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USING REGRESSION MODELS IN ANALYSING HIGHWAY STORMWATER LOADS OF SELECTED AREAS IN ILORIN METROPOLIS

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ABSTRACT: *The concentrations of inorganic and organic substances (biochemical oxygen demand, chemical oxygen demand), cations (Pb^{2+}, Fe^{2+}, Cu^{2+}, Mn^{2+}), anions (NO_3^-, PO_4^{3-}) and physical analysis (Total suspended solids, oil and grease and pH), were determined in storm water runoff collected from selected areas in Ilorin metropolis. The samples were taken between April to July 2004 and the analysis was done using Hellige comparator and ultra violet-visible spectrophotometer. Regression analysis model was carried out on each concentration of storm water runoff loads in relation to vehicle; some of the variables such as chemical oxygen demand, iron, manganese, oil and grease showed dependence on vehicular counts. The others including nitrate, pH, total suspended solid, lead, phosphate and biochemical oxygen demand were not dependent on vehicular counts*.

KEYWORDS: Regression models, storm water, Ilorin metropolis

INTRODUCTION

Storm water is the most significant non point source of water pollution in most places. The runoff from rainfall and melting snow impairs transportation, farming and other land-use activities therefore; storm water is drained from the land as quickly as possible via ditches and pipes (Ferguson, 1998). This leads to flushing of different materials into streams, lakes and oceans: sediments, oil, fertilizer and pesticide residues, as well as organic residues from vegetation, animal droppings and garbage (Marsh, 1996). The rise of urban storm water pollution more or less parallels the development of automobiles industry. In the past ninety years, the number of automobiles in the world has grown from a few thousand to more than five hundred million. In some well developed countries such as United States and Britain there are now more than a million miles of paved roads and countless acres of parking lots, driveways, garages and other hard surfaces for automobiles (Grossa, 1996). In addition, to improve road safety in northern cities (United States, United Kingdom) salt was used to deice roads and this becomes part of the storm water pollution load; the salt content in expressway drains during spring runoff may be a hundred levels in fresh water. Unfortunately, it remains standard engineering practice to release contaminated storm water directly to streams as the quickest and cheapest way out (Malina et al, 1998).

In Nigeria, storm water runoff that arises causes a lot of wear out on the streets which leads to erosion problems and if the storm water runoff is not channelled into stream it causes obstruction and traffic jam for automobiles in some urban and rural areas in Nigeria, such as Lagos, Adamawa and Ilorin metropolis (Oyebande, 1990). To solve all the problems of storm water, storm water quality modelling is used to analyse and provide insight into the control of non point source storm water constituents (Oyebande, 1990). Most common types of storm water predictive method include regression models and determinate simulation models. The primary difference among the models is the philosophy regarding the origin of constituent in the storm water runoff (Youg et al., 1996). Although, regression models has been used to carry out analysis of storm water in the past, it has been criticized as being poor predictors when applied beyond the original data set or region from which they were developed (Driscoll et al, 1990); however this statement is universally true of all water quality modelling methods.

Storm water loads are problems which need immediate solution, so continuous efforts directed by common sense and experience can be applied to reduce the resulting problems. It is desired to seek appropriate solutions to the problem and identify the processes that affect runoff loads and analyze the constituents in the storm water loads.

The study seeks to answer the question of how traffic counts affects the storm water runoff loads which includes: total suspended solids; chemical oxygen demand, phosphate, nitrate, pH, biochemical oxygen demand, lead, iron, manganese, oil and grease and also to know how regression analysis can be used to analyse the runoff loads. There is also the need to know the problems caused by vehicles on storm water loads and how it could be controlled. The output of the model is the estimated constituent load at the edge of the pavement. The study is restricted to four areas in Ilorin metropolis, Kwara State. The locations are Taiwo, Unity, Post Office and Fate Road which is used as control area (all are randomly selected within Ilorin).

METHODOLOGY

Site Description and Photographs

Taiwo Road [T-20 site 1]: This area is one of the busiest routes in Ilorin. The water sample was collected from the pot hole close to an automobile garage on Taiwo Road, where a petrol station is situated nearby.

[T-20 site 1]

Unity Road [U-20 site 2]: This is predominantly business organization environment, but there is a presence of a metal work outfit and mechanic workshop close to the Unity bridge where welding and spilling of engine oil by the mechanics is done.

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[U-20 site 2]

Post – office Road [PO-20 site 3]: This area is situated along one of the major roads on Ilorin, thus there is high vehicular counts. There is also a petrol station nearby.

[PO-20 site 3]

Fate Road [F-20 site 4]: This area is situated between Tanke and Basin road and thus, the area has low vehicular count. The water samples were taken from a pot-hole in front of University staff quarters, Fate road.

[F-20 site 4]

Sample Collection and Preservation

The storm water samples were collected into two litre clean bottles. For the biochemical oxygen demand determination the samples was put inside into pre-sterilized bottles and aluminium foil was used to air tight the bottles to avoid temperature changes. Also chlorinated water and potassium iodide are the reagents that were used to sterilize the glass stopper bottles so as to prevent microbial activities and the storm water samples are incubated at 20^{o}C for five days. The samples were collected during the rainfall. The date of sampling, the time of sampling and the number of vehicles per five minutes was recorded during each collection. The storm water sampling analysis was carried out thirteen times to actually know the difference in variations of each storm water runoff loads and also how the rate of vehicles moving on the highway affects the runoff flow.

Research Instrument and Analysis

Instrument that was used in carrying out the analysis are: the electric pH meter for pH; Hellige turbid meter (NTU) for turbidity; Lovibond comparator 2000 colour disc (Hazen) for colour; thermometer for temperature; ultra violet-visible spectrophotometer and Hellige comparator for metal and non-metal were used using the appropriate powder pillow, colour disc and wavelength; titrimetric method for biochemical oxygen demand and chemical oxygen demand (American Environmental Protection Agency, 1988).

RESULTS AND DISCUSSIONS

Results of the Experiment

These are the results that were obtained for the thirteen times storm water analysis carried out with its features which includes: the sampling date, the sampling time, vehicles per five minutes and others as tabulated below

Table 1A: PHYSICAL PARAMETERS AT T-20 SITE 1

STORM NUMBER	DATE	TIME	N.O.V	PH	TURB. (NTU)	TEMP. (^oC)	COL. (Hu)
1	01/04/04	9.40PM	42	6.8	12.5	25.0	35
2	18/05/04	8.18PM	60	6.9	10.5	24.5	20
3	18/05/04	5.36PM	80	6.9	12.0	25.0	25
4	20/05/04	12.30PM	63	6.9	11.5	25.0	30
5	23/05/04	8.30AM	60	6.8	10.0	24.0	25
6	25/05/04	9.45PM	50	6.9	11.5	24.5	30
7	26/05/04	8.50AM	65	6.8	10.0	25.0	40
8	28/05/04	7.45AM	65	6.9	12.0	25.0	30
9	30/05/04	9.30PM	40	7.1	13.5	25.0	40
10	31/05/04	8.00AM	65	7.1	12.0	25.0	35
11	01/06/04	6.50PM	55	6.9	13.5	24.5	35
12	04/06/04	7.50AM	50	6.9	14.0	25.0	42
13	01/07/04	7.00AM	70	6.9	6.5	24.0	20

Source: Author's field work

Table 1B: CHEMICAL PARAMETERS AT T-20 SITE 1

STORM NUMBER	TSS mg/l	COD mg/l	BOD mg/l	OIL mg/l	PHO mg/l	NIT mg/l	Fe mg/l	Pb mg/l	Mn mg/l
1	50	2.1	3.0	4.5	2.7	5.5	6.0	0.05	0.4
2	45	1.7	4.2	3.0	1.6	5.2	5.5	0.04	0.3
3	40	1.9	3.6	2.5	1.4	5.0	5.0	0.03	0.35
4	45	1.8	3.4	2.4	1.3	5.1	5.1	0.04	0.40
5	40	1.9	4.1	2.5	1.5	5.1	5.4	0.03	0.20
6	50	2.0	3.8	1.8	1.3	5.0	5.2	0.03	0.20
7	40	2.4	4.6	1.2	1.0	4.2	4.8	0.01	0.25
8	45	2.4	3.0	2.0	1.5	4.6	4.5	0.02	0.20
9	50	3.2	4.6	1.4	1.3	3.8	5.0	0.02	0.25
10	40	2.6	4.8	1.2	1.2	3.6	4.8	0.02	0.25
11	35	2.2	4.6	1.6	1.4	3.4	4.4	0.01	0.20
12	35	2.1	4.2	1.5	1.35	3.2	4.2	0.01	0.25
13	40	2.1	3.8	12.0	2.5	7.6	0.2	0.05	0.50

Source: Author's field work

*N.O.V (VH) -Number of vehicles; TURB-Turbidity; TEMP-Temperature; COL-Colour; TSS-Total suspended solid; COD-Chemical Oxygen Demand; BOD5-Five day Biochemical Oxygen Demand; OIL- Oil and Grease; PHO-Phosphate; NIT-Nitrate; Fe-Iron; Pb-Lead; Mn-Manganese

Table 2A: PHYSICAL PARAMETERS AT U-20 SITE 2

STORM NUMBER	DATE	TIME	N.O.V	PH	TURB. (NTU)	TEMP. (^oC)	COL. (Hu)
1	01/04/04	9.50PM	48	7.4	23.5	25.0	90
2	18/05/04	8.11AM	75	7.2	21.0	25.0	40
3	18/05/04	5.30PM	90	7.1	20.0	25.0	45
4	20/05/04	12.38PM	70	7.1	21.0	25.0	50
5	23/05/04	8.15AM	75	7.1	20.5	24.5	45
6	25/05/04	9.30PM	55	7.3	20.5	25.0	40
7	26/05/04	8.15AM	70	7.2	20.0	25.0	40
8	28/05/04	7.25AM	75	7.1	10.5	25.0	30
9	30/05/04	9.20PM	45	7.1	12.0	25.0	35
10	31/05/04	8.10AM	75	7.1	10.0	25.0	25
11	01/06/04	6.40PM	65	6.9	11.0	24.5	25
12	04/06/04	7.40AM	70	7.1	10.0	25.0	25
13	01/07/04	7.10AM	65	6.3	8.0	24.0	30

Source: Author's field work

Table 2B: CHEMICAL PARAMETERS AT U-20 SITE 2

STORM NUMBER	TSS mg/l	COD mg/l	BOD mg/l	OIL mg/l	PHO mg/l	NIT mg/l	Fe mg/l	Pb mg/l	Mn mg/l
1	85	2.5	4.4	12.5	5.0	8.5	9.0	0.30	0.65
2	85	2.3	3.8	9.5	2.8	7.8	8.5	0.35	0.55
3	75	2.1	3.6	8.0	2.5	6.6	9.0	0.25	0.60
4	80	2.0	3.4	7.0	2.4	6.5	9.1	0.26	0.65
5	80	2.2	3.7	8.0	2.7	7.7	8.4	0.34	0.54
6	70	1.9	3.4	6.0	2.4	6.9	8.4	0.30	0.50
7	70	2.2	3.0	4.8	2.0	5.8	7.8	0.20	0.45
8	65	2.0	3.0	5.4	2.0	6.5	5.5	0.20	0.45
9	70	1.6	3.2	3.8	2.0	5.8	5.0	0.20	0.50
10	55	2.0	4.2	3.3	2.0	5.5	5.2	0.20	0.45
11	50	2.4	4.0	3.0	3.4	5.0	5.0	0.25	0.40
12	30	2.4	3.8	2.8	1.8	4.0	5.0	0.15	0.30
13	46	1.8	3.6	15.0	3.2	5.6	0.4	0.07	0.30

Source: Author's field work

Table 3A: PHYSICAL PARAMETERS AT PO-20 SITE 3

STORM NUMBER	DATE	TIME	N.O.V	PH	TURB. (NTU)	TEMP. (^oC)	COL. (Hu)
1	01/04/04	9.30PM	42	7.2	15.0	25.0	75
2	18/05/04	8.45AM	65	7.2	19.5	25.0	45
3	18/05/04	5.23PM	60	7.2	18.5	25.0	45
4	20/05/04	12.50PM	65	7.2	16.0	25.0	50
5	23/05/04	8.00AM	60	7.1	19.0	24.5	50
6	25/05/04	9.20PM	50	7.3	19.0	25.0	60
7	26/05/04	7.45AM	60	7.3	17.5	24.0	55
8	28/05/04	7.15AM	65	7.3	16.0	25.0	50
9	30/05/04	9.10PM	40	7.2	18.5	25.0	60
10	31/05/04	8.20AM	65	7.2	16.0	25.0	50
11	01/06/04	6.25PM	65	7.1	14.5	25.0	40
12	04/06/04	7.30AM	65	7.2	13.0	25.0	35
13	01/07/04	7.20AM	60	6.8	19.0	24.0	80

Source: Author's field work

TABLE 3B: CHEMICAL PARAMETERS AT PO-20 SITE 3

STORM NUMBER	TSS mg/l	COD mg/l	BOD mg/l	OIL mg/l	PHO mg/l	NIT mg/l	Fe mg/l	Pb mg/l	Mn mg/l
1	70	1.8	2.8	8.0	2.2	7.5	7.2	0.08	0.5
2	70	1.9	5.6	7.5	3.4	6.4	6.8	0.04	0.35
3	75	2.1	4.4	7.5	3.0	6.0	6.5	0.04	0.30
4	80	2.1	4.2	7.4	2.8	5.0	6.4	0.05	0.35
5	65	1.8	5.5	7.0	3.3	6.3	6.7	0.02	0.34
6	55	1.6	4.8	5.0	3.4	6.4	6.3	0.03	0.30
7	50	2.0	3.0	3.6	2.8	6.0	6.5	0.03	0.35
8	60	1.8	5.2	4.0	3.6	5.8	6.0	0.02	0.40
9	70	1.6	4.8	3.6	2.8	5.5	6.5	0.03	0.30
10	60	2.0	3.8	3.4	2.6	5.0	6.3	0.02	0.35
11	50	2.0	3.4	3.0	2.4	5.2	6.5	0.02	0.40
12	45	1.6	3.2	3.0	2.6	5.1	6.3	0.02	0.30
13	68	1.6	3.2	24.0	3.0	4.2	1.1	0.05	0.45

Source: Author's field work

Table 4A: PHYSICAL PARAMETERS AT F-20 SITE 4

STORM NUMBER	DATE	TIME	N.O.V	PH	TURB. (NTU)	TEMP. (^oC)	COL. (Hu)
1	01/04/04	10.20PM	20	6.9	17.5	25.5	70
2	18/05/04	7.24AM	35	7.1	27.0	24.5	80
3	18/05/04	5.50PM	40	7.2	29.0	25.0	70
4	20/05/04	1.00PM	30	7.2	28.0	25.0	75
5	23/05/04	7.45AM	45	6.9	26.5	24.0	85
6	25/05/04	10.15PM	30	7.2	24.0	24.5	75
7	26/05/04	7.20AM	40	7.3	22.0	25.0	70
8	28/05/04	7.00AM	38	7.2	20.0	25.0	65
9	30/05/04	8.45PM	20	7.3	19.0	25.0	60
10	31/05/04	7.45AM	35	7.2	17.5	25.0	55
11	01/06/04	6.10PM	40	7.2	16.0	24.5	50
12	04/06/04	7.00AM	25	7.2	15.0	24.5	45
13	01/07/04	6.20AM	25	6.8	10.5	24.0	45

Source: Author's field work

Table 4B: CHEMICAL PARAMETERS AT F-20 SITE 4

STORM NUMBER	TSS mg/l	COD mg/l	BOD mg/l	OIL mg/l	PHO mg/l	NIT mg/l	Fe mg/l	Pb mg/l	Mn mg/l
1	65	2.0	4.6	6.5	3.4	8.0	6.0	0.15	0.30
2	95	1.4	4.8	4.5	2.3	9.6	5.0	0.10	0.30
3	80	1.8	4.0	5.0	2.5	9.0	5.0	0.10	0.01
4	85	1.9	3.8	4.0	2.4	4.0	5.1	0.11	0.35
5	90	1.5	4.9	4.0	2.2	9.5	4.8	0.09	0.20
6	80	1.5	4.8	3.5	2.2	9.0	4.4	0.07	0.20
7	70	2.6	4.2	4.2	2.6	6.4	4.8	0.03	0.30
8	75	1.8	4.6	4.4	2.0	6.6	6.0	0.02	0.30
9	70	2.0	4.8	3.8	1.6	6.0	6.0	0.03	0.30
10	65	1.8	3.0	3.6	1.6	5.8	4.8	0.03	0.30
11	60	1.6	3.2	3.2	1.9	5.6	4.5	0.02	0.30
12	45	2.1	4.0	3.6	3.0	5.4	4.5	0.02	0.35
13	54	2.0	2.4	16.0	2.8	6.8	0.7	0.03	0.35

Source: Author's fieldwork

From the above results the following accounts for their variations which include:
Period of discharge is different: This implies that sometimes oil and grease, diesel, petrol and other petroleum products with domestic discharges may have been discharged at any point in time; where the sample is being collected determine how high or low the variations of the parameter; rate of erosion- as more things are exposed to the surface erosion goes off; material discharge into a gutter at every point in time is different that is, water sample taken from the gutter before is cleaned will be certainly different from the water sample taken when the gutter is not cleaned; presence of gases in the atmosphere; dust effect at any point in time will be different and have effect on it.

ANALYSIS OF RESULTS USING SIMPLE REGRESSION

Ho: Null Hypothesis H1: Alternative Hypothesis
Fitted model of regression of storm water loads on N.O.V (VH).
$Y = \alpha + \beta Xi$
Where Y = Dependent variables; α = Intercept; β = Regression coefficient; Xi = Independent variable; i = Number of variables.
Hypothesis: $Ho: \beta = 0$ vs. $H1: \beta \neq 0$
$Ho: \beta = 0$ this implies that the regression coefficient is not significantly different from zero
Decision Rule: Accept H_o if p-value contains zero and reject Ho if p-value does not contain zero
(a) Effect of the traffic counts on the total suspended solid (TSS) collected from selected areas in Ilorin metropolis?

$$TSSi = \alpha + \beta VHi$$
$$TSSi = 72.75019 - 0.20863VHi$$

The overall mean of TSS_i is 72.75019. However, for every unit increase in VH, TSS_i is reduced by a function of 0.20863. Based on the p-value that contains zero, Ho is not rejected and it can be concluded that effect of VH is not significant.
(b) Effect of traffic count on Biochemical Oxygen Demand from selected areas in Ilorin metropolis?

$$BODi = \alpha + \beta VHi$$
$$BODi = 4.29935 - 0.0066VHi$$

The overall mean of BOD_i is 4.29935. However, for every unit increase in VH, BOD_i decreases by a function of 0.0066. Based on the p-value that contains zero, Ho is not rejected and effect of VH is not significant. This summarizes that traffic count has no effect on the BOD.
(c) Effect of traffic on COD from selected areas in Ilorin metropolis?

$$CODi = \alpha + \beta VHi$$
$$CODi = 1.7995 + 0.003396VHi$$

The overall mean of COD_i is 1.7995. However, for every increase in VH, COD_i increases by a function of 0.003396. The p-value does not contain zero therefore, we reject Ho and can conclude that effect of VH is significant.
(d) How do vehicles has effect on oil and grease of selected areas in Ilorin metropolis?

$$Oil\ and\ greasei = \alpha + \beta VHi$$
$$Oil\ and\ greasei = 4.67967 + 0.01190VHi$$

The overall mean of oil and grease is 4.67967. However, for every increase in VH, oil and grease increase by a function of 0.01190. The p-value does not contain zero therefore, Ho is rejected and it is concluded that effect of VH is significant.
(e) Effect of vehicles on nitrate of selected areas in Ilorin metropolis

$$NITi = \alpha + \beta VHi$$
$$NITi = 7.02938 - 0.01864VHi$$

The overall mean of NIT_i is 7.02938. However, for every unit increase in VH, NIT_i decreases by a fraction of 0.01864. The p-value contains zero therefore, Ho is not rejected. It reveals that the effect on VH is not significant.
(f) How do vehicles has effect on phosphate loadings of selected areas in Ilorin metropolis?

$$PHOi = \alpha + \beta VHi$$
$$PHOi = 2.53341 - 0.00400902VHi$$

The overall mean of PHO_i is 2.53341. However, for every unit increase in VH, PHO_i reduces by a function of 0.00400902. The p-value contains zero therefore, Ho is not rejected that is, effect of VH is not significant.

(g) pH and vehicles loadings of selected areas in Ilorin metropolis has effect on each other?

$$pHi = \alpha + \beta VHi$$
$$pHi = 7.173 - 0.0018704VHi$$

The overall means of pHi is 7.173. For every unit increase in VH, pHi decrease by a function of 0.0018704. The p-value contains zero therefore, Ho is not rejected and VH is not significant.

(h) Iron loadings and vehicle from selected areas in Ilorin metropolis has effect on each other?

$$Fei = \alpha + \beta VHi$$
$$Fei = 4.134 + 0.0249VHi$$

The overall mean of Fe_i is 4.134. For every unit increase in VH, Fe_i increases by a function of 0.0249. The p-value does not contain zero therefore, the effect of VH is significant.

(i)Lead loadings and vehicles from selected areas in Ilorin metropolis has effect on each other?

$$Pbi = \alpha + \beta VHi$$
$$Pbi = -0.01053 + 0.00187322VHi$$

The overall mean of Pb_i is -0.01053. For every unit decrease in VH, Pb_i increases by a function of 0.00187322. The p-value does not contain zero, therefore Ho is rejected that means VH is significant.

(j) Manganese loadings and vehicles from selected areas in Ilorin metropolis has any effect on each other?

$$Mni = \alpha + \beta VHi$$
$$Mni = 0.21850 + 0.0025523VHi$$

The overall mean of Mn_i is 0.21850. For every unit in VH, Mn_i increases by a function of 0.0025523. The p-value does not contain zero, therefore Ho is rejected and VH is significant. In other words, there is significant relationship between Mn and VH.

DISCUSSION OF RESULTS

The concentrations of cations (Mn^{2+}, Pb^{2+}, Fe^{2+}, Cu^{2+}), anions (NO_3^-, PO_4^{3-}), tests for oxygen demands by inorganic and organic substances (BOD and COD), physical analysis (pH, TSS, oil and grease), analysed showed variations for storm water runoff samples. Test of significance was carried out using simple regression analysis. No significant difference at 95% probability level for the various samples of storm water runoff collected in Ilorin metropolis which was tested.

The effect of VH on TSS, BOD, NO_3^-, PO_4^{3-}, Pb^{2+} and pH were not significant and this was expected because of the following reasons: the nature of materials suspended into the water which the runoff carries away, the amount of microbial activities present in the runoff water at a particular period of time, that is the level of consumption of oxygen either high or low, the nature of the underlying soil over which the runoff nature of materials been discharge into the flow runoff are determined, the determination of alkalinity and acidity of the runoff water are the causes and not dependent on vehicles.

Oil and grease with COD were dependent on VH because the major sources of these organics are through vehicular spills, also a lot of mechanics when they work on the engine they discharge petroleum products in the course of their repairs and when rain falls it strips it along and so oil and grease is shown in the runoff. Also, moving vehicles with leaking engines and improper packing also contributes oil and grease on the roads. Vehicles also emit carbon monoxide and the chemical oxygen demand will affect the amount of oxygen present at a particular point in time. What contributes to the significant of VH on Fe^{2+} was not really the traffic but the dissolution effect on the rock strata of the soil and the chemical weathering effect of the water on the iron that changes the ferrous state of the iron to the ferric state that is, rusty aspect due to hydration. The effect of VH on Mn^{2+} was significant and what contributes to this physically is that in the course of still production there is high degree of manganese and when water comes with such framework chemical weathering occurs with materials been carried by the runoff causing dissolution of manganese into the water body.

RESEARCH IMPLICATIONS

The data generated can be used as a base line for reducing storm runoff which eventually cause flooding and erosion problems that leads to road damage. Also for proper environmental impact assessment the runoff should not be directly channelled into streams which serve has source of consumption for the people around that locality. Motorists are also exposed to risk if roads are not properly tarred. This research will help to reduce disposal of waste in our gutter channel system which when blocked will cause the overflow of the Asa River in Ilorin metropolis, Kwara state, Nigeria. The regression method can be set as a model for determining physical and chemical parameters in runoff or other activities determined in water analysis.

CONCLUSION

Significant differences are observed in the relationship between traffic counts and concentration of storm water runoff loads and this helped us to conclude that the wearing out of roads through storm runoff causes erosion and potholes on the roads. It can also be seen from the study that channelization of the storm water runoff to water works department and recycling for human use or industrial use is essential. Also, environmental protection agency should be alert to clean the street immediately after rainfall so as not to damage the tarred roads that has been constructed.

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