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*Research Article*

# Sustainable Manufacturing- A Case Study on the treatment of Effluent discharged from Rings and Pistons Manufacturing Plant

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***Abstract***

*The paper focuses on the challenges/impacts of chromium in effluents discharged from industries and evaluates the alternative treatment options used to treat, recover or recycle chromium from the waste water. Moreover, utilization of water and its minimization is analysed keeping in consideration different norms and regulations. The study has been conducted on Shriram Pistons and Rings Ltd., Ghaziabad. The study includes various processes involved in manufacturing of pistons and rings, the effluents coming out from processes and the treatment methods undertaken for the reduction of harmful wastes in the discharge. Also, the amount of water utilized is measured in the whole treatment process with the aid of the pre-installed instruments in the industry.*

***Keywords:*** *sustainable, water utilization, effluent treatment, rings and pistons manufacturing*

## 1. Introduction

Chromium is highly toxic and carcinogenic to human beings, animals, plants and the general environment (soil and water sediment). We aim to reduce the Chromium (VI) extract from the manufacturing processes of Pistons and Rings fabricated in chromium process treatment plant of Sri Ram Pistons and Rings Limited and making the overall manufacturing methods sustainable from various aspects considering severe repercussions of Chromium (VI) on human health and ecosystem. Though many treatment options were evaluated to prevent its consequences on the environment, neither of them could achieve to treat or recover chrome 100%. Treatment options are either; inefficient, complicated, energy demanding, costly or applicable to a certain parts of the world due to technology or skilled man power demand. In order to tackle this serious challenge stringent environmental regulation with law enforcement has to be exercised to use better treatment system which is widely applicable. Moreover, the general public, all concerned organizations and the government need to be aware of it and work together to reach zero discharge level or at least within the norms.

## 2. Sustainable Manufacturing

The US Department of Commerce's Sustainable Manufacturing Initiative defines sustainable manufacturing as the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities & consumers and are economically sound.

- It embraces economic, environmental and social aspects
- It minimizes the diverse business risks in any manufacturing operation
- It maximizes new opportunities that arise from improving the processes and products


**Fig.1** 3D aspects of sustainable manufacturing (Source: US Department of Commerce, 2011)

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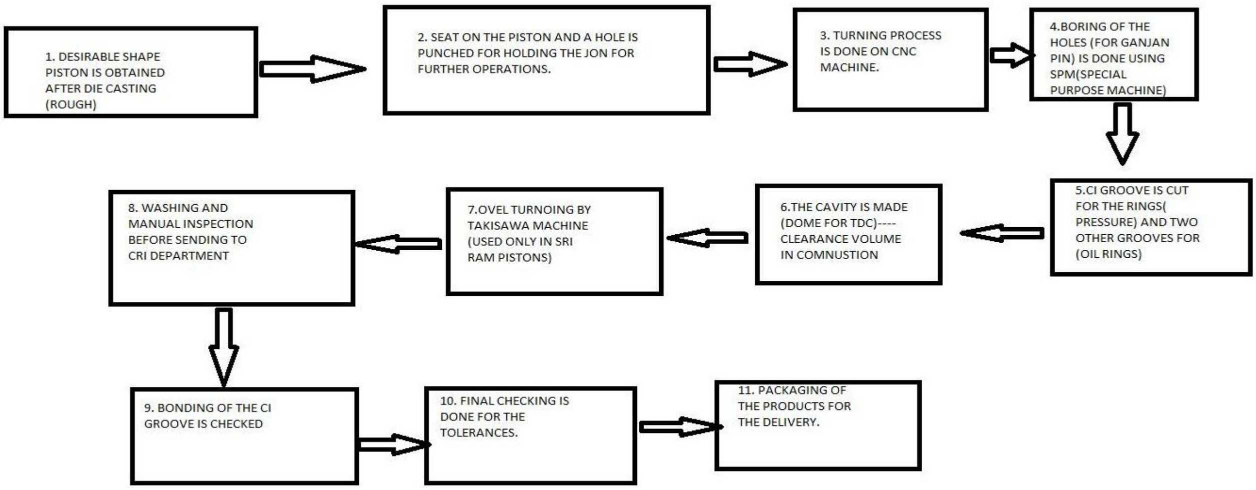


**Fig.2** Piston manufacturing process flow diagram (Source: SPRL, Ghaziabad)

## 3. Piston and Ring Manufacturing

Piston manufacturing includes various processes such as foundry, boring, turning, drilling, grinding, reaming etc.

The foundry is the beginning of the piston manufacturing process. At the foundry, the die is prepared by heating it to operating temperature for approximately one hour. This process allows the die to readily accept the molten material when it is poured. The material used is 10% silicon content aluminium. The dies used are 5 pieces and 3 pieces. These dies are made from cast iron with steel inserts for the gudgeon pin holes and the cores. The cores dictate the placement of the gudgeon pin and can be located to give offset pins or square pins. At the boring stage of the piston manufacturing, the casting has the gudgeon pin hole rough machined and the locating bung machined. Turning of the casting is carried out on CNC (Computer Numeric Control) machinery. This equipment is the most accurate and fastest available for this application with very tight tolerances and extremely fast spindle speeds. The castings are placed in the lathe on a bung and held in place by a solid rod through the gudgeon pin hole. A draw bolt is activated in the chuck which draws the rod toward the chuck and holds the piston in place.

### Finishing process

*Grinding*

This process involves the final size being machined on the piston. The grinder machines the skirt of the piston only and in the majority of cases is cam ground. Cam grinding ensures the piston will grow evenly in the bore of the engine. A perfectly round piston will expand unevenly during use because of the uneven placement of material in the casting

*Reaming*

The final machining process for the piston is that of reaming. This process involves the piston being placed in a bath of oil and reamed at different sizes to reach the final size required. Since the pin boring process is

only rough it is necessary to ream the pin bore a number of times to achieve the surface finish and size required. Reaming is not a fast process and is only partially automated (there are automatic feeds on the reaming machines).

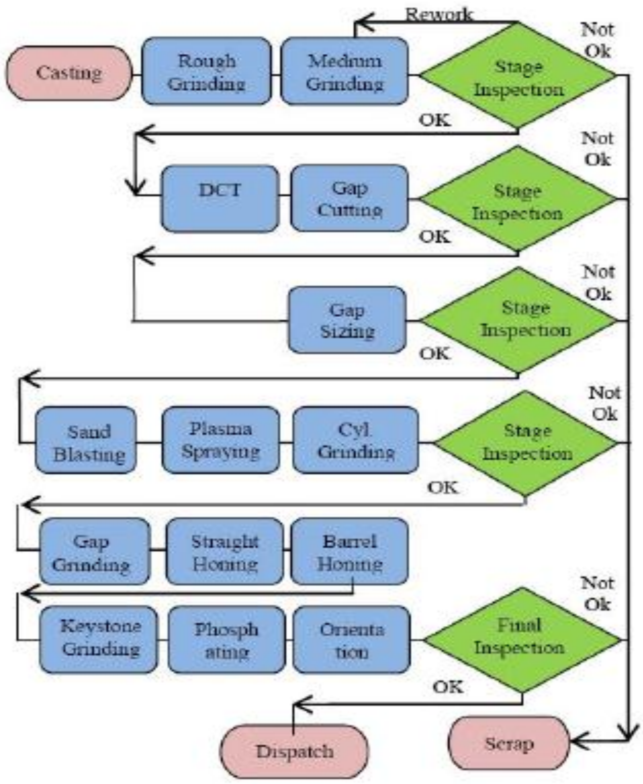


**Fig.3** Chromium plated rings manufacturing process flow diagram (Source: SPRL, Ghaziabad)

## 4. Hexavalent Chromium Waste Treatment

In the plating industry, electrolytic deposition of metals is essential. The process increases corrosion-resistant properties, corrects dimensions for finishing, and improves wear qualities. After electroplating is completed, the plated parts are rinsed with water in one or more rinse tanks. Eventually this rinse water becomes contaminated with plating solution drag out to be effective, and must be replaced. This presents a serious environmental problem since the rinse water is highly concentrated in toxic chromates. The abatement of pollution from such wastes includes recovery of raw material or total destruction in a waste treatment system.

Chromium-6 in water can be treated in one of two ways:

•Direct removal of chromium VI, or
•Reduction of chromium VI to chromium III, followed by removal of chromium III.

A bench-scale study sponsored by the American Water Works Association Water Research Foundation identified four technologies which are most promising for application by drinking water systems. These technologies include: anion exchange, coagulation and precipitation of reduced chromium III, adsorption via sulphur modified iron media, and membrane treatment such as nano-filtration and reverse osmosis. Conventional treatment, coagulation and filtration, can remove chromium III from water, but not chromium VI. A treatment profile survey of water systems treating surface water showed that conventional treatment was able to remove between 40% and 100% of total chromium from water.

Worldwide chromium contamination of soils has arisen predominantly from the common practice of land-based disposal of tannery wastes under the assumption that the dominant species in the tannery waste would be the thermodynamically stable Cr (III) species. However, recent detection of significant levels of toxic Cr (VI) in surface water and groundwater in different part of the world raise critical questions relating to current disposal of Cr-containing wastes. Cr (VI) is far more mobile than Cr (III) and more difficult to remove from water. It is also the toxic form of Cr, approximately 10 to 100 times more toxic than Cr (III) by the acute oral route, presumably owing to the stronger oxidizing potential and membrane transport of Cr (VI). The EPA classifies Cr (VI) as a known human carcinogen via inhalation, but classifies Cr (III) as not known to cause cancer. The most common Cr (VI) forms are chromate ($CrO_4 2^-$), and hydrogen chromate ($HCrO_4^-$) also called bichromate. The relative amount of these two species depends on pH.

Dichromate ($Cr_2O7$ 2–) can also occur. Cr (VI) compounds are anions. The corresponding oxidation of Cr (III) to Cr (VI) also occurs, particularly in the presence of $MnO_2$ and bacteria (Richard and Bourg, 1991). However, the kinetics is slow.

**Table 1** Comparison between Cr(VI) and Cr(III)

| Cr(VI) | Cr(III) |
|---|---|
| Exists in oxidizing environment | Exists in reducing environment |
| Highly soluble in water | Less soluble in water |
| High mobility in water and soils | Less mobility in water and soils |
| Weak adsorption to the soil | Strong adsorption to the soil |
| Highly toxic, Carcinogenic and Mutagenic | Less toxic |

## 5. Chromium treatment plant (ETP)

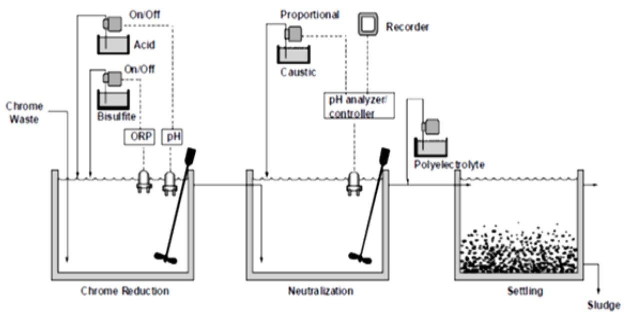


**Fig.4** Typical Two-stage Hexavalent Chromium Destruct System

For a typical two-stage chromium destruct system as shown in **Fig.**4, two pH control systems and one ORP control system are required. All three controllers should be the on/off type that has a control relay with adjustable dead band. It is recommended that the controllers also have alarm relays to alert the operator of conditions outside the normal range.

A typical control system supplied GLI International consists of:

- Two pH Sensors and Analysers
- One ORP Sensor W/Platinum Electrode
- Three Sensor Mounting Hardware Assemblies

Rinse water with chromium wastes is usually treated with a two-stage process (**Fig.**4 ). The first stage changes hexavalent chromium Cr(VI) to a chemically unstable state known as trivalent chromium Cr(III). In this interim state, trivalent chromium freely bonds to hydroxide in the second stage of the treatment process. The final result is a non-toxic precipitate; chromium hydroxide $Cr(OH)_3$.

•*First Stage*

The most common treatment method for reducing hexavalent chromium to trivalent chromium is by using chemical reducing agents such as sulphur dioxide ($SO_2$), sodium bisulphite ($NaHSO_3$) or sodium meta-bisulphite ($Na_2S_2O_5$). The following equation illustrates the reaction that takes place when sodium bisulphite is used:

Chemical Reaction Involved
Chrome Reduction

$2CrO_3+2NaHSO_3+2H_2SO_4 \longrightarrow Cr_2(SO_4)_3+Na_2SO_4+3H_2O$

This reaction will progress rapidly between 2 and 3 pH. Retention time can be minimized by keeping the wastewater within this pH range. This is accomplished using a pH controller to add an acid such as sulphuric acid ($H_2SO_4$).After achieving the proper pH; an ORP (oxidation reduction potential) set point must be established. Typically, it is in the range of 200 to 300 mV. The absolute ORP value will vary from process to process and with pH changes. A shift of up to 150 mV can occur with a change of just one pH unit. Therefore, tight pH control is necessary during this stage. The actual ORP set point must be specifically determined for each application. When the reaction is completed, a sudden drop in the ORP value will occur (typically 20 to 50 mV).

- *Second Stage*

After the first-stage reaction is complete, calcium hydroxide, Ca $(OH)_2$, commonly known as lime, must be added to the wastewater using a second pH controller to increase and maintain an 8 pH or higher value. This is necessary for the precipitation of chromium hydroxide to occur. The precipitate can be easily separated and diverted for disposal. The following equation illustrates this precipitate reaction:
Neutralization

$2Cr_2(SO_4)_3+12NaOH \longrightarrow 4Cr(OH)_3(ppt.)+6Na_2SO_4$

The Environmental Protection Agency has established standards for the plating industry that require the destruction of chromates. Compliance is usually achieved by reducing hexavalent chromium to trivalent chromium with precipitation to chromium hydroxide – a harmless, non-toxic substance.

The main disadvantage of this treatment method is the need to reduce the wastewater to between 2 and 3 pH to assure a rapid reduction rate. The wastewater must then be neutralized before discharge. These steps consume large amounts of chemicals and tend to significantly increase the volume of sludge with unreacted precipitants.

## 6. Water quality observation

Water before treatment

Water after treatment

**Fig.5** Change in the properties of water before and after treatment

**Table 2** Concentration of Chromium (mg/l) before and after treatment

| S.no. | Cr(VI) content (mg/l) Before | Cr(VI) content (mg/l) after |
|---|---|---|
| 1.Electroplating | 8.2 | 0.8 |
| 2.Electroplating | 9.3 | 0.4 |
| 3.Electroplating | 8.8 | 0.2 |
| 4.Electroplating | 8.6 | 0.2 |

## 7. Consumption of chemicals

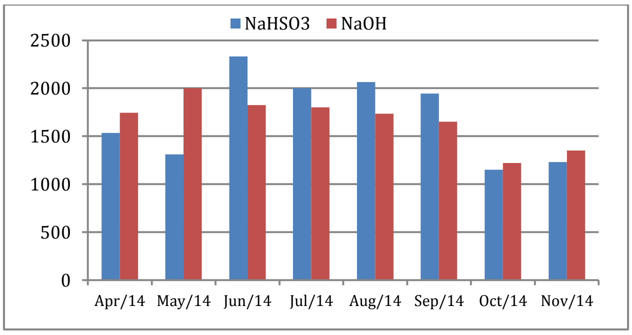


**Fig.6** Monthly Consumption of Sodium Hydroxide and Sodium Bi-Sulphite at SPRL, Ghaziabad (Source: SPRL, Ghaziabad)

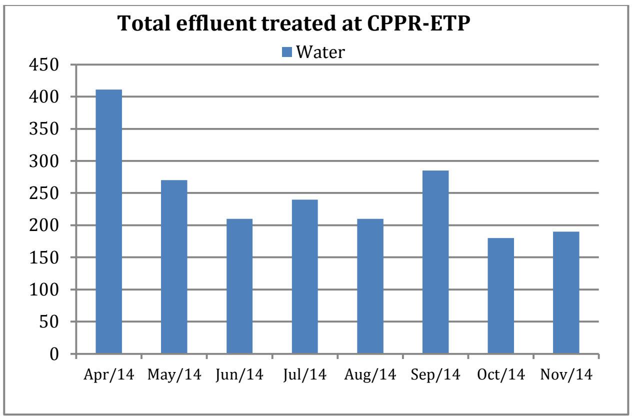


**Fig.7** Monthly Utilization of Water (in kilo-litre) at SPRL, Ghaziabad (Source: SPRL, Ghaziabad)

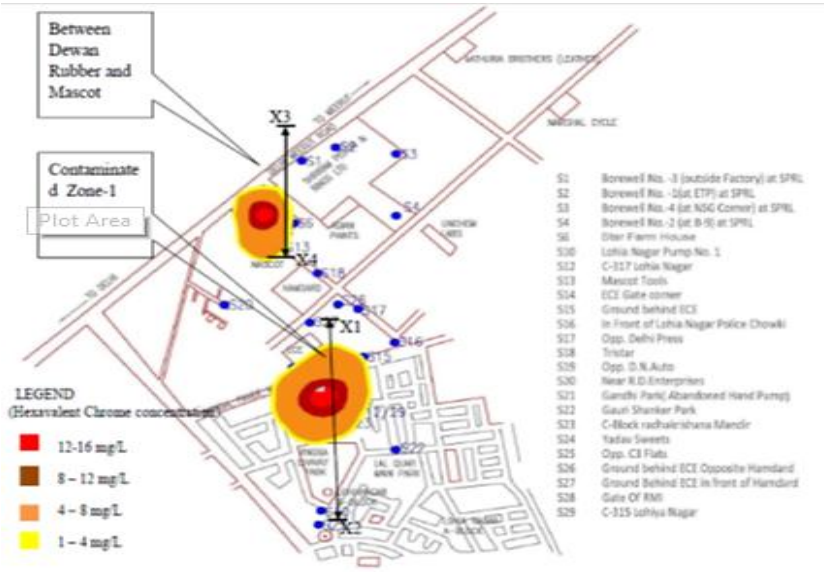


**Fig.8** Hexavalent Chromium concentration in areas nearby SPRL, Ghaziabad

## 8. Layout of nearby areas

It is shown in fig.8

## 9. Effluent Treatment discharged from Chromium Treatment Plant

*9.1 RWT 10 is a Mobile Water Treatment Plant*

The technology is developed by IWET of Czech Republic.

**Fig.9** RWT 10 is a Mobile Water Treatment Plant

It is fully automatic and is controlled by computer technology AMIT, which is equipped with special software for managing all processes from the treatment of raw water input to output clean drinking water. The water treatment plant is designed for treating water from rivers, streams, industrial effluent water and wells. This treatment plant can be compactly mounted up to 20' (6 m) shipping container which ensures hassle free truck and ship transport to even remote areas where setting up such plant can be quite costly.

It has a completely different system for the production of drinking water on the basis of a consistent gradual filtering and separation of undesirable substances in water natural form sophisticated combinations developed equipment, filtration filter abrasive material (sand filters) the absorption of a carbon-containing filter material and post-treatment.

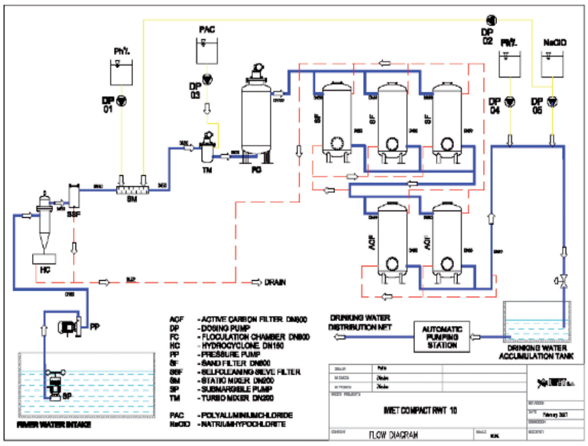

**Fig.10** Process flow diagram

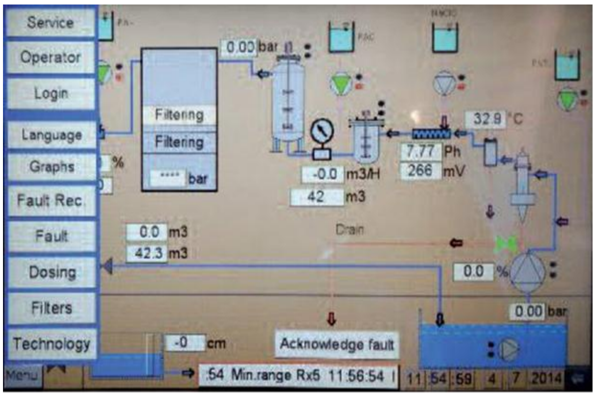


**Fig.11** Display of the Machine

*9.2 Specifications*

•Length: 6,000 mm
•Width: 2,400 mm
•Height: 2,400 mm or equal with container 20'
•Rated Output: 10 $m^3$/ hour
•Energy Consumption: 400 V, 50/60 Hz, 7 kW
•Chemical Consumption:
•To reduce pH: $H_2SO_4$ 96% conc. or HCL 31% conc. Max. 15g/m3
•To increase pH: $Na_2CO_3$ 100% conc. or $K_2CO_3$ 100% conc.Max.20g/m3
•For chlorination: NaClO 15% act.
•For flocculation: PAC – poly-aluminium-chloride 9% Al Max. 10g/m3
•Filters:
There are 2 filters in this equipment
Sand Filter: Sand with size 0.6 – 1.1 mm
Active Carbon: Granulate Active carbon

*9.3 Basic components of RWT10*

•Active Carbon Filter
•Dosing Pump
•Pressure Pump
•Flocculation Chamber
•Hydrocyclone
•Sand Filter
•SSF
•Static Mixer
•Submersible Pump
•Automatic Self Cleaning Sieve Filter
•Turbo Mixer

*10.4 Advantages*
•Treated water quality corresponds with World Health Organization (WHO) requirements.
•Low investment and operating costs.
•Long life package units with easy maintenance and transport
•Easy start-up and operation due to pre-programmed Pneumatics
•Logic Control (PLC).
•No special skilled operators required.
•Quality drinking water will be available only in a few minutes.
•Available in varies range of product from capacity 1 m3/hours up to 200m3/hour
•All the undissolved substances larger than 100 microns are eliminated.

## 10. Water utilization and requirement

Growing population coupled with sustainable developmental efforts has an increasing stress on water resources. The uneven distribution over time and space of water resources and their modification through human use and abuse are sources of water crises in many parts of the world. All these result in intensifying the pressure on water resources leading to tensions, conflict among users and excessive pressure on the environment. These demand the planners and policy makers for a proper management of water resources. This, in turn, calls for a reliable and adequate statistics on water and related aspects.

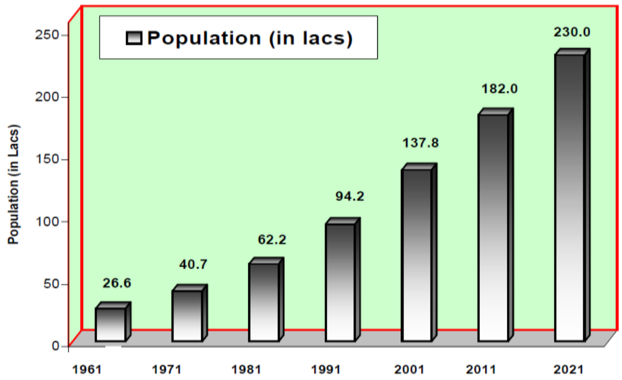


**Fig.12** Decadal population growth (Source: Central Pollution Control board)

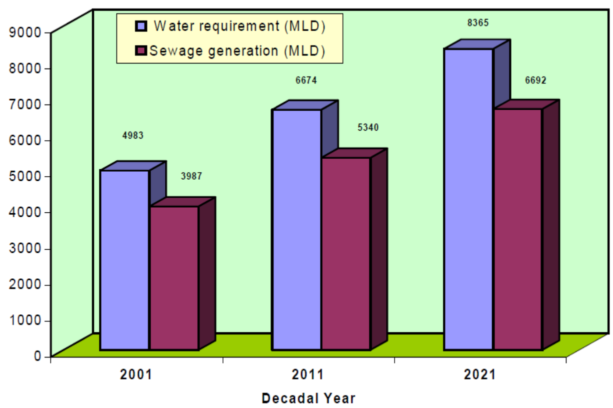


**Fig.13** Decadal water requirement and waste water generation in Delhi-NCR (Source: Central Pollution Control *Board)*

According to World Water Assessment Program (Central Water Commission Statistics) water use has been growing at more than the rate twice of population increase in the last century and by 2021, 1800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions.
The Scenario
•Poor drainage and irrigation practices have led to water logging and salinization of approximately 10% of the world's irrigated lands.
•How the world uses freshwater: Irrigation- about 70%, Industry - about 22%, Domestic use - about 8%

## 11. Online continuous monitoring system for Effluents

With rapid industrialisation, it is becoming a need and necessity to regulate and minimise inspection of industries on routine basis. Therefore, efforts need to be made to bring self-discipline in the industries to exercise self-monitoring & compliance and transmit data of effluent and emission to SPCBs/PCCs and to CPCB on continuous basis. In recent years online water quality monitoring technology has received quite attention and interest in context of providing accurate and continuous water/waste water quality information. Some commercially available systems for monitoring parameters are Turbidity, Colour, Fluoride, Sodium, Ammonia, Chlorides, Nitrate, etc.

The SPCBs and PCCs have prescribed standards for various pollutants emitted/ discharged by the industries as notified under the Environment (Protection) Act, 1986. The compliance monitoring needs to be strengthened to ensure that treated industrial effluent complying with the stipulated norms is only discharged by the industries. For strengthening the monitoring and compliance through self-regulatory mechanism, online emission and effluent monitoring systems need to be installed and operated by the developers and the industries. Various technologies are available for monitoring the effluent quality in terms of the parameters specified in the directions issued by CPCB.

| Parameter to be monitored | Available Technologies | Number of Vendors | Approx. Cost in Rs. Lakhs |
|---|---|---|---|
| 1. pH | 1. Electrode Method | >10 | 0.75 |
| 2. COD | 1. UV-Vis Spectro-photometry (Entire spectrum scanning) | >4 | 12.00 (COD+TSS) +Controller & DAS & Data Transmission |
| | 2. Combined Combustion Catalytic Oxidation at 680°C and NDIR Method (TOC) | >4 | 24.00 (COD) +Controller & DAS & Data Transmission |
| 3. TSS | 1. Scattered light IR Method | >4 | 3.00 |
| | 2. UV-Vis Spectro-photometry (Single wavelength) | >4 | 3.00 |
| Ni | 1. Voltametery | >1 | 20.00 |
| Cr | 1. Colorimetric method | >3 | 12.00 |
| | 2. UV-Vis Spectroscopy (Entire spectrum scanning) | >4 | 10.00 |
| 3. Flow | 1. Magnetic /Ultrasonic | >4 | 0.75 |

**Fig.14** Details of Parameters and Feasible Technologies Required to be installed for Real Time Continuous Effluent Monitoring Systems in Engineering Units like Electroplating *(Source: Government of India)*

Online analysers are a better tool to extend in-time information on compliance of ETP and CETP to the prescribed norms to regulator. The real time measurement for important parameters will give detail information continuously which laboratory instruments fail to give as random once in a month or quarter information is too less to understand discharge compliance. The industries falling in 17 category of highly polluting industries, the grossly polluting industries discharging directly/indirectly into river Ganga or its tributaries and Yamuna Common Effluent Treatment Plants (CETP) and Sewage Treatment Plants (STPs), Common Bio Medical waste and Common Hazardous waste incinerators have to install real time effluent quality monitoring system.

**Fig.15** Online Monitoring System

• *Advantages:*

a. Online monitoring systems provide continuous measurement of data for long periods of time, at the monitoring site of interest, without skilled staff being required to perform the analysis.

b. All the major steps in traditional analysis like sample collection, preservation, transportation, sample pre-treatment, calibration, reagent addition and sample analysis procedures are usually automated in on-line analysers.

c. In case of sudden disturbance in the system, compared to conventional methods the on-line.

*Observations*

**Table 3** Effluent Water Input Values

| | | |
|---|---|---|
| Turbidity | *NTU* | 5000 |
| Hardness | *ppmCaCO3* | 500 |
| Na | *ppm* | 200 |
| Cl | *Ppm* | 250 |
| SO4 | *ppm* | 400 |
| TDS | *ppm* | 1000 |
| TSS | *ppm* | 10000 |
| Fe | *ppm* | 10 |
| Mn | *ppm* | 2 |
| Oil | *ppm* | 0.5 |
| Cr | *Ppm* | 0.2 |

**Table 4** Effluent Water Output Values

| | | |
|---|---|---|
| Turbidity | *NTU* | 5 |
| Colour | *PtCo* | 15 |
| pH | | 6.5-8.5 |
| Oil | *ppm* | 0.01 |
| Fe | *ppm* | 0.3 |
| Mn | *ppm* | 0.1 |
| Al | *ppm* | 0.2 |
| Cr | *ppm* | 0.01 |
| TSS | *Ppm* | 0.5 |

**Fig.16** Quality of water after treatment

## Conclusion

The concentration of dissolved chromium in water is observed which is used for washing of 80,000 rings and 40,000 valves manufactured per day, after plating it with chromium metal. Further, we studied their Effluent treatment process in the ETP Plant.

•The two step Precipitation of Chromium and removing the sludge.

•Studied water utilization in the plant.

For reducing the concentration of chromium, following techniques are suggested

• Improvisation of Manufacturing Processes and implementation continuously improving technologies so as to reduce Cr (VI) effluent in waste water.

• Use of other coating materials which are less harmful such as Molybdenum etc.

• Setting up Pilot ETP Plant wherever possible for efficient treatment of chromium.

• We can also improvise the technology by using PVDF (Poly-vinylidene fluoride) membrane to improve the performance.

It is observed that the water discharged from chromium-treatment plant can be treated using IWET-RW10 pilot treatment plant is safe for drinking purpose and other purposes. This effective and efficient method is suggested to minimize the water utilization in chromium treatment plants.

Considering the data of Nov, 2014 obtained from SPRL-Ghaziabad which is 190Kl water utilized.

In the absence of RW 10 pilot plant, the effluent treatment by chromium-treatment plant removes about 90% of chromium. About 20% of treated water is utilized in flushing and washing purposes while remaining 80% water is discharged off as waste.

If the RW 10 pilot plant is installed, the 80% of water that gets discharged can be treated to produce water safe for drinking purpose.

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