CHEMICAL ENGINEERING TRANSACTIONS
VOL. 66, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866108

Distribution of Heavy Metal Pollutions in Changbai Mountain Scenic Area Based on Pollution Load Model

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In recent years, as tourism industry develops in super express, the environmental issues occurred in tourist destinations have aroused people's wide concern. This paper focuses on the chemical pollution from annual runoff of highways and plank roads in the Changbai Mountain Scenic Area. After literature analysis and field survey, a mathematical model is built to analyze the scenic environment of Changbai Mountain, based on which to choose two highways and two plank roads in the catchment areas of lakes there for test analysis under all conditions. Analysis results help build a pollution load model based on the unit load factors. In the end, the model is used to count up the loads of total phosphorus in chemical pollutants discharged from each highway into lakes in Changbai Mountain. The findings reveal that, although the pollution load factor of the plank roads is high, the total phosphorus pollution from highway is even greater.

1. Introduction

In recent years, with the rising of the tourism industry develops, the environmental issues triggered in tourist attractions have increasingly aroused people's common concern. Up to now, there are lots of environmental pollutions at various degrees in many scenic spots. In addition to this, people more concern scenic contaminations caused by tourism traffic and tourism population, as well as how these contaminations ruin soil and vegetation, how to prevent against them, but focus less on chemical pollution of lakes.

Non-point source pollution (Colvile et al., 2001) is caused by dissolved contaminants infiltrated into the receiving water body by way of the runoff formed by heavy precipitation. It is dispersive and contains the pollutions from chemical industry, atmospheric dustfall and agriculture. Road surface runoff (Ongley et al., 2010), as a single surface purpose, will produce the non-point source pollution with heavy intensity that can seriously ruin receiving water. It thus has been gradually developed into an independent branch of discipline. In the study of surface runoff on roads, foreign scholars mainly focus on the contents, composition and impact factors of pollutants in road runoff, as well as the migration process of pollutants from road surface to receiving water, and how pollutants play an effect on the water quality of receiving water (Pravdić, 1995). While in the study of this field, China is still in its infancy, even there are still few studies on how the surface runoff of the highways in scenic sports has an effect on the surrounding lakes. The Event Mean concentration (EMC) (Katircioglu, 2014) of runoff is a widely used method for calculating the loads and surface runoff pollutants. In 1987, American scholar Schueler proposed a simple computation model, i.e. $Lt=[(CF)(\Psi)(A)(P)(C)\times 100]$ (Zhang and Gao, 2016).

Based on the above analysis, this paper takes the annual runoffs of highways and plank roads in Changbai Mountain Scenic Area as a study case to conduct a survey on the chemical pollution caused by them in the local water catchment of lakes. However, due to the unique geographical conditions in the Changbai Mountain Scenic Area, there are precipitation and rainfall intensity different from other areas, so that we cannot simply refer to some fruits borne previously. It is required to uncover the characteristics of runoff pollution in light of their specific conditions. Based on a brief analysis of the environmental background of Changbai Mountain Scenic Area, an artificial rainfall experiment is conducted on this area. The analysis of the runoff evolution process at each time period determines the unit load factor based on which we build a calculation model for the pollution load of highways and plank roads. In the end, this model is resorted to calculate the chemical pollutants (phosphorus) from annual runoff in Changbai Mountain Scenic Area.

Please cite this article as: Xin J., 2018, Distribution of heavy metal pollutions in changbai mountain scenic area based on pollution load model, Chemical Engineering Transactions, 66, 643-648 DOI:10.3303/CET1866108

2. Establishing a total phosphorus pollution load model of annual runoff in study area

2.1 Environmental background

The Changbai Mountain Scenic Area (Greiner et al., 2001) lies in the southeast of Jilin Province. As a national AAAAA tourist attraction, it belongs to the temperate continental mountain climate affected by the monsoon, where there there is annual precipitation between 700 ~1400 mm, mainly concentrated in June ~ September of a year. Nature has endowed it with rich resources, many kinds of animals and plants, so that it has reputations as the rare “species gene bank” and “natural museum” in the world. The scenic spot gets its name for resorts with great fames such as “Shenshan, Shengshui, Qilin, and Xianguo”.

The heat production supply industry and particle board manufacture industry are major sources of chemical industry pollution near the Changbai Mountain Scenic Area. Each year, industrial waste water produced there reaches up to 119.96 million t. and untreated domestic waste water of 1.82975 million t. is discharged into the surrounding water bodies every year. Soot, exhausts, dust and other chemical pollutants more seriously pollute the air in the local (Daby, 2003).

2.2 Analysis of artificial rainfall experiment data

In the Changbai Mountain Scenic Area, in addition to the spacious virgin forests and lofty, exotic mountains, the lakes and hot springs are also an epitome of its tourism value. Phosphorus in chemical pollution as an element restricted in the pelagic nutrition is chosen as an indicator for chemical pollution herein (Noronha et al., 2002).

As visitors on highways and plank roads in Changbai Mountain Scenic Area get denser, it is impossible to collect field data. For this purpose, two highways and two plank roads in each lake catchment area of Changbai Mountain are chosen for study. Artificial rainfall method acquires experiment data, and its simulation device consists of three parts: water feed system, voltage regulator, and rainfall system (Metcalfe et al., 2011). The rainfall process lasts for 30 minutes, and runs according to the rainfall intensity of 0.64mm/min that occurs once every three years in the Changbai Mountain Scenic Area. After runoff starts, the net flow needs to be collected once every 3 minutes, and calculated based on the last sink, together with time duration, rain intensity, TP concentration, and area of the runoff plot and other data.

(1) Analysis of artificial rainfall experiment data

Concentration process images in each time frame on highway and plank road are shown in Fig. 1 and 2.

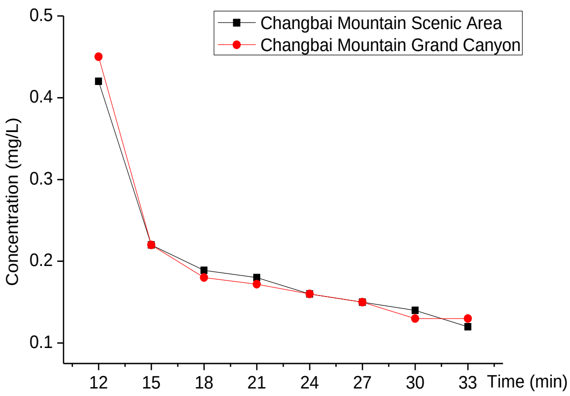

Figure 1: Public path concentration curve

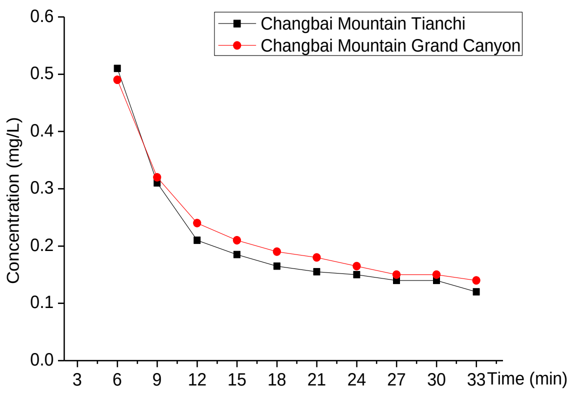

Figure 2: Trail runoff concentration curve

Table 1 gives runoff data in each time frame on highways.

Table1: Runoff data at various times of the road

Location \ Time		3	6	9	12	15	18	21	24	27	30	33
Changbai Mountain Scenic Area	Packet net flow(L)	0	0	0	39.8	85.6	91.4	91.4	97.3	91.4	91.4	85.6
	Net flow coefficient	86.5%										
Changbai Mountain Grand Canyon	Packet net flow(L)	0	0	0	27.9	69.4	97.8	97.8	91.4	97.8	80.9	68.1
	Net flow coefficient	87.8%										

Table 2 gives the runoff data in each time frame on plank roads.

Table 2: Stack path data for various periods of time

Location	Time	3	6	9	12	15	18	21	24	27	30	33
Changbai Mountain Tianchi	Packet net flow(L)	0	28.4	68.3	79.7	84.4	84.4	84.4	90.8	90.8	97.2	33
	Net flow coefficient	93.4%										
Changbaishan Hot Springs	Packet net flow(L)	0	28.4	68.3	68.3	84.4	79.7	84.4	90.8	90.8	97.2	29
	Net flow coefficient	91.2%										

The loads on highways and plank roads in each time frame are listed in Table 3.

Table 3: Load values for road and plank roads at various times

Location	Time	3	6	9	12	15	18	21	24	27	30	33
Highway	Changbai Mountain Scenic Area	0	0	0	16.09	19.07	17.45	16,62	15.70	13.85	12.93	10.3
	Changbai Mountain Grand Canyon	0	0	0	12.08	15.24	17.66	16.88	14.77	14.72	10.52	9.02
Boardwalk	Changbai Mountain Tianchi	0	14.53	21.1	16.75	15.81	14.10	9.87	13.65	12.76	13.58	4.07
	Changbaishan Hot Springs	0	13.98	21.88	19.17	17.97	16.24	15.38	15.04	13.65	14.53	4.76

Based on above findings, the process of cumulative loads in the experiment area can be built (Châtel et al., 2010). Cumulative loads can be calculated by the formula as follows: $L_{i,t}=L_{i,t}-1+C_t\times Qt\times \Delta t$.
Where: L represents the cumulative load value at a certain moment; C represents the measured concentration at a certain moment; Q represents the runoff at a certain moment; Δt represents the time interval.
As shown in Fig. 3 and 4, the cumulative loads of artificial rainfall on the Changbai Mountain highway and the plank road are counted up, respectively.

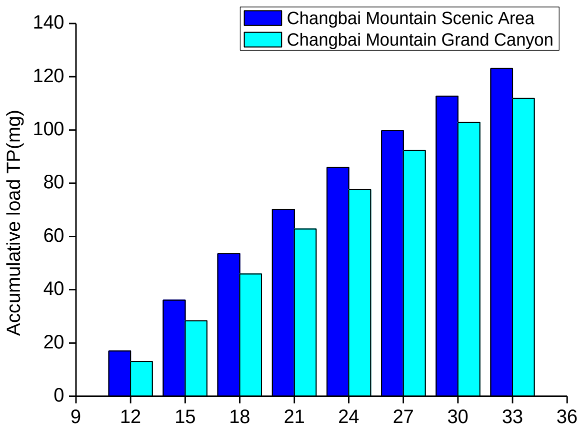

Figure 3: Artificial Rain Accumulated Load Process Statistics for Highways

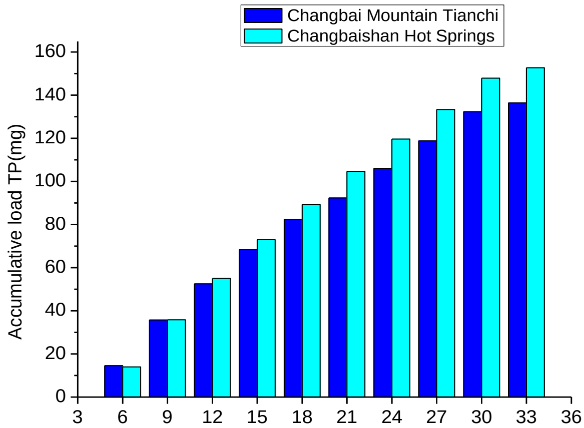

Figure 4: Artificial Rain Accumulated Load Process Statistics on the Plank Road

(2) Process analysis
The runoff generally undergoes four processes, i.e. initial loss, climbing period, stabilization period and decay period (Kocasoy, 1995). The highway runoff forms in 10 minutes or so after the precipitation with initial loss of 1.125mm, while the runoff of the plank roads is done so in about 5 minutes after precipitation. Its initial loss is 0.54mm. It turns to a stable period after a climbing period of about 5 minutes, keeping about 15 minutes for highway and 20 minutes for plank road, respectively.
The concentration formation experiences three processes, i.e. initial scour, decay, and plateau period (Jonathan et al., 2011). In the early period of rainfal., the TP (water quality) concentration significantly heaves in the later stage due to the fact that the rain absorbs free dust from the highly loaded pollutants. Within 4-5 minutes, after the free dust moves out of highly loaded pollutants, the TP concentration gradually decreases. After most fractions of the free dust are removed (within 15-18 minutes), the TP concentration gets relatively stable.
From the chart of cumulative loads, it can be seen that the load image is equivalent to a unitary quadratic polynomial curve.

Based on the above chart and process analysis, we attempt to use EMC to construct a surface runoff load model based on unit load (Stoop, 1999).

2.3 Establishing a total phosphorus pollution load model of annual runoff in study area

Based on the above analysis and the annual pollution load model proposed by the American scholar Schueler, appropriate indicators are chosen to correct it herein. A linear equation is built as the annual runoff pollution load model for the Changbai Mountain Scenic Area, as shown below (Chen et al., 2013): $L=\alpha F\gamma PRAE$
Where, L is the annual emission loads of pollutants; αis the unit load factor of pollutants; F is the ratio of the prediction period to the appropriate density of the standard period; γ is the sweep frequency parameter; A is the area of highway or plank road; E is the environmental characteristic factor; P is total annual rainfall; R is an effective rainfall factor.
According to the definition of the rainfall event by the United States Geological Survey and the artificial precipitation data analysis as above, the criteria that runoff rainfall cannot occur in the Zhangjiajie scenic spot are determined, as shown in Table 4.

Table 4: Cannot produce standards for runoff rainfall

Condition / Location	Can not produce runoff	Load required for the rainfall
Highway	Rainfall in a single field≤1.125	Rainfall in a single field≥1.125
Boardwalk	Rainfall in a single field≤0.6	Rainfall in a single field≥0.6

3. Checking calculation of experiment data from Zhangjiajie using the load model

3.1 Calculation of pollution load factor

Based on survey data, the pollution load factors of highways and plank roads in the Zhangjiajie scenic spot are calculated using the formula $\alpha = \overline{CV}/_{PA} = \sum_{i=1}^{n} Ci \times Vi /_{PA}$, as shown in Table 5 and 6, then $\alpha_{highway}$=0.178675, $\alpha_{boardwalk}$=0.181577.

Table 5: Public path data

Location	Time	3	6	9	12	15	18	21	24	27	30	33
Changbai Mountain Scenic Area	Packet net flow	0	0	0	40.4	86.6	93.1	93.1	98.1	93.1	93.1	86.6
	Group concentration	0	0	0	0.41	0.21	0.188	0.19	0.17	0.16	0.13	0.12
	Total load	123.0915										
	Total runoff	681.6										
	α_1	0.170656543										
Changbai Mountain Grand Canyon	Packet net flow	0	0	0	39.1	78.6	79.2	89.3	84.3	89.2	90.1	85.3
	Group concentration	0	0	0	0.41	0.21	0.188	0.19	0.17	0.16	0.13	0.12
	Total load	111.7803										
	Total runoff	634.5										
	α_2	0.175135247										

Table 6: Runway flow data

Location	Time	3	6	9	12	15	18	21	24	27	30	33
Changbai Mountain Tianchi	Packet net flow	0	28.4	68.3	79.7	85.4	85.4	85.4	91.3	91.3	96.8	35
	Group concentration	0	0.52	0.32	0.20	0.183	0.166	0.156	0.14	0.15	0.15	0.13
	Total load	136.41										
	Total runoff	745.6										
	α_1	0.18079										
Changbaishan Hot Springs	Packet net flow	0	3.04	59.4	68.1	78.3	79.3	80.2	82.2	86.3	88.1	45
	Group concentration	0	0.48	0.31	0.23	0. 22	0.18	0.19	0.164	0.16	0.16	0.13
	Total load	151.78										
	Total runoff	724.9										
	α_2	0.1873242										

3.2 Calculating total phosphorus loads on highway and plank road in study area based on the pollution load model

By formula (2) $L=\alpha F\gamma PRAE$, where parameters E and F are uniformly set to 1, for calculating the TP on the plank road, γ=1, and for the highway, it is determined by the number of rainfalls in a year (Chatzinikolaou et al., 2010). Tables 7 and 8 give TP loads for the Changbai Mountain Scenic Area highway and plank road based on the pollution load model.

Table 7: Highway TP load data

Numbering	Ⅰ	Ⅱ	Ⅲ	IV	V	VI
Location	Changbai Mountain Scenic Area	Changbai Mountain Grand Canyon	Changbai Mountain Tianchi	Changbaishan Hot Springs	Black outlet	Julongquan
Highway area	15129	15665	19982	8318	16529	0
Road load factor	0.180864					
Average annual rainfall	574.2					
Average annual rainfall	522					
Percentage of total rainfall	89.98%					
Highway TP load into the lake	11.0568162	10.08431	14.6148323	6.129875	12.23393	0
Highway TP total load into the lake	54.82787					

Table 8: TP load data on the plank road

Numbering	Ⅰ	Ⅱ	Ⅲ	IV	V	VI
Location	Changbai Mountain Scenic Area	Changbai Mountain Grand Canyon	Changbai Mountain Tianchi	Changbaishan Hot Springs	Black outlet	Julongquan
Highway area	4785	2324	10369	3255	4449	0
Road load factor	0.180569					
Average annual rainfall	574.2					
Average annual rainfall	522					
Percentage of total rainfall	89.98%					
Highway TP load into the lake	4.541291	2.1542478	9.4652378	3.04703269	4.1486734	0
Highway TP total load into the lake	23.5387238					

As can be seen from the results in Tables 7 and 8, the total phosphorus pollution from the highway is more serious than that from the plank road for the following reasons. On the one hand, the road area is larger than the plank road. On the other hand, the highway is greatly affected by the surrounding environment. A lot of chemical pollutants are scoured onto the highway, but the load factor of the plank road is higher than that of the highway. The reason is that the plank road is a wooden structure, which makes chemical pollutants easy to deposit due to the inconvenience for cleaning them.

4. Conclusions

The chemical pollutions caused by annual runoffs from highways and plank roads of Changbai Mountain scenic areas are explored herein with reference to domestic and foreign literature on non-point source and surface runoff pollutions of roads. The specific conclusions are derived as follows:

On the basis of the characteristics of the Changbai Mountain scenic area itself, and with data preparation, the artificial rainfall experiment designed here gives the evolution laws of the runoff volume, runoff concentration, subsection loads, and cumulative loads in each time frame.

Based on data from artificial rainfall experiment, the annual surface runoff pollution load model proposed by the American scholar Schueler underlies the highway and plank road pollution load model as built hereof, and appropriate correction is also done with appropriate indicators.

Chemical pollution from annual runoff of highways and plank roads in Changbai Mountain Scenic Area are calculated using this model proposed herein. The results reveal that, although the pollution load factor of the plank roads is high, the total phosphorus pollution of the highway is greater.

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