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Water Footprint Analysis of Ceramic Tiles Industry

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Abstract: The term "water footprint" refers to a full picture of the amount of water utilized in the extraction, production, and disposal stages of a product's lifespan. . Due to the nature of its manufacturing methods, which need the use of water at several stages, including shaping, drying, and glazing, the tiles business is recognized for being water-intensive. By carrying out a thorough water footprint analysis of the tile sector, namely in the Morbi area. this study will offer insightful information and support the tiles industry's sustainable growth, guaranteeing its long-term survival and reducing its influence on Morbi Center's water resources.

Keywords: Water Footprint, Morbi, Tiles Industries, Waste Water, Rate of Consumption of Water, Water Audit

I. INTRODUCTION

One of the biggest worldwide users of water resources is the tile industry. In light of growing worries about environmental sustainability and water shortages, it is critical to evaluate and examine the tile industry's water footprint in order to comprehend its environmental impact. In the tile industry, "water footprint analysis" refers to a thorough evaluation of the overall amount of freshwater used during production, both directly and indirectly. Water utilized in the manufacture, transportation, and disposal of waste products related to tile manufacturing are all included in this analysis. A number of factors are usually taken into account in the analysis, such as the wastewater produced during the production process, the freshwater consumption per unit of tile produced, and the water sources utilized by tile makers. To completely evaluate the water footprint, it also considers the whole supply chain, from the extraction of raw materials to the distribution of the finished product. To sum up, the introduction of water footprint analysis for the research work in the tile industry seeks to give a thorough grasp of the water consumption of the sector and its effects on the environment. Researchers may help establish sustainable practices and policies in the tile business by measuring and analysing the water footprint.

II. STUDY AREA

The Morbi Ceramic Zone is located in the Morbi district of Gujarat, India and is one of the largest ceramic manufacturing hubs in the country. The ceramic zone Morbi is known for its production of various types of ceramic products such as tiles, sanitary ware, and tableware. Here the study area is for ceramic and vitrified tiles production in Morbi region. The second largest ceramic manufacturing group in the world, Morbi produces 70% of the ceramics made in India. There are more than 1000 units of ceramic factories in the city. Some details of Morbi Ceramic Tiles Industries give in Table : 1.

Table: 1 Morbi Ceramic Industry at a Glance

Details	Data
Number of factories	800+ within the zone, 650+ in border region
Share of India's Ceramic Tiles Production	~70%
Share of India's sanitary ware production	~85%
Annual revenue	INR 40,000 corers (USD 5 Billion)
Direct and indirect employment	Over 5 lakh (5,00,000) people
Annual production capacity of Tiles factory	Over 300 Million square meters
Annual ceramic Tiles exports	INR 10,000 corers (USD 1.25 Billion)

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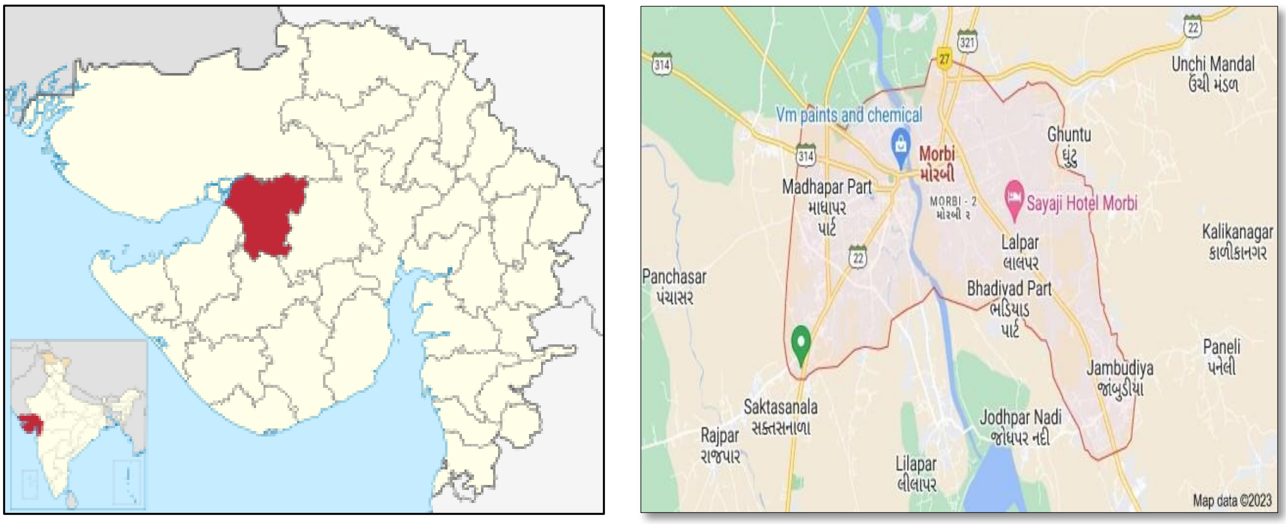

Fig. 1 Study Area Map

III. DATA COLLECTION

Quantifying the water footprint of the glazed/vitrified tiles industry which is located in Morbi district, including the blue, green, and grey water components, involves a comprehensive assessment of water use at different stages of the production process. First, compile information on the primary water supply in each of the factories. Gather data regarding the amount of water used in the several steps of production, such as blending (raw material mixing), moulding, drying, glazing, and burning(firing). Reach out to tile production facilities and gather the necessary information. For collection of data preparing the sample survey and analyze it then after doing final survey in which necessary data can be collected and further work will done on basis of it. Below Table 2 shows the sample survey of one of the ceramic tiles industry at Morbi.

Table : 2 Sample Survey of Industry

QUESTION	ANSWER
Total water consumption	2400 ltr per day
Total water consumption	Bore well
Primary water sources	Ground water , Municipal water
Water consumption during manufacturing processes	Mixing, shaping , glazing
Primary raw materials used in tile production	Zink , china clay , ink , frit
Volume of wastewater generated	10%
Efforts to reduce the water footprint, such as process improvements or wastewater reuse	Waste water reuse

Here to collect the more data of the various factories the secondary survey of the tiles manufacturing factory is arranged. Average value of the collected data shown in below Table :3, because large amount of industries surveyed for this research work. General over view, stake holder interviews and get information about water consumption in manufacturing stage were used to collect primary data. In secondary data collect the information about daily production of that unit (in box) , size of the tiles (in mm) , manufacturing process like raw material mixing , firing, glazing , sizing and total volume of water consumption in particular stage . Then collect the data of water reuse in that factory on the basis of it water footprint can be calculated Data of firing temperature , clay content which is use in raw material and also collect the data of main source of the water in that unit.

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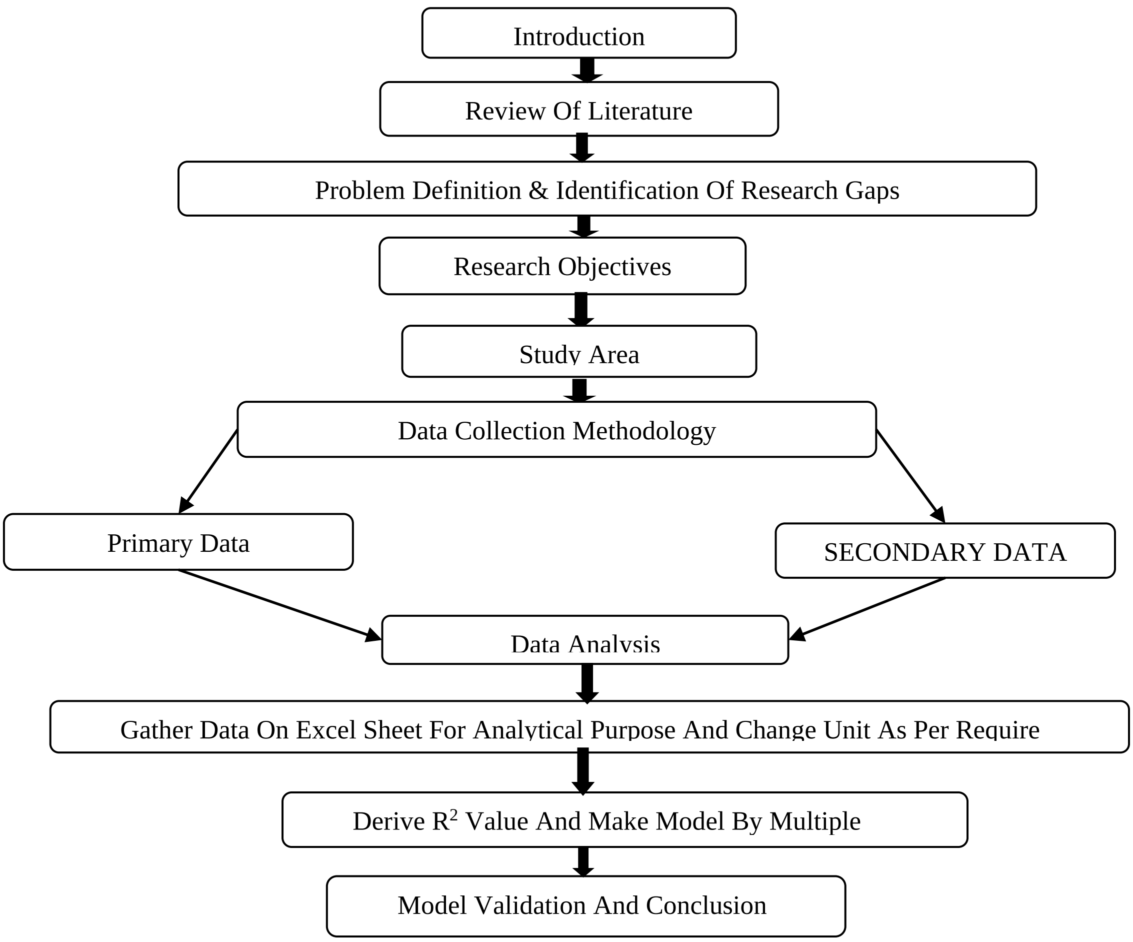
Table : 3 Avg. Value of Secondary Survey

Daily production	18, 000 box					
Process	Water Consumption	Unit Produced	Total Water Consmption			
Material Processing	630 lit/ ton	312 ton	1,46,000 liter			
Glazing	2.7 lit/ sq m	20,000 sq m	34,000 liter			
Sizing	2.1 lit/unit	36000 unit	48,000 liter			
Total Water			2,29,000 liter			
Water Reuse			76,000 liter			
Total Water Footprint			1,52,000 liter			
Raw Material Wastage	3%					
Firing Temperature	1150 *C					
Clay Content	53%					
water Reuse technology	ETP					
source of Water	GW	60%	Canal	35%	Rain	5%

IV. METHODOLOGY

MORE DATA COLLECTED OF TILES INDUSTRIES WHICH IS LOCATED IN MORBI REGION. IT WILL BE REANALYZED USING APPROPRIATE STATISTICAL METHODS TO ESTIMATE THE WATER FOOTPRINT, IDENTIFY POTENTIAL AREAS FOR IMPROVEMENT, AND PROPOSE STRATEGIES TO REDUCE THE WATER FOOTPRINT.



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V ANALYTICAL PART

Industry no.	Stage 1 Water Consumption per Square Meter	Stage 2 Water Consumption per Square Meter	Stage3 Water Consumption per Square Meter	Water Footprint per Sq. M.	Sustainability Index base on Rain Water	Sustainability Index base on Ground Water
	Independent Variable 1 **M**	Independent Variable 2 **G**	Independent Variable 3 **S**	Dependent Variable **WF**	Index 1	Index 2
1	2.520512	0.608399	1.216799	2.781254	1	3
2	0	0.631313	0.315657	0.094697	1	2
3	5.234506	1.221385	1.395868	4.711055	1	2
4	1.527051	0.21815	0.4363	1.527051	1	5
5	0.086207	0.064655	0.064655	0.12931	1	3
6	9.478673	0	1.895735	11.30111	1	2
7	18.09325	4.175365	5.567154	18.09325	1	3
8	62.5	26.78571	44.64286	98.21429	1	3
9	9.638554	3.212851	1.606426	13.65462	3	5
10	4	1	2	6.3	1	5
	AVG.	AVG.	AVG.	AVG.		
	10.49412	2.220842	3.553243	11.40998		
	STDEV	STDEV	STDEV	STDEV		
	9.67756	2.96711	4.840491	12.47874		
	CORREL WITH W.F.	CORREL WITH W.F.	CORREL WITH W.F.	CORREL WITH W.F.		
	0.940548	0.827717	0.85937	1		

Stage 1 Water Consumption per Square Meter = Water consumption in material processing per square meter (per day calculation)

Stage 2 Water Consumption per Square Meter = Water consumption in Glazing unit per square meter

Stage 3 Water Consumption per Square Meter = Water consumption in Sizing unit per square meter

Above avg. Value and Stand deviation value is for all collected data of industries.

1 to 10 are sample data of the industries for analytical purpose.

In analytical part category of the industry shown , understanding of condition of categorise the industry as per Table : 4.

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Table : 4 Categorization Scale

Category	Description	Rationale
5	**Predominantly Reliant on Renewable sources** : > 80% rain water and surface water , < 20% ground water	Priorities sustainable water sources,minimizing dependence on finite groundwater reserves .
4	**Balanced and sustainble:** 50-80% rain water and surface water , 20-50% ground water	Utilizes a significant amount of renewable sources while acknowledging the possibility of needing some ground water .
3	**Moderately sustainble :** 20-50% ain water and surface water , 50-80% ground water	Uses some renewable sources but relies more heavily on ground water , requring improvement .
2	**Limited use of Renewable sources :** <20 % rain water and surface water , >80 % ground water	Primarily reliant on ground water , raising sustainbility concern and potential long - term water security risks.
1	**Minimal to No use of Renewable sources :** Negligible or no rain water and surface water use , almost entirely dependent on ground water	Least sustainbility practice putting significat strain on ground resources .

Regression analysis :

The collected data from multiple production unit with various firing temperature, clay content, water consumption in various stage of manufacturing process. We'll use linear regression, which assumes a straight line relationship between the water footprint and independent variable (water consumption in stage 1 – raw material mixing process M) in Image 1.

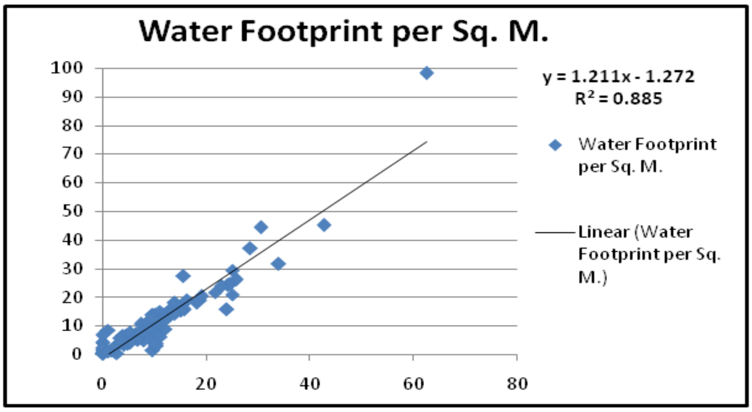

Image : 1 Linear Regression

Dependent variable (Y): Water consumption in raw material mixing process(M).

Independent variable (X): Water footprint (WF).. This is used to predict or explain the variation in water consumption during the mixing process. It quantifies how a unit change in water footprint is associated with change in water consumption during raw material mixing. Strong linear relationship the regression line will have a significant slope, indicating how much water consumption changes for each unit change in water footprint.

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Multiple Linear Regression :

Model: WF = 0.86M +0.3G + 0.78S – 1.08

WF – Water Footprint per square meter

M – Water consumption in raw material mixing per square meter

G – Water consumption in glazing per square meter

S – Water consumption in sizing per square meter

Model is in form of: $\beta0 + \beta1x1 + \beta2x2 + \beta3x3$

VI RESULT AND DISCUSSION

Table : 5 Summary of overall fit

R squared	r2 = 0.95
Adjusted R-Squared	$r^2adj = 0.95$
Residual standard error	2.88 on 98 degrees of freedom.
Overall F statistics	601.02 on 3 and 98 degrees of freedom
overall p-value	0

The correlation coefficient (R) is equal to 0.98, indicating a significant connection between the observed and predicted data. The adjusted R square is equal to 0.95, indicating that the predictors (Xi) account for 94.8% of the variance of Y. It means that there is very strong correlation between the predicted data and observed data. Result of multiple linear regression indicates that there was a very strong collective significant effect between the M, G, S, and WF, ($p <$ 0.001, $R^2 = 0.95$, $R^2_{adj} = 0.95$).

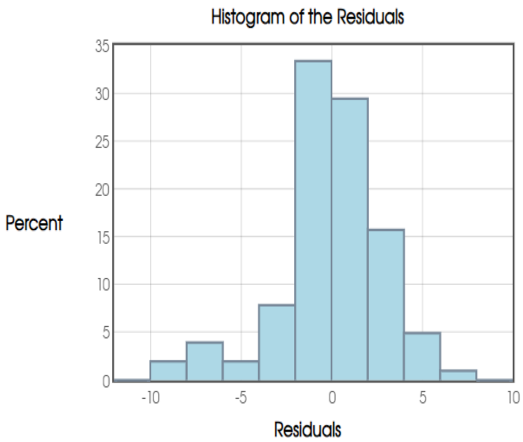

Image : 2 Histogram of Residual

Validate the model for collected data in MATLAB show the error in between +2 and -2 which is shown in Image 3 which is very permissible in limit.

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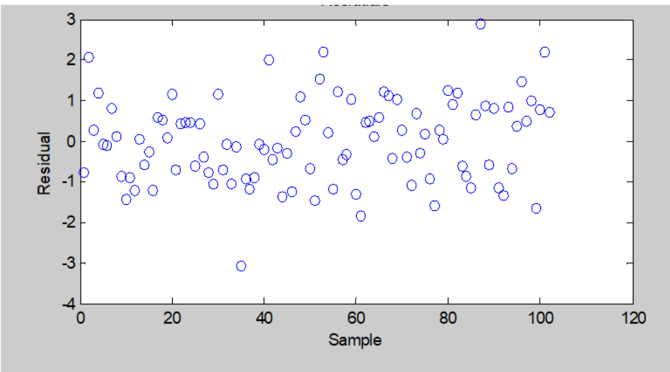

Image : 3 Data Validation

VII CONCLUSION

The robust goodness of fit of the model is indicated by the adjusted R-squared value of 0.95, which indicates that it is not significantly impacted by outliers or irrelevant predictors. Strong correlations between the predictors are confirmed by the correlation matrix, which shows correlation coefficients ranging from roughly 0.71 to 0.94. The model has a symmetrical distribution around the median and a comparatively small residual standard error of 2.88, according to the residuals analysis. This indicates that most residuals lie within the interquartile range, indicating that the model's predictions are generally close to the actual values. Overall, based on the provided predictors, the resulting regression equation and model show a high degree of accuracy in forecasting the water footprint. This conclusion, which shows the model's suitability for real-world applications, is backed by both statistical measurements and graphical confirmation. The study proposes a multiple regression model for estimating Water Footprint for Ceramic Industry. The model suggest that since the manufacturing process consumes the most amount of water and, Highlighting the need for activity optimization during this process. This shall help immense in reducing water usage. Moreover, the sizing process also utilizes considerable water, this for emphasizes the need for reduction in water usage during this process.

RECOMMENDATION

- The actual water footprint can vary depending on factors like the type of ceramic product, production methods and water efficiency of the facilities. Ceramic manufacturing can significantly impact water resources in water-stressed regions. Implementing water conservation measures like rainwater harvesting, recycling waste water, and using low-water glazes can considerably reduce the water footprint.

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