



“A study on applying lean manufacturing concept to enhance efficiency and sustainability of ETP plant in small scale manufacturing units”

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Abstract: In the current era of unexpected small-scale manufacturing unit growth, treating wastewater before it is discharged becomes vital for these units. The following study explains how, by using different practices, we can optimize the dynamics of an effluent treatment plant (ETP) while maintaining compliance with government regulations and improving the plant's sustainability and efficiency. It is crucial for the environment and society that wastewater be treated with proper operational excellence and in accordance with the standards to be used for it.

Key Words:- ETP (Effluent Treatment Plant), Wastewater Treatment, Environment Compliance, Sustainability and Efficiency, Small Scale manufacturing Units

1. INTRODUCTION

In a time when urbanization and industrialization have reached previously unheard-of levels, any organization or business involved in the manufacturing sector often has water waste on hand. Proper disposal of waste water is crucial for all industries to prevent harm to the environment and public health. When it comes to cleaning industrial wastewater before releasing it into the environment, an effluent treatment plant, or ETP, is required and essential. Aquatic lakes, biodiversity, and human health are significantly impacted by untreated water found in open environments or water bodies. Waste water has a high concentration of organic debris and chemical confinement, which is why this occurs. Industries are required by global government and environmental agencies to clean their waste water before releasing it into the environment. These agencies have established guidelines and regulations. ETPs are becoming increasingly important in pursuing the harmony between the environment and the industry ecosystem as global industrialization continues to soar. It delves further into the functioning of many industries, the development of technology, and how it contributes to efforts to create a better and greener world. The process of purifying industrial waste water for safe disposal or reuse in the environment is known as an effluent treatment plant, or ETP. By using both chemical and physical treatments, influent can be hidden from effluent. Where,

- **Influent** represent for untreated industrial waste water.
- **Effluent** represents for treated industrial waste water.
- **Sludge** represents for solid part separated from waste water by ETP.

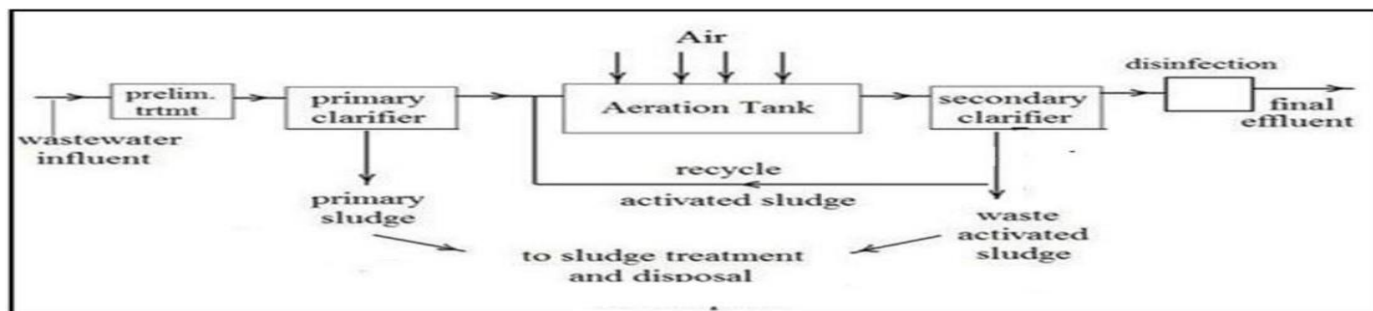


Figure:- General Working of ETP Plant

Here ETP plant operations will be conducted in different stages with the different treatment mechanism as shown below table,

Stages Of Treatment	Treatment Mechanism
Preliminary Treatment	Physically
Primary Treatment	Physical + Chemical
Secondary Treatment	Biological + Chemical
Tertiary Treatment	Final Discharge + Sludge

Here large solid particles are removed from wastewater using physical mechanisms in an Effluent Treatment Plant (ETP) during the initial stage of treatment. Screening and grit removal are two examples of these procedures; screens remove trash, and grit chambers settle heavier particles. These procedures guarantee the first separation of solids prior to additional processing.

Physical and chemical mechanisms are used in the first stage of wastewater treatment at an Effluent Treatment Plant (ETP). While chemical coagulants help in particle aggregation, physical processes such as sedimentation settle suspended materials. This two-pronged strategy makes it easier to eliminate both solid and colloidal contaminants, which sets the stage for further treatment procedures.

An Effluent Treatment Plant (ETP) uses chemical and biological processes for wastewater treatment in its secondary stage. With biological treatment, organic pollutants are broken down by microorganisms using activated sludge or biofilm processes. Further nutrient removal may be accomplished using chemical treatments, which would improve the wastewater's overall purity.

In the final polishing phase for safe disposal, an ETP's tertiary stage of wastewater treatment is concentrated. The production of high-quality effluent involves the use of sophisticated procedures like filtration, chemical coagulation, and disinfection. In parallel, sludge produced during treatment is dried, dewatered, or treated in another way to dispose of or reuse it in an environmentally friendly manner.

2. RESEARCH GAP

According to the reviews of the literature, all of the studies primarily concentrate on the lean manufacturing concept or the individual ETP plant. If lean is applied to an ETP plant, however, the studies essentially rely on general research on it. In this case, however, the study only looks at the application of the lean manufacturing concept to small-scale manufacturing units in order to determine whether applying the specific concept can improve the sustainability and efficiency of those ETP plants.

3. LITERATURE REVIEW

This knowledge was discovered by numerous literature reviews, some of which are included below:

[December, 2016], Article from International Journal of Civil Engineering by Rakesh Singh Asiwal, Dr. Santos Kumar Sar, Shweta Singh, Megha Sahu from Department of Applied Chemistry. [Source goggle, (<http://surl.li/mhuxe>)], A presentation slide by Dr. Gazala Habib Department of Civil Engineering IIT Delhi. [December 2021, IJARST Journal], A Review Paper on ETP Parag Ninawe, Amol Ninawe and Tushar Deotare. [2012, The McGraw-Hill Companies] 5th edition of book “water treatment plant design”. “Recent Advances in Wastewater Engineering” by Dr. S. N. Kaul, Dr. Tapas Nandy, Dr. L. Szpyrkowicz and Dr. R. K. Trivedy. This wastewater treatment facility transfers influent wastewater to effluent water for treatment. Additionally, it aids in the decrease of water pollution and encourages businesses to recycle water so that resources can be used again in accordance with legal requirements. [April – June 2020, (www.iaraindia.com)] UGC Approved Journal, Study on “ANALYSIS OF WASTE WATER TREATMENT IN INDIA” by Ekta Banik & Rishav Singh. [October 2016], Article in “Imperial Journal of Interdisciplinary Research (IJIR). The government has previously taken several measures to manage pollution as a serious problem for society posed by the expanding manufacturing sector. Numerous contaminants found in wastewater can be dangerous to both humans and the environment. The Ministry of Forests and Climate Change has mandated that all enterprises utilizing ETPs must convert influent water into fluent in accordance with government guidelines before they are permitted to release industrial waste water into the environment or into bodies of water. [Asian Journal of Chemistry, 2016], Efficiency of Effluent Treatment Plants and Threat to Human Health and Aquatic Environment in Bangladesh by Parul Akhtar, Yunus Ahmed, Faridul Islam, Khorshed Alam, Meherunnesa Mary, Md. Zahidul Islam, M. Mosharef H. Bhuiyan And Zahira Yaakob. A blog on “Cleantech water” on their web site on “How to Optimize Wastewater Treatment Plants for Maximum Efficiency? [2018, IJARST], Performance Evaluation and Treatment Optimization of ETP and STP- Review. [Chemical Engineering Research Bulletin 13(2009) 61-66 / Khan et al.] Financial and technical limitations lead to inadequate treatment in textile plants. Process optimization through strategic monitoring may result in cost savings and increased market competitiveness. [November, 2004] report of “Maharashtra pollution control board” on operation and maintenance of ETP plant by Dr.D.B.Boralkar. [Melton, (2005)] explores the benefits of lean manufacturing for the process industries having different kind of unfruitful waste that can damage at very high level. In addition to these ETP plant optimizations, lower energy use and waste production. Additionally, centralized ETP initiatives can help both large and small-scale enterprises by lowering costs, increasing investment, and ensuring compliance. It is also possible to view key performance metrics and determine how long an ETP could last under given circumstances. [Shah Chandrasekaran and Linderman (2008) delve into implementation patterns of Lean within various contexts. This is discussed in the International Journal of Production Research. [2021, IOP publishing, S.R. Lie and R.D. Kusumustuti] on Process improvement using lean manufacturing. Papadopoulos and Ozbayrak (2005) share experiences and insights from the lean journey in the Journal of Manufacturing Technology Management. Diann Daniel, Executive Editor Blog on google. [<https://shorturl.at/zFWZ6>]. [Source Google, (<http://surl.li/mhuxe>)], A presentation slide by Dr. Gazala Habib Department of Civil Engineering IIT Delhi. “Recent Advances in Wastewater Engineering” by Dr. S. N. Kaul, Dr. Tapas Nandy, Dr. L. Szpyrkowicz and Dr. R. K. Trivedy. [2012, The McGraw-Hill Companies] 5th edition of book “water treatment plant design” The term "lean manufacturing" describes an approach that applies and minimizes waste. Waste can refer to any number of things, but in this context, waste is anything that is identical or not adding value, and you are paying for it. The lean idea simply identifies waste and uses various tools, tactics, and strategies to preserve the object's sustainability and efficiency.

4. RESEARCH OBJECTIVES

1. To examine if peoples are on lean manufacturing are connected to their views on advanced technologies in ETP operations.
2. To examine the difficulties in using ETP technology to Lean principles in small-scale production with the goal of improving sustainability and efficiency.
3. To analyze the annual report of Ministry of environment, forest and climate change report- India, regarding wastewater and solid waste management.

5. HYPOTHESIS

H0 (Null Hypothesis):- Peoples opinion about lean manufacturing principles is not linked to their views on advanced technologies in ETP operations.

H1 (Alternate Hypothesis):- Peoples opinion about lean manufacturing principles is connected to their views on advanced technologies in ETP operations.

6. METHOD AND SAMPLING

RESEARCH DESIGN	Qualitative analysis
SOURCES OF DATA	Primary data + Secondary Data (Both)
DATA COLLECTION METHODS	<ul style="list-style-type: none"> Primary through survey questions with google form. Government and regulatory reports. Expert opinion and consultations. It can be also from the survey responses of google form.
POPULATION	Students, Professor, Plant supervisor, Person having knowledge or expertise in ETP plant.
SAMPLING METHOD	Purposeful Sampling

7. DATA ANALYSIS

Now let's dive into the analysis of the answers that participants provided through a Google Form. In the mechanical and engineering departments, the 113 responders in our sample size comprise both instructors and students. Moreover, employees with management expertise, industry specialists, or plant supervisors may comprehend the principles of lean manufacturing and how an ETP functions. These are the findings and the respondents' interpretations related to the research issue. The two charts below show respondents' familiarity levels with the lean manufacturing concept and ETP plant on a scale from 1 to 5. Here 1 represents for the **NOT FAMILIAR** and whereas 5 for **VARY FAMILIAR**. Here it can happen that one person is known to lean manufacturing concept is not familiar with the ETP plant. Same can goes for lean manufacturing concept too and so that these two variable are not dependent to each other. Responders are responding to the asked questions as per their knowledge regarding both ETP plant and lean manufacturing concept. The following table just represent out of **113** samples how much familiar respondents are to the concepts?

Respondents are familiar following things				
Scale of 1 to 5	Lean Mfg. Concept		ETP plant	
1	16		15	
2	18		20	
3	24	79	25	78
4	21		28	
5	34		25	

The following table, which shows the data to analyze if lean manufacturing ideas are associated with cutting-edge technology in ETP operation, is what we found according to the questionnaire. The observed value table for respondent frequency is shown in the following table,

Observed value table / Actual range table

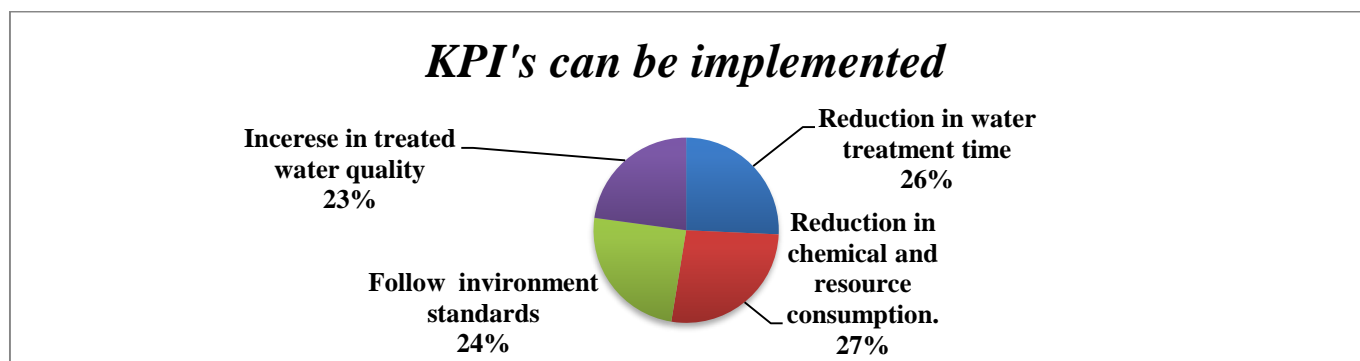
Lean mfg. options	Real time monitoring and control of ETP Process.	Optimize resource usages through automated adjustment.	Total frequency.
By reducing water consumption through efficient use of chemical and treatment agents.	73	90	163
By maximizing the use of renewable energy sources for ETP operations.	43	60	103
All of the above.	36	72	108
Grand Total	152	222	374

In this case, the chi-square test and the corresponding p-value enable us to determine the significance of the link between categorical variables and draw well-informed conclusions regarding their independence or association. The null hypothesis is rejected and evidence of a connection between the variables is found if the p-value is smaller than the selected significance level, which is frequently represented by alpha and is typically set at 0.05. The null hypothesis cannot be rejected if the p-value is higher than the significance level, which suggests that there is not enough data to draw the conclusion that the variables are related. For chi-square test we needed the expected value table to calculate P-Value in MS excel. So by applying following formula $(\text{Row total} * \text{column total} / \text{grand total})$ for each cell we got the following table,

<i>Expected range table</i>	
66.25	96.75
41.86	61.14
43.89	64.11

By using MS excel we got the $(P\text{-Value}=0.17)$ which is greater than 0.05 so that here alternate hypothesis will be rejected and null hypothesis is accepted here that *“Peoples opinion about lean manufacturing principles is not linked to their views on advanced technologies in ETP operations.”*

The study finds no significant association between opinions on Lean Manufacturing principles and views on advanced technologies in ETP operations ($p = 0.17$). This suggests that Lean Manufacturing beliefs may not influence perceptions of advanced technologies, necessitating further exploration of factors shaping attitudes in this context so that in the further exploration there are certain charts which qualitatively interpreted where research follows the small scale of manufacturing units so that as per the respondents we can go for the measurement of following KPI's (Ker Performance Indicator) where following chart refers to tell which can be implemented to sustain and enhance the efficiency of ETP plant.



After all these there are certain identified problems which be issue in small scale manufacturing units and those are as listed below,

- ✧ Limited financial resources for initial setup and training.

- ✧ Resistance to change among existing ETP operators.
- ✧ Integrating Lean practices with existing ETP technology.
- ✧ Cost of software and skill operating training.
- ✧ Ensuring compliance with environmental regulations while implementing Lean.
- ✧ Standard operating procedures sometime not used to save cost and it affects the efficiency of ETP plant.
- ✧ Proper ratio of chemical should be used where in small scale manufacturing unskilled operator not using it.

These all can be optimize and increase the efficiency and sustainability of ETP by applying following things,

- 1) By optimizing the ETP process flows and minimizing waste generation.
- 2) Through standardizing ETP operation procedures for consistent results.
- 3) By implementing 5S practices to organize and maintain the ETP area.
- 4) Proper sold and other waste material, it should be taken care it would not harm or being hazardous to anyone.
- 5) Establishing regular testing and analysis protocols for effluents.
- 6) Implementing real-time monitoring systems for key pollutants.

We can use different tool to our ETP plant as per convenience fits to organization are listed in table and by applying them we could enhance the efficiency and sustainability of ETP plant.

<i>Lean manufacturing tools</i>	<i>Application</i>	<i>Benefits</i>	<i>Limitations</i>
Value Stream Mapping (VSM)	Analyzing ETP process flows.	Identifies waste, streamlines processes	Time-consuming, requires expertise
5S Methodology	Organizing and maintaining ETP area.	Improves cleanliness, reduces downtime	Initial implementation may be costly
Kaizen Events	Continuous improvement of ETP processes	Encourages employee involvement, boosts morale	May disrupt workflow during events
Kanban Systems	Managing inventory levels	Reduces excess inventory, minimizes waste	Can be complex to set up and manage
Standardized Work	Establishing ETP operation procedures	Ensures consistency, reduces errors	Resistance to change from employees
Error Proofing	Preventing errors in ETP operations	Minimizes mistakes, improves quality	Initial setup costs and maintenance
Just-In-Time (JIT)	Minimizing waste in ETP processes	Reduces lead times, saves resources	Reliance on suppliers, risk of delays

Ministry of Environment, Forest and Climate Change annual report regarding wastewater and solid waste management,

When we apply any lean manufacturing tool with our ETP plant so as per the following government report we can treat the effluent as follows table,

Combination	Quality of Effluent	Treatment options
High TDS, and high COD and equivalently high BOD	Waste is not easily biodegradable but toxic	<ul style="list-style-type: none"> ▪ Thermal decomposition (based on calorific value) ▪ Chemical oxidation by hydrogen peroxide, ozone <i>etc.</i> ▪ Evaporation + secured landfill
High TDS, High COD and high difference between COD and BOD	May be toxic; not suitable for biological treatment; mostly inorganic salts	<ul style="list-style-type: none"> ▪ Chemical treatment (recovery, precipitation <i>etc.</i>) ▪ Evaporation + secured landfill of evaporated residue

Combination	Quality of Effluent	Treatment options
High TDS, high BOD and low difference between COD & BOD	Highly organic effluent fully biodegradable	<ul style="list-style-type: none"> ▪ Anaerobic + Aerobic treatment ▪ If quantity is less, incineration (based on calorific value) + secure landfill of incineration ash
High TDS, low BOD and low BOD & COD difference	Only inorganic salts, no need for biological treatment	<ul style="list-style-type: none"> ▪ Solar evaporation ▪ Forced evaporation (after separation of volatile organic matter) ▪ Membrane technologies
Low TDS, and high COD and equivalently high BOD	Highly organic effluent, may not be easily biodegradable	<ul style="list-style-type: none"> ▪ Thermal decomposition ▪ Chemical oxidation by hydrogen peroxide or ozone or sodium hypochlorite <i>etc.</i> ▪ Chemical + biological treatment
Low TDS, High COD and high difference between COD and BOD	Highly inorganic effluent, not suitable for biological treatment	<ul style="list-style-type: none"> ▪ Chemical recovery ▪ Chemical oxidation + biological treatment
Low TDS, high BOD and low difference between COD & BOD	Organic effluent, fully biodegradable	<ul style="list-style-type: none"> ▪ Anaerobic + aerobic treatment
Low TDS, low BOD and low BOD & COD difference	Low organic and low inorganic effluent	<ul style="list-style-type: none"> ▪ Recycle and reuse (after preliminary treatment)

✧ Here TDS represents for Total Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water.

✧ COD represents for chemical oxygen demand (COD) is the amount of oxygen consumed when the water sample is chemically oxidized.

- ✧ BOD represents for biochemical oxygen demand represents the amount of dissolved oxygen (DO) consumed by biological organisms when they decompose organic matter in water.

8. FINDINGS OF STUDY

The following study finds,

- You should have basic knowledge of both ETP plant and lean manufacturing concept to integrate them.
- Advanced technology can be applied but it is not necessarily for small scale of manufacturing units it could be on the particular ETP plant and its circumstances.
- Without advanced technology also ETP plant can be operated but basic standard and operating procedures should be followed.
- Different ratio of chemical should be used as per the treatment needed.
- By applying different lean manufacturing tool to assist the ETP operations should be implied in such a way that it could be used to its optimum level.
- A person having at least basic knowledge about ETP plant and lean manufacturing concept to work upon it. (Avoid use of unskilled worker without taking care of cost).
- All the government rules, regulations and norms should strictly be followed by small scale of manufacturing units because somewhere it's concerned with environment and society.
- With regards to ETP operations units should be careful to its financial resources, upgradation of technology as per need, standard operating procedures and chemical contains should be strictly used in proper way.

9. LIMITATIONS OF STUDY

- Here only 113 respondents can be lesser to more result oriented study.
- As purposeful sampling is used in research to collect the responses it may happen that respondents are having biased response to questionnaire.
- Different geographical condition can be for different setup of ETP plant to different manufacturing industry as per their convenience that is not considered into study.
- For different scale of ETP plant there can be different results for the study but basics will remain same.
- Factors beyond the researcher's control, such as changes in regulations or economic conditions, may influence the study outcomes.
- Ethical constraints such as confidentiality or privacy concerns may restrict the type or scope of data collected.
- Findings from the study may not be applicable to all small-scale manufacturing units or may not generalize to other contexts beyond the study population.

10. SUGGESTIONS TO STUDY

- Ensure the sample size is sufficient to provide meaningful insights and statistical power.
- Collaborate with industry partners to gain access to real-world data and insights.
- Incorporate stakeholder perspectives through interviews or focus groups to capture diverse viewpoints.
- Explore case studies of successful Lean-ETP integration initiatives to identify best practices and lessons learned.
- Address skill gaps through training initiatives and establish partnerships with academic institutions for research support.
- Different tools and techniques suggested in study can become individual topic to be studied.
- Different countries annual report can be compared as following study only contains Indian government report to analyze.
- More quantitative and statical tool along with life cycle assessment (LCA) can be used for in depth analysis for the future studies related to this kind of topic.

11. REFERENCES

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- https://en.wikipedia.org/wiki/Lean_manufacturing
- [2012, The McGraw-Hill Companies] 5th edition of book “water treatment plant design” The term "lean manufacturing" describes an approach that applies and minimizes waste.

