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RESEARCH PAPER

Impact of Kiln Operation on Smog Duration (Production): A Case Study of Traditional Manual Red Brick Kilns of North Sindh Pakistan

[1]Siraj Narejo, [2]Amir Mustafa, [3]Umair Rajput

1. Assistant Professor (Economics), Government Degree Science College, Gambat, Sindh, Pakistan
2. Program Manager, Innovative Growth Solutions
3. PMAS Arid Agriculture University, Rawalpindi, Punjab, Pakistan

***Corresponding Author:** amirmustafa@gmail.com

ABSTRACT

This research paper's main objective is to determine if smog duration (thus production) increases or decreases (in vicinity) with kiln operation . Smog is air pollution. It is social cost and negative externality. Smog appears usually at the time of 3am to 5am and lasts usually up to 2pm to 4 pm in target area of North Sindh. Its duration is between 9 hours to 13 hours. It starts in the month of November and lasts up to February. Smog starts in Punjab and later appears in North Sindh. Sample of 90 kilns is used but only 54 of these operate in winter. Purposive sampling is used. In the regression model *'total smog hours'* is the Y variable and x variables are winter work day length, brick dry time, quantity of water used, fuel type, quantity of fuel burnt and total winter production. *Winter day length* ranges between 8 to 10 hours. On average it is 08 hours. Usually 600 liters of *water* are required for 1000 brick making. Mainly five types of fuel is used at kilns i.e. *tootar*, *furt*, *bakas*, local firewood and dung. It usually takes longer for bricks in winter to dry because of small days with less intensity of sun. It means more water vapors in air. Many model variables are insignificant. Only variables having any significant impact on the smog production are *winter day length (at brick kilns) and brick dry time (in winter).* Y Intercept tells that if all variables are zero there will be decrease of 227 smog hours near that kiln. Error term is ±75.2 hours. It is recommended for the authorities that Smog is somehow caused by kilns. It is question of further cautious research to implement rules.

KEYWORDS Smog, Winter, Kiln Activity, Red Brick, North Sindh, Sindh, Pakistan

Introduction

Smog is air pollution. It is social cost and negative externality. Smog appears usually at the time of 3am to 5am and lasts usually up to 2pm to 4 pm in target area of North Sindh. Its duration is between 9 hours to 13 hours. It starts in the month of November and lasts up to February. Smog starts in Punjab and later appears in North Sindh.

Some experts say that smoke is the cause of smog in winter season. Kilns use fuel, water, air , etc. Smog is caused by specific particulate matter. If further analysis is done it can determine physical and chemical constituents that cause this pollution. This research paper's main research question is to determine impact of kiln operation on smog. If smog increases or decreases with kiln operation, it is the objective of research to find answer to this.

Sample of 90 kilns is used but only 54 of these operate in winter. Purposive sampling is used. Demographically there is no North Sindh officially. It is for the convenience that such demographic distribution is used here in this research. There are many districts of the North Sindh. But for this research only three districts are chosen i.e. Khairpur, Sukkur, and Larkana. North Sindh traditional kilns are divided into three categories by scholar based on production level , infrastructure, land area and annual operating time i.e. small, medium and large kilns. Production of average bricks is 230429, 2465477 and 7147059 bricks for small, medium and large kilns respectively. Large kilns can produce 15 Million bricks in a year.

Average acreage is 1, 3.5 and 5.5 acres for small, medium and large kilns. On the average there are 21, 49 and 108 laborers at small, medium and large kilns respectively. small kilns don't produce bricks in winter season as it is difficult to dry and demand is also low. Net profit is 281808, 3647403 and 14908971 Rs for small, medium and large kilns as calculated in income statement.

In the model "smog hours" is the Y variable. Smog appears usually at the time of 3am to 5am and lasts usually up to 2pm to 4 pm. Its duration is between 9 hours to 13 hours. It starts in the month of November and lasts up to February. This may be for 2 to 4 months. Smog starts in Punjab and later appears in North Sindh. Winter day length ranges between 8 to 10 hours. On average it is 08 hours. Usually 600 liters of water are required for 1000 brick making. Mainly five types of fuel are used at kilns i.e*tootar, furt, bakas,* local firewood and dung. Fuel quantity used, bricks dried during winter, brick dry time are also variables in smog model. It usually takes longer for bricks in winter to dry because of small days with less intensity of sun. It means more water vapors in air.

Literature Review

The air pollution from kilns are CO_2, SO_2, CO, NO_x, and SPM (Suspended Particulate Matter). (Palash Patra et al., 2015). GHG emitted due to burning of kiln fuel include CO2, CO, CH4, N2O, NO and NOX (Alam & Starr, 2009).

Emissions from kilns can be quantified. They used three tier assessments to check level of pollutants sent in the air by kilns i.e.(Kaleemullah sheikh , 2020). They used AERMOD model.

- Pollution from kiln stacking
- Pollution from ground level dispersions
- The health risks (short term and long term) due to emissions.

Emissions are classified as 3 carcinogenic and 2 non-carcinogenic.

According to them (SeshanandaSanjel et all, 2016) there are five types of pollutions by kilns which affect human health i.e. COX, NOX, Hydrocarbons, Sulfur dioxide and dust.

SOx are oxides of ulphur consist of SO 2 and SO3. Coal burning cause 74% of SOx pollution. Rubber is burnt initially to start burning process at kiln. NOxare caused by burning fuel in the air. It is derived through Nitrogen oxidation. It has role in ozone formation too. NOx in air causes creation of O3 by sun radiation. Kilns are route cause for the precursor gases for the Ozone formation. (Seshananda Sanjel , 2016)

SPM (suspended particulate matter): These are liquid or solid particles spread in air due to fuel burning at kilns. size is less than 100 µm. It is dust of coal etc. produced by incomplete combustion. These fine dust etc particles remain in air for hours. (Seshananda Sanjel , 2016). Increase in kiln quantity has affected visibility in winter days. PM_{10} and TSP (Total suspended Particles) can enter lungs at kilns. labour is affected.

Table 1
air pollution values (mg/m^3) (SeshanandaSanjel et all, 2016)

	Pre kiln operation	Kiln operation period
PM10	0.029	0.05
TSP	0.033	0.056

Dust weight from kilns(Ismail et al) has shown 23.8 to 46.0 g/m2/month at 50 m distance from the operating kiln. cadmium and chromium are heavy elements inside dust samples. These are added at a rate of 0.08 and 0.52 g / m 2 /m onth respectively.

According to estimation the annual Naples emissions in the form of PM, CO, NOx and SOx are 80, 30, 7, and 5 tons respectively. (SeshanandaSanjel et all, 2016)

Kiln emissions affect crops (conifers) more in summer and spring than winter. (Bhat MohedSikander , 2013)

Solution for air pollution is to use VSBK technology to decrease open burning of the bricks. Use of high sulphur coal should not be used at the kilns. Calcium carbonate or Calcium Hydroxide can be used to desulphurise the coal. (Rizwan Khan , 2007)

Hypotheses

Hypothesis testing at aggregate level : Regression models overall significance is tested.

$H_{0:}$ Kiln operation has no impact on smog

$H_{1:}$ Kiln operation has impact on smog

Hypothesis testing At individual level:If significance level is less than 0.05 H0 (Null Hypothesis) will be accepted

H1: Winter work day length has sufficient impact on Total smog hours
H2: Brick dry time has sufficient impact on Total smog hours
H3: Quantity of water used has sufficient impact on Total smog hours
H4: Fuel type (burnt at kiln) has sufficient impact on Total smog hours
H5: Quantity of fuel burnt has sufficient impact on Total smog hours
H6: Total winter brick production has sufficient impact on Total smog hours

Material and Methods

After severe smog it was the need of the time to check relation between smog hours and kiln activities. Nature of research is applied, restricted to target area and distributed through three years of doctoral thesis process. Population includes 90 kilns of North Sindh. It is sample size. Sampling is nonrandom purposive sampling with focus on the target districts.Data is primary and collected by survey of the 90 kilns. But data is incorporated in model from only those kilns that produce bricks in the winter. Instruments of research include survey, interviews based on questionnaire form. Results are valid / reliable with literature and overall doctoral thesis results. Data analysis techniques used are regression, ANOVA with hypothesis testing. SPSS statistical software is used. Model is simple multiple linear regression. Y variable is “Total smog hours”, and x variables are winter work day length, brick dry time, quantity of water used, fuel type, quantity of fuel burnt and total winter production. Small kilns operate only few specific summer months of the year because of the unavailability of the labour and less demand in the winter. On average small kilns remain active 5.8 months, medium kilns for 8.3 months and large kilns for 9.8 months. Overall 8.5 months activity (average) for all 90 kilns

Total Smog Hours: it is dependent variable. Smog appears usually at the time of 3am to 5am and lasts usually up to 2pm to 4 pm. It is asked in questionnaire form.

Winter work day length: It is asked in the questionnaire form from kiln management (*Munshi*). It usually ranges between 8 to 10 hours.

Quantity of Water Used: It is asked in the questionnaire form. Usually 600 litres of water are required for 1000 brick making.It usually takes longer for bricks in winter to dry because of small days with less intensity of sun. it means more water vapours in air.

Fuel type used: It is asked in the questionnaire form.It is to see impact of volume burning on the smog. Following types of ordinary and special fuels are used,

Table 2
types of ordinary and special fuels

Fuel	Fuel description
Normal	Fire wood (date palm branches and leaves, cotton wood, etc) (for small kilns)
Normal	*Dung* or manure or *Shena**
Normal	Waste (Rubber, plastic shoes etc)
Normal	*Tootar* (*of rice*)*
Normal	*Furt** (types : mustard /Rai and chickpea/channa)
Normal	*Bakas** (sugarcane residual from mill)
Normal	Coal
Normal	*Booro**
Special	Hard wood of *Devi/Sheesham/Tari/date palm*

**Shena, Tootar, Furt ,Booro and bakas* are local terms used for different types of fuel. Special fuel types used are Hard wood of Tari/Sheesham, Babur/Acacia , Devi /English Acacia and Date palm trunks. Special fuel is used to ignite/start burning of bricks at kilns.

Fuel Quantity: It is asked in the questionnaire form in *Maunds*.

Bricks produced in winter: It is asked in the questionnaire form.

Brick Dry Time in winter: It usually takes longer for bricks in winter to dry because of small days with less intensity of sun.

Regression Model (smog/externality/ social cost Model): Purposive sampling is used. In the regression model *'total smog hours'* is the Y variable and x variables are winter work day length, brick dry time, quantity of water used, fuel type, quantity of fuel burnt and total winter production. Regression is performed in SPSS. Following regression equation is formed.

$$Y=a+ \beta_1X_1+ \beta_2X_2+ \beta_3X_3+ \beta_4X_4+ \beta_5X_5+ \beta_6X_6\pm U$$

Regression models overall significance is tested as,

H_0: $\beta_1 = 0,....B_7 = 0$ (i.e. there is no relation between x and y variables at all)

H_1: $\neq 0$ (It means at least one of the independent variables shows a relation with dependent variable.)

H_0: Kiln operation has no impact on smog

H_1: Kiln operation has impact on smog

Hypotheses tested at individual level are,

H1: Winter work day length has sufficient impact on Total smog hours

H2: Brick dry time has sufficient impact on Total smog hours

H3: Quantity of water used has sufficient impact on Total smog hours

H4: Fuel type (burnt at kiln) has sufficient impact on Total smog hours

H5: Quantity of fuel burnt has sufficient impact on Total smog hours

H6: Total winter brick production has sufficient impact on Total smog hours

Results and Discussion

Smog duration is between 9 hours to 13 hours. It starts in the month of November and lasts upto February. This may be for 2 to 4 months. Smog starts in Punjab and later appears in North Sindh. 22% said smog lasted for 1 month. 77 % said it lasted for 2 month, 1% said it lasted for 1.5months.

Kilns are close for business on all Fridays. On other days kilns operate. Their working day starts very early in summer and late in winter. Mostly kilns are operated or active throughout the year except for peak winter months because of shorter day time and low demand of bricks.Winter period is between (October to March) (Elagib& Mansell, 2000). On average it is 08 hours.

Increase in kiln quantity has affected visibility in winter days. In winter relatively less bricks are made due to small day time and less availability of sunlight to dry bricks. This is why small kilns dont operate in winter.

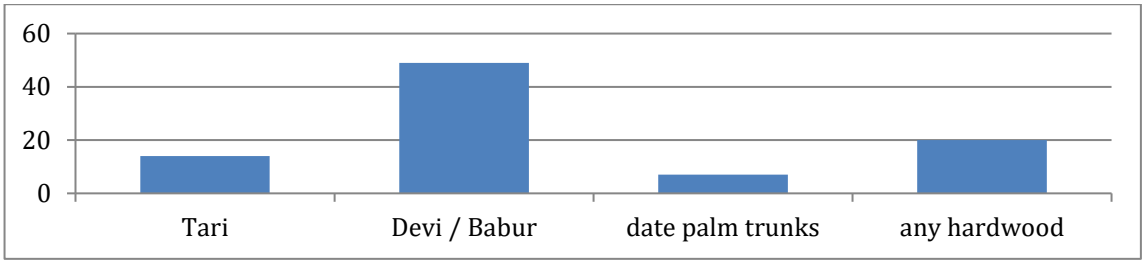

Figure 1: Special fuel types used at kiln

Following is the relationship between fuel type and Bhelli bricks production.

Table 3
Fuel relation with waste bricks

Fuel	% Bricks wasted
Tootar	11.06
Bakas	11.9
Furt	12.01
local wood	12.63
Dung	16.08

Table 4
Fuel Quantity

			Small kiln		
	average EOQ		**average order size**	**increase or decrease**	**total annual demand**
fuel	2195.935	54.89838	41.07143	increase order	830.3571
			Medium Kiln		
	Average EOQ		average order	increase or decrease	Total annual demand
fuel	59655.68	1491.392	313.3333	increase	11500
			Large kiln		
	EOQ average		average order	increase or decrease	total annual demand
fuel	154796.7	3869.91	335.8824	increase	35988.24

ROP (Re order point)for fuel is 22, 196 and 470 *maunds* for small, medium and large kilns respectively.

EOQ (Economic Order Quantity) for fuel is 55, 1491 and 3869 *maunds* for small, medium and large kilns respectively.

Table 5
winter kilns producing *chakars*

Item	Khairpur	Larkana	Sukkur
Average chakars	9.363636364	4.4	12.71428571
winter production Kilns	38	5	11

Table 6
Summer and winter production

Summer production		Winter Production	
Chakars	Average production	chakars	average production
2 to 5	1594911	0	0
6 to 10	3060000	1	374464.3
11 to 15	5420833	2	341071.4
15 to 20	7590000	3	300000
		4	423888.9
		6	400000

Table 7
Brick Dry Time in winter

Steps (Days)	Large kiln	Medium kiln	Small kiln
stacking to dry	0.25	0.25	0.25
average dry time (winter, summer)	5.5	5.5	5.5

In winter bricks dry in between 7-10 days before put into fire. It takes 1-3 days in summer. In average it takes 15-20 % of the total operating cycle.

Table 8
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.859[a]	.738	.704	75.25660

a. Predictors: (Constant), FuelType, WinDayLength, WinBrickSryTime, WaterQused, FuelMaunds, WinBricksProduced

Table 9
ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	749146.187	6	124857.698	22.046	.000[b]
	Residual	266187.146	47	5663.556		
	Total	1015333.333	53			

a. Dependent Variable: SmogHours
b. Predictors: (Constant), FuelType, WinDayLength, WinBrickSryTime, WaterQused, Fuel Maunds, WinBricksProduced

Table 10
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-227.981	97.169		-2.346	.023
	WinDayLength	83.602	11.583	.619	7.218	.000
	WinBrickDryTime	10.637	1.902	.501	5.594	.000
	WaterQused	-.002	.003	-.081	-.926	.359
	FuelMaunds	.001	.006	.025	.180	.858
	WinBricksProduced	-16.037	42.250	-.055	-.380	.706
	FuelType	-2.431	6.320	-.030	-.385	.702

a. Dependent Variable: SmogHours

Equation formed is

$$Y=-227.981+ 0.619X_1+ 0.501X_2-0.081X_3+ 0.025X_4-0.055X_5- 0.030X_6\pm75.2$$

Many model variables are insignificant. Only variables having any significant impact on the smog production are winter day length (at brick kiln) and brick drytime (in winter). Y Intercept tell If all variables are zero there will be decrease of 227 smog hours near that kiln. Smog is caused by kiln activity.

Conclusion

Research question is about heavy Smog appearance around the kilns combined with crop production decrease. Average distance of a kiln from village is between 150-820. There is usually inverse relation between quantity of kilns around a village and distance of kiln from that village.. There are 1-10 kilns around a village. Only 25% prefer to live near kilns. There are 30-30k houses in villages/town near a kiln. Kiln waste is in the form of *carry*, roro, wood, dust, ash, etc, and is usually dumped / spread in locality. In summer wind flows from South. Most of the houses are affected. In winter wind flows from North. In winter the process of falling of ash/dust is slow. Problems caused by the kilns for the people who live nearby are smog, Dog problem, Asthma, TB, Headache, Heat stroke, Kidney stone and Dust allergy. 77% said that smog lasted for 2 months. Only 55 kilns have trees inside.

Recommendation

It is functioning or operating of a brick kiln that causes air pollution in form of smog. Pollution (smoke from Chimney) in the air due to brick manufacturing includes sulphur oxide, nitrogen dioxide, carbon monoxide and CO_2. Smog is associated with the production of smoke by kilns. Black carbon is prominent particulate form of pollution. Smoke from chimneys causes breathing problems to villagers living near working kilns. Usually coal is used to fire these chimneys. New Zig Zag technology can be used to counter smog problem by decreasing the usage of coal. Punjab is severally affected by smog problem that's why clean air commission is being made to protect Punjab cities from this particulate pollution.

Solution for air pollution is to use VSBK technology to decrease open burning of the bricks. Use of high sulphur coal should not be used at the kilns. Calcium carbonate or Calcium Hydroxide can be used to desulphurise the coal. (Rizwan Khan et al., 2007)

It is recommended for the authorities that Smog is somehow caused by kilns. It is question of further cautious research to implement rules.

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