Quest Journals
Journal of Research in Business and Management
Volume 10 ~ Issue 8 (2022) pp: 79-87
ISSN(Online):2347-3002
www.questjournals.org

Research Paper

"Technological Innovation for Optimizing Water Consumption: A Case Study for sustainable painting process"

Veer Shivajee
New Delhi, India

Abstract
The purpose of this research is to identify the technological innovations used to optimize the water consumption in the painting process of automotive manufacturing. Further the research aims at suggesting strategies to minimize the water consumption and inspire other industries to improve their process to get competitive advantage and environment protection. Both qualitative and quantitative research methods are applied while conducting the study in two-wheeler automobile Original Equipment Manufacturer (OEM) and its ancillaries' units. They refer to manufacturing automobile components and have implemented zero water discharge in their main plant by recycling the water through technological innovations in their existing units. In this research paper, a structured framework is prepared to evaluate the impact of technological innovation in context of challenges and opportunities for optimizing the water consumptions in painting process in an automobile organisation and its supply chain. An identification of opportunities and challenges from the empirical data from eight manufacturing units could be used to developed strategies for implementation in similar manufacturing units. The findings also reveal systematic implementation of zero water discharge requirements to eliminate business failures risk and improve conversion manufacturing cost. This research work contributes to the understanding of challenges, opportunities and developing strategies for implementing zero discharge in other manufacturing units. Future research is proposed to minimize the use and waste of water in the manufacturing processes and to encourage rapid implementation of zero water discharge requirements in existing manufacturing and getting competitive cost benefits.
Keywords – *Zero, Discharge, Digitization, Environment, Protection, Water,Management,s Sustainable, Technology*

R**eceived 04 July, 2022; **R**evised 15 August, 2022; **A**ccepted 17 August, 2022 © The author(s) 2022. **P**ublished with open access at **www.questjournals.org

I. Introduction

World Leading manufacturers in developing countries like India aggressively going towards zero discharge implementation in close loop supply chain through digitization in existing process and have high levels of environmental awareness among employees. However, it is uncertain which practices have to be implemented and how they have to be implemented in the manufacturing sector of automobile companies.

Automobile assembly plants worldwide face increasing pressures in the environmental arena.

These pressures come in the form of stringent, complex, and costly regulations and demands from a growing number of stakeholders for improved environmental performance. In the past, most companies in the United States approached environmental compliance as an added cost of production, installing end-of-pipe technologies to their manufacturing processes rather than evaluating fundamental process or technology changes which could prevent pollution at the source. Increasing costs of traditional modes of compliance and advances in materials and process technology, however, are driving some companies to consider more innovative approaches to environmental problems (Richards and Pearson, 1998).

Changes in environmental awareness programme by the Indian government over the last few years, including legal requirements, pressure from customers as well as government, the need for water use and consumption management, reuse of water in manufacturing processes, water recovery, and changes in manufacturing process, have influenced supply chain management. Thus, companies are aggressively doing improvement in manufacturing processes, product and system to make traditional industry into green manufacturing in supply chain and green supply chain has attracted interest among researchers and practitioners over the past two decades (Dubey et al., 2015).

If we see the current economic growth rates at global level, it has been analysed and forecasted that demand of ground water by 2030 will be more than 40% of current water consumption (Addams,2009). At present, the demand from manufacturing industry consumes 22% of withdrawal of ground water at global level, while the water consumed by manufacturing industry is more than agricultural consumption in most of developed countries (Gleick,2003). There is significant growth in manufacturing Industries, particularly within developing countries, water consumption (*see Figure 1)* in global manufacturing industry is set to increase by more than 5 times by 2050, that is from 245 to 1552 billion m3 at the baseline of 2000 (OCED,2015).

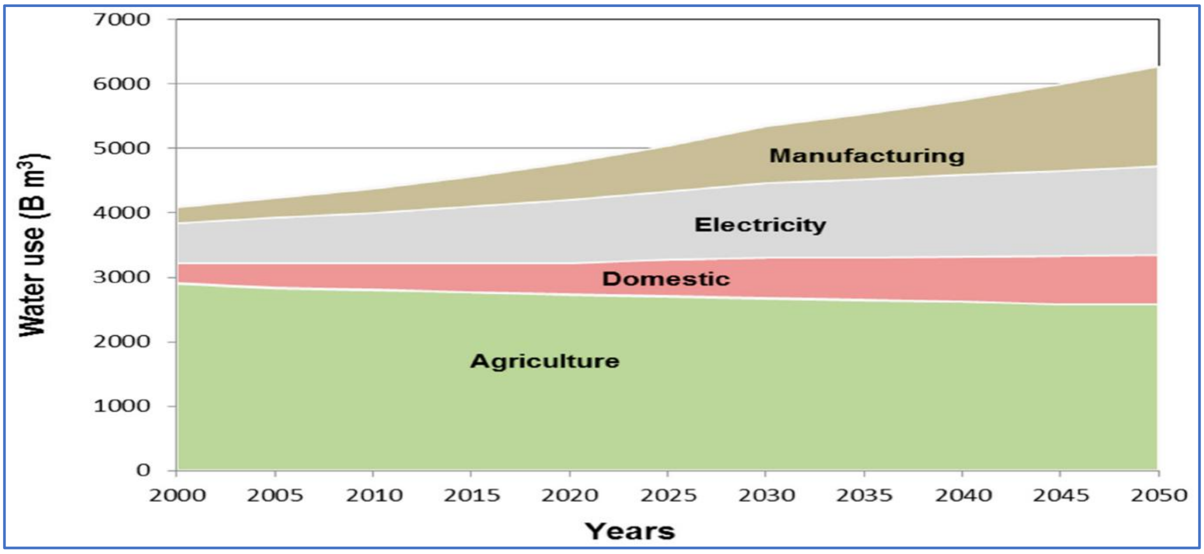

Figure 1. Projected water consumption by different sectors at global level (*Sachidananda, Webb & Rahimifard,2016*)

Pressure from stakeholders, such as government regulators, community activists, non-governmental organizations and global competition are triggering factors for companies to adopt a certain level of commitment towards green and sustainable practices Hassini et al., (2012) stress the importance of studies that focus on practical applications and industry-specific research. Waste management was the most widely used technique among the researchers and green purchasing and life cycle assessment practices were less widespread comparatively. Water consumption and its uses are rarely discussed and used for research by the researchers.

Many study has been conducted on Original Equipment ManufacturerOEMs producing four-wheelers but no study is conducted on the process of OEMs producing two-wheelers. This paper bridges the gaps in previous literature and attempts to analyse the existing painting process of automotive industry and its ancillaries to evaluate its water consumption. Further the study would suggest the improved processes by means of which OEMs can save huge water consumption in the painting processes.

II. Literature Review

This section provides a detailed review on the past researches conducted across the globe in managing the water consumption in the automobile sector along with a description about the process that involves the same.

2.1The Automotive Manufacturing Process

In today's automotive landscape, vehicle manufacturing is an extremely complex processinvolving many suppliers beyond the original equipment manufacturer (OEM). Unlike the earlydays of Ford's manufacturing, where Henry Ford sought to build a completely integrated plant athis Rouge River no OEM aspires to directly control the entire value chain ofvehicle production. Rather, many vehicle systems are outsourced to suppliers, while OEMs tendto focus on vehicle architectures, engines, and drivetrains. It is in the final assembly plant wherethese systems are integrated into the finished product.

Final automotive assembly comprises three main processes: body, paint, and general assembly, depicted in Figure 1.1.

Figure 2. The three major components of an automotive company

In the Weld shop, the basic frame of the vehicle is fabricated. Originally, vehicle bodies were fabricated of steel sheet. But over a time of period it has been converted into tubular components which precluded the use of elevated cure temperatures in the subsequent coating process. After the weld shop the vehicle is sent to the paint shop where coatings and sealers are applied to both interior and exterior surfaces. Lastly in the final assembly, the coated body is mated with the interior systems, engine, drivetrain, suspension and wheels (Andrews, Nieuwenhuis, & Ewing, 2006). Final assembly plants vary widely in the processes employed and capacities. In North America and Europe, most vehicle assembly processes are highly automated, with the greatest concentration of labour content in the final assembly steps. In countries with lower labour costs, significant labour inputs may be utilized in other assembly areas. The relatively wide variety of vehicles, both in terms of size and price, generates variety in the assembly processes employed. However, in general, as common vehicle architectures proliferate, more commonality in processing will be employed. Also, assembly plants will tend toward higher flexibility to maximize capacity utilization, so the investments in product development and manufacturing can be amortized over a larger number of vehicles.

2.2 The automotive paint process and water consumption

Painting process is most costly process in the automotive industry. The purposes of the process are to give more attractive appearance to the vehicles and to provide the layer of protection against corrosion and weathering. The painting process include a few other processes such as pre-treatment, primer process, top coat process and clear coating for glossing the product(Akafuah, Poozesh, Salaimeh, Patrick, Lawler, & Saito, 2016). Automotive coating is a complex multistage process where vehicles are typically processed in a serial fashion. The main details of the basic painting process of any automotive two-wheeler manufacturer are outlined in Table 1. Process times described below do not include vehicle inspection and routing times. The description below follows that of Andrews, Nieuwenhuis, & Ewing (2006).

Basic Pre-treatment Process in Automotive Parts Painting				
S.No	**Paint Process**	**Process Time (Min)**	**Bath Temp (in deg c)**	**Purpose**
1	Degreasing-1	10	45-50	Knock off the dirt, dust and oil particles
2	Degreasing-2	10	45-50	Sticky oil cleaning
3	Degreasing-3	11	45-50	Final Cleaning
3	Water Rinsing-1	7	Ambient	Rinse off degreasing
4	Water Rinsing-2	7	Ambient	Rinse off degreasing
5	Water Rinsing-3	10	Ambient	Rinse off degreasing
6	Surface Conditioning	4	Ambient	Activating surface for phosphating
7	Phosphating	13	45-50	Phosphate coating to paint bonding
8	Water Rinsing-4	7	Ambient	Rinse off Phosphating Chemical
9	Water Rinsing-5	7	Ambient	Rinse off Phosphating Chemical
10	DM Water Rinsing-6	7	Ambient	Rinse off Phosphating Chemical
Total Time in Process		93		

Table :1 Basic Pre-treatment Process in Two-wheeler Painting

Pre-treatment process is very necessary process on the metal surface before painting to produce strong, durable adhesive bonds between the metal and paint(Blohowiak,1999). First process is degreasing, used to clean the metal surface and it consumes 6.0 m3/day. Second Process is water rinsing, it is used to remove the degreasing layer from component surface. Third process which is very important and used to activate the metal surface for phosphating(James’1959). Next process, phosphate conversion coating is used to prevent the corrosion and give the adhesion to paint film(Narayanan,1994) and finally DM water rising is used to neutralise the surface.

The uses of water in these processes as important as raw material for manufacturing of any automotive vehicles (Bras, 2012). According to (John, 2014) average direct water use is 5.20 and 5.95m3/vehicle for manufacturing, data taken from 12 original equipment manufacturers' (OEM's) sustainability reports are examined for the years 2006 to 2010. To get the reference for study of Indian two-wheeler manufacturer, the water consumption/uses in, the water consumption data taken from sustainability reports of top selected top automotive vehicles maker worldwide compiled and summarized in Fig 2.

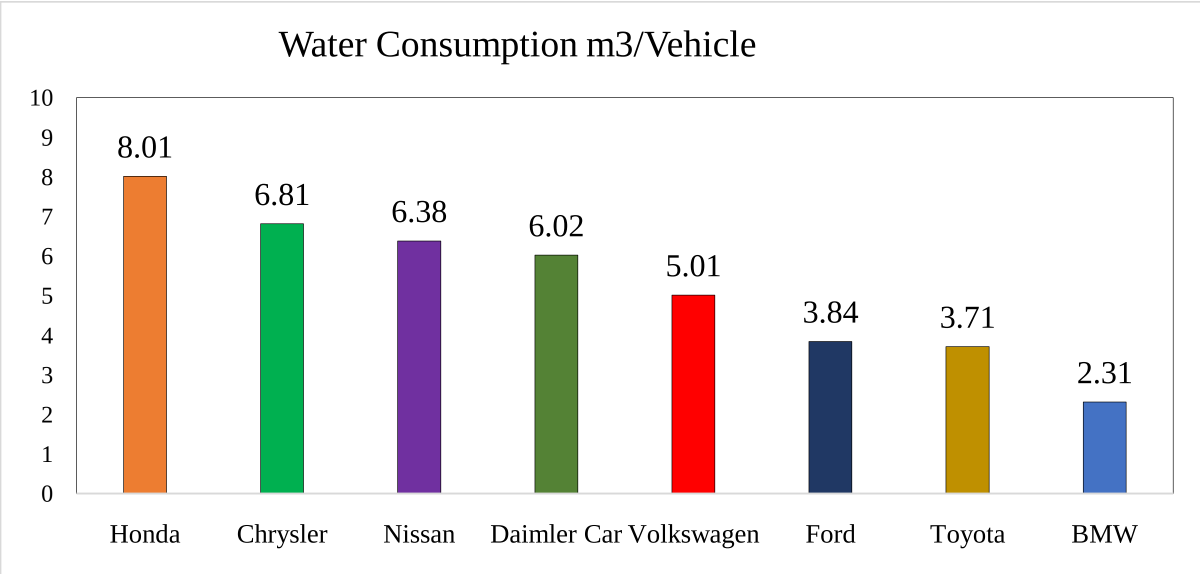

Fig:2 Water Consumption m3/vehicle of top vehicle manufacturer

The water consumption per vehicle was not calculated in the report by the OEMs. The total water consumption per vehicle was calculated by taking the total production and using the water consumption figures from the OEMs sustainability reports.

Several studies have been conducted in the past discussing about the optimisation of water consumption across industries. Like Gao, Wang, Dong, Cai, Zhu & Du (2011) studied about the water consumption situations in steel industry where water is mostly used for cleaning and cooling purposes. The study conducted in China shows a positive result where the optimisation of consuming water can be reduced by 11.1 % and the discharge of waste water can be further reduced by 94.54%. The model highlighted in the study follows the Substance Flow Analysis (SFA) criteria and reports that with water recycle measures adopted through it the efficiency of water resource can be increased by 5.69% with its environmental efficiency being increased by 37.8 %.

Schlei-Peters, Kurle, Wichmann, Thiede, Herrmann & Spengler (2015) investigated the water and energy efficiency in the automotive industry with a proposed model based on the cooling system with five components namely- filter system, pump, two sets of open cooling towers and the heat exchanger. When employing the new methods of cooling system a decrease of 44,768 kWh of energy and water saving of 983m^3 of waste per annum is observed. Further when the temperature used in this stage at 23^{0}C is changed to 24^{0}C, the energy and water saving capacities are further changed to 13, 389 kWh to 4147 m^3 of water waste per annum. However when combining both the models gives a total savings of 55,208 kWh for energy and 4,992 m^3 for that of water waste per annum. The authors provide an integrative approach to save both energy and water during manufacturing processes in an automotive industry while realising the impact of each other on themselves during the process of production.

Cuviella-Suárez, Colmenar-Santos, Borge-Diez & López-Rey (2018) studied about a management tool that would help in the process of water consumption in the industry of sanitary-ware. The study finds a relationship between consumption levels and the environment. Making improvements in the electrical efficiency can help reduce the consumption of electrical energy and with the help of the heat restored using re-direction of kiln to dryers and ventilation units, the water consumed can be reduced by using it for distillation rather than conducting a reverse osmosis.

Chigare, Kamat & Patil (2020) reviewed about the water wastage treating methods in the automobile industries in India. The waste water generated from automobile industries mostly is contaminated with oil, grease, paint impurities, coolants, chloride, phosphate paint etc. resulting in a pungent smell of the waste water.

While stating the examples of Bajaj Auto Ltd., one of the top automobile companies in India, the authors suggested that recycling of water is an important aspect of managing water waste. The company is known to recycle and reuse the water in the production process with no chemical and pollution discharge. The treatment procedure should include removal of the solids in waste water like oil, grease etc. Secondary form of treatment would include using micro -organisms for removing colour of water, the oil and phenol present in it. The third is tertiary treatment where electro-dialysis methods are used for finally removing the wastes and to purify the waste water. The authors found that waste water from automobile industries are less effluent compared to those coming from pharmaceutical companies or chemical industries. Thus, treating the waste water to be able to reuse and recycle is easier and must be encouraged.

According to Business Standard (2020), there is a rise in the water crisis among the auto companies . Automobile giant Hyundai Motor have started using extensive measure for water management in their factories pertaining to the problem of scarcity of water. Nissan another major player in the industry have opted for waterless car washing strategies as it could save around 162 Litres of water per car. Maruti Suzuki has also been reported to adopt water management techniques across the factory. Hence, all the big players in the market have already forecasted the rising crisis that would arise in the coming time when continouing production procedures at the plant. They are thus equipping themselves with the appropriate measures and it is important that research too in this field is enhanced to realise the severity of this problem and put forward methods that are beneficial to the automible industry at such a critical state.

Hence, this research is an attempt to generate a method through which the process of saving water in the production process can be optimised.

III. Problem Statement and Framework

In this section, we will evaluate the exiting painting process of automotive manufacturer in context of water uses/consumption in painting processes. The problem of finding the feasibility of optimizing water consumption solution is proposed in the framework.

3.1 Problem Statement

Given a set of water-usingwater-disposing processes as per fig-3 is designed by Durr and Combat which are the major supplier of paint shop.

Water uses = Water Input/Vehicle Production (M3/Vehicle) -------------------------------- (1)

Water Consumption= {Water Uses (m3)-Water Discharge (m3)}/Total Production----- (2)

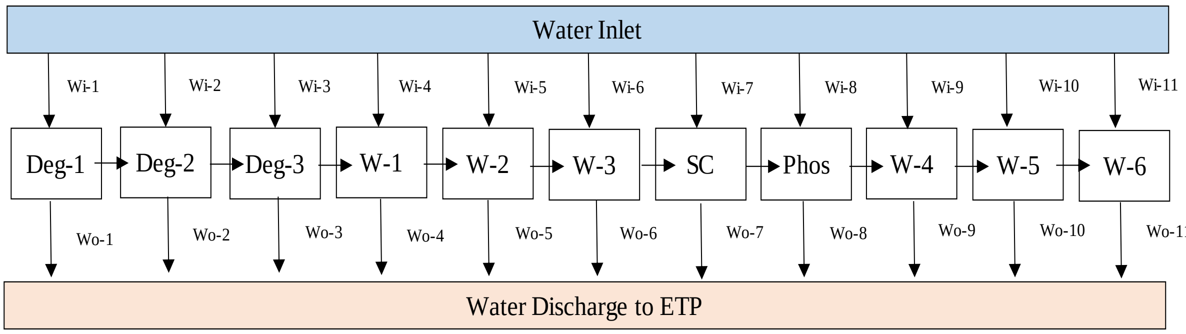

Fig:3 Water uses during Pre-treatment Process in Paint Shop

Deg-1, Deg-2, Deg-3 are the degreasingchemical used as a cleaning processes, SC and Phos are surface conditioning and phosphate respectively. Water-1, 2,3,4,5 and 6 are used for rinsing the surface.The wi-1, wi-2 …...wi-11 are the water uses or intake water, wo-1, wo-2 ……. wo11 are the water discharge respectively.As per this paper, it is desired to re-design the process flow of water streams betweenthe pre-treatment and effluent treatment process of waste water dischargeunits. So, the overall freshwater consumptionis minimized or sometimeseliminated, while each ofthe processes as per fig-3 receive water of adequate quality maintaining all the parameters of individual bath.Since the amount of water discharged should be the same asthe amount of freshwater taken out, the objective ofminimizing the overall freshwater consumption as per equation-2, asper problem statement. It can be done by optimizing the water uses and water discharge through water waste 4Rs principles (Reduction, Reuse, Recycling and Recovery) concept. Thus, the solution to this problem answers the feasibility of optimizing the water uses in painting processes.

3.1 Solution Procedure

The proposed solution of this problem assumes constant reuse of uncontaminated water from last process discharge to previous processas fresh water in form of inlet water. The basic purpose to remove discharge water concentrations of contaminants as proposed by Wang and smith(1994), The fresh water and waste water can be minimised by using innovative technologies and software (Brundtland,1996).In our approach, we visited a automotive OEM and its seven suppliers,we mapped the complete process and identified discharge points which can be used as inlet water for previous process. In fig-4, we suggested the modified processes of fig-3. We suggested following changes

1- Deg-2 discharge(Wo2) which is coming through cascading to minimising the contamination and same amount of water (wi2) is coming to same bath to maintain the bath water level. We are proposing wo2 can be used in place of Wi1 as inlet water.

2- In the same way Deg-3 (Wo3) is the cleanest water which is suggested to as fresh water for Deg-1(Wi-1) or Deg-2(Wi-2).

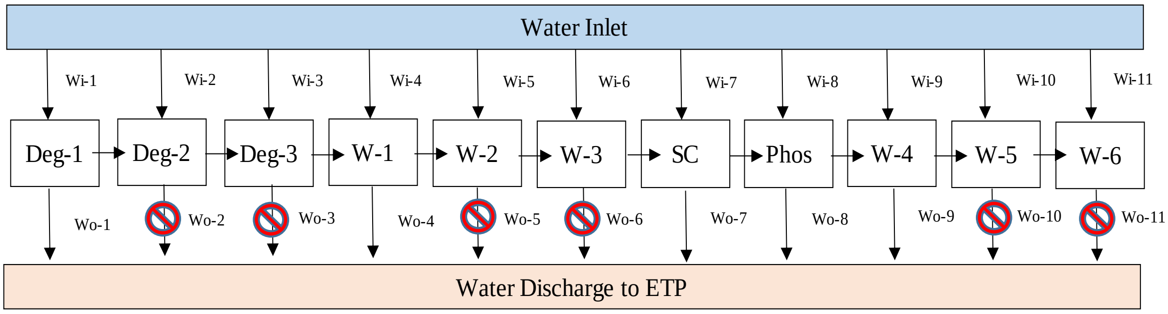

Fig:4 Modified process of water discharge in pre-treatment process

3- In the same way Wo5, Wo6, Wo10 and W11 can be used instead of fresh water for previous processes.

4- Through this process we can save total Wi1+Wi2+Wi4+Wi5+Wi9+Wi10 on daily basis.

IV. Objectives of the Research

In order to arrive at a better water saving technique in the automobile industry during the course of the research the following objectives are set for the purpose of the study-

1. To prepare a structured framework to evaluate the impact of technological innovation in water consumption process in automobile industry.
2. To identify the challenges and opportunities in optimizing water consumptions in the painting process in automobile companies using technological innovations

V. Case Studies

Using the above models of modified processes in three different plant, all three paint shop cases are optimized by modifying the existing processes. Total 40% water uses are reduced in painting pre-treatment processes.

5.1Cases 1&2

ABC Ltd. is the world's largest two-wheeler selling automobile company which is expanding their business in the automobile industry across the globe. They have started manufacturing activities in Bangladesh and South Africa. It is currently manufacturing a wide variety of vehicles ranging from 100 cc to 250cc vehicles in five plants. ABC Ltd. has been manufacturing two wheelers in India since 1984. The OEM is having 11 paint shops as a whole at different locations. The model in Figure 4 is applied in three paint shops where reportedly 40% water is saved in the pre-treatment process as shown in table-2. Total 9.5 m^3/day water is saved using this process between Degreasing-1 to Degreasing-3. Total 20 m/day water is saved between water rinsing -1 to water rinsing-6 after making corrections in the existing line. All the quality standards are met in the requirements in components which were painted with the new modified process. There is total of 41% water saving per day with new process being implemented.

Water Saving in Pre-treatment Process				
S.No	**Paint Process**	**Water Uses(Inlet) m^3/Day(Before)**	**Water Uses(Inlet) m3/Day(After)**	**Observation**
1	Degreasing-1	6.5	3.5	3 m^3/day water used as input from Deg-3

2	Degreasing-2	6.5	0	6.5 m^3/day water used as input from Deg-3
3	Degreasing-3	10	10	10 m^3/day water being used in deg-1&2
3	Water Rinsing-1	8	2	6 m^3/day water used as input from WR-3
4	Water Rinsing-2	8	0	8 m^3/day water used as input from WR-3
5	Water Rinsing-3	14	14	14 m^3/day water being used in WR-1&2
6	Surface Cond.	4	4	Activating surface for phosphating
7	Phosphating	5	5	Phosphate coating to paint bonding
8	Water Rinsing-4	7	0	7 m^3/day water used as input from WR-6
9	Water Rinsing-5	7	0	7 m^3/day water used as input from WR-6
10	Water Rinsing-6	14	14	14 m^3/day water being used in WR-1&2
Total Time in Process		90	52.5	**Total saving 41% Water m3/day**

Table 2- Water saving in modified pre-treatment process

5.2Case 3

In this case water base painting processes (ACED) is adopted for saving water. There is a total of 46% water saving observed with modified process.

Water Saving in ACED Painting Process				
S.No	**Paint Process**	**Water Uses(Inlet) m^3/Day(Before)**	**Water Uses(Inlet) m^3/Day(After)**	**Observation**
1	Hot water	6.5	6.5	
2	Pre Degreasing	6.5	1	5.5 m^3/day water used as input from Deg-3
3	Degreasing	5	0	5 m^3/day water being used from WR-2
3	Water Rinsing-1	8	0	8 m^3/day water used as input from WR-3
4	Water Rinsing-2	17.6	17.6	17.6 m^3/day water being sent to Deg-2&3
5	Water Rinsing-3	0.5	0.5	Soda being used
6	Surface Cond.	0.5	4	Activating surface for phosphate
7	Phosphate	1	5	Phosphate coating to paint bonding
8	Water Rinsing-4	5	0	7 m^3/day water used as input from WR-6
9	Water Rinsing-5	5	0	7 m^3/day water used as input from WR-6
10	Water Rinsing-6	16	14	14 m^3/day water being used in WR-4&5
11	Electro deposition	2	2	
12	Ultra filtration-1	0	0	
13	Ultra filtration-2	0	0	
14	Ultra filtration-3	0	0	
15	Water Rinsing-7	18	10	8 m^3/day saved by installing Ro system
Total Time in Process		91.6	48.6	**Total saving 46% m3/day**

Table 3- Water saving in modified ACED Painting process

Addition of a Reverse Osmosis (RO) system is highly recommended here to save paint as well as water from being discharged. RO system is reportedly under installation and there is an expectation of 8m^3/day of water and 2 Litres of paint to discharge which will further reduce the Effluent Treatment Plant (ETP) working time.

VI. Results and Discussion

Thesoft water is one of the most important natural resources which can be used as a consumable or raw material byan organisation to produce a product. However, as a fast pace of urbanization and industrial development, the problem of water scarcity has intensified and become a major constraint to minimise the use of water in sustainable development. Hence, scientific modification in the existing system and rational water utilization without compromising with quality of product is biggest challenge for any automotive organisation. In this study, we tried to optimise the use of water in pre-treatment process in an automotive organisation and its ancillary. During implementation of developed framework in automotive organisation, we observed following challenges

6.1 Challenges

Three-quarters of the Earth's surface is almost covered in water.Still, the industry supply of water is steadily decreasing due to growing demand, pollution and sanitation issues as well as climate change. We faced three major challenges while implementing the frame work at existing line.

1. Implementing the framework at running production line was the biggest challenge.
2. Cutting pipe lines and welding of the joints to make them leak proof.
3. Fear of loss of production

6.2 Opportunities

In India where demand for water is huge, many companies are struggling to find and fulfil the water they require to run their businesses. In 2004, for instance, Pepsi Bottling and Coca-Cola closed down plants in India that local farmers and urban interests believed were competing with them for water. In this study, we realised four big opportunities for an automotive organisation in implementing this frame work.

1- Due to government pressure to minimise the water uses in industry and as per McKinsey Dec'2009 report, the businesses everywhere could face similar challenges during the next few years.

2- Closing the gap between supply and demand by deploying water productivity improvements across the supply chain

3- Opportunities to implement Industry 4.0 to digitalize the process for monitoring the water consumption in real data form.

4- Same improvements can be implemented horizontally in other plants or unit to get similar benefits.

The study puts forward a framework that while being implemented across real life scenarios portrayed efficient results. The implementation of technological innovations in the manufacturing processes of automobile sectors open a wide range of possibilities to reduce the water consumption. The technological avenues in today's world are dynamic and easily accessible. Exploring and employing these techniques into the benefit of the industry as well as the environment would in future reap fruitful results.

VII. Conclusion

This paper focused on optimizing of the amount of water consumed in pre-treatment process, the concept is used the 4 R's (reduce, recover, reuse and recycle) to optimise the use of water consumption (Asano 1996). We implemented our framework model in three paint shop units and started saving 40% water in each process on daily basis. Two priorities for further research have also been identified. Firstly, there is a need for targets for reducing pressure on global freshwater resources. Second, 100 % recycling of water in painted processes. Due to the increasing threat of climate change there are changes observed across various natural sources. Water being one of them it is very important on the part of every manufacturer to ensure its optimum uses while conducting the various processes of producing their offerings. The reduction of 40 % water with each daily application indicates a sufficient amount of reduction in the water consumption which in a course of few years have the potential to make a considerable amount of impact on the improvement of environmental difficulties. It is thus been attempted through this research that there are methods through which a noticeable amount of difference can be executed towards the optimum use of water in every step of the manufacturing process. The application of this model suggested would be beneficial to the automobile sector as well as towards reducing the growing problems of climate change. Moreover, human as consumers in the society desires a progressive improvement in the quality of life. The industry has been advancing and upgrading to keep pace with the technologically advancing world and are innovating new technologies to delight the consumers. The industry can continue to improve people's living standards and fulfil their expectations by providing customized and very high quality of products with competitive advantage in cost through optimization of resources in manufacturing units and setting up a better and healthy work environment inside the factory for employees as well.

The research conducted here leaves further scopes for future research in two forms. Firstly, there is a need for targets for reducing pressure on global freshwater resources which could be taken up by researchers in the future to address the problem and explore the possibilities. Secondly, there is an interesting scope to find out if 100 % recycling of water in painted processes can be implemented. The solutions resulting from these two possibilities can further help in the process of sustainable development of the automobile sector .

References

[1]. Addams, L., Boccaletti, G., Kerlin, M. &Stuchtey, M. (2009). Charting Our Water Future-Economic Frameworks to Inform Decision-Making. McKinsey & Company: New York, USA.

[2]. Akafuah, N., Poozesh, S., Salaimeh, A., Patrick, G., Lawler, K., & Saito, K. (2016). Evolution of the Automotive Body Coating Process—A Review. Coatings, 6(2), 24.

[3]. Andrews, D., Nieuwenhuis, P., & Ewing, P. D. (2006). Black and beyond—colour and the mass-produced motor car. Optics & Laser Technology, 38(4-6), 377–39.

[4]. Asano, T. & Levine, A. D. (1996). Wastewater reclamation, recycling and reuse: past, present, and future. Water Science and Technology, 33(10-11), 1-14.
[5]. Blohowiak, K. Y., Osborne, J. H. & Krienke, K. A. (1999). Surface pretreatment of metals to activate the surface for sol-gel coating. U.S. Patent No. 5,869,140.
[6]. Bras, B., Tejada, F., Yen, J., Zullo, J., & Guldberg, T. (2012). Quantifying the Life Cycle Water Consumption of a Passenger Vehicle. SAE Technical Paper Series.
[7]. Brundtland, G. H. (1987). Report of the World Commission on environment and development:" our common future.United Nations.
[8]. Buehner, F. W. &Kumana, J. D. (1996). Freshwater and Wastewater Minimization: Concepts, Software and Results. Chemputers IV Conference, Houston.
[9]. Chigare, R., Kamat, S.R., & Patil, J. (2020). A Review of the Automobile Industries Waste Water Treatment Methodologies. International Research Journal of Engineering and Technology, 6(6), 974-977.
[10]. Cuviella-Suárez, C., Colmenar-Santos, A., Borge-Diez, D., & López-Rey, Á. (2018). Management tool to optimize energy and water consumption in the sanitary-ware industry. Journal of Cleaner Production, 197, 280–296.
[11]. Dubey, R., Gunasekaran, A., Papadopoulos, T. & Childe, S.J. (2015). Green supply chain management enablers: mixed methods research. Sustain. Prod. Consum., 4, 72-88.
[12]. Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st- century business. Environmental Quality Management, 8 (1), 37-51.
[13]. Gao, C., Wang, D., Dong, H., Cai, J., Zhu, W., & Du, T. (2011). Optimization and evaluation of steel industry’s water-use system. Journal of Cleaner Production, 19(1), 64–69.
[14]. Gleick, P. H. (2003). WATERUSE. Annual Review of Environment and Resources, 28(1), 275–314.
[15]. Govindan, K. & a Soleimani, H. (2017). A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus. Journal of Cleaner Production, 142 371-384.
[16]. Hart, S. L. (1997). Beyond greening: strategies for a sustainable world. Harvard business review, 75 (1), 66-77.
[17]. Hassini, E., Surti, C. & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. Int. J. Prod. Econ., 140, 69- 82
[18]. James, M. (1959). Pretreatment solution for phosphate coating, method of preparing the same and process of treating metal surfaces. U.S. Patent No. 2,874,081.
[19]. Jayal, A.D., Badurdeen, F., Dillon Jr., O.W., &Jawahir, I.S. (2010). Sustainable manufacturing: modeling and optimization challenges at the product, process and system levels. CIRP J. Manuf. Sci. Technol., 2, 144-152.
[20]. Bras, J. B. & Guldberg, T. (2014). Vehicle manufacturing water use and consumption: an analysis based on data in automotive manufacturers’ sustainability reports. The International Journal of Life Cycle Assessment, 19(1) , 246-256.
[21]. Narayanan, T. S. N. (1994). Phosphate conversion coatings-a metal pretreatment process. Corrosion Reviews, 12 (3-4) , 201-238.
[22]. OECD. Water—The Right Price Can Encourage Efficiency and Investment. Available online: http://www.oecd.org/env/resources/watertherightpricecanencourageefficiencyandinvestment.htm (accessed on16 November 2015).
[23]. Raluy, G., Serra, L. & Uche, J. (2006). Life cycle assessment of MSF, MED and RO desalination technologies. Energy, 31, 2025–2036.
[24]. Richards, D. & Pearson, G. eds. (1998). The Ecology of Industry: Sectors and Linkages. National Academy of Engineering, National Academy Press, Washington, D.C.
[25]. Sachidananda, M., Webb, D. P. &Rahimifard, S. (2016). A concept of water usage efficiency to support water reduction in manufacturing industry. Sustainability ,8(12) ,12-22.
[26]. Schlei-Peters, I., Kurle, D., Wichmann, M. G., Thiede, S., Herrmann, C., & Spengler, T. S. (2015). Assessing Combined Water-Energy-Efficiency Measures in the Automotive Industry. Procedia CIRP, 29, 50–55.
[27]. Wang, Y. P. & Smith, R. (1994). Wastewater minimisation. Chemical Engineering Science , 49(7), 981-1006.