Proceedings of the 2006 IASME/WSEAS International Conference on Energy & Environmental Systems, Chalkida, Greece, May 8-10, 2006 (pp440-474)

# Environmental Effects of Chrome Composite Leather-Clad Rollers Commonly Used by Cotton Roller Ginning Industries and Design and Development of Chromeless Rubberized Cotton Fabric Roller for Cotton Double Roller Ginning Machines

Gurumurthy Vijayan Iyer,
MNM Jain Engineering College,
36, Venkatesh Nagar Main Road,
Virugambakkam, Chennai-600 092,
INDIA

Nikos E. Mastorakis
WSEAS European Office
Agiou Ioannou Theologou 17-13,
15773, Zografou, Athens,

*Abstract:* This review paper realizes the hazards of chromium contamination and pollution caused by the use of Chrome Composite Leather-Clad (CCLC) rollers commonly used in cotton roller ginning industries and attempts to eliminate the chromium contamination and pollution during the cotton ginning process. The cotton ginning process is the first phase of mechanical operation in cotton textile production. Cotton grown in the plant, commercially known as seed-cotton (or kapas), consists of 24 to 40 seeds per boll. Most of the cotton ginning operations are performed by using double roller (DR) gins which serve an important role in the ginning industry. The cotton roller ginning 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. About 80% of the seed-cotton produced in India is ginned in DR gins. The roller is a vital part of the gin and one requiring considerable attention. The peculiar gripping action or adherence of the cotton fibres to roller covering surface is an important element in the success of cotton roller ginning process. Presently, there are about 4500 ginneries using 210 000 CCLC rollers (another 50 000 to 80 000 as spares) per year. The roller packing of the DR gin is made of CCLC element, which contains about 18 077 to 30 783 mg/kg (ppm) as total chromium of trivalent and hexavalent forms which are toxic to human health. When the seed-cotton is ginned, due to persistent rubbing of CCLC rollers over the fixed knives, the ginned lint cotton adsorbs about 143 to 1990 mg/kg (ppm) as total chromium of trivalent and hexavalent forms and the cotton products carry with it of about 17 to 250 mg/kg (ppm) of chromium which according to Indian Standards (MOEF-157, 1996) for yarn and fabrics, should not be more than 0.1 mg/kg (ppm). Lint cotton and cotton dust are the good adsorbents of Cr (III) and Cr (VI) from Chrome Specific Dust (CSD) being powdered during the ginning process. The chromium contamination in cottonseeds and edible oil are 0 to 312 mg/kg (ppm) and corresponding Indian Standards is 2 mg/kg. This causes chromium-poisoning, leading to skin disorders and liver damage in humans and animals. Subsequently the same or less amount is carried till textiles effluent, which according to environmental standards should not be more than 2 mg/L. The chromium traces found contain hexavalent chromium being adsorbed from chromium-contaminated lint, yarn, fabrics, seeds and by products and textiles 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 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. carcinogenecity, mutagenecity and corrosiveness. Traces of Cr (VI) are found even in analar grade trivalent compounds and complications do arise due to reduction in nature of these traces that affect the organic tissues of the body. These regenerating effects occur rapidly and are dependent of the dose.Air pollution studies are made to monitor the gin house air in terms of total dust level concentration, bio-availability, worker dose, valence state of the chromium, duration of exposure and the quantity of reparable and suspended particulate matter concentration. The suspended particulate matter (SPM) in cotton-gin buildings is 2495 μg/m3 and chromium concentration is 1994 mg/kg (ppm), which according to environmental standards should not be more than 500 μg/m3 and 2 ppm respectively. The respirable suspended particulate matter (RSPM) in cotton-gin buildings is 4232 μg/m3 and concentration of chromium is 150 ppm. Gin and mill workers are directly exposed to air pollution problems and are vulnerable to health hazards. Ginning factories are located 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 with CSD. Since ginning being a seasonal activity over a few months of the year, it was not possible to study the health aspects. Further there were no medical/ health records available/provided. The three pollutants, viz., cotton dust, chromium and leather powder and/or other foreign matter, under favourable conditions of sunlight (photo energy), humidity, temperature and air movement interact and produce CSD which is a serious pollutant due to a synergistic interacting function.

To offset the unsafe chromium contamination and pollution from cotton ginning industries, chrome-free rubberized cotton fabric (RCF) rollers or eco-friendly rollers both for laboratory and commercial studies have been designed, fabricated and experimented on a special-built gin roller experimentation device (GRED) and double roller (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 material which contributes to its energy consumption, ginning rate potential, eco-friendly parameters, cotton technological parameters, mechanical engineering analysis and to search a better roller covering materials. Seven types of roller covering materials with different rubber compounding and multiple fabrics composition are tested in GRED and DR gins. The RCF rollers made with this experimental covering materials are tested (1) to find obvious shortcomings in performance such as short roller life, wear rate, temperature and lint contamination and (2) to establish the existence of some ginning rate potential.

On the basis of 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. This 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. 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. 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 upto an estimated life of seven years than more of a few months of CCLC rollers. Besides, it ensures the following advantages.

(1) There is negligible wear and tear and also 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 rubberized cotton fabrics has a surface finish conducive to high ginning efficiency,

(3) 50% reduction in the weight of the rollers consume 25% less in energy consumption that is power saving of 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 to 7 dB (A) due to inherent properties and cushioning effects,

(5) Eco-friendly cotton and its products can be obtained.

(6) Labour output / hr is 2.4 standard performance rating, that is twice than CCLC ginneries because of 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 being 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 found 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 the cleaner environment with benefits to society, industry owners, traders, workers, employees and the Government.

## Objectives and Need of the Present Research

This research paper realizes the hazards of chromium contamination and pollution caused by the use of dust-producing grinding of chrome composite leather-clad (CCLC) rollers commonly used in cotton roller ginning industries and attempts to nullify this problem during the cotton ginning. The research has been carried out with the following objectives:

- To identify and study the environmental problems existing with the present chrome rollers employed in cotton roller ginning industries.
- To design and develop an eco-friendly chrome-free roller and evaluate its performance with particular reference to environmental and techno-commercial aspects in ginning industries.

With the author's research background and practical experience in ginning and textile industries, present study is attempted to eliminate this problem to the great extent at the source itself, through a suitable design and development of an eco-friendly, pollution-free chrome less roller for cotton roller gins. An eco-friendly roller ginning process has been developed for replacing conventional CCLC roller ginning process to eliminate the chromium contamination and pollution from cotton roller ginning industries so as to meet the requirements of environmental standards while maintaining high quality spun yarns and woven fabrics meeting the international standards.

# 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, K.R., 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.*, G.*hirsutum*, G.*barbadense*, G.*arboreum*, G.*herbaceum* and hybrids are cultivated (Vijayan Iyer, G., 1999). Cotton production has been estimated at 1594 lakh bales (each bale weighs 170 kg of lint cotton) during 1999-

2000 in the world. The lint cotton requirement for 2002-2003 AD is projected as 190 lakh *bales*.

Cotton, grown on the plant is seed-cotton (or *kapas)* consists of 24 to 40 seeds per boll (Plate-1). This is subjected to ginning process after being transported from the cotton farm to the ginning mill (Figure-1). The manufacturing process of cotton textiles consist of two steps namely, (i) fabrication of the cloth (Figure-2) and (ii) processing and finishing (Figure-3). There are about 4,500 ginning and pressing units in India (Plate-2). Of these, about 3,600 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* (Plate-3). The bales are transported to either spinning mills or composite mills (Plate-4). There are about 3,200 small and big spinning mills and 400 composite mills containing 33 million of spindles frames (Vijayan Iyer, G., 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 Iyer,G. (1999). Plate-5 shows *lint cotton* obtained from ginning process. 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 *staple length* cotton varieties, whereas 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 serves an important role in the ginning industry. In northern zone (comprising of some areas in Punjab, Haryana and Rajasthan States), 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 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 Iyer. G., *1995)* .

The principle of cotton roller ginning process was invented by McCarthy (Townsend J.S., et.al., 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 figure- 4 shows the working of cotton roller ginning process. Plate-2 is the close-up photograph of cotton roller ginning machines.

The principle of roller ginning process is depicted in figure-4. In these gins, spirally grooved leather rollers (Plate-6), pressed against fixed knives, are made to rotate at a definite speed of 100 to 120 rpm. Crank or eccentric shaft close to leather rollers gives rise to oscillation action at 960 opm of moving knives (Vijayan Iyer, G. and Parthasarathy, M.S., *1998).* When the seed-cotton is fed to the machine, 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 number of times and due to the *'push-and-pull'* action; the fibres are separated from the seeds carried forward on the rollers to be dropped out of the machine. Plate-7 indicates fixed knife (or stationary knife), moving knife and seed grid of DR gin. The ginned cotton seeds dropped down through the grid slots. Plate-8 shows cotton seeds get collected in seed pit through a screw conveyor.

The roller constitutes an important element of 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*, these countries did not allow this type of hides to be used and obsolete these roller gins. Sheep and Buffalo chrome tanned hides, were used as substitutes in the roller ginning machines, though the *interfibrillary action* is not satisfactory compared to walrus hides. The roller materials *viz.,* ordinary leather, newspaper, corkboard, and coconut coir were also tried, but have 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. Figure-5 represents countries using CCLC roller ginneries in the world.

Several rollers are required in an 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 1025 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 Iyer, G. and Parthasarathy, M.S., *1993)*. The stationary knife is held tightly against the roller and a moving knife to pull the seed from fibres, which are held by the stationary knife and roller. Figure-7 depicts schematic diagram of cotton roller ginning process and its nomenclature. Sufficient pressure ranging about 5.6 to 7.0 kg/cm$^2$ is kept between roller and stationary knife (RSK) to gin seed-cotton as much as capacity without causing excessive heat of roller (Glum, N. Marvin, 1964). General gauge setting configuration is shown in figure-8.

Plate-9 shows CCLC washer being used in ginning industries. In this conventional ginning process *CCLC* rollers emit chromium in environment due to constant dust-producing grinding action, which contaminates the cotton and its products beyond the safe limits of eco-standards. Since the semi finished chrome leather washers contain 3 to 4% as 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 Iyer, G. , *2000)*. This results in *chrome specific dust (CSD)* production during the process of ginning operation, which is the major environmental chromium contamination and pollution problems from roller ginning industries in the nine cotton growing States of India (Figure-6). 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 diseases among ginnery and textile mill workers. The chrome specific dust pollutes the gin-house air and the cotton processing workers suffer from chromium bound diseases and physiological disorders. The chromium adsorbed into lint causes allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septums to cotton processing workers. Toxic effects are produced by prolonged contact with airborne or solid or liquid chromium contamination and pollution even in small quantities. Cotton seeds get contaminated with chromium from the source (Vijayan Iyer, G., Gurdeep Singh and Saxena , N.C. , 2001).

The work presented in this article is intended to identify the environmental and health-related problems faced when CCLC rollers are used. 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 realizing the hazards of chromium contamination in lint cotton, seed, yarn, fabric and textile effluent and air pollution problems due to chrome specific dust 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. Suitable eco-friendly roller ginning process to eliminate this unsafe chromium contamination and pollution in the environment has been presented in this research review paper. An extensive and exhaustive study was undertaken for the design and development of eco-friendly, pollution-free, chromeless, rubberized cotton fabric (RCF) rollers to modify the present conventional CCLC rollers.

## 2. Literature Review

### 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 J.S. Walton T.C. and Martin J. , *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 1840 (Gillum, N., and Marvis, *1964)*.

### Description and Performance of CCLC Rollers in Double Roller Gins

The roller is the major component of Double Roller (DR) gins. The gin roller length varies from 1025 to 1148 mm with a diameter varying from 178 to 180 mm suitable for operation. The roller consists of 78 to 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 Iyer, G., ***1999***). Plate-9 shows the close-up photograph of chrome composite leather-clad washer for making CCLC roller gin rollers. Figure-9 is the engineering drawing of the cladding of chrome composite leather-clad washers comprising of roller of a double roller ginning machine. Basic Chromium Sulphate (BCS) $Cr\ (OH)\ SO_4\ nH_2O$ and impure chromate having 45-50 % basicity are used during the *chrome leather tanning process* for making such CCLC flaps (Vijayan Iyer.G. , *1998*). The various unit operations involved in making washers to final shape of the roller are (i) The washers are filled in a steel shaft having 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. Plate-10 shows close-up photograph of filled and pressed chrome washers assembled in the form of a roller in DR gin. The roller is to be pressed on both sides by adding required number of washers on each side, (iii) The pressed roller is turned and finished to diameter 180 mm in a center lathe, (iv) Spiral grooves are made on the surface of the finished rollers. The finished roller is ready for grooving operation by using band saw; initially by marking 'U'-shaped spiral grooves, fixing in the grooving machine and lastly spiral grooves are made on the roller surface by band saw or circular saw cutting machine (Shete, D.G. and Sundaram ,V., ***1993).***.

The ginning efficiency primarily depends upon the surface speed of the roller and number of working strokes on the moving knife (Shete, D.G., *et.al.*, 1993). While operation of these rollers in the ginning machines, the rate of ginning goes on declining when the roller diameter is reduced. At the end of cotton season having three months duration, the roller is reduced to 114 mm in diameter, the washers are removed from the shaft. Again the new washers are recovered and cladded in shaft. The worn out and consumed washer disks after considerable period of usage for about three months are shown in Plate- 11. Plate-12 Filled and Pressed CCLC washers assembled in the form of a roller of DR Gin.

## Environmental Impacts of CCLC Rollers

Environmental impacts of CCLC rollers are assessed from the pollutants *viz., cotton dust* and *chrome specific dust* (CSD) in the mill atmosphere. Their sources and health effects are briefly described below.

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. Figure 10 shows is the layers of cotton seed coat or pericarp particle. 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 due to the inhalation of cotton dust over long period of time (Shirley Vol. II, 1982). It is a permanent disabling lung disease. The symptom is chronic cough ending in chronic bronchitis (respiratory disorder). India has a large number of ginning and textile mills employing 48% of all the factory workers (Rao, M.N., 1995). About 55% of mill workers suffer from *byssinosis* disease (Rao, C.S., 1995). As per the rough estimate during field survey/discussions with ginning industry management, presently, there are about 213 000 CCLC rollers, which comprise of 17 040 000 CCLC washers are used for a cotton season of three 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 are wearing out constantly and exorbitantly contaminating the ginned lint cotton with chromium and 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, woven fabrics in macro level. During the wet textile processing stage, the concentration of chromium in the effluent is precipitated in micro amount. The chromium concentration is reduced in micro amount during beating operations, blow room mechanical cleaning and carding process (G.Vijayan Iyer., *1997*). 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 lead to skin disorders, liver damage on human and animal liver. Oil cakes consumed by animals were found with chromium poisoning diseases.

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

The air pollution due to CSD and cotton dust, which is responsible for synergistic (augmentative) health complications of chromium based diseases and byssinosis diseases on ginning industry workers. Almost most of the mills in India *are not provided* with dust control systems. Nor 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 to 40 years for *menial jobs* and male workers in the age group of 18 to 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 has 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 an year, (iii) the workers are reluctant to go for their medical checkup 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 the present study pertains to assess environmental chromium pollution during the cotton ginning process.

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 namely, vegetable tanned leather, eco-friendly tanned leather, including rubber and rubber-processing technology and modifying the present CCLC roller ginning system has 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. The roller gins are adjusted using gauges / spacers as per the CIRCOT standards (Vijayan Iyer, G. and Parthasarathy, M.S.,*1993).* Gin operation, repairs and maintenance including regular grooving operations were performed as per CIRCOT standards (Vijayan Iyer,G. 1999) .

To study environmental chromium pollution and contamination levels from roller ginning operations, an exhaustive study was made covering four sites each having a large number of 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 methods, 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 characterize 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 analyzed at 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 Central Pollution Control Board, (CPCB) Delhi. Cotton technological tests were carried out in Central Institute for Research on Cotton Technology (CIRCOT), Mumbai. Laboratory ginning studies on rollers were conducted in CIRCOT, Mumbai. Commercial ginning studies on rollers were performed 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, CCLC roller samples collected during grooving operation, soil samples from the region of investigation is made, root of the plant for bio-availability, fibre, yarn, fabric samples, textile effluent samples, the standard American Public Health Association (APHA) method was followed for chromium (as total and hexavalent) analysis using AAS. Respirable and suspended particulate matter quantity in gin house air were monitored using High Volume Air Sampler (HVAS) with cascade impactor with appropriate glass fibre filters. (Rao, M.N. and Rao, H.V.N. , *1989)***.**The quantity of pollutants are collected in HVAS as 8 hours basis and analyzed 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 is conducted by the author at Guntur, Bailhongal, Sendwa, Surendranagar, India, Tanzania and other countries, where maximum number of ginning factories are situated to survey the health effects and occupational health hazards. Since ginning being a seasonal activity over a few months of the year, it was not possible to study the health aspects. Further there were no medical/ health records available/provided. To design and develop eco-friendly RCF rollers , the ginning investigations were carried out at Central Institute for Research on Cotton Technology (CIRCOT), Mumbai. The laboratory rollers for Gin Roller Experimentation Device (GRED) were designed and fabricated at Calcutta at a local manufacturing firm. Plate-13 is the closeup photograph of GRED while in operation. Figure-11 is engineering drawing of pollution-free rubberized cotton fabric (RCF) chrome less washers for laboratory gins (GRED). The close-up photograph of the RCF chromeless washer for pilot model roller is given in Plate-14. Such type 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 ginning factories at Bailhongal and Sendhwa. Environmental analysis was done in Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textile laboratory, Mumbai. Mechanical properties were analyzed in various mechanical engineering laboratories. Plate-15 is the photographic view of pilot model roller gin assembled with pollution-free rubberized cotton fabric (RCF) chrome less rollers while in operation. To design and develop eco-friendly RCF rollers, the following instruments and methods have been used.

| **Instruments/ Equipments Used** | **Specimen/Material/Test** | **Methods Used** |
|---|---|---|
| Gin Roller Experimentation Device (GRED), CIRCOT Lab. Model Gin, McCarthy Gin and Bajaj Double Roller 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 |
| High Volume Instrument, Scanning Electron | Cotton technological fibre tests, namely 2.5% staple length, | As per technological leaflets of CIRCOT |

| | | |
|---|---|---|
| Microscope, Baer Sorter (CIRCOT). | uniformity ratio, strength, micronaire, grade and fineness. | |
| CIRCOT Uster Evenness Tester, Lea Tester, Twist Analyzer ( CIRCOT) | Cotton technological yarn/ fabric tests, namely, yarn strength, count, count strength product, twist/25 mm, hariness and Uster evenness | As per technological leaflets of CIRCOT |
| Compaction meter, Dynamometer, INSTRON-1122 & Load cell 2511-101, DO Durometer, Rockwell's Hardness Tester and Thermometer. | 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 2226 | Noise levels | Standard Method |
| Rubber processing and testing instruments | Fabrication and testing of rubberized cotton fabric roller | Rubber Board specifications |

Methodology for Construction of Roller Gin Rollers

- Complete investigations pertaining to RCF covering materials were done. The rollers were covered with packing type made from multiple layers of cotton fabric bonded together with a rubber compound. Rollers made from RCF; its different composition 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 *gin roller experimentation device (GRED)* and *commercial double roller (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 below:

(i) The coefficient of friction was carried out in *INSTRON 1122* load cell *2511-101* full range *10,20,30 to 500 g*. The friction between the roller coverings to the cotton tuft were 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 indendor 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 *thermometer* during the ginning operation.

(vi) GRED was used to experiment the CCLC roller and chrome-free RCF roller. The environmental parameters were namely lint cotton contamination, Cr(VI), Cr(III), noise level, energy consumption, roller wearing rate, whole seeds %, cut seed %, cotton dust and chrome specific dust found out.

(vii) Cotton technological parameters like ginning time, ginning rate potential, ginning percentage, lint cotton (or *fibre)* parameters and spun yarn parameters were analyzed so as to find out the performance evaluations of RCF roller to its suitability as an alternative in the conventional CCLC roller ginning process.

Cotton technological parameters studied

- ♦ Ginning parameters
  (i) Ginning Time, (ii) Cut Seed %, (iii) Ginning %
- ♦ Fibre properties
  (i) 2.5 S.L, (ii) Uniformity Ratio, (iii) Strength, (iv) Micronnaire, (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. RCF roller *manufacturing technology* for commercializing 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 analyzed for Commercial studies.

# 4. Results and Discussions

An experiment is conducted to find out the wearing and compactness rate of CCLC rollers used by roller ginning industries for a season lasting three months. At the start of season the diameter of rollers are 180 mm. At 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 18 ginning machines. The results are presented (Table-1). Apart from the wear and tear rate, the table expresses the quantity of pollutants generating during the operation, viz. chromium, leather powder, cotton dust and chrome specific dust. It is found that the wearing rate is 0.033mm / hour and the percentage material removed per roller 43.8%. The final diameter at the end of study is nearing 140mm. The compaction rate is 0.050 mm/hour. Figure-12 depicts a graph showing wearing rate of dust-producing grinding of CCLC roller and RCF 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 is –0.010 to –0.050 mm, i.e. –10 to –50 μm per hour. Wearing rate is 0.033mm / hour and the percentage material removed per roller is 43.8%.

Characterization and environmental assessment studies of chromium pollution existing with the CCLC rollers were conducted. Chromium analysis report of cotton lint samples, seed and seed linter, seed-cotton samples, fibre, yarn and fabric samples are provided in Tables 2 to 4. The CCLC roller contains 18 077 mg/kg (ppm) to 30 780 mg/kg (ppm) as total chromium (3 to 4% as total chromium). This included trivalent and hexavalent chromium. During the ginning operation, lint cotton adsorbs chromium particles which contains 143 mg/kg (ppm) to 1994 mg/kg (ppm). The CCLC roller is grooved at the start of each shift and filing or turning of the roller for leveling is done to get uniform diameter at start of each season. At that time, the wearing of roller is more and presence of chromium to the extent of 1994 mg/kg (ppm) with lint. The total weight of chromium removed during a cotton season of 16 hours per day is 450 to 600 grams per gin roller gin. The chrome specific dust from one ginning machine enters in to environment and being adsorbed in 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 to 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) of its carcinogenecity 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 effects occur rapidly and dependent of the worker dose and exposure time.

**TABLE-2**

**Chromium Contamination Levels in Cotton and Its Products**

Source: Chrome Composite Leather-Clad (CCLC) roller = 18 077 to 30 783 mg/kg

Bio-availability for chromium uptake on cotton = 3 ppm

| Sl.No. | Cotton and its Products | Total Chromium | Environmental Standards *MOEF Notification -157 (Indian Standard) |
|---|---|---|---|
| 1. | Lint cotton | 143-1990 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 | - |

- * Ministry of Environment & Forests Notification No.157, Dated 1 st May 1996.

Following are 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 | **Environmental Standards, $LD_{50}$ |
|---|---|---|---|
| 1. | Ginning point | 51-173 ppm | 50 ppm |
| 2. | CCLC grooving point | 17-1994 ppm | 50 ppm |

**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 5g 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 5g each 3 samples | 7240 |
| 4. | Bijapur soil sample 1 g each 10 samples | 2 |
| 5. | CCLC roller kept at 800 °C and ash samples are taken 5g each – 3 samples | 30598 |
| 6. | Dust-producing, grinding CCLC roller powdered samples 10 g each – 3 samples | 30783 |

| | | |
|---|---|---|
| 7. | Dust-producing, grinding CCLC in roller ginnery-I, 3 samples | 18077 |
| 8. | CCLC sample in roller ginning mill – II, 3 samples each 1 g each | 28900 |
| 9. | CCLC roller dust-producing, grinding chrome powder taken during grooving operation– 3 samples each 1 g | 18305 |
| 10 | Chromium settable particulate lint falling from ginning that was point after grooving operation – 5 samples each 5g | 28900 |
| 11 | Ginned lint type I cotton using laboratory gin fitted with CCLC roller grooving operation – 3 samples each 1 g | 7689 |
| 12 | Chromium contaminated ginned lint in SR gin with CCLC roller during regular operation-3 samples,1g each | 143<br>1994 |
| 13 | Root of the plant for chromium uptake for bio-availability from plant – 10 samples 1g each | Nil |
| 14 | Ginned chromium contaminated lint type – II cotton in laboratory gin with CCLC – 3 Samples each 1g | 21 |
| 15 | LRA 5166 chromium contaminated sample DR gin with CCLC roller – 3 samples each 5g | 44 |
| 16 | LRA 5166 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 to 45 |
| 18 | Chromium contaminated yarn samples from CCLC roller ginning mill-II | 25 to 68 |
| 19 | Chromium contaminated yarn samples made from DCH-32,3 samples each 1g from grey, mercerized and dyed yarn | 40 to 250<br>89 to 159 |

| | | |
|---|---|---|
| 20 | Chromium contaminated fabric samples made from DCH-32 , 3 samples | 45 to 250 |
| 21 | Chromium contaminated card frame samples during carding , 3 samples each 1g | 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 |

**TABLE-4**

**Results of Total Chromium Analysis**

| Sl. No. | DESCRIPTION | TOTAL CHROMIUM mg/kg (ppm) |
|---|---|---|
| 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 | 1966.4 |
| 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 | 2353.4 |
| 35. | Seeds from chrome rollers | 159 |
| 36. | Cotton seed oil | 259 |

## TABLE-5

**(i) Monitoring Results of SPM and RSPM in Various Ranges**

**(ii) Chromium Concentration in Ambient Air and Mill Air**

**(iii) Total Chromium Analysis in SPM and RSPM Dust Samples**

| Sl. No | PARTICULATE MATTER DESCRIPTION | QUANTITY OF DUST CONC.IN AMBIENT AIR $\mu g/m^3$ | CHROMIUM CONTENT AS TOTAL Cr IN DUST,ppm | CONC. OF Cr. IN AIR $\mu g/m^3$ |
|---|---|---|---|---|
| 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 | 2723 | 90 | 245.07 |
| 3 | SPM Collected – While HVAS monitored without factory in operation and rollers were grooved | 2495 | 1994 | 4975.03 |
| 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 to 3 microns-HVAS monitored and rollers were grooved | 26.3 | 142 | 3.7346 |
| 7 | RSPM 3 to 5 microns-HVAS monitored and rollers were grooved | 76.5 | 153 | 11.7 |
| 8 | RSPM 5 to 7 microns – HVAS run when rollers were grooved | 50 | 86 | 4.3 |
| 9 | RSPM 7 to 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 to 3 microns-HVAS monitored inside factory at full swing | 107.6 | 119 | 12.80 |
| 12 | RSPM 3 to 5 microns-HVAS monitored inside factory at full swing | 121.1 | 103 | 12.47 |
| 13 | RSPM 5 to 7 microns-HVAS monitored inside factory at full swing. | 545.3 | 124 | 67.65 |
| 14 | RSPM 7 to 10 microns-HVAS monitored inside factory at full swing. | 2141.8 | 123 | 263.44 |
| 15 | RSPM below 1 micron–HVAS monitored inside factory. | 75.7 | 190 | 14.38 |
| 16 | RSPM 1 to 3 microns-HVAS monitored inside factory | 105 | 132 | 13.86 |
| 17 | RSPM 3 to 5 microns–HVAS monitored inside factory | 128.3 | 295 | 37.84 |
| 18 | RSPM 5 to 7 microns–HVAS monitored inside factory | 448.4 | 152 | 68.15 |
| 19 | RSPM 7 to 10 microns | 4232.0 | 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 to 5 microns-HVAS run without factory in operation and rollers were grooved | 24.6 | 123 | 3.025 |

| | | | | |
|---|---|---|---|---|
| 22 | RSPM 3 to 5 microns-HVAS monitored without factory in operation and rollers were grooved | 25.6 | 68 | 1.74 |
| 23 | RSPM 5 to 7 microns-HVAS monitored without factory in operation and rollers were grooved | 68.0 | 56 | 3.8 |
| 24 | RSPM 7 to 10 microns-HVAS monitored without factory in operation and rollers were grooved | 75.1 | 133 | 9.983 |

Discussions relevant to Table-5

Twenty-four samples were analyzed in cotton ginning mills situated at Sendhwa, Madhya Pradesh by using HVAS with cascade impactor. Total chromium analysis was reported as alarmingly very much high against the *safe limits* for the dust samples below 10 microns. 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$^3$ as 24 hours 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$^3$. Further,

1. SPM at PSD cut off to about 40 to 45 μm was 2495 μg/m$^3$; chromium content in dust collected was 1994 ppm; chromium concentration in air was 4975 μg/m$^3$
2. RSPM was 9 to 4232 μg/m$^3$; chromium content in dust collected was 173 ppm; chromium concentration in air was 554 μg/m$^3$. *PSD < 10 μm.*

Histogram showing Chromium Contamination and Pollution Levels

Histogram was prepared based on the available data-base in tables 2 to 5. Figure-13 shows histogram of the total contamination and pollution levels due to atmospheric chromium in cotton ginning and textile mill plant. Figure-13 also depicted 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. The histogram represents 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. Plate-16 shows chromium-contaminated cotton seeds caused chromium poisoning.

Chromium Transport and its Adsorption into Cotton and Products

Chromium Pollution in Cotton Ginning and Textile Mills

There are two investigations have been carried out for analyzing chromium adsorption property into cotton dust, lint cotton, spun yarns, woven fabrics and chromium pollution in cotton ginnery and textile mills. Figure-14 depicts the flow chart of chromium transport and adsorption in a ginning and textile mill. Tables-6 and 7 are the Chromium Pollution Consolidated Samples' Report and Relevant Eco-Standards for the seasons-I and II.

Tannery Chromium Pollution Load Analysis

**TABLE-8**

**Tannery Chromium Pollution Load Analysis**

| Sl.No. Description | Indian Leather Survey | Present Analysis |
|---|---|---|
| 1.Total Cr in chrome leather | 13157-16142 ppm | 45333.3 ppm |
| 2.Total Cr in waste water | 5250-8240 | 23111.1 |
| 3.Quantity of chromium applied/kg pelt | 21.4 kg/1000 kg | 68 kg/1000 kg |
| 4.In terms of total Cr | 21400 | 68000-68444 |
| 5.Total chromium in composite waste | 8000-11000 | 14000-20000 |
| 6.$Cr^{+6}$ in ppm or mg/l in waste water coming from chrome tanning process (hexavalent chromium impurity content) | 2000-5000 | 3500-5000 |
| 7.Chromium content in roller gin rollers | 13200-30000 | 20000-40000 |
| $Cr^{+6}$ impurity content in roller | 6000-8000 | 10000-12000 |

Chromium compounds like dichromate, sodium chromate and sulphate of *30% to 60% basicity* are used in the tanning industries. The impure chromates have hexavalent form of chromium salts mixed with chromium sulfate for making semi-finished leather. This has been used for making ginning rollers by the locally made indigenous manufacturers in Kanpur, Ahmedabad, Chrompet and Chennai. The chromium percent contained in leather was approximately 3 to 4 by weight basis. Table-8 depicts that about 66% of the total chromium compounds applied during tanning process were absorbed in leather and remaining was discharged to effluent .

## Basis of Design and Development of Eco-friendly Chrome Less 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 chrome less roller, which can be an alternative to the existing CCLC rollers.

An exhaustive material studies are done for the suitable material's selection of the gin rollers which are made of Walrus animal 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 to adhere the fibre on the surface. This particular property is studied extensively for the for different materials and combination of different materials so as to design and fabricate laboratory gin chrome less rollers for gin roller experimentation device (GRED) and prototype eco-friendly chrome less rollers for existing DR gins. (Plate-15 to 19) Plate-17 is the gin roller experimentation device (GRED) while in Operation . The plate depicts GRED assembled with RCF Laboratory roller successfully ginning out seed-cotton.

One of the associated objectives of laboratory studies are 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.

## Rubber Processing Technology Manufacturing RCF Rollers

Specifications and rubber compounding were followed as per standards from Rubber Board and IS- 3400 (Rubber Board, 1990). The rubber processing technology for making RCF roller was studied at 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 rubberizing |
| Covering on roller | 9.07 kg for steaming on the calendar |
| Wrapping | Processed in the designed mould |

Vulcanization of rubber-canvas in close calendar; steam from boiler at 155°C for 1 hour

Unwrapping from the designed mould

Turning on lathe

### Step-II: Fabrication

| | |
|---|---|
| Bore size | : 50 mm X 50 mm square/50 mm E/E Hex |
| Outside diameter | : 180 mm |
| Length | : 1020 mm |

Rubber having two layers cotton fabric was used up to 140 mm for rubber reinforcement. Later, 11 layers of cotton fabric and rubber were used from 140 mm to 180 mm diameter.

The fabrication of roller was done in prepared mould form and sleeve as per the drawing. 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 minimized 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 got 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 done using the facilities of Rubber Board. The laboratory has got the required machineries/equipments to facilitate the processing and testing of the rubber industry. The RCF Rollers were manufactured using these facilities.

Testing of Gin Rollers

The fabricated rollers were assembled for testing in laboratory model gins (GRED) at a cotton research laboratory (CIRCOT), Mumbai (Shete, D.G, et.al.,1993). Rollers made were also 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. Plate-20 & 21 shows chrome-free, eco-friendly *roller ginned* lint cotton obtained from RCF roller gins. The ginned sample and subsequent processing of the lint cotton stage to spun yarn samples were analyzed for the ginning parameter, fibre properties, yarn properties and environmental aspects using the RCF rollers and CCLC rollers that is with the both 'system before modification and after modification'. Figure-15 is the manufacturing drawing of rubberized cotton fabric roller for double roller gins .

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 in size due to the presence of rubber. This has prevented formation of small size particles. The particle sizes analysis carried for these samples and found out to be 75 to 150 microns. 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 has resulted in less wearing rate of rollers. Plate-22 shows wearing study made on 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 seven years *(Shelf life)* because of its hardness 90 DO during usage. Experiments regarding this wearing rate were being done on commercial scale using DR gins. Figure-12 depicts graph of wearing rate of CCLC roller and eco-friendly chrome-free roller of DR gins. Appropriate ratio of rubber and cotton fabric was analyzed after the study of wearing rate of rollers. The present RCF roller contained *20% rubber is to 80% cotton fabric*. IS 3400 and Rubber Board specifications were followed for vulcanizing cotton fabrics. The weight of this roller was less compared to leather roller because of its inherent core construction and manufacturing technology of RCF. Therefore, there was smooth and gentle action on removal of fibres took place during the ginning process.

The *stickiness* property of rubber particle increased the particle size of gin emission. This was analyzed by the *particle size analyzer*. The particle size was found to be lying in the range of 75 microns and above but not less than 75 microns. These particles can be filtered by 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 pollution-free alternative compared to CCLC roller.

## Concluding Remarks

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 to 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 in spite of wear.

Plate-23 shows the close-up photograph of eco-friendly lint cotton obtained from RCF Roller ginneries. On the basis of 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. Plate-24 is the close up photograph of RCF roller ginning machine working for commercial trial production.

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. Given below the table 9 showing data of engineering analysis of eco-friendly cotton lint and chromium contaminated lint. Table-10 and Table-11 represents high volume instrument (HVI) and scanning electron microscope (SEM) test results related to the cotton technological parameters of the lint cotton obtained from CCLC and RCF gins.

**TABLE-9**
**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 four days | daily |
| 3. | Grooving of gin roller frequency period | Every five 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 (wearing up to 30 000 μm) | 844 Machine-hour | 437.5 Machine-hour |
| 12. | Friction of roller to lint cotton | 0.768 | 0.123 |

**TABLE 10**
**HIGH VOLUME INSTRUMENT (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. | Color/grade/appearances | Yellowish and Very good | White shining, poor |

**SCANNING ELECTRON MICROSCOPE TEST**

| | | | |
|---|---|---|---|
| 18. | Wax content proportion | 0.3% and better dye 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 |
| 28. | 2.5% Span length, mm | 28.5 | 28.2 |
| 29. | Uniformity Ratio, % | 47.0 | 47.2 |

**TABLE-11**

| 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 |

## Comparative Economics

Comparative economics have been worked out for the chromeless RCF roller ginneries and CCLC rollers ginneries ; that is for both the 'System before and after modifications' and for commercialization to the ginning industries (Table- 12).

**TABLE-12 ; 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 Rs.7/- to 20/- per washer/ disk. The washers can be used for 2 to 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 done at frequent intervals. Lower productivity.<br><br>Cr contamination and pollution problems are there in major cotton growing areas in India, Tanzania, Africa and Egypt. | *Initial cost is Rs. 88/- per washer.*<br>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 seven years.<br>There is zero maintenance.<br>Considering the maintenance and washer replacement cost, the washer cost worked out to be Rs.18/- per washer. No grooving is required except in initial maintenance. High productivity. Cleaner production. No waste in product.<br>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 Rs.1,500/-per roller | Initial total cost is Rs. 1350/- per roller | Rs. 150/- |
| 3. | Washer replacement cost for a ginning industry having 12 DR gins is Rs. 72,000/- per cotton season. | Washer replacement of a ginning industry having 12 DR gins is Rs. 62,800/- per cotton season | Rs. 9,200/- |
| 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 |

## 5. Conclusions and Suggestions

The roller is the major component of a gin stand. The chrome composite leather clad (CCLC) roller is commonly covered with chrome composite leather-clads bonded and stitched together in the form of 78 to 80 numbers of compressed disks at a pressure of 14 kg/cm2 and mounted on a steel shaft. This CCLC roller is pressed against the stationary knife at a pressure of 2.5 to 4.1 kg/cm2 . The roller rotates at a speed of 100 to 120 rpm and beater oscillates at 960 opm. Due to the friction between roller and stationary knife, 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 an year due to wear and tear action arising out of grinding action, resulting in dust production action during the process of ginning operation. On the surface of the rollers spiral grooves are made everyday 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 has been reduced upto 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 three months) during a cotton season. The CCLC roller wear out study revealed that nearly 40 to 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 chrome specific dust (CSD) emissions from the ginning point. The CCLC rollers used in ginning industries get powdered during ginning operation and enter the environment as chrome specific dust. It was observed that the chrome specific dust 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 not to be more than 0.1 ppm. The CCLC roller coverings contained 18 077 to 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 to 1990 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 left out after ginning process are carried, such that spun yarns get contaminated to the tune of 17 to 250 ppm as total chromium against the safe limit of 0.1 ppm. The CSD contains 4232 μg/m3 including RSPM and SPM concentration and 1994 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 that the maximum permissible level as 2 ppm and 200 μg/m3 and in the case of lint is more than 71 times of the accepted level, 2 mg/kg (ppm). Worker dose and exposure chromium level on 8 hour basis are 35 times more than the standards of ACHIH TLV (American Conference on Governmental Industrial Hygienists –Thresh Hold Limit Valve) and US OSHA (United States Occupational Safety and Health Adminstration). 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. Considering the fact that out of 190 lakh bales of lint cotton produced per annum, about 152 lakh bales are processed in these ginneries, it is quite important to note that the lint cotton so obtained is being contaminated by chromium at significant concentration level. Processed cotton seeds, which are 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

Source: Chrome composite leather-clad (CCLC) roller = 18,077 to 30,783 mg/kg (ppm)

Bio-availability for chromium uptake on cotton = 3 ppm

| Sl.No. | Cotton and its Products | Total Chromium | Environmental Standards *MOEF Notification -157 |
|---|---|---|---|
| 1. | Lint cotton | 143-1990 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 | - |

- * Ministry of Environment & Forests Notification No.157, Dated 1 st May 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 | **Environmental Standards, $LD_{50}$ |
|---|---|---|---|
| 1. | Ginning point | 51-173 ppm | 50 ppm |
| 2. | CCLC grooving point | 17-1994 ppm | 50 ppm |

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

It was observed that the chrome specific dust 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 not to be more than 0.1 ppm. The samples, namely, lint cotton, yarn, fabrics, seed, linter, edible oil and oil cake were found contaminated and their levels were in the range of 110 to 1990 ppm obtained from the source of dust-producing grinding CCLC rollers sample which contained 18,077 to 30,783 ppm. 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.

Gin and mill workers are directly exposed to air pollution problems and are vulnerable to health hazards. Ginning factories are located 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 with CSD. Since ginning being a seasonal activity over a few months of the year, it was not possible to study the health aspects. Further there were no medical/ health records available/provided.

To offset this serious problems of chromium contamination and pollution from cotton ginning industries, chrome-free rubberized cotton fabric (RCF) rollers both for laboratory and commercial studies have been designed, fabricated and experimented on a special laboratory-built gin roller experimentation device (GRED) and double roller (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 contribute 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 is not carried out properly. This pollution-free, 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 (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 roller and stationary knife, temperature of this roller is increased upto 55 °C, which facilitate rapid ginning operation. 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 to 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 in spite of wear.

On the basis of 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 commercialization to the industries.

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 upto an estimated life of seven years than more of a few months of CCLC rollers. Besides, it ensures the following advantages.

(1) There is negligible wear and tear and also 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 rubberized cotton fabrics has a surface finish conducive to high ginning efficiency,
(3) 50% reduction in the weight of the rollers consume 25% less in energy consumption that is power saving of 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 to 7 dB (A) due to inherent properties and cushioning effects,
(5) Eco-friendly cotton and its products can be obtained.
(6) Labour output / hr is 2.4 standard performance rating, that is twice than CCLC ginneries because of 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 being 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 found 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 the cleaner environment with benefits to society, industry owners, traders, workers, employees and the Government.

Further, the following recommendations are suggested;

1. Most of the cotton ginning operations are done using roller gins in India, Africa, Tanzania and Egypt. Out of the lint obtained from these CCLC roller ginneries in this countries, it is quite important to appreciate the fact that the lint so produces is contaminated with chromium powder produces 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 or 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, Government and Regulator should come forward to subsidize 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 environment.

4. Comprehensive studies on Air Pollution particularly in the ginning environment and its correlation with socio-economic and health studies need to be carried out.

## Acknowledgements

The authors are thankful to Director, Indian School of Mines, Branch-I.I.T., Dhanbad – 826 004, India for giving permission to publish this research review paper. The Authors are also thankful to Mr. Shrish R. Shah, Member, Indian Cotton Development Council (ICDC), Ministry of Agriculture (Govt. of India) who has sponsored this research project. The author of this research paper is also thankful to FACULTY DEVELOPMENT BUREAU OF ALL INDIA TECHNICAL EDUCATION , New Delhi for awarding the prestigious faculty-specific AICTE EMERITUS FELLOWSHIP DURING 2005-2008.

## References

1. Bandyopadhyay, K. and Gangopadhyay, A. and Son, N.N. (*2000).* "Adsorption Study on Fly Ash as a Waste Resource for the Removal of Chromium." World Congress on Sustainable Development Proceedings, Vol. I, pp. 532-539,

2. Gillum, N., and Marvis, *(1964).* " Properties of Roller Covering Materials", United States Department of Agriculture (USDA), Technical Bulletin No.1490, Washington: pp.1-45, *1994*.

3. Morton Lippman. *(1991*). "Book on Asbestos and Mineral Fibres." Elsevier Publishers, pp. 34-134, *1991*.

4. Rao, C.S. *(1995).* "Book on Environmental Pollution Control Engineering." Wiley Eastern Ltd., pp. 1-79*, March*, *1995.*

5. Rao, M.N. and Rao, H.V.N. (*1989).* "Book on Air Pollution." Tata McGraw Hill Publishing Co.Ltd., New Delhi, pp.35-56, *1989.*

6. Reference No. 157, MOEF Notification No.157, *dated 4.5.1996*.

7. Shete, D.G. and Sundaram ,V. (*1993).* "Some Practical Hints for Better Ginning of Cotton with Roller Gins." ICMF Journal, *October, 1983*.

8. Shirley Institute "Research Encyclopaedia-II." Manchester, Cotton Dust Hazards, Textile Series Memories, pp. 23-56, *1982.*

9. Sujana, M.G. and Rao, S.B. (*1997).* "Unsafe Chromium." Science Reporter, pp.27-30, *Sep.1997.*

10. Townsend J.S. Walton T.C. and Martin J. (*1940*) Roller Gin Construction, Operation and Maintenance, U.S. Department of Agriculture, Washington, USA.

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

12. Vijayan Iyer, G. , Vizia, N.C. and Krishna Iyer, K.R. (*1993*). "A Simple Device to Prevent Backlash in Roller Gins. " Journal of Textile Association-pp. 129-130 , September, 1993.

13. Vijayan Iyer, G. and Parthasarathy, M.S. *(1993).* "Some Practical Hints on Precleaning and Ginning." Indian Textile Journal, pp.28-32, October, 1993.

14. Vijayan Iyer G. (*1994).* "Study of Backlash in Double Roller Gins." The Cotton Gin and Oil Mill Press, Texas, USA, pp. 12-13 & 22, June 25 , 1994.

15. Vijayan Iyer, G. and 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 at Bhopal on November,12, 1994 .

16. Vijayan Iyer. 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 "held at CIRCOT, Bombay on 26 th April, 1995.

17. Anap.G.R., Vijayan Iyer. G. and 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, No.1995-1996, pp. 101-104., 1995-1996.

18. Vijayan Iyer, G. *(1996*). "Setting and Adjustments in saw Gin Stand for Improved Quality Cotton. " Journal of Textile Association-March 1996, pp. 288, *1996*.

19. Vijayan Iyer, G. and Parthasarathy, M.S. *(1996)*. "Design of a Mote Grooving Tool and Its Holder for Rollers of Roller Gins." Journal of Institution of Engineers (I), TX, Volume 77*, April, 1996*.

20. G.Vijayan Iyer. (*1997)*. A referred short note on "Development of a Pollution-free Gin Roller for Roller Ginning Industries." November, 1997.

21. G.Vijayan Iyer. *(1997*). "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 of Indian School of Mines, Dhanbad , December, 1997.

22. Vijayan Iyer, G.*(1998*)."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.

23. Vijayan Iyer, G. and Parthasarathy, M.S. *(1998)*. "Ottai Ka Vikas / Developmet in Ginning." Journal of Institution of Engineers (I), Hindi Section of Institution of Enginers (India) *, 1998*.

24. Vijayan Iyer.G. *(1998*). " Environmental and Health Effects of Chrome Composite Leather Clad Rollers Commonly Used by Cotton Roller Ginning Industries . " The Textile Industry and Trade Journal, July,1998.

25. Vijayan Iyer.G. *(1998*). " Environmental and Health Effects of Rollers Used in Ginning Industries. " Journal of Textile Association, pp 87-94, July-August 1998.

26. Vijayan Iyer,G. (1999). " Cotton Ginning and Lint Quality." The Textile Industry & Trade Journal, pp. 73-80, 1999.

27. Vijayan Iyer, G. (*1999)*. "Unsafe Chromium Contamination and pollution in Cotton Ginning Industries." ENVIROCON 99, 15 th National Convention of Environmental Engineers , November 26-27, 1999, Proceedings of Institution of Engineers (India) , 1999.

28. Vijayan Iyer, 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. Jan. 20-23, Calcutta , Book Chapter, Tata McGrew-Hill Publishing Co.Ltd. pp 118-140, 2000.

29. Vijayan Iyer, G., Gurdeep Singh and Saxena , N.C. (2001). "Environmental and Health Effects of Rollers Used in Cotton Roller Ginning Industries " Indian Journal of Environmental Protection , IJEP 21 (6): Vol.21, No.21, No.6, June, 2001, pp. 499-507 , June , 2001.

30. Vijayan Iyer.G. and Gurdeep Singh. *(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 , A.P.H. Publishing Corporation , New Delhi pp 75-86 , 2002 and accepted for publication in American Society for Agricultural Engineers Journal of Applied Engineering in Agriculture, USDA , 2002.

31. Vijayan Iyer, G., and Gurdeep Singh. (*2002)*. "Process of Manufacture of Improved Eco-friendly Cotton Lint for Better Physical and Chemical Properties / Dye Catch Properties." Patent filed , 2002.

32. G.Vijayan Iyer. (*2002*) . "Research and Development - Environmental Hygiene" Hindustan College of Engineering - Skroll , 2001-2002.

33. Vijayan Iyer G. (*2002).* "Environmental Impact Assessment of Chrome Rollers Used by Cotton Roller Ginning Industries. " Accepted for Publication in Journal of Cotton Gin and Oil Mill Press, Texas, USA. (2002).

34. Vijayan Iyer. *(2002*). " Environmental Effects of Chrome Rollers Used by Cotton Roller Ginning Industries and Design and Development of Eco-friendly Alternative" Ph.D. Thesis of Indian School of Mines, Dhanbad, September, 2002.

35. Vijayan Iyer, G. (*2002).* A referred letter by SITRA on "Unsafe Chromium Contamination and Pollution in Cotton Ginning Industries." South India Textile Research Association, July 17, 2002