber compounding (IS-3400)

Natural rubber = 100 unit

Zinc oxide = 10 unit

Stearic acid = 2 unit

Accelerator = 1 unit

Anti-oxidant (non-staining agent) = 1 unit

Processing oil = 10 unit

White filler = 40 unit

Titanium dioxide = 10 unit

Sulphur = 2.5 unit

Resin = 20 unit

Rubber compounding (Rubber Board)

Natural rubber = 100 unit

ZnO = 5.0 unit

Stearic Acid = 2.0 unit

S.P. (Processing oil) = 1.0 unit

Silica (ppt) = 25.0 unit

Whiting = 20.0 unit

Clay = 50.0 unit

Al. silicate = 25.0 unit

Wooden resin = 5.0 unit

$TiO_2$ = 5.0 unit

CBS (accelerator) = 1.0 unit

Sulphur = 2.5 unit

Process description

Step I: Machinery and relevant process

| | |
|---|---|
| Mixing mill | Rubber-mixing compounding |
| Lathe | For making wooden core and for cutting extruded product |
| Calendar | Cotton fabric rubberising |
| Covering on roller | 9.07 kg for steaming on the calendar |
| Wrapping | Processed in the designed mould |

Vulcanisation of rubber–canvas in close calendar; steam from boiler at 155°C for 1 hour unwrapping from the designed mould and turning on the lathe.

Step II: Fabrication

| | |
|---|---|
| Bore size | 50 × 50 mm square/50 mm E/E Hex |
| Outside diameter | 180 mm |
| Length | 1,020 mm |

Rubbers having two layers of cotton fabric were used up to 140 mm for reinforcement. Later, 11 layers of cotton fabric and rubbers were used from 140 to 180 mm diameter (Figure 13), Phase-XIII of EHIA.

**Figure 13. Rubbers having two layers of cotton fabric**

The fabrication of the roller was conducted in prepared mould form and sleeve as seen in Figure 13. After preparation of mould sleeve, the washers of 18 mm thick were cut and supplied on piece rate or weight rate system. The cost of the roller was minimised by giving less reinforcement of cotton fabrics in the surface. Plain circular winding with rubber compounding was used to cover over the core shaft.

Step III: Testing of rubber and its chemicals

The Rubber Board has a full-fledged laboratory for the identification of various rubbers, testing of rubber chemicals and rubber products, as per national and international standards. Most of the tests were carried out using the facilities of the Rubber Board. The laboratory has the required machineries/equipment to facilitate the processing and testing of the rubber industry. The RCF rollers were manufactured using these facilities.

### *4.7. Testing of gin rollers*

The fabricated rollers were assembled for testing in laboratory model gins (GRED) at a cotton research laboratory (CIRCOT), Mumbai (Shete & Sundaram, 1993). Rollers made were and assembled in *DR gins* at Belgaum and Sendhwa. The environmental and technological parameters were studied to assess the feasibility of the newly developed rollers as compared to the CCLC rollers. The rollers were successfully ginning out seed-cotton. Figures 14 and 15 show the CCLC washer and difference of chrome-free, eco-friendly *roller ginned* lint cotton obtained from RCF roller gins.

**Figure 14. Chrome-free and eco-friendly roller ginned lint cotton**


**Figure 15. CCLC washer and RCF roller gin**

The ginned samples and subsequent processing of the lint cotton stage to spun yarn samples were analysed for the ginning parameters: fibre properties, yarn properties and environmental aspects using the RCF rollers and CCLC rollers for both 'system before modification and after modification'. Figure 16 shows the manufacturing drawing of RCF roller for DR gins, Phase-XI of EHIA.

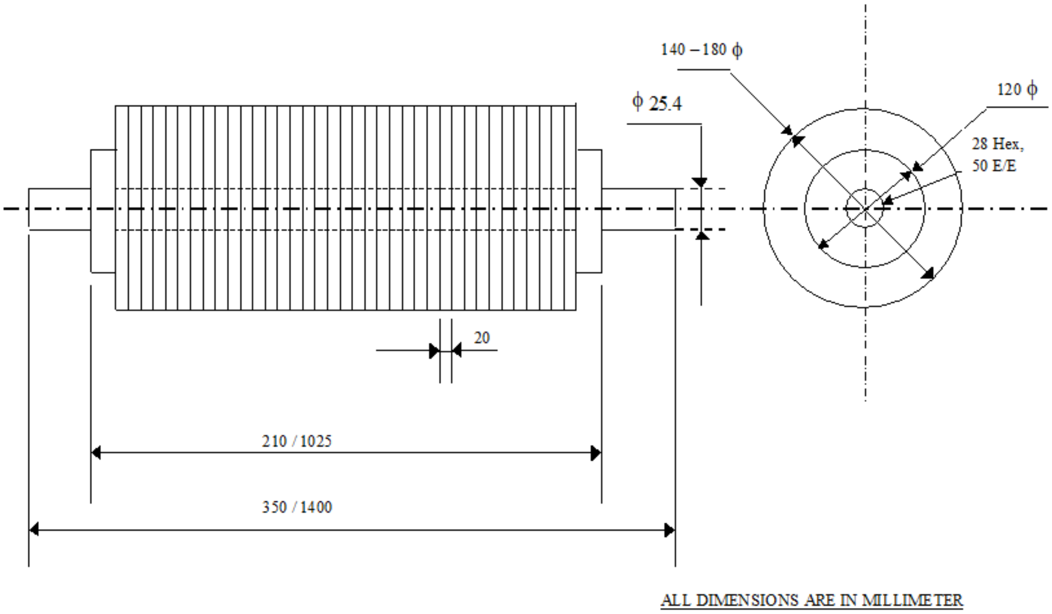


**Figure 16 Assembly drawing of rubberised cotton fabric (RCF) washers for making RCF rollers of double roller gins.**

### *4.8. Size reduction study of eco-friendly, chrome-free RCF roller*

The *size of the total dust* due to combination of cotton dust, rubber and fabric powder was found to be of comparatively bigger due to the presence of rubber. This prevented the formation of small size particles. Particle sizes analysis was carried out for these samples and they were 75–150 μ. Practically, the cotton dust generated due to this roller is comparative to leather because the *interfibrillary* action of fabric surface enabled the cotton fibres to adhere at a faster rate. Moreover, with this property, there was no need of grooving of rollers, which were required often. This resulted in less wearing rate of rollers. Figure 17 shows the photographs of the wearing study made on newly developed eco-friendly, chrome-free RCF rollers assembled in the existing DR ginning machine, Phase-VII of EHIA.

**Figure 17. Newly developed eco-friendly, chrome-free RCF rollers assembled in existing DR ginning machine**

It is mentioned that the expected roller span life shall be about 7 years *(Shelf life)* because of its hardness (90 DO) during usage. Experiments regarding the wearing rate were carried out on commercial scale using DR gins. Figure 18 shows the graph of wearing rate of CCLC roller and eco-friendly chrome-free roller of DR gins, Phase-XI mitigation step of EHIA.

Appropriate ratio of rubber and cotton fabric was analysed after the study of wearing rate of rollers. The present RCF roller contains *20% rubber is to 80% cotton fabric*. IS3400 and Rubber Board specifications were followed for vulcanising cotton fabrics. The weight of this roller is less compared to the leather roller because of its inherent core construction and manufacturing technology of RCF. Therefore, smooth and gentle actions of the removal of fibres take place during the ginning process.

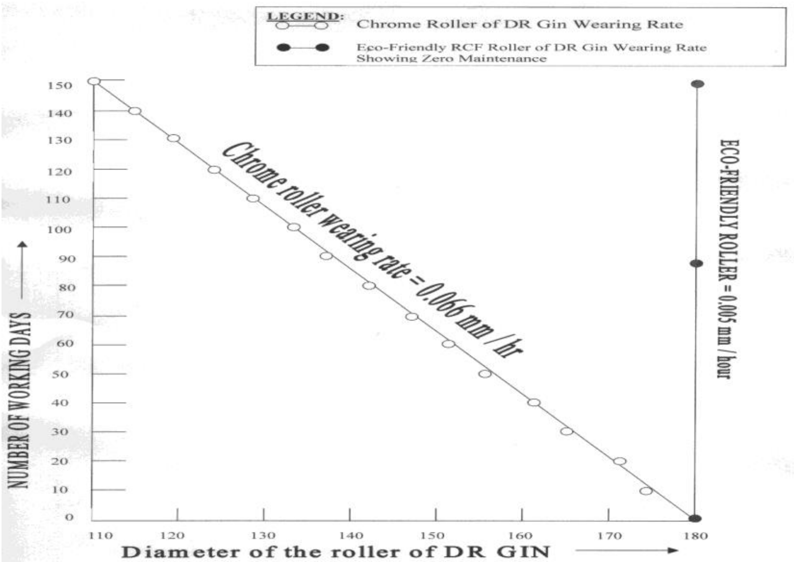


**Figure 18. Graph of wearing rate of dust-producing grinding of chrome roller and eco-friendly roller of DR gins.**

The *stickiness* of rubber particles increased the particle size of gin emission. This was analysed by the *particle size analyser*. The particle size was found to be within the range of 75 μ and above, but not less than 75 μ. These particles are filtered by the hair in the human nose and no toxic effects are reported with rubber. Therefore, it has been proved that the RCF roller with the 'system after modification' was found to be a pollution-free alternative compared to the CCLC roller.

### *4.9. Design and development of eco-friendly rollers for cotton DR gins*

The manufacturing technology, design engineering features and assembly drawings show that the conventional fabric and rubber roller gin covering material is selected with the following characteristics, namely

1. Hardness of 90 (type DO durometer)
2. 9–10 layers of fabrics 20 mm length
3. Thickness of fabrics 1.2 mm
4. The rubber compounding is resilient and
5. 0.76 mm of fibre bristles protrude beyond the rubber surface is maintained despite wear.

Figure 19 shows the close-up photograph of eco-friendly lint cotton obtained from RCF Roller ginneries, Phase-VII mitigation step of EHIA.

**Figure 19. Close-up photograph of eco-friendly lint cotton.**

Based on the design and development of various rollers with subsequent performance evaluation studies, the chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton. Figure 20 shows the close-up photograph of RCF roller ginning machine working for commercial trial production.

**Figure 20. Close-up photograph of RCF roller ginning machine.**

The cost economics study reveals that eco-friendly RCF roller ginnery sounds better in all aspects with reference to environmental, cotton technological and techno-commercial aspects. Table 7 shows the data of engineering analysis of eco-friendly cotton lint and chromium contaminated lint. Tables 8 and 9 represents HVI and SEM test results related to the cotton technological parameters of the lint cotton obtained from CCLC and RCF gins, Phase-IX of EHIA, respectively.

**Table 7 Data of engineering analysis of eco-friendly cotton, lint and chromium-contaminated lint**

| Sl. No. | Particulars | Eco-friendly gin roller/ginned lint | Chrome gin roller/ ginned lint |
|---|---|---|---|
| 1. | Seed index | 7.07 | 7.34 |
| 2. | Knife blunting | Every 4 days | daily |
| 3. | Grooving of gin roller frequency period | Every 5 days | daily |
| 4. | Power at no load, 400 V | 1.28 KW | 1.6 KW |
| 5. | Power at full load, 400V | 1.696 KW | 1.92 KW |
| 6. | No load current | 4 A | 5 A |
| 7. | Full load current | 5.3 A | 6 A |
| 8. | Seed fuzz | 6.2 % | 5.0 % |
| 9. | Diameter reduction per machine hour | 37.89 μm | 64 μm |
| 10. | Production per machine hour | 38.26 kg | 36 kg |
| 11. | Expected useful life of washer | 844 machine hour | 437.5 machine hour (wearing up to 30,000 μm) |
| 12. | Friction of roller to lint cotton | 0.768 | 0.123 |

Table 8. HVI test results of lint cotton

| Sl. No. | Particulars | Eco-friendly gin roller/ginned lint | Chrome gin roller/ ginned lint |
|---|---|---|---|
| 13. | 2.5% Span length | 27.7 | 28.6 |
| 14. | Tenacity, g/tex | 21.3 g/tex | 22.2 g/tex |
| 15. | Uniformity ratio, UR% | 46 | 45 |
| 16. | Short fibres,% | 3.5% | 4.0% |
| 17. | Colour/grade/appearances | Yellowish and very good | White shining, poor |
| | | SEM test | |
| 18. | Wax content proportion | 0.3% and better Catching properties | Nil Poor dye Catch properties |
| 19. | Dye up-take | Very good | Poor |
| 20. | Scanning physical and chemical properties | Very good | Poor |
| 21. | 2.5% span length, mm | 35.6 | 35.4 |
| 22. | Uniformity, % | 46.0 | 44.0 |
| 23. | Baer sorter, Mean length, mm | 32.3 | 32.8 |
| 24. | Elongation | 40.0 | 42.0 |
| 25. | Short fibre, % | 14.6 | 16.4 |
| 26. | Tenacity, g/tex | 28.6 | 27.8 |
| 27. | Micronnaire | 3.0 | 2.8 |

**Table 9**

| Sl. No. | Particulars | Eco-friendly gin roller/ginned lint | Chrome gin roller/ ginned lint |
|---|---|---|---|
| 30. | Short fibre, % | 6.2 | 5.2 |
| 31. | Tenacity, g/tex (1/8"stello gauge) | 21.8 | 21.4 |

| | | | |
|---|---|---|---|
| 32. | Elongation | 6.0 | 5.7 |
| 33. | Micronnaire | 3.4 | 3.3 |
| 34. | Leaf | 3.0 | 4.0 |
| 35. | Area ,% | 0.60 | 0.7 |
| 36. | Trash Count | 28 | 28 |
| 37. | Rd | 67.7 | 67.8 |
| 38. | +b | 14.5 | 14.5 |
| 39. | Colour Grade | 24.4 | 24.4 |
| 40 | SCI | 128.0 | 129.0 |
| 30. | Short fibre, % | 6.2 | 5.2 |
| 31. | Tenacity, g/tex (1/8”stello gauge) | 21.8 | 21.4 |
| 32. | Elongation | 6.0 | 5.7 |
| 33. | Micronnaire | 3.4 | 3.3 |
| 34. | Leaf | 3.0 | 4.0 |

#### *4.10. Comparative economics*

Comparative economics have been worked out for the chrome less RCF roller ginneries and CCLC rollers ginneries, that is for both the ‘system before and after modifications’ and for commercialisation to the ginning industries (Table 10).

**Table 10. Present status comparative economics as on date**

| Sl. No. | CCLC rollers for DR gins (system before modification) | Eco-friendly, chrome-free RCF roller for DR gins (system after modification) | Saving with RCF roller |
|---|---|---|---|
| 1. | Initial cost \$0.12–\$0.29 per washer/disk. The washers can be used for 2–3 months in a cotton season. About two times, new washers are to be replaced in an year. Maintenance cost is ten times more than RCF roller gins, because of roller grooving, gin-settings and pressure adjustments are to be carried out at frequent intervals. Lower productivity. Cr contamination and pollution problems are there in major cotton growing areas in India, Tanzania, Africa and Egypt. | Initial cost is \$1.25 per washer. Though the initial cost of the RCF roller is 11 times more than the life of CCLC roller, the high price is compensated, as it is durable up to 7 years. There is zero maintenance. Considering the maintenance and washer replacement cost, the washer cost worked out to be \$ 0.25 per washer. No grooving is required except in initial maintenance. High productivity. Cleaner production. No waste in product. Chromium contamination and pollution problems are not there. | Though the initial cost is more, washer replacement and maintenance cost is 8 times less than the CCLC washer. |
| 2. | Initial total cost is \$21.4 per roller | Initial total cost is \$19.3 per roller | \$2.15 |
| 3. | Washer replacement cost for a ginning industry having 12 DR gins is \$1,029 per cotton season. | Washer replacement of a ginning industry having 12 DR gins is \$897 per cotton season | \$132 |
| 4. | Medical charges for treating the workers is abnormal | Charges for treating the workers is very less in respect of chromium pollution problem and benefits increase manifold | Safe environment |
| 5. | Labour output per hour is 1.2 standard performances rating | Labour output per hour is 2.4 standard performances rating which is twice than CCLC ginning industries because of cleaner environment | Safe environment |

| | | | |
|---|---|---|---|
| 6. | Gin output is 1.25 times less than the RCF ginning industries. | Gin output is of about 1.25 times more than the CCLC rollers because of the developed roller made up of RCF and has got a surface finish conducive to high ginning efficiency. | 1.25 times |
| 7. | Cumulative power consumption is three times more as compared to RCF gins. | Cumulative power consumption is three times less as compared to CCLC gins. | Three times |
| 8. | Washer is consumable. | Washer is not consumable. | 7 years life |
| 9. | Unsafe chromium contamination and pollution. | Safe environment. No chromium pollution in the environment. | Eco-friendly technology |
| 10. | EHIA attached (Vijayan, 1998) | EHIA attached.<br>Strategic environmental Assessment has been reported. (Vijayan, 2018) | |

**5. Conclusion and suggestions**

This research article realises the hazards of chromium contamination and pollution caused by using CCLC rollers that are commonly used in cotton roller ginning industries and attempts to eliminate the chromium contamination and pollution during the cotton ginning process. EHIA can be defined as the systematic identification and evaluation of the potential health impacts of proposed projects, plans, programmes, policies or legislative actions relative to the physical–chemical, biological, cultural and socio-economic components of the total environmental health (Vijayan, 2018). As per the World Health Organisation (WHO, 1987), the purpose of the EHIA process is to encourage the consideration of the environmental health in planning and decision-making and to arrive at actions that are more environmentally compatible (Iyer, 2007). Three of the most significant environmental health requirements are environmental health inventory, EHIA and environmental health impact statement. EHIA was conducted in Indian cotton roller ginning factories during the research years 1998–2018. The roller is the major component of cotton roller gin stand. The CCLC roller is commonly covered with CCLCs bonded and stitched together in the form of 78–80 numbers of compressed discs at a pressure of 14 kg/cm$^2$ and mounted on a steel shaft. This CCLC roller is pressed against the stationary knife at a pressure of 2.5–4.1 kg/cm$^2$. The roller rotates at a speed of 100–120 rpm and the beater oscillates at 960 opm. Due to the friction between RSK, the temperature of the CCLC roller was found to increase up to 47.2°C in a room temperature of about 34°C, while the temperature of RCF roller was increased up to 55°C.

Several rollers are required in a year due to wear and tear action arising out of grinding action, resulting in dust production during the process of ginning operation. On the surface of the rollers, spiral grooves are made every day to increase friction and to enable the removal of the fibres in ginning operation. The CCLC rollers add to the chromium burden of the environment, which are toxic to human health. It was observed from the results of CCLC rollers wear out data that the diameter of the rollers had been reduced up to 135 mm from the original value of 180 mm, with the average roller thinning rate of 0.066 mm/hour after 150 shifts of operation (that is 75 working days over 3 months) during a cotton season. The CCLC roller wear out study revealed that nearly 40%–45% of roller covering material was removed before replacement. This explains that the rollers are subjected to copious amounts of wear, thereby giving rise to dust containing chromium called CSD emissions from the ginning point.

The CCLC rollers used in ginning industries get powdered during ginning operation and enter the environment as CSD. It was observed that the CSD contaminates cotton and its products. The chromium contamination levels for cotton and its products were abnormal for all the samples except that the cotton samples obtained from RCF roller gin rollers, i.e., eco-friendly ginning industries. As per the environmental standards (MOEF Notification No.157, 1996), chromium content in cotton and its products is not to be more than 0.1 ppm. The CCLC roller coverings contained 18,077–30,783 mg/kg, (ppm) as total chromium. When the seed-cotton is ginned, the ginned lint cotton gets contaminated to the extent of 143–1,990 ppm as total chromium. Due to persistent rubbing of CCLC rollers over stationary knives and adsorption property, chromium from CSD as well as pericarp particles remaining after the ginning process is carried out, wherein spun yarns get contaminated to the tune of 17–250 ppm as total chromium against the safe limit of 0.1 ppm. The CSD contains 4,232 $\mu g/m^3$ including RSPM and SPM concentrations and 1,994 mg/kg (ppm) as total chromium. The chromium uptake from the soil (bio-availability) is 3 ppm. These levels in the case of chrome rollers and CSD are 15,382 and 21 times more than the maximum permissible level as 2 ppm and 200 $\mu g/m^3$ and in the case of lint it is more than 71 times the accepted level, 2 mg/kg (ppm), respectively. Worker dose and exposure chromium level on 8 hours basis are 35 times more than the standards of the American Conference on Governmental Industrial Hygienists –Thresh Hold Limit Valve and United States Occupational Safety and Health Administration.

The variations in concentration levels were because of the coating of chromium with fine dust particle and adsorption properties on to the cotton and its products. The chromium was not detected from RCF ginned lint cotton as there is no chromium in the source, which confines the eco-standards.

Because out of 300 lakh bales of lint cotton produced per annum about 210 lakh bales are processed in these ginneries, it is quite important to note that the lint cotton obtained is being contaminated by chromium at significant concentration levels. Processed cotton seeds, which are an important source of edible oil, simultaneously get contaminated by chromium. Following are the significant findings of chromium contamination of the samples with relevant eco-standards:

**Chromium contamination level in cotton and its products**

**Bio-availability for chromium uptake on cotton = 3 ppm**

| **Sl. No.** | **Cotton and its Products** | **Total Chromium** | **Environmental Standards [a]MOEF Notification -157** |
|---|---|---|---|
| 1. | Lint cotton | 143–1,990 ppm | 0.1 ppm |
| 2. | Spun yarns | 17–250 ppm | 0.1 ppm |
| 3. | Woven fabrics | 17–45 ppm | 0.1 ppm |
| 4. | Cotton seeds | 0–312 ppm | |
| 5. | Edible oil | 0–259 ppm | |
| 6. | Oil cake | 0–190 ppm | |
| 7. | Linter | 0–159 ppm | |
| CCLC roller = 18,077–30,783 mg/kg (ppm). | | | |

[a]Adapted from MOEF Notification No.157 (1996).

Following are the significant findings of chromium in dust samples with relevant eco-standards:

**Chromium level in dust samples:**

| **Sl.No.** | **Source of Dust** | **Total Cr** | **[a]Environmental Standards $LD_{50}$** |
|---|---|---|---|
| 1. | Ginning point | 51–173 ppm | 50 ppm |
| 2. | CCLC grooving point | 17–1,994 ppm | 50 ppm |

[a]Adapted from U.S. National Institute of Occupational and Safety Hazard Standards (1992).

It was observed that the CSD contaminates cotton and its products. The chromium contamination levels for cotton and its products were abnormal for all the samples except that the cotton samples obtained from RCF roller gin rollers, i.e. eco-friendly ginning industries. As per the environmental standards (MOEF Notification No.157, 1996) (Annexure-VII), chromium content in cotton and its products should not to be more than 0.1 ppm. The samples, namely lint cotton, yarn, fabrics, seed, linter, edible oil and oil cakes, were found to be contaminated and their levels were in the range of

110–1,990 ppm obtained from the source of dust-producing grinding CCLC rollers sample which contained 18,077–30,783 ppm. The variations in concentration levels were because of the coating of chromium with fine dust particles and adsorption properties on to the cotton and its products. Chromium was not detected from RCF ginned lint cotton as there is no chromium in the source, which confines the eco-standards.

Gin and mill workers are directly exposed to air pollution problems and are vulnerable to health hazards. Ginning factories are in and around seed-cotton (or *kapas*) growing areas and employ women for menial jobs. The women often come along with children for performing their jobs like (i) feeding seed-cotton to the gins, (ii) collecting lint, seed and floor sweeping, (iii) cleaning and grading of seed-cotton and (iv) light activities. The children are directly exposed to CSD. Since ginning is a seasonal activity, over few months of the year, it was not possible to check the health aspects. Furthermore, there are no medical/health records available or provided.

To offset this serious problem of chromium contamination and pollution from cotton ginning industries, chrome-free RCF rollers for both laboratory and commercial studies have been designed, fabricated and experimented on a special laboratory-built GRED and DR gins. These rollers are covered with packing-type roller covering material made from multiple layers of cotton fabric bonded together with a rubber compound.

The associated objectives of laboratory studies were to define the physical properties of a roller covering material, which contributes to its energy consumption, ginning rate potential, eco-friendly parameters, cotton technological and mechanical engineering analysis and to search a better roller covering material. Seven types of roller covering materials with different rubber compounding and multiple fabrics composition are tested in GRED and DR gins. Two rollers are abandoned primarily due to higher wear and tear rate, adhesive failure and ginning not carried out properly. The pollution-free and chrome-free RCF rollers were found successful in ginning out seed-cotton in an environment friendly way, while maintaining high ginning rate potential, cotton technological parameters of lint, yarn and fabric properties.

The RCF rollers made with experimental covering materials are tested (1) to find obvious short comings in performance, such as short roller life, wear rate, temperature and lint contamination, and (2) to establish the existence of some ginning rate potential. Five RCF rollers are found effective and successful in ginning out seed-cotton. One of the specimens of the fabrics and rubber packing-type gin roller covering material is superior to all types tested in ginning rate potential (kg of cotton ginned per unit time at maximum feed rate) and in amount of energy consumed (work required to gin a kg of lint). Due to friction between RSK, the temperature of this roller is increased up to 55°C, which facilitates rapid ginning operations. The manufacturing technology, design engineering features and assembly drawings show that the conventional fabric and rubber roller gin covering material is selected with the following characteristics, namely:

1. Hardness of 90 (type DO durometer)
2. 9–10 layers of fabrics 20 mm length
3. Thickness of fabrics 1.2 mm
4. The rubber compounding is resilient and
5. 0.76 mm of fibre bristles protrude beyond the rubber surface is maintained despite wear out.

Based on the design and development of various rollers with subsequent performance evaluation studies, chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton. Cost economics study reveals that eco-friendly RCF roller ginnery sounds better in all aspects with reference to environmental, cotton technological and techno-commercial aspects. This improved technology is amenable for commercialisation to the industries.

Although the initial cost of the RCF roller is 11 times more than the life of CCLC roller, the high price is compensated, as it is durable up to an estimated life of 7 years than more of a few months of CCLC rollers. In addition, it ensures the following advantages:

1. There is negligible wear and tear and zero maintenance.
2. High ginning efficiency and output of about 1.25 times more than the CCLC rollers because the developed roller made up of RCFs has a surface finish conducive to high ginning efficiency.
3. 50% reduction in the weight of the rollers consumes 25% less in energy consumption that is power saving that is three times less compared to CCLC roller ginneries.
4. It is observed that the noise level in eco-friendly ginneries is reduced to a range of 4–7 dB (A) due to inherent properties and cushioning effects.
5. Eco-friendly cotton and its products can be obtained.
6. Labour output/hour has a 2.4 standard performance rating, that is twice the CCLC ginneries, because of a cleaner environment.
7. Medical charges for treating the affected workers decrease manifold.

The newly designed and developed eco-friendly ginneries eliminate chromium contamination and pollution from cotton ginning industries. These give rise to control at-source pollution control, such that the industries meet the requirement of environmental standards enforced by many countries and high-quality yarns and fabrics meeting international standards be produced. The industries will be free from chrome-related contamination and pollution problems, occupational and non-occupational health hazards. The ginneries have been tested commercially and are found to be better in all aspects with reference to cotton technological parameters, dye-catching properties, physical and chemical properties. It could be successfully used commercially as an improved alternative in cotton ginning industries for a cleaner environment with benefits to society, industry owners, traders, workers, employees and the government.

Furthermore, the following recommendations are suggested:

1. Most of the cotton roller ginning operations were carried out using roller gins in India, Africa, Tanzania and Egypt. Out of the lint obtained from these CCLC roller ginneries in this country, it is quite important to appreciate the fact that the lint produced is contaminated with chromium powder which produces a deleterious effect on the people working in the vicinity. Yarn and seed obtained is also contaminated with chromium. Toxic effects are produced by prolonged contact with airborne, solid or liquid chromium contamination and pollution even in small quantities. Hence, it is imperative that a policy decision be taken to replace the presently used CCLC rollers with eco-friendly rollers or vegetable tanned leather rollers.
2. Industry and government and regulator should come forward to subsidise this venture in view of its demonstrated and proven techno-commercial feasibility in connection with eco-friendliness.
3. Immediate action must be required by the concerned government regulatory agencies for transfer of eco-friendly technology to the ginning industries, and thus save the environment.
4. Comprehensive studies on environmental pollution and control particularly in the ginning environment and its correlation with socio-economic and health studies need to be carried out.

**Acknowledgements**

The author is thankful to *International Journal of Emerging Trends in Health Sciences*. Thanks to Prof. Dr. Gurdeep Singh for Ph.D. guidance as per the following references:

1. Iyer, Vijayan Gurumurthy. '*Environmental Effects of Chrome Rollers Used by Cotton Roller Ginning Industries and Design and Development of an Eco-Friendly Alternative',* Ph.D. Dissertation. Singh, G.: Dhanbad Indian School of Mines. Centre of Mining Environment (Presently: Department of Environmental Science & Engineering), 2003. Date of Ph.D. registration is 23. 05. 1998 reference letter number Ph.D. Registration Number

633012/CME/Acad/99, dated 08.06. 1999 as a Research Scholar with effect from 23.05.1998. Date of Viva-voce Examination / Completion of Ph.D. on 12.03.2003.

2. Iyer, Vijayan Gurumurthy et al. '*Studies on Environmental and Health Effects of Chrome Composite Leather-Clad Roller Commonly Used By Cotton Roller Ginning Factories and Development of Pollution-Free RCF Roller*', M. Tech. Dissertation, Singh, *G*.: Dhanbad Indian School of Mines University, Centre of Mining Environment, 1997.

The author is thankful to Mr. Shirish R. Shah, M/S Bhaidas & Cursondas Company, Mumbai, who has sponsored this research project. The author is thankful to Engineering Council of India for Coordinatorship during 2020–2021.

## References

Anap, G. R., Vijayan, I. G. & Krishna Iyer, K. R. (1995–1996). A resume of the investigations carried out on the precleaning and ginning of indian cottons. *The Textile Industry and Trade Journal,* 101–104.

Bandyopadhyay, K., Gangopadhyay, A. & Son, N. N. (2000). Adsorption study on fly Ash as a waste resource for the removal of chromium. *World Congress on Sustainable Development Proceedings, I*, 532–539.

Gillum, N. & Marvis, (1964). Properties of roller covering materials (pp. 1–45). Washington, DC: United States Department of Agriculture (USDA).

Gurumurthy, V. I. (1997a). *A referred short note on Development of a pollution-free gin roller for roller ginning industries*.

Gurumurthy, V. I. (1997b). *Studies on environmental and health effects of chrome composite leather-clad rollers commonly used by cotton roller ginning factories and development of pollution-free rubberized cotton fabric roller* (M. Tech. Thesis). Indian School of Mines, Dhanbad, India.

Iyer, V. G. (2007). Eco-friendly rubberized cotton fabric roller development for cotton roller gins. *Journal of Agricultural Safety and Health, 13*(1), 33–43.

MOEF Notification No.157. 1996.

Morton, L. (1991). *Book on asbestos and mineral fibres* (pp. 34–134). Amsterdam, Netherlands: Elsevier Publishers.

Rao, C. S. (1995). *Book on environmental pollution control engineering* (pp. 1–79). New Delhi, India: Wiley Eastern Ltd.

Rao, M. N. & Rao, H. V. N. (1989). *Book on air pollution* (pp. 35–56). New Delhi, India: Tata McGraw Hill Publishing Co. Ltd.

Shete, D. G. & Sundaram, V. (1993). Some practical hints for better ginning of cotton with roller gins. *ICMF Journal*.

Shirley Institute. (1982). *Research encyclopaedia-II* (pp. 23–56). Manchester, UK: Cotton Dust Hazards, Textile Series Memories.

Sujana, M. G. & Rao, S. B. (1997). Unsafe chromium. *Science Reporter,* 27–30.

Townsend, J. S. Walton, T. C. & Martin, J. (1940) *Roller gin construction, operation and maintenance*. Washington, DC: U.S. Department of Agriculture.

U.S. National Institute of Occupational and Safety Hazard Standards. 1992.

Vijayan, G. I. (2018) *Strategic environmental assessment (SEA) process for green information technology and management engineering systems towards sustainable education process business excellence achievements*. In Proceedings of the 2018 International Conference on Information Technology and Management Engineering (ICITME2018) (ISSN: Part of 1951-6851, Volume 148) ISBN: 978-94-6252-607-5 Series: Advances in Intelligent Systems Research (AISR) held during August 26–27, 2018 at Beijing, China. The website is http://www.itmeconf.org/. The paper has been published in abstract book of ICITME2018 page number 7 and 8 entitled "Strategic Environmental Assessment (SEA) Process for Green Information Technology and Management Engineering Systems towards Sustainable Education Process" Paris, France: Atlantis Press. Publication dated 26 th August 2018, 37–148.

Vijayan, I. G. (1994). *Study of backlash in double roller gins* (pp. 12–13 & 22). Mesquite, TX: The Cotton Gin and Oil Mill Press.

Vijayan, I. G. (1995). *A resume of the investigations carried out on the precleaning and ginning of Indian cottons. Resume of research on mechanical processing released in the seminar on recent advances in mechanical processing*. Bombay, India: CIRCOT.

Vijayan, I. G. (1996). Setting and adjustments in saw gin stand for improved quality cotton. *Journal of Textile Association,* 288.

Vijayan, I. G. (1998a). Environmental and health effects of chrome composite leather clad rollers commonly used by cotton roller ginning industries. *The Textile Industry and Trade Journal*.

Vijayan, I. G. (1998b). Environmental and health effects of rollers used in ginning industries. *Journal of Textile Association, 59*(2), 87–94.

Vijayan, I. G. (1998c). Pollution-free rubberized cotton fabric washer/roller for cotton roller gins. Patent filed on 12.5.1998 vide Gazette notification No. 276/Bom/98, 1998.

Vijayan, I. G. (1999). Cotton ginning and lint quality. *The Textile Industry and Trade Journal,* 73–80.

Vijayan, I. G. (1999). *Unsafe chromium contamination and pollution in cotton ginning industries*. Envirocon 99, 15th National Convention of Environmental Engineers, Proceedings of Institution of Engineers, Kolkata, India.

Vijayan, I. G. (2000). *Unsafe chromium contamination and pollution in cotton ginning industries. World congress on sustainable development engineering and technological challenges of the 21 st Century* (pp. 118–140). Calcutta, India: Tata McGrew-Hill Publishing Co. Ltd.

Vijayan, I. G. (2002). *A referred letter by SITRA on Unsafe Chromium Contamination and Pollution in Cotton Ginning Industries.* Coimbatore, India: South India Textile Research Association.

Vijayan, I. G. (2002). *Environmental effects of chrome rollers used by cotton roller ginning industries and design and development of eco-friendly alternative* (Ph.D. thesis). Indian School of Mines, Dhanbad, India.

Vijayan, I. G. (2002). *Environmental impact assessment of chrome rollers used by cotton roller ginning industries*. Mesquite, TX: Accepted for Publication in Journal of Cotton Gin and Oil Mill Press.

Vijayan, I. G. (2002). *Research and development – environmental Hygiene*. Hindustan College of Engineering, Skroll.

Vijayan, I. G. & Gurdeep, S. (2002). *Environmental impact studies of chrome rollers used by cotton ginning industries and design and development of chrome less RCF roller. Environment, Pollution and Management Book* Chapter No.3 (pp. 75–86). New Delhi, India: A. P. H. Publishing Corporation, and accepted for publication in American Society for Agricultural Engineers Journal of Applied Engineering in Agriculture, USDA.

Vijayan, I. G. & Gurdeep, S. (2002). *Process of manufacture of improved eco-friendly cotton lint for better physical and chemical properties/dye catch properties*. Patent Filed.

Vijayan, I. G. & Parthasarathy, M. S. (1993). Some practical hints on precleaning and ginning. *Indian Textile Journal,* 28–32.

Vijayan, I. G. & Parthasarathy, M. S. (1994). *Design of mote grooving tool and its holder for rollers of roller gins*. Paper presented and discussed at the National Seminar on Recent Advances in Textile Technology and Textile Industry concurrently held with Ninth National Convention of Textile Engineers, Bhopal, India.

Vijayan, I. G. & Parthasarathy, M. S. (1996). Design of a mote grooving tool and its holder for rollers of roller gins. *Journal of Institution of Engineers (I), 77*.

Vijayan, I. G. & Parthasarathy, M. S. (1998). *Ottai Ka Vikas/developmet in ginning. Journal of Institution of Engineers (I)*. Kolkata: India: Hindi Section of Institution of Enginers.

Vijayan, I. G, Vizia, N. C. & Krishna Iyer, K. R. (1993). A simple device to prevent backlash in roller gins. *Journal of Textile Association,* 129–130.

Vijayan, I. G., Gurdeep, S., & Saxena, N. C. (2001). Environmental and health effects of rollers used in cotton roller ginning industries. *Indian Journal of Environmental Protection*, *21*(6), 499–507.