International Journal of Research Studies in Science, Engineering and Technology
Volume 6, Issue 4, 2019, PP 15-22
ISSN : 2349-476X

Stochastical Model to Predict the Environmental Pollutions Caused by Vehicle Tire Wears Abrasion in Tehran Iran

Siamak. Boudaghpour

Department of Civil Engineering, K.N.Toosi University of Technology, Tehran, Iran,

Corresponding Author: *Siamak. Boudaghpour, Department of Civil Engineering, K.N.Toosi University of Technology, Tehran, Iran*

ABSTRACT

Pollutions caused by vehicles operation are always serious issue in environment. Although the pollutions produced by vehicles exhaust fumes have been considered but also the problem of pollution caused by wear of tires and rubber small particles have less considerations. Tire filings often contain acidic chemicals that in contact with water and asphalt can lead to dissolution and creation secondary hazardous pollutions in urban ground water and waste surface water. Corrosion of asphalt, and creation of pollutants caused by pitch of asphalt, in urban groundwater and surface water. Due to the lack of data regarding tires small particles generated by rubber in Tehran to quantify and evaluate more accurately the amount of pollution caused by rubber abrasion and then prediction its value by using stochastic models. Tire chips left on the streets and roads surface are dissolved in rainwater and contaminate ground and surface water. The essential measurements for their treatment in Tehran refineries should be considered. On the other hand the large volume of filings in Tehran could lead to other environmental problems, such as respiratory problems caused by the scattering of particles in no rain and dry days, that is added to air pollution problems caused by vehicle exhaustis fumes. Using to chastic models, amount of rubber filings in Tehran can accurately be predicted for the coming years, and by present of solutions for reduction and control of rubber filing losses.

Keywords: *Stochastic modeling, vehicles pollution prediction, rubber abrasion, surface water.*

INTRODUCTION

Tehran a city of millions of different types of vehicles and motor bicycles with a very heavy traffics daily faces with the huge amount of abraded tires small particles. Where tire wear particles have been recognized as a harmful factors to the environment for several decades. The potential health and environmental impacts associated with traffics related to tire wear particles have received little public attention. In recent years with growing the number of vehicles in big cities more than %10 of air and surface road pollutions caused due to tire abrasion.

Although between used and new tires and also tires with different chemical content the production of tire abraded particles are considerably different but their harmful effects to environment cannot be negligible. One of the effective processes to reduce and control the hazardous effects of small particles of abraded tires is to use stochastically models to predict the amount off abraded tires small particles. Various types of stochastic models are tested in present studies where the best model with suitable fitness and prediction has been proposed.

METHODOLOGY

To determine the amount of pollutions caused by tire wear, first step is to find statistics on the number of vehicles, But for two reasons, a different approach have been adopted in this study: First, statistics on the number of vehicles are related to last few years, while to build a statistical model, whatever number of data is less, the error of model is more. Second, even if the full statistics of the number of vehicles in Tehran are available, the number of licensed cars cannot correctly determine the number of effete tires. Perhaps there are cars that due to a lot of use in a period less than one year, their tires are worn and replaced, vice versa the cars that are underused, their tires are not replaced for a long time. Therefore to calculate the amount of rubber filings remained on the streets, annual fuel consumption of Tehran have been used. At first step statistics on fuel consumption in Tehran is determined. Then due to the wide variety of vehicles, all vehicles used in Tehran, are equivalent to two vehicle types (A, B) according to fuel type, and then wear of tires of these two vehicles and tire filings production capacity per consumption of unit fuel-one liter for each vehicle is studied having statistics on annual fuel consumption, the total annual volume of begot tire chips is calculated. The next step is to collect statistics on Tehran annual precipitation in order to evaluation of surface water pollution. By combining these two steps' data, annual pollution caused by tire filings of vehicles in Tehran is calculated. Finally the process of modeling is performed using the statistical software Mini Tab, and results presented in the tables and graphs is analyzed.

The Method of Collecting Statistics on Fuel Consumptions

Statistics on fuel consumption have been extracted from the computerized database *Oil Refining and Distribution Company*. Statistics on fuel consumption for whole country are available from 1934 till 2011 but considering statistics on fuel consumptions are recorded from 2006 til 2011, the share of fuel consumption of Tehran is determined according to recent statistics, and average value of recent years' consumptions is applied for previous years. Calculations of diesel and gasoline consumption in Tehran are given in Table 1.

Table1. *Calculation of the share of fuel consumption in Tehran, according to available statistics*

	Gasoline consumption in whole country 1000 L/D	Gasoline consumption in Tehran 1000 L/D	% of gasoline consumption For Tehran	Diesel consumption in whole country 1000 L/D	Diesel consumption in Tehran 1000 L/D	% Of Diesel consumption For Tehran
2006	73660	10442	14.18	86220	6266	7.27
2007	64450	9456	14.67	89750	5114	5.70
2008	67000	9988	14.91	92500	4726	5.11
2009	64800	9868	15.23	92800	5109	5.51
2010	61300	9781	15.96	95200	4627	4.86
			ave = 15			ave = 5.7

Table2. *presents statistics on fuel consumptions in Tehran*

	Gasoline consumption in whole country 1000 L/D	Gasoline consumption in Tehran 1000 L/D	Diesel consumption in whole country 1000 L/D	Diesel consumption in Tehran 1000 L/D
1991	24566	3684.9	55093	3140.301
1992	26885	4032.75	57211	3261.027
1993	29397	4409.55	60159	3429.063
1994	31274	4691.1	62214	3546.198
1995	31359	4703.85	59770	3406.89
1996	32940	4941	62495	3562.215
1997	34973	5245.95	64271	3663.447
1998	37701	5655.15	63794	3636.258
1999	39142	5871.3	63140	3598.98
2000	42535	6380.25	66669	3800.133
2001	45806	6870.9	69082	3937.674

But all diesel fuels are not consumed in the transportation sector. Statistics on percent of diesel in the country's transportation sector to whole diesel consumption in the country has been presented from 1999 till 2009. In present study, according to the statistics, an average value taken as the criterion to determine the percentage of diesel consumption in transportation sector of Tehran. The results of calculations have been shown in Table 2.

Table3. *Percent ratio of diesel in the country's transportation sector to whole diesel consumptions in the country*

Year	percent of diesel in the country's transportation sector to whole diesel consumption in the country
1999	54.24
2000	54.85
2001	55.14
2002	57.44
2003	56.79

2004	56.72
2005	56.99
2006	52.74
2007	53.23
2008	53.17
2009	52.34
average	54.877

Based on the above criteria, diesel consumptions of Tehran in the transportation sector for sample years are calculated and are presented in Table 4.

Table4. *Diesel consumption of Tehran in transportation sector*

year	Diesel consumption of Tehran (1000 Lit/Day)	Diesel consumption of Tehran in transportation sector (1000 Lit/Day)
1991	3140.301	1723.397189
1992	3261.027	1789.651618
1993	3429.063	1881.869774
1994	3546.198	1946.153462
1995	3406.89	1869.701232
1996	3562.215	1954.943592
1997	3663.447	2010.499714
1998	3636.258	1995.57839
1999	3598.98	1975.120224
2000	3800.133	2085.51299
2001	3937.674	2160.995491

Total statistics on daily gasoline and average diesel consumption in Tehran

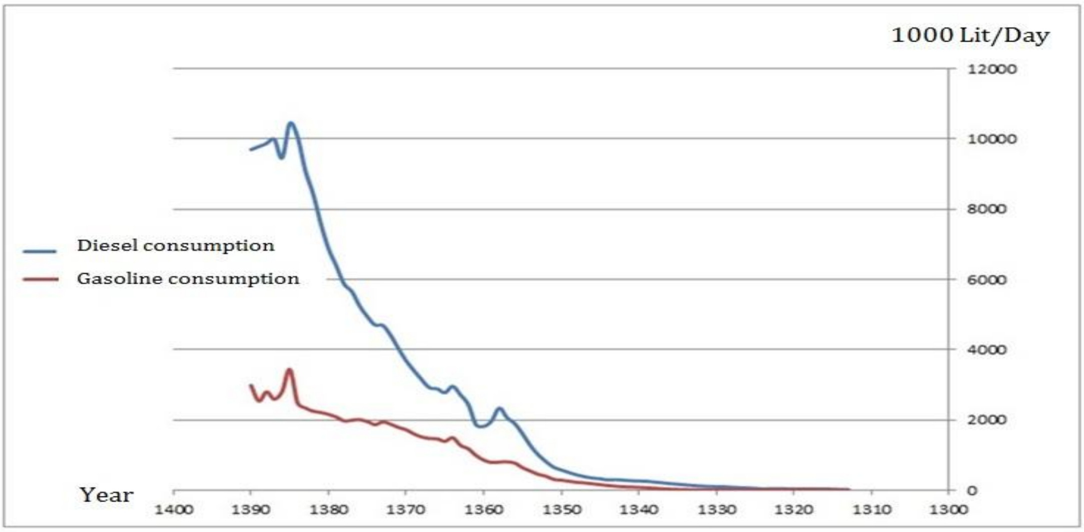

Fig1. Total statistics on daily average gasoline and diesel consumption in Tehran

Determination of Equivalent Vehicles Depending on Fuel Type Consumption

In the present model, vehicles depending on fuel type gasoline or diesel are divided into two types. Vehicles (A), as representative of all gasoline vehicles and trucks (B) as representative of selected diesel. On the other hand, the impact of hybrid vehicles due to lack of statistics on exact fuel consumption and because of instability in the use, are ignored in the model. Wheel diameter and width of tires for vehicle A, are considered 20 inch and 10 inch respectively, and for vehicle B, mentioned parameters areconsidered14 inch and 185 mm.

Survey of the Various Tires' Wear, Choice of Equivalent Tire and Calculation of Coefficients of Pollution Caused by Tire Abrasion (LA And LB)

Mean depth of tread in a new tire is 3/8 inches, and safety of tire is acceptable until 1/16 inches depth. Therefore thickness of tire that is worn on the road surface, is obtained by following equation:

$$t = \frac{3}{8} - \frac{1}{16} = \frac{5}{16}\ in = 7.97\ mm$$

having outer diameter and width of tire, volume of rubber that worn on the road surface can be calculated by following equation:

$$V = (\pi \times D \times B \times t) \times n \quad ; \quad D = 2H + d$$

In the above equation, **V** shows volume of produced chips from a vehicle's tires, **D** is the outer diameter of tires, **B** is tire width, **t** is mean thickness of tire’s tread, **n** is the number of vehicle tires, **H** is width of tire’s sidewall and **d** is inner diameter of tire. In Table 5, each of the characteristics and volumes of produced chips of tires for cars A and B are presented.

Table5. Calculation of volume chip, produced by vehicle tires

Type of vehicle	n	H (mm)	D (mm)	D (mm)	B (mm)	T (mm)	V (m^3)
A (car)	4	148	357	653	185	7.97	0.0120972
B (truck)	6	204	510	918	255	7.97	0.03516205

Besides tire of a truck is durable over 130,000 km and tire of a car over 80,000 km .On average, **A** vehicle consumes 8 liter gasoline and **B** vehicle consumes 12 liter diesel per 100 km distance. There for the distance traveled by **A** and **B** vehicles groups for unit fuel consumption per liter are12.5 and 8.3 km respectively. Considering the above achievements can be easily calculated which is consumed during full use of vehicles tires.

Volume of consumed fuel for full use of A group vehicles tires till allowed abrasion = $\frac{80000}{12.5} = 6400\ lit$

Volume of consumed fuel for full use of B group vehicles tires till allowed abrasion = $\frac{130000}{8.3} = 15663\ lit$

According to achievements of above equations and table 5, **A** group vehicle produces 0.0120972 m^3 tire chips for consumption of 6400 liter gasoline and **B** vehicle produces 0.03516205 m^3 tire chips for consumption of 15663 liter diesel. Therefore volume of the tire chips can be calculated for consumption per unit volume fuel:

Produced tire chips by **A** group vehicle for consumption of unit volume fuel = $L_A = \frac{0.0120972}{6400} = 1.8902 \times 10^{-6}\ m^3/lit$

Produced tire chips by **B** group vehicle for consumption of unit volume fuel $= L_B = \frac{0.03516205}{15663} = 2.2449 \times 10^{-6}\ m^3/lit$

There for annual volume of tire chips can be calculated by multiplying L_A and L_B coefficients and volume of consumed fuel for each year.

Calculation of Tire Chips Volume per Year

Volume of tire chips caused by **A** and **B** groups vehicles and total volume of produced tire chips have shown in figure2.

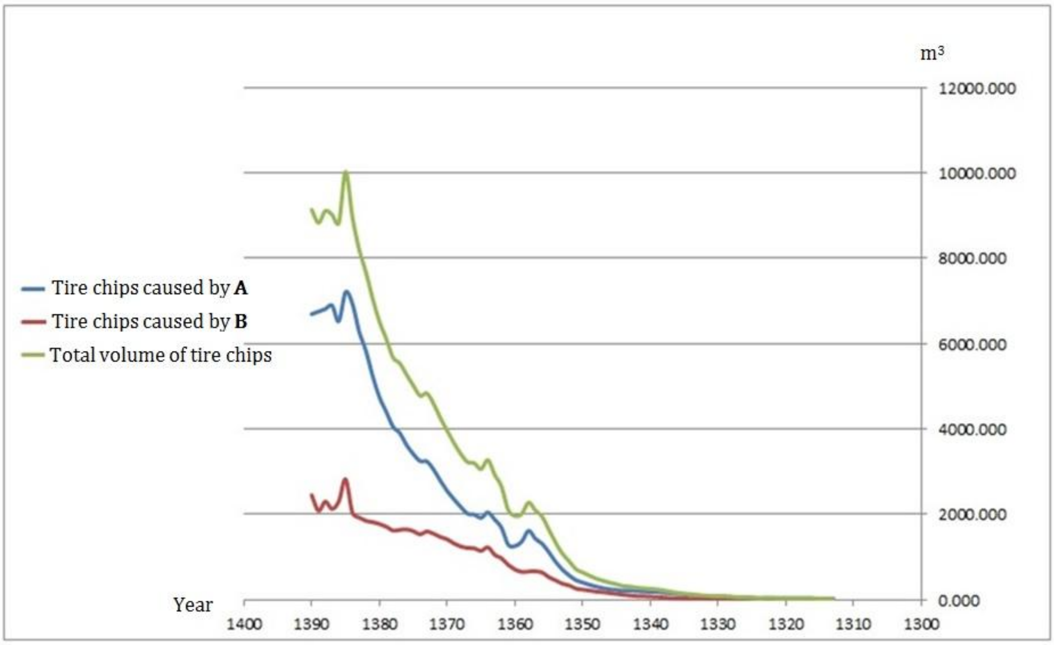

Fig2. *Calculation of tire chips volume (m^3) per 1000 m^3 rain water*

Gathering Statistics for Annual Rain Fall In Tehran

Table6. *Statistics on annual rain fall in Tehran*

Year	Annual rainfall (mm)	Year	Annual rainfall (mm)	Year	Annual rainfall (mm)	Year	Annual rainfall (mm)
1952	204.7	1967	143.6	1982	224.4	1997	259.9
1953	251	1968	121.8	1983	330.6	1998	221.9
1954	292.1	1969	301.7	1984	205	1999	182.1
1955	222.5	1970	320.2	1985	297.1	2000	196.4
1956	163.3	1971	180.9	1986	142.2	2001	171.4
1957	175.2	1972	204.4	1987	283.2	2002	188
1958	303.8	1973	362.9	1988	336.1	2003	317.3
1959	191.8	1974	171.7	1989	220.5	2004	303.2
1960	129.1	1975	300.8	1990	198.6	2005	236.8
1961	208.6	1976	196.9	1991	130.8	2006	236.8
1962	182.1	1977	273.5	1992	288.4	2007	199.8
1963	206	1978	240.8	1993	324.8	2008	216.7
1964	214.5	1979	254.2	1994	246.5	2009	240.3
1965	190.1	1980	300.3	1995	244.6	2010	222
1966	150.6	1981	193.3	1996	223.5	2011	316.3

Calculation of rainfall volume in Tehran is done by multiplying the amount of rainfall height city area 686 km^2. Note that the expansion of Tehran and changes of its area during the years of present study are ignored.

Calculation of Annual Pollution Caused by Tires Abrasion

In calculation the amount of pollution caused by tire abrasion have been done by considering 70% of rainfall volume as surface runoff. This volume of rainwater washes road surface and tire chips are dissolved in it. For determination of pollution, volume of tire chips resolved in 1000 m^3 rainwater is calculated and presented it table7.

Table7. *Volume of tire chipsin (m^e) per 1000 m^e volume of rainwater*

Year	Volume of tire chips (In 1000 m^3 rainwater)	Year	Volume of tire chips (In 1000 m^3 rainwater)	Year	Volume of tire chips (In 1000 m^3 rainwater)	Year	Volume of tire chips (In 1000 m^3 rainwater)
1952	0.000844579	1967	0.005720404	1982	0.019473009	1997	0.042199631
1953	0.00078246	1968	0.007534138	1983	0.016715159	1998	0.051960962
1954	0.000760241	1969	0.003376506	1984	0.029693982	1999	0.064831303
1955	0.001167159	1970	0.003640241	1985	0.022910064	2000	0.064793168
1956	0.001796285	1971	0.00731166	1986	0.044781578	2001	0.079108019
1957	0.001884861	1972	0.007226096	1987	0.023483986	2002	0.078022252
1958	0.001269048	1973	0.005136033	1988	0.019961314	2003	0.05033372
1959	0.002302883	1974	0.013036567	1989	0.032252186	2004	0.056317535
1960	0.003837474	1975	0.009231882	1990	0.038406642	2005	0.078874175
1961	0.002512305	1976	0.017312625	1991	0.062958431	2006	0.08813432
1962	0.003022434	1977	0.014811127	1992	0.03067887	2007	0.091965951
1963	0.002826389	1978	0.018064413	1993	0.029391953	2008	0.086644222
1964	0.002956287	1979	0.018608882	1994	0.040814245	2009	0.078909913
1965	0.003442811	1980	0.013934057	1995	0.040672836	2010	0.082818421
1966	0.004963172	1981	0.021121231	1996	0.046687928	2011	0.06014372

Results and Discussion

Software has been used to a stochastic model for prediction of pollution caused by tire abrasion in Tehran. The actual data changes have been modeled by constant functions and future changes have been predicted based on resulting functions. Then, moving average method has been used for modeling. Moving average of time series is one of the smoothing chniques of time series' actual plot; Random elements in some of time series may be strong enough to destroy any regularity in time series, and need to be smoothed. This method is based on the idea that every major random changes in each time, if its average with surrounding points be taken, its impact would be negligible. In this process the prediction is made according to the following equation:

$$MA(q) = \varepsilon_i - \theta_1 \varepsilon_{i-1} - \theta_2 \varepsilon_{i-2} - \cdots - \theta_q \varepsilon_{i-q}$$

Where, q is order of moving average, ε is there is dual error or residue, Andθ1, θ2,…are coefficients of the moving average which are calculated based on the correlation between the data. Models of moving average are shown in Figures7and8.

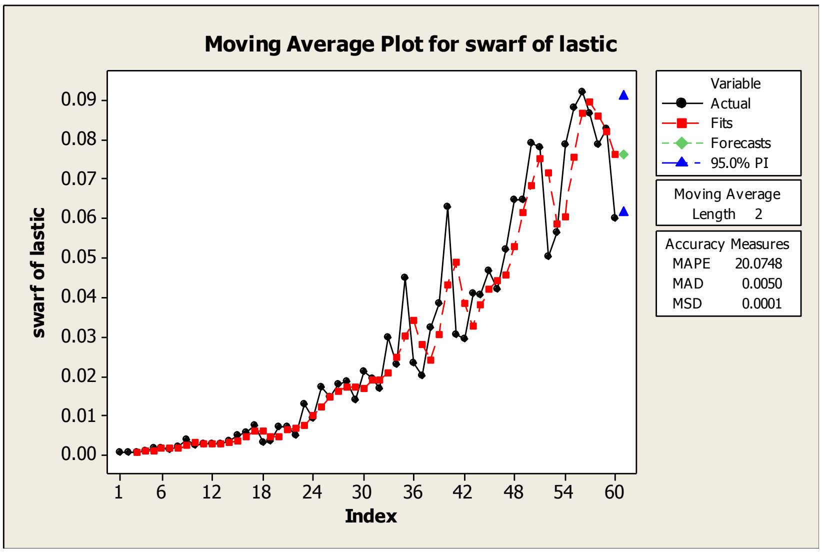

Fig7. *Moving Average (length2)*

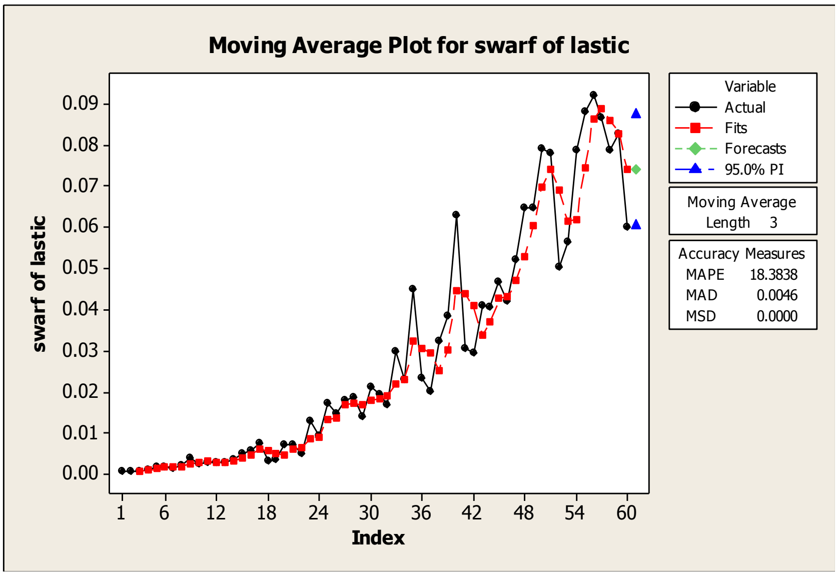

Fig8. *Moving Average (length3)*

Among the various tested stochastically models most of sum of squared errors belongs to the exponential and linear models, respectively. The lowest error is related to three orders moving average model.

Table8. *Comparison of different methods' sum of error squares*

Used method		Sum of squared errors (based on modeling according to existing data: until 1390)
Trend Analysis	Linear	$7.36 * 10^{-3}$
	Quadratic	$4.14 * 10^{-3}$
	Exponential	$17.67 * 10^{-3}$
	S-curve	$5.19 * 10^{-3}$

Moving Average	Second order	$3.24 * 10^{-3}$
	Third order	$2.72 * 10^{-3}$

Therefore third order moving average model has been selected as the best model to predict the pollution. Besides Pollution in year 2013, based on available statistics (1952till 2011) has been calculated. Contamination in year 2013 according to new statistics has been calculated and this process has continued similarly till year 2022. The final graph is shown in Figure 9.

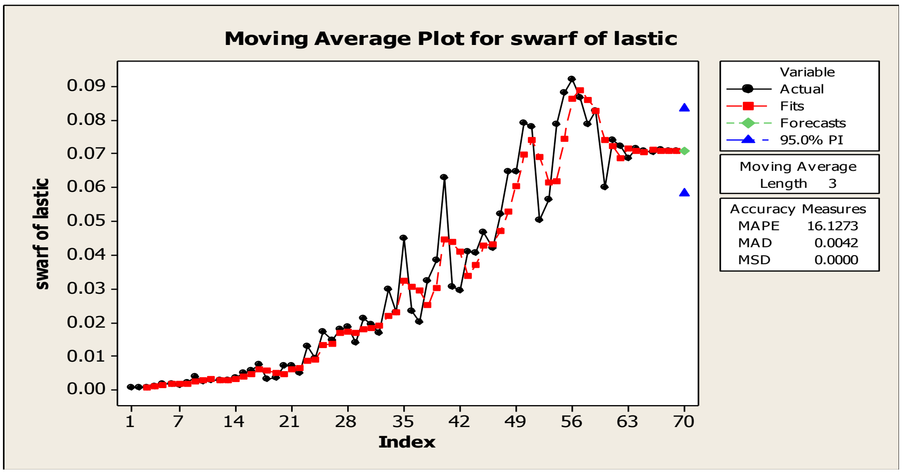

Figure9. *pollution prediction in year 2022, according to existing and modeled statistics*

By comparing the various types of stochastic models it is achieve that moving average model has the most adaption to real data and seems to be a suitable model for pollution prediction in future. Although in year 2014 the graph moves smoothly and does not show oscillation. The reason can be attributed to the increased number off also statistics. A statistical model can predict the changes for a few years and whatever it moves away form latest statistic. A more unreal statistics can be applied in the model then error of model increases.

Conclusions

Based on present study following results have been achieved.

- Tire chips residual in Tehran streets have growing yearly with the steeply slope. It can increase the air pollutions by creating suspended particles reasonably. Besides in rainy days it produces waste water contained tire particles with considerably high amount of tire particles content which can cause difficulty in waste water treatments in refineries.
- Among tested various types of stochastic models moving average model shows considerably suitable fitness to actual data as compare to others.
- Accuracy of a stochastic model reduces by increase off alse data, and in the present study, the model for the early years (2012till2014) has more credibility.
- By prediction of tire chips volume, we can predict the contamination caused by it, which enters to treatment plant via surface water, and then we can find a solution for its treatment.

References

[1] Naik, T.R. and Singh, S.S., "Utilization of Scrap Tires", Center for By - Products Utilization, Report No. CBU-1990-04, Department of Civil and Engineering Mechanics, University of Wisconsin - Milwaukee, April 1990 .

[2] Environmental Protection Agency, "Rubber Reuse and Solid Waste Management", A technical report, Part 1, Part 11 and 111, U.S. Environmental Protection Agency, 1971.

[3] Roy, K.A., "The Less Traveled Roads to Scrap Tire Disposal" November 1988, pp. 41 - 44.

[4] Chamberlin, W.P., and Gupta, P.K., "Use of Scrap Automobile Tire Rubber in Highway Construction", Special Report 85, Engineering Research and Development Bureau, New York State DOT State Campus, Albany, New York, May 1986.

[5] Lundy, J. R., Hicks, R.G., and Richardson, E., "Evaluation of Rubber- Modified Asphalt Pavement Performance - Mt. St. Helens Project", Presented at the Annual Meeting of the Association of Asphalt Paving Technologists, Reno, Nevada, February 1987.

[6] World Wastes, "Old Tire Makes Roads", April 1990, pp.34.

[7] “SC Tire Dump Still Not Cleaned up.” The State. http:// www. thestate. Com /news/ local/ article 13920128 .html (accessed July 22, 2015).

[8] Waste Tire Program Annual Report to the General Assembly (Energy and Environment Cabinet, Department for Environmental Protection, Division of Waste Management. 2014). http://waste.ky.gov/Waste%20 Tire %20 Program %20 Report/Waste %20 Tire %20 Report %20 2014%20 1-15-15-FINAL.pdf. 3 US EPA, OSWER. “Frequent Questions Scrap Tires.” Collections & Lists. http :// www. epa. gov/osw/conserve/ materials/tires/faq.htm#que

Citation: *Siamak. Boudaghpour." Stochastical Model to Predict the Environmental Pollutions Caused by Vehicle Tire Wears Abrasion in Tehran Iran", International Journal of Research Studies in Science, Engineering and Technology, vol. 6, no. 4, pp. 15-22, 2019.*