



## The Effect of Paved Roads on Organic Carbon Content of Soil in Taham Dam Basin

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### ABSTRACT

**Background:** Contamination of water and soil through non-point sources such as road runoff causes environmental concern. The aim of this study is to determine the effect of Zanjan – Chavarzagh road on the total organic carbon (TOC) content of sediments in tributaries and the river that lead to Taham Lake.

**Methods:** In tributaries and the river 69 soil and sediment samples were taken and the Total organic carbon (TOC) was measured according to Walkely-Black method. Also, Taham Dam Basin area and its hydrologic properties were calculated by Global Information System (GIS) software.

**Results:** Results showed that, TOC concentration has a significant negative relationship with the distance from the lake. TOC in soil samples taken from hillside of the road had significantly lower mean and median concentration (median= 3262, mean = 4083 ± 3461 mg/kg) than the valley side (median = 5324, mean = 6178 ± 3980 mg/kg). The check dams across the tributaries and the river have not been effective in the reduction of TOC in sediments.

**Conclusion:** Roads in the Taham Dam Basin, increases TOC content of soil and sediments in Taham dam basin. TOC moves toward Taham dam lake.

## 1. Introduction

Storm water from roads is considered as a major source of pollution in our environment [1,2]. The types and amounts of pollutants on road can vary widely from place to place. Many of these compounds are deposited on roads as a result of ordinary traffic activities, such as fuel leakage and the wear and tear of vehicle parts [3].

Traffic characteristics (such as traffic load and average speed), weather conditions, dry periods before a rainfall, and rainfall intensity affect the emission of roads runoff pollutants [4]. Pollutants transferred with road runoff are divided into suspended solids, heavy metals, biodegradable organic matters, organic micro-pollutants,

pathogenic organisms, nutrients and petroleum products [5]. Without treatment, these components may find their way directly into surface water or penetrate into the soil of the roadside [1]. Since organic pollutants are associated with particles and sediments, they are possibly more serious during heavy rain [6]. Pollution of water resources and depletion of water quality through urban areas runoffs threaten aquatic life and human health [1].

Surface runoff and aerial dispersion are two main paths of road pollutants dispersion. The first one directly transfers the pollutants to receiving waters and the second one indirectly does it by airborne dust [7].

Due to exploitation limitations from groundwater resources, Taham dam in Zanjan-Iran was constructed to provide raw water to a drinking water treatment plant. Taham Lake Basin is a part of Sarem Saqlu River and Zanjanroud Basin which in turn is a part of the Ghezel Ozen river basin (the main branch of the Sefid Rood River) [8].

Considering the presence of a road through a valley and the river leading to the lake, transfer of organic and inorganic pollutants from the road to the lake is possible. In this study, the effects of road on TOC concentration in soil and sediment samples taken from tributaries and Taham river basin were analysed.

## 2. Materials and Methods

### 2.1. Sampling

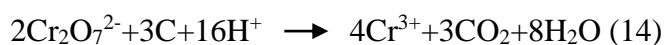
Using the geographic information software and Google Earth™ Satellite images of the Basin, the tributaries which road runoffs are directly discharged to (valley side), and the tributaries which there is no possibility to receive road runoff (hillside), were identified (Fig. 8). On the other hand, basin area, sub-basins, length and slope of the paved-roads were calculated via Global Information System Software (ESRI's ArcGIS software, version 10). There has been several check dams between the road and the lake which may capture contaminated soil and sediments. The check dams were specified on map as sampling points. Considering the resources, 69 samples were collected within three days of sampling operation. Samples were taken from 5-10 cm depth of soil. In order to prepare soil samples, a 2-

mm sieve was used to separate roots and other coarse materials [9]. All samples were kept in zippered nylon bags. Coordinate of sampling locations were taken using a GPS. [10]. Samples were transported to the laboratory using a cool box and stored in a fridge at 4°C until TOC analysis [11].

### 2.2. Measuring organic carbon

TOC is a gross measure of all forms of organic carbon including petroleum hydrocarbons and natural organic matter. Although there are several methods by which it can be measured, the simplest to perform in a laboratory is the well-known Walkely-Black method, a colorimetric procedure that requires no elaborate equipment. In this method, organic material is oxidized to carbon dioxide by potassium dichromate ( $K_2Cr_2O_7$ ) under acidic conditions (Eq. 1) [12].

Dissolved ions of orange red  $Cr^{6+}$  become green after reduction to  $Cr^{3+}$  ions. The green color intensity is measured by spectrophotometric method in wavelength of 540 – 670 nanometers [11, 13].



(Eq. 1)

This method is limited in high concentrations of organic matter (more than 50000-60000 mg/kg) [14]. Briefly, 5 ml of 0.28 molar dichromate potassium was added to 0.5 g of soil sample and mixed thoroughly. Then 7.5 ml of sulfuric acid was added and after dilution with distilled water, samples were cooled at room temperature for 30 minutes. Oxidized samples were centrifuged for 10 minutes at speed of 2000 rpm. Resulted solution was transferred to a Spectrophotometer cuvette and absorbance of sample was recorded [13]. To determine TOC recovery, it was necessary to prepare soil with no organic matter.

Briefly, 10 g of soil was burned by electrical stove for 2 hours at 700°C. Different and specified concentration of glucose was spiked to the burned soil and then soaked in distilled water. The resulted mud was mixed thoroughly using a magnetic stirrer for 1 hour. Finally, TOC concentration was measured as described in section 2.2. Percentage of recovery was calculated

by dividing observed TOC concentration by expected value. To control reliability of TOC measurements, acceptable standard deviation of

duplicate samples was considered less than 1 g/kg [13].

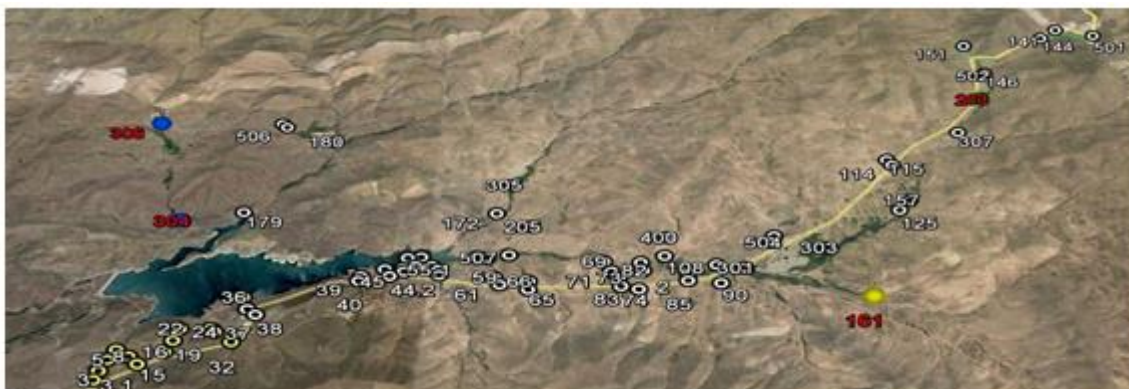


Fig. 1: Google Earth™ Satellite images of the Taham dam basin and sampling point.

2.3. Statistical Analysis of Results

A Graph Pad Prism Software (vers.5.04) was used to analyze all data during four steps. These steps are identifying Statistical and Central Dispersion Indices, evaluation of the data distribution and normality/abnormality, investigation of the presence of difference or significant relationship in various categories through parametric and nonparametric tests according to the data distribution and ultimately drawing comparative charts to better clarify statistical analyses [15].

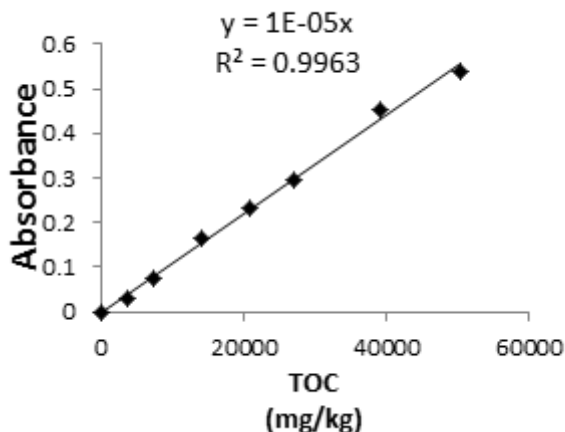


Fig. 2: Calibration curve and equation used to determine TOC in soil samples.

3. Results and Discussion

3.1. Analytical result

A calibration curve was prepared by a series of seven different concentrations of glucose in distilled water (Fig. 2).

The recovery of method for seven spiked samples was 99.7 – 134.8%.

3.2. Effect of sampling locations on TOC

It was reported that, in a forest, organic carbon content of soil in roadside is less than collected

soil samples out of the road. It was suggested that, cutting trees to construct the road reduces humus and microorganism content of the soil [16].

In order to investigate the effect of sampling locations on TOC in soil, sampling locations were classified into five different groups including waterway, check dam, river side, lake side, and parking areas. The mean and median concentrations of TOC in each group is illustrated in figure (3). Significant difference between the median concentration of TOC in samples tak from

Due to abnormal distribution of data, nonparametric Kruskal-Wallis test was used to compare the median values of TOC concentration

among groups. The obtained results indicate a parking areas and river side (p-value: 0.0128,  $\alpha$ : 0.05).

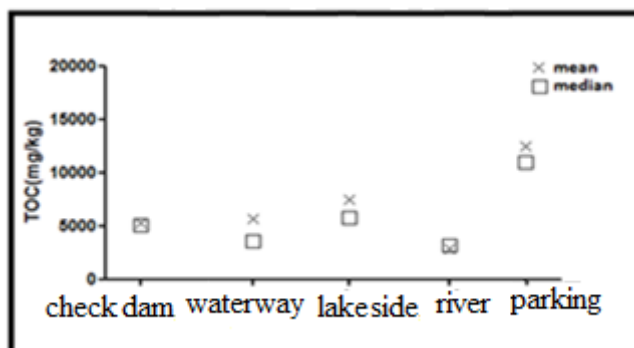


Fig. 3: Mean and median of soil TOC in different types of sampling points.

### 3.3. Effect of elevation on TOC

A research in Yazd province, Iran, demonstrated that TOC in soil decreases as altitude increases. This observation was explained by falling temperature and existence of fewer plants in the places with higher elevations [17]. In contrast, another study showed that organic matter increases with increasing elevation. It was explained by lower decomposition rate of organic matter compared to the higher elevation.

Therefore, it seems that TOC accumulates in the soil of higher elevations [18,19]. In a similar research, it was reported that increasing altitude has a positive significant effect on organic matter in soil. It was suggested that, higher rain fall, more growth of vegetation, and low decomposition rate compared to lower elevation increases organic content of soil [20]. However, in the present study, temperature does not alter a lot because of low elevation changes; therefore, it cannot affect concentration of organic matter.

Because data are not distributed normally, the correlation between TOC concentration in soil and elevation was analyzed by Spearman's correlation test. According to the obtained results, there is a negative significant relationship between TOC and elevation (Table 1) (p-value = 0.012, Spearman r = -0.301).

Sampling locations were divided based on elevation of points in 50 m-increments, Figure (4) was plotted which clearly shows decreasing TOC content of soil with increasing elevation.

Table 1: Spearman coefficient and p-value for relationship of total soil organic carbon and elevation.

P-value	Spearman r	Relationship of soil TOC and elevation
0.012	-0.301	N=69

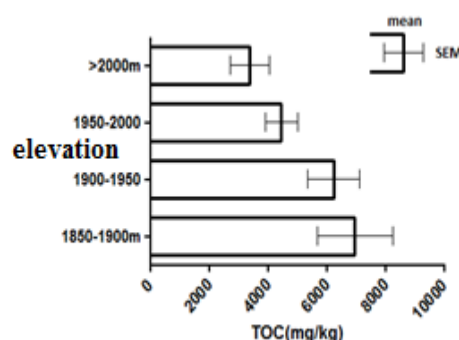


Fig. 4: TOC in elevation of points in 50 m increment.

### 3.4. Effect of distance from lake or river on TOC

All points of sampling in valley side of the road were situated between road and lake /river. Correlation between TOC and distance from lake or river was studied. Due to abnormal distribution of data, spearman correlation analysis was used.

According to the presented results in Table (2), TOC concentration has a significant negative relationship with the distance from the lake. The sampling points were divided into 11 groups from 100 meters to 800 meters and a comparative test was conducted. In addition, these points with two other data groups on the lake and river side and the point of more than 800 m were compared.

**Table 2:** Spearman coefficient and p- value for correlation between soil TOC and distance from the lake and river.

P-value	Spearman r	soil TOC and distance from the lake
0.039	-0.250	

N=69

### 3.5. Comparing soil TOCs in hill side and valley side of the road

In order to study the effect of wind on distribution of pollutants, the mean concentrations of Total petroleum hydrocarbon (TPH) in soil were determined at distances from 1 to 60 m in both side of a road. It was revealed that, there was no significant difference between windward and leeward of the road [21].

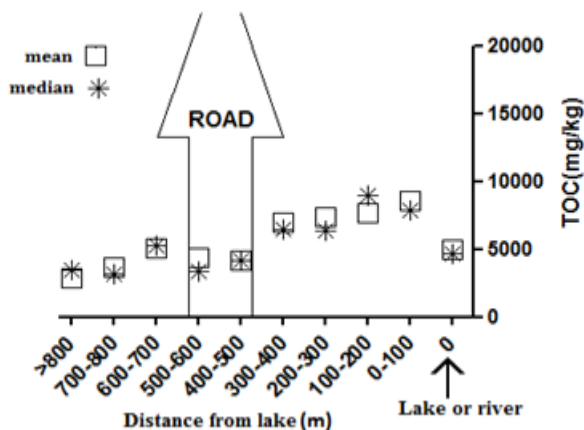
Sampling points were divided to “hill side and valley side of the road” groups and presented in Table (4), due to non-normal distribution of data, according to Shapiro–Wilk test through Mann-Whitney paired test, it is clear that median of TOC in valley side of the road is significantly more than that of hill side of the road. In figure (6) the higher value of TOCs mean and median in valley side of the road is obvious.

### 3.6. Effect of distance from the road on TOC

In a comparative study in an urban area, it was shown that soil organic matter is influenced by urban age and distance of roads [22]. It was shown that, there is significantly positive correlation between TPH and TOC content of the soil. It was suggested that, TOC content of the soil is a useful tool to recognize TPH contaminated soils [14, 23, 24].

Based on the reviewed literature, it was supposed that road affected TOC content of soil. Therefore, distance from the road was a determinant factor in surveying road effects on the soil. Statistical analysis for investigating the correlation between TOC and distance from the road was carried out using 29 samples at the valley side of the paved-road. Due to abnormal data, spearman correlation test was used. According to the presented results in Table (5), TOC concentration has an insignificant relationship with the distance from the road.

Sampling points in tributaries, check dams and parking areas were divided to 8 groups based on distance from the road in a 100 m increments in



**Fig. 5:** Total soil organic carbon in distance of 200 meters from the river and lake.

In Table (3) - no significant difference was observed among the groups. However in Figure (5), decreasing trend of the soil TOC with increasing of distance from the lake/river and lower concentration of soil TOC in lake and riverside is obvious.

both hill and valley sides. All groups were shown in figure 7. Kruskal-Walis comparative test was used due to abnormal distribution of data. A

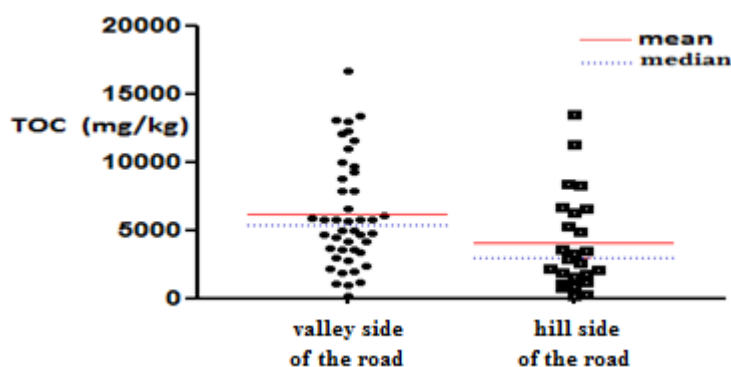
significant difference was observed among the groups (p-value: 0.47,  $\alpha$ : 0.05).

**Table 3:** Result of comparative test of soil TOC in 100m and more-distance from the lake.

	0	0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	>800
Number of values	15	6	6	6	6	5	6	4	8	7
Median	4640	7874	9002	6404	6422	4203	3321	5287	3211	3442
Mean	4974	8589	7649	7328	6936	4203	4322	5046	3621	2906
Passed normality test?	Yes	No	No	No	No	No	No	No	Yes	Yes
<b>Kruskal-Wallis test</b>										
P value:	0.220									
Are medians significant different? (P < 0.05)	No									

**Table 4:** The comparative tests results of the soil TOC in hill side and valley side of the road.

	Hill side of the road N=25	Valley side of the road N=44
Passed Shapiro-Wilk normality test? (alpha=0.05)	No	No
	P value: 0.015	P value: 0.008
Median	3262mg/kg	5324mg/kg
Are medians signif. different? (P < 0.05)	Yes	
	P value: 0.021	



**Fig. 6:** Soil TOC in hill side and valley side of the road.

In Figure (7), significant increase of TOC content of the soil is notable in a distance of 0-100 m from the road. It can be due to emission of organic pollutants and petroleum hydrocarbons from traffic activity. On the other hand, concentration of TOC increases gradually in Distance of more than 200 m of the valley side of the road. It can suggest that TOC increases in the samples taken from relatively flat areas where sediments were deposited. This observation is accordance with the previous research, which reported that concentration of TOC in soil apparently increases with increasing distance from the road [25].

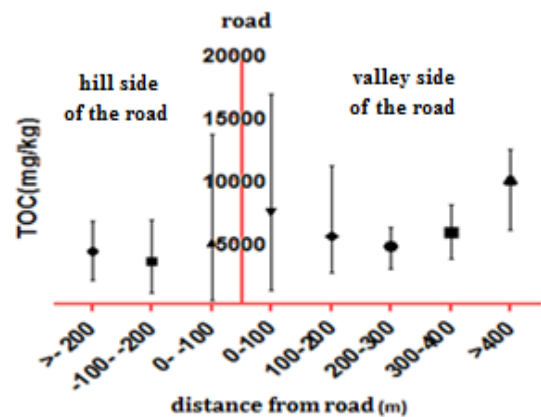


Fig.7: Soil TOC in 100 m-distances of the hill side and valley side of the road.

Table 5: Statistical analysis of relationship between TOC with distance from the road.

P-value	Spearman r	TOC and distance from road
0.909	-0.022	N=29

3.7. Effect of valley and hill side on TOC

In order to determine the effect of the road, sampling points were divided to three groups of “hill side of the road”, “first points of the valley side of the road”, and “valley side of the road” (figure8).



Fig. 8: Schematic view of the sampling points.

Although higher median and mean concentration of TOC is clear in the first point of valley side (figure 9). Results presented in table (6) show that, there wasn't significant difference in median and mean concentration of TOC among

groups.

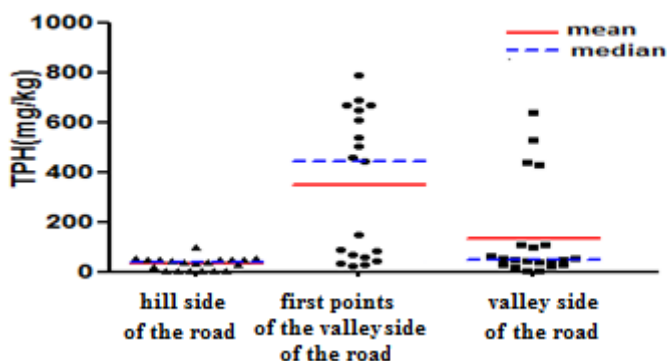
3.8. Effect of length, slope, and density of roads in each sub-catchments on TOC

The effect of length, slope and density of roads

in each sub-basin on TOC was compared using Spearman and Pearson coefficient. Presented results show that there is no correlation between them.

**Table 6:** Statistical tests results of soil TOC in three groups of hill side, valley side and road side points.

Title	first points of the valley side	valley side of the road	hill side of the road
N	20	20	20
Median	6158	5706	3084
Mean	7131	5777	4445
<b>Shapiro-Wilk normality test</b>			
P value	0.1880	0.1228	0.0272
Passed normality test (alpha=0.05)?	Yes	Yes	No
<b>Kruskal-Wallis test</b>			
P value			0.1236
Do the medians vary signif? (P < 0.05)?			No



**Fig. 9:** Mean and median of soil TOC in hill side, valley side and first point of valley side of the road.

**Table 7:** The results of correlation tests for investigating the effect of length, slope, and density of road in sub basins on TOC.

TOC	Pearson correlation test		Spearman correlation test	
	Correlation coefficient	P-value	Correlation coefficient	P-value
Correlation with road length	-0.207	0.478	-0.209	0.474
Correlation with slope	-0.026	0.930	0.073	0.805
Correlation with density	0.169	0.565	0.051	0.864

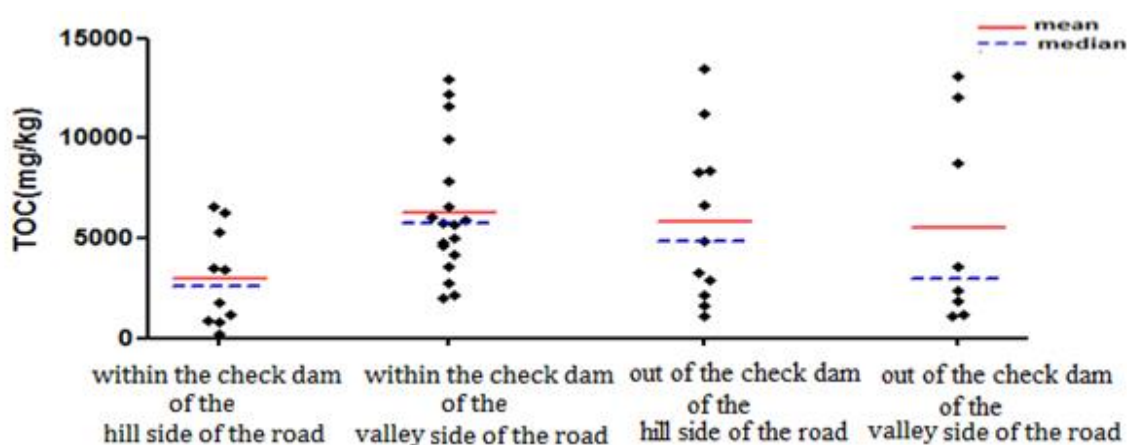


### 3.9. Effect of Check Dams on TOC

To determine the effect of check dams to block TOC movement, the samples taken from check dams and tributaries were classified into four groups of “within the check dam in the hill side of the road”, “out of the check dam in the hill side of the road”, within check dam in the valley side of the road and “out of the check dam in the valley side of the road”.

Parametric and non-parametric tests were performed to compare four groups. There was no

significant difference in median and mean of TOC among groups shown in Figure (10) (p-value: 0.0985,  $\alpha$ : 0.05 for Kruskal-Wallis test and p-value: 0.158,  $\alpha$ : 0.05 for One-way analysis of variance). According to situation of the check dams in the valley side of the road in the path of runoff and non-significant different in soil TOC concentration between tributaries and check dams, it is possible to say that the check dams are not effective in reduction of organic content of soil in downstream.



**Fig. 10:** Mean and median concentration of soil TOC in and out of check dams in hill side and valley side of the road.

## 4. Conclusions

This study shows that, in the valley side of the road, concentration of TOC is more than the hill side.

The TOC content of soil significantly increases as distance of sampling points from Taham dam lake decreases. In other words, there is an increasing trend of TOC from higher elevations toward the dam lake. Moreover, road causes significant increase in TOC content of soil in valley side of the road compared to hill side. This observation can be explained by washing out of pollutants from roads toward lower elevation in

the valley side. The minimum concentration of TOC observed in collected sediments from river.

This can be explained by erosion of sediments during high flow seasons. Check dams are not significantly effective to reduce TOC content of sediments in downstream. In conclusion, this study showed that paved roads in Taham dam basin significantly increases TOC content of soil and sediments which move toward the dam lake.

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