



## Anthropogenic and Natural Influences on Soil Organic Carbon Fractions: A Case Study on Soils of Meyghan Lake in Arak, Iran

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**ABSTRACT** Monitoring and assessment of soil organic carbon (SOC) in the soils of arid areas are very important. The objectives of the study were to evaluate the responses of extractable and particulate organic matter in soils around Meyghan Lake in Arak (Iran) to surface water-inflows. Two layers (0-30 cm and 30-60 cm) of soils were sampled in the release sites of municipal wastewater and 3 rivers. Different fractions of SOC were measured and statistically analyzed. The soil sampled from the release sites of municipal wastewater had the highest total organic carbon (14.1 mg TOC g<sup>-1</sup> topsoil) and free particulate organic matter (8.07 mg FPOM g<sup>-1</sup> topsoil) due to better soil condition for plant growth. In contrast, the soil sampled from the release sites of wastewater of sodium sulfate plant had the lowest total organic carbon (3.50 mg TOC g<sup>-1</sup> topsoil) and all of the fractions. The cold water extractable OC (CWEOC), occluded particulate organic matter (OPOM) and the heavy fraction (HF) as slow fractions responded to soil sampling time better than active fractions. They significantly increased in the soils sampled in fall. The means of CWEOC, hot water extractable OC (HWEOC) and OPOM were higher in the soils sampled from the eastern part of the lake with higher clay and moisture contents and lower elevation. They responded better to the soil properties controlling the biological activity and biodegradation. The best fraction for the study of short-term changes of SOM by anthropogenic and natural effects was FPOM in these non-agricultural lands.

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Small lakes in arid regions are sensitive ecosystems. These lakes respond rapidly to anthropogenic influences and water-inflows. Soil and sediment organic carbon (OC) can provide crucial information about man-made changes (Vreca and Muri, 2010). Organic carbon has different chemical and chemical forms in soils and sediments. So the variability of total soil organic carbon (SOC) may not provide sufficient information about the changes of different forms of OC in soil and sediments. Hence many researchers fractionated SOC into components for a clearer recognizing of the response of the constituents to the soil and water management (Lutzow et al., 2007; Shindo *et al.*, 2006; Sohi et al., 2000). The SOC pools are labeled as fast or reactive, slow or transitional and inert or recalcitrant (Safari Sinegani, 2015). The active SOC pools are responsive and have turnover rates less than 10 years (1-2 years) (O'Rourke et al, 2015). The water extractable organic carbon (WEOC) on average comprises 0.3–1% of the TOC in arable soils, and it is

an active pool (Cookson et al., 2005; Jones et al., 2004). The light fraction obtained by density fractionation without aggregate dispersion is another active pool if black or inert carbon pool is considered. The light fraction may consist of free and occluded particulate organic matter (FPOM and OPOM) fractionated without and with aggregate dispersion (Safari Sinegani, 2015). Free POM was mineralized 2–14 % during a 66-day incubation, representing 2–12% of total OC mineralization in soil (Monaghan and Barraclough, 1997). The other components of SOM are occluded particulate organic matter (OPOM) and heavy fraction (HF) which mineralize slowly and release low levels of N and P in soils. Their turn over time is near 10-15 years (Boone, 1994; Curtin and Wen, 1999; Monaghan and Barraclough, 1997; Sollins et al., 1984). Meyghan playa has the biggest shallow and natural saline water in Markazi province, Iran. Following the industrialization and urbanization in Arak city, a lot of man-made solid and liquid wastes

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have been carried into the Meyghan Lake by natural seasonal rivers. In addition, the secondary effluent of wastewater of Arak city and the wastewater of sodium sulfate plant have been discharged into the saline lake of this playa. The total contents of heavy metals in water, soil and sediment of this region have been studied by (Ghadimi and Ghomi, 2013; Zhang and Shao, 2014). The vegetation and flora of Meyghan playa have also been studied (Akhani Sinegani, 1989). But there was no information about changes of soil organic matter in this semiarid region. We conducted an experiment to examine the changes of soil C pools in two sampling times and in 4 sampling sites affected by surface water-inflows of Meyghan Lake in Arak (Iran). Two sampling sites may be affected by anthropogenic surface water-inflows with receiving municipal wastewater and sodium sulfate plant wastewater and the others may not be affected by anthropogenic surface water-inflows by receiving seasonal Shahrab and Frahan rivers. The specific aims of this work were: (i) to clarify the effect of surface water-inflows on soil and sediment organic carbon and (ii) to characterize and compare the response of different SOC fractions to anthropogenic and natural influences of surface water-inflows in Meyghan playa.

## MATERIALS AND METHODS

**Soil sampling site:** The soil samples were collected in the sites around Meyghan lake placed in north of Arak city in the southern part of Markazi province, Iran (fig.1). The Meyghan playa catchment, a semi-arid zone, is located between latitudes 34°06'-34°19' N and longitudes 49°42'-49°57' E in the northwestern of Iran. The annual average air temperature of Arak city is 13.8°C while its annual rainfall is 315 mm. The cover of vegetation and flora (less than 5%) on the sampling sites were mainly halophytic plants. They

are composed of 1) *Halocnemum strobilaceum*, 2) *Salicornia europaea*, 3) *Juncus maritimus*, 4) *Phragmites australis*, 5) *Bolboschoenus maritimus*, 6) *Aeluropus litoralis*, 7) *Nitraria schoberi*, 8) *Sipa steppe* at the margin of basin and many other plants like *Alyssum linifolium* were also founded in this region (Akhani Sinegani, 1989). In addition to these native plants, some other new hydrophilic plants as Cyperaceae family can be founded in the release site of municipal wastewater of Arak city. Gharakahriz and Ashtian seasonal streams and many minor streams from the Farmahin, Amanabad and Haftadgoleh areas feed the playa. In addition, wastewater of sulfate sodium plant in southern part of the lake and municipal wastewater of Arak city directly discharged to Meyghan Lake. The average water depth in Meyghan Lake is approximately 0.5 m with a maximum depth of about 1.5 m. In spite of a large catchment area, the Meyghan playa receives very little natural water due to present arid climatic conditions (Zamani, 1999). Two layers (0-30 cm and 30-60 cm) of soils were sampled from 4 sampling sites in 3 replicates. Sampling sites were the release sites of municipal wastewater, Shahrab River, Farahan River and wastewater of sodium sulfate plant in Meyghan Lake. Samplings were done twice in May and November 2014. Figure1 shows map of the studied area and location of 4 sampling sites. Table 1 shows the properties of the sampled soils (Safari Sinegani and Safari Sinegani, 2017). As indicated, sampled soils from positions 1 and 2 (the release sites of Arak municipal wastewater and Shahrab river) in the eastern part of Meyghan Lake, had lower moisture contents due to lower elevation and higher clay contents compared to those sampled from positions 3 and 4 (the release sites of Farahan river and wastewater of sulfate sodium plant). Lands of the west part of the lake are a little higher, with a more coarse texture.

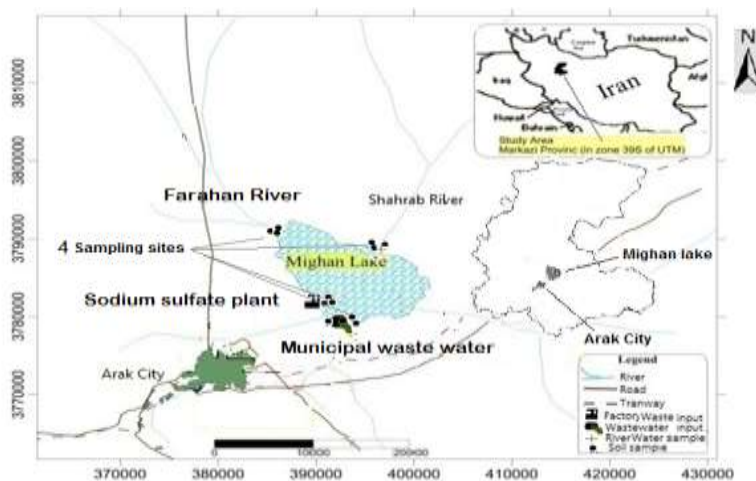


Fig. 1. The map of Iran, Markazi province and Meyghan playa in Arak city with the 4 sampling sites.

**Table 1:** Soil sampling sites and properties of the sampled soils<sup>#</sup>

Sampling Site	Depth (Cm)	GPS location (UTM)		Elevation (m)	Soil Texture	Clay (%)	Silt (%)	Sand (%)	Om (%)	EC 1:2 (dS m <sup>-1</sup> )
1	0-30	390312	3779164	1660	Clay	20	43.6	36.4	26.3	0.95
	30-60				Clay	14	45.6	40.4	26.5	2.26
2	0-30	396597	3788876	1660	-	-	-	-	36.4	19.79
	30-60				-	-	-	-	33.1	10.88
3	0-30	385342	3791903	1662	Clay loam	34	37.6	28.4	20.2	4.78
	30-60				Sandy clay loam	26	27.6	46.4	22.2	2.89
4	0-30	388599	3781049	1662	-	-	-	-	19.7	32.29
	30-60				-	-	-	-	28.9	26.25

#- 1) Municipal Wastewater, 2) Shahrab River, 3) Farahan River and 4) Sodium sulfate Factory Wastewater

Be reminded that the soils sampled from the positions of Shahrab River and wastewater of sodium sulfate plant were so full of salt that a large part of them was dissolved when measuring the percentage of sand, silt and clay and the small part of the remaining soil strongly attached to each other and sharply settled down. So the data of soil particle size analysis for these salty lands have not been reported in table 1. Soil salinity in the release position of Shahrab River and wastewater of sodium sulfate plant (positions 2 and 4) was much more than soil salinity in the two other sites.

*Organic carbon analysis:* The sampled soils by shovel and pick were air dried in lab temperature and pass through 2 mm sieve before organic carbon analysis. The methods applied in soil organic carbon fractionation were presented briefly in figure 2. Total soil organic carbon in each sample was determined by ferrous ammonium sulfate method (Walkley and Black, 1934). Different fractions of SOC were also measured. The cold water and hot water extractable SOC (CWEOC and HWEOC) were measured according to the method applied by Gregorich et al.

(2003) using cold water followed by hot water extraction. The CWEOC was extracted from soils by adding 150 ml of distilled/deionized water to a tube containing 15 g of air-dried soil. The soil: water suspension was shaken for 30 min and centrifuged at 4500 rpm for 20 min. The supernatant solutions were decanted and passed through a washed filter paper. The HWEOC was measured in these soils as following. Water was added to the wet soil in the bottom centrifuge tube to 150 ml. The tubes were placed in a water bath at 80 °C for 16 h. Then the HWEOC was extracted as above. The amounts of CWEOC and HWEOC were determined in the extracts by K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> oxidation and titration with Fe(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub> (Walkley and Black, 1934). These amounts were reported in term mg OC g<sup>-1</sup> soil. Light and heavy fractions (LF and HF) of SOM in density fractionation were determined with the modified method of Strickland and Sollins (1987) and used by Compton and Boone (2002) (Compton and Boone, 2002; Strickland and Sollins, 1987).

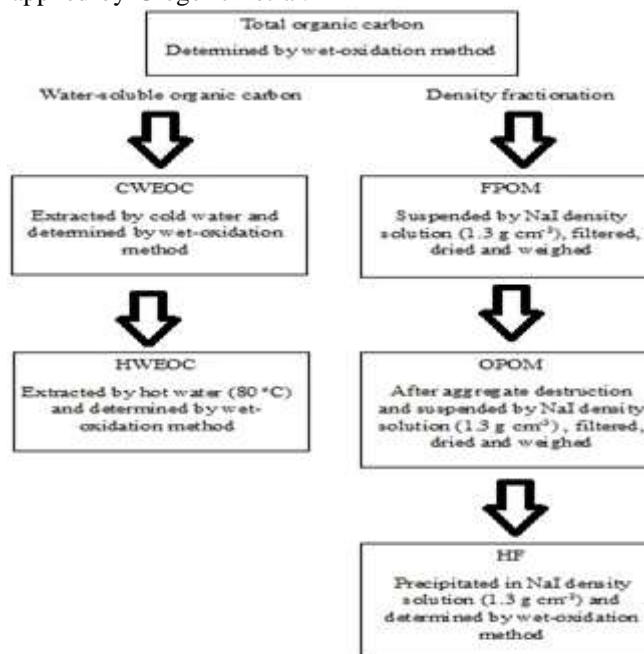


Fig. 2. Soil organic carbon fractionation scheme applied in this study

Ten grams of soils were dispersed in 20 ml of sodium iodide solution (NaI,  $d=1.30 \text{ g cm}^{-3}$ ). After shaking the tubes by hand (30 s) they were centrifuged (3000 RPM for 10 min). The floating LF was gathered on filter paper. The addition of NaI solution and the separation of LF were repeated until no LF obtained. The light fraction gathered on the filter paper was washed and oven dried for 48 h at 50 °C. The dry weight of LF was reported in term of mg SOM  $\text{g}^{-1}$  soil. This fraction was FPOM. For measuring OPOM, once again 20 ml NaI was added on the precipitated soil particles in the centrifuge tube and shake for detaching and dispersing soil mineral particles from OPOM. Then same as FPOM, the light fraction was separated, weighed and reported in term of mg SOM  $\text{g}^{-1}$  soil. This fraction was OPOM. The amounts of FPOM and OPOM were reported in term of mg OM  $\text{g}^{-1}$  soil. The washed soil particles in centrifuge tube were oven-dried in 50 °C and the HF of SOC was determined by the wet-oxidation method (Walkley and Black, 1934). The amounts of HF were reported in term of mg OC  $\text{g}^{-1}$  soil.

*Statistical analyses:* The completely randomized design was applied for data analysis of this factorial experiment. With 3 replicates the following factors were applied: 1) soil sampling sites in 4 levels at 4 release sites of surface water-inflows in Meyghan

Lake (municipal wastewater, Shahrab and Farahan rivers, and wastewater of sodium sulfate plant), 2) soil sampling depths in 2 levels (0-30 and 30-60 cm) and 3) soil sampling times in 2 levels (May and November, 2014). ANOVA was done by the Statistical Analysis System (SAS Institute., 1992). Data were also statistically analyzed for standard deviation and means were calculated. The effect of the mentioned factors on the SOC forms in the sampled soils was assessed by Duncan’s new multiple range tests ( $p<0.05$ ). The response and variability of the studied SOC fractions to anthropogenic and natural sources of variation were interpreted and recorded according to those analyses.

**RESULTS AND DISCUSSION**

Table 2 shows the analysis of variance of TOC and its different fractions in 2 layers of 4 sampled soils from Meyghan Lake in two seasons. The variability and response of CWEOC and HWEOC and especially HF were markedly low. The CWEOC was only depended on the main effects of soil sampling sites, depth and time, but HWEOC and HF in addition to those main effects were depended on the interaction between soil sampling site and depth. The dependence of TOC to soil sampling time was not statistically significant ( $p>0.05$ ).

**Table 2:** Analysis of variance (mean square, MS) of cold water and hot water extractable organic carbon (CWEOC and HWEOC) values (mg OC  $\text{g}^{-1}$  soil), free and occluded particulate organic matter (FPOM and OPOM) values (mg OM  $\text{g}^{-1}$  soil), heavy fraction (HF) value (mg OC  $\text{g}^{-1}$  soil), and total organic carbon (TOC) content (%) in 2 layers of 4 sampled soils from Meyghan lake #

Source	DF	CWEOC	HWEOC	FPOM	OPOM	HF	TOC
Sampling Site (Ss)	3	5.35**	10.40**	90.88**	6.05**	9.68**	1.69**
Soil depth (Sd)	1	0.57**	1.79**	37.45**	9.49**	15.34**	1.50**
Sampling time (T)	1	0.48*	0.22*	6.35**	6.22**	11.23**	0.01
Ss*D	3	0.04	0.15*	6.09**	0.62**	1.07*	0.07**
Ss*T	3	0.08	0.03	3.45**	0.82**	0.73	0.08**
Sd*T	1	0.09	0.02	0.48	0.67*	0.32	0.03
Ss*Sd*T	3	0.11	0.04	0.62	0.29*	0.12	0.10**
Error	32	0.07	0.05	0.51	0.12	0.34	0.01
CV		27.14	15.65	18.55	21.76	18.13	13.69

#- \* MS is significant at the 0.05 level. \*\* MS is significant at the 0.01 level.

**Table 3:** Mean test of cold water and hot water extractable organic carbon (CWEOC and HWEOC) values (mg OC  $\text{g}^{-1}$  soil) in topsoil and subsoil of 4 sampled soils from Meyghan Lake in spring and fall #

Sampling time	CWEOC				HWEOC					
	Spring		Fall		Mean	Spring		Fall	Mean	
Site	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Site 1 Topsoil	0.93c	0.12	1.71a	0.21	<b>1.32BC</b>	1.64ef	0.12	2.07cd	0.12	<b>1.86C</b>
Site 2	1.79a	0.33	1.86a	0.12	<b>1.82A</b>	2.79a	0.37	2.71ab	0.33	<b>2.75A</b>
Site 3	0.93c	0.54	1.14bc	0.45	<b>1.04CD</b>	1.57efg	0.12	1.79de	0.33	<b>1.68C</b>
Site 4	0.07d	0.12	0.14d	0.06	<b>0.11E</b>	0.21h	0.19	0.36h	0.12	<b>0.29E</b>
<b>Mean</b>	<b>0.93B</b>		<b>1.21A</b>			<b>1.55A</b>		<b>1.73A</b>		
Site 1 Subsoil	1.00bc	0.25	1.07bc	0.21	<b>1.04CD</b>	1.21g	0.12	1.29fg	0.21	<b>1.25D</b>
Site 2	1.43ab	0.12	1.64a	0.33	<b>1.54AB</b>	2.21c	0.33	2.36bc	0.21	<b>2.29B</b>
Site 3	0.71c	0.12	0.86c	0.37	<b>0.79D</b>	1.21g	0.12	1.36fg	0.25	<b>1.29D</b>
Site 4	0.04d	0.04	0.07d	0.12	<b>0.06E</b>	0.20h	0.20	0.21h	0.21	<b>0.21E</b>
<b>Mean</b>	<b>0.80B</b>		<b>0.91B</b>			<b>1.21B</b>		<b>1.30B</b>		

#- 1) Municipal Wastewater, 2) Shahrab River, 3) Farahan River and 4) Sodium sulfate Factory Wastewater; Means with the small same letter are not significantly different. Means with the capital same letter in each column are not significantly different.

It was interesting that OPOM had the highest response to the soil sampling site, depth and time. We expected that the response of this fraction to soil sampling time had been insignificant. This yearly time variability shows that this fraction of SOC in this semiarid land takes part in microorganism nourishment actively. Unexpectedly the variability of FPOM was lower than that of OPOM. Although the main effects of sampling site, depth and time on FPOM were statistically significant ( $p < 0.01$ ), the effect of the interaction between sampling time and depth and the effect of the interaction between sampling time, depth and site on FPOM were not statistically significant ( $p > 0.05$ ). This may be related to the higher activity of FPOM compared to OPOM. In this study, the scale for sampling time was so large that the fast changes of FPOM may not be seen and revealed. If the variation of FPOM will be studied in a shorter time interval, this result for the variability and response of FPOM compare with OPOM may be higher. The mean of CWEOC was lower than the mean of HWEOC in each sampling site, depth and time (table 3). The soil in Shahrab river site had the highest CWEOC and HWEOC at two sampling depths. They were 1.82 and 2.75 mg g<sup>-1</sup> soil respectively in topsoil (0-30 cm) of this site. These fractions of SOC were also high in soil sampled from the release site of Arak municipal wastewater. In the topsoil of this site, they were 1.32 and 1.86 mg g<sup>-1</sup> soil respectively. The lowest CWEOC and HWEOC were measured in soil sampled from the release site of wastewater of sulfate sodium plant. They were 0.11 and 0.29 mg g<sup>-1</sup> soil respectively. Similar results obtained in the subsoil sampled from these sites. The soil sampled from the release sites of Shahrab River and municipal wastewater compared to the soils sampled from the release sites of Farahan River and wastewater of sulfate sodium factory, had higher CWEOC and HWEOC. Here in each sampling site, the CWEOC measured in topsoil was higher than that in subsoil but this difference was not statically significant ( $p < 0.05$ ). However, the difference of

HWEOC in topsoil and subsoil was higher and significant in most cases. In contrast, the response of CWEOC compared to HWEOC to the sampling time was higher. The mean of CWEOC in the topsoil of the sampled soils increased significantly from 0.93 mg g<sup>-1</sup> soil in spring to 1.21 mg g<sup>-1</sup> soil in fall (table 3). This increase was not significant for CWEOC in subsoil and HWEOC in topsoil and subsoil of sampled soils. The response of FPOM to soil sampling site was significant and the highest FPOM was measured in topsoil and subsoil of the municipal wastewater site. The means of FPOM in the topsoil and subsoil were 8.07 and 6.43 mg g<sup>-1</sup> soil respectively. These values were significantly different and higher than those in soils sampled from the other sites. The lowest FPOM was measured in topsoil and subsoil of the release site of the wastewater of sodium sulfate plant. The means of FPOM in these soils were 0.70 and 0.53 mg g<sup>-1</sup> soil respectively. The mean of FPOM in the topsoil of the release site of Sharab River was not significantly different from that of Farahan river site. However, the FPOM contents in the subsoil of these sites were different. It was higher in the subsoil of Farahan river site. The response of FPOM to soil sampling depth was significant and it was significantly higher in the topsoils. Except soil sampled from sulfate sodium wastewater release site that is unsuitable for plant growth, each soil had significantly higher FPOM mean in upper layer compared to its mean in the lower layer. The response of FPOM to soil sampling time was also significant in the upper layer. The mean of this fraction in topsoil increased from 4.25 mg g<sup>-1</sup> soil in spring to 5.18 mg g<sup>-1</sup> soil in fall. The time variability of FPOM was not statically significant in the subsoil. The response of OPOM to soil sampling site was significant and the highest OPOM was measured in the topsoil and subsoil of the municipal wastewater and Shahrab river sites. The means of OPOM in the topsoil of these sites were 2.37 and 2.76 mg g<sup>-1</sup> soil respectively (table 4).

**Table 4:** Mean test of free and occluded particulate organic matter (FPOM and OPOM) values (mg OM g<sup>-1</sup> soil) in topsoil and subsoil of 4 sampled soils from Meyghan Lake in spring and fall #

Sampling time	FPOM				OPOM					
	Spring	SD	Fall	SD	Mean	Spring	SD	Fall	SD	Mean
Site 1 Topsoil	6.48bc	0.17	9.67a	0.33	<b>8.07A</b>	1.64cde	0.44	3.09b	0.33	<b>2.37AB</b>
Site 2	4.93de	0.29	5.03de	1.77	<b>4.98C</b>	1.84cde	0.60	3.67a	0.67	<b>2.76A</b>
Site 3	4.99de	0.31	5.26cd	0.64	<b>5.12C</b>	2.26c	0.21	2.28c	0.07	<b>2.27B</b>
Site 4	0.62g	0.07	0.77g	0.33	<b>0.70E</b>	0.44hi	0.15	0.97fgh	0.33	<b>0.71DE</b>
<b>Mean</b>	<b>4.25B</b>		<b>5.18A</b>			<b>1.55B</b>		<b>2.50A</b>		
Site 1 Subsoil	5.70cd	0.44	7.15b	1.86	<b>6.43B</b>	0.77fghi	0.18	1.35def	0.33	<b>1.06D</b>
Site 2	1.33g	0.35	1.35g	0.33	<b>1.34E</b>	1.20efg	0.12	1.93cd	0.33	<b>1.57C</b>
Site 3	3.23f	0.30	3.77ef	0.29	<b>3.50D</b>	1.39def	0.32	1.64cde	0.44	<b>1.52C</b>
Site 4	0.48g	0.17	0.58g	0.00	<b>0.53E</b>	0.21i	0.13	0.58ghi	0.00	<b>0.40E</b>
<b>Mean</b>	<b>2.69C</b>		<b>3.21C</b>			<b>0.89C</b>		<b>1.38B</b>		

#-1) Municipal Wastewater, 2) Shahrab River, 3) Farahan River and 4) Sodium sulfate Factory Wastewater; Means with the small same letter are not significantly different. Means with the capital same letter in each column are not significantly different.

These values were significantly higher than those in the soils sampled from the other sites. So similar to CWEOC and HWEOC soils with higher moisture and clay contents sampled from the eastern part of the lake had higher OPOM means (table 1). Similar to other fractions, the lowest OPOM was measured in topsoil and subsoil of the release site of the wastewater of sodium sulfate plant. The means of OPOM in these soils were 0.40 and 0.71 mg g<sup>-1</sup> soil respectively. The response of OPOM to soil sampling depth was significant and it was significantly higher in topsoil. Except soil sampled from sulfate sodium wastewater release site, each soil had significantly higher FPOM mean in upper layer compared to its mean in the lower layer (table 4). The response of OPOM to soil sampling time was significant in topsoil and subsoil of sampled soils. Its mean in topsoil increased from 1.55 mg g<sup>-1</sup> soil in spring to 2.50 mg g<sup>-1</sup> soil in fall. These values for subsoil were 0.89 and 1.38. It shows that the response of OPOM to soil sampling time is higher than the response of the other fractions. It can accumulate in topsoil and subsoil during plant growth season. The highest HF was measured in the topsoil of the release sites of natural Shahrab and Farahan rivers. The means of HF in the topsoil of these sites were 4.64 and 4.55 mg g<sup>-1</sup> soil respectively (table 5). Like other OC pools, this fraction had significantly lower contents in the subsoil. However, the highest HF was measured in the subsoil of the release sites of the municipal wastewater and Shahrab river sites. The means of HF in the subsoil of these sites were 3.16 and 3.17 mg g<sup>-1</sup> soil

respectively. The lowest HF was measured in the topsoil and subsoil of the release site of the wastewater of sodium sulfate plant. The means of HF in these soils were 2.90 and 1.53 mg g<sup>-1</sup> soil respectively. The response of HF to soil sampling depth was significant and it was significantly higher in the topsoil of all sites. The response of HF to soil sampling time was also significant in topsoil and subsoil of sampled soils. Its mean in topsoil increased from 3.22 mg g<sup>-1</sup> soil in spring to 4.35 mg g<sup>-1</sup> soil in fall. These values for subsoil were 2.25 and 3.06 mg g<sup>-1</sup> soil. The mean of TOC in the topsoil of municipal wastewater site was (1.41 %) significantly higher than those in soil sampled from the other sites. Although there was no significant difference between TOC contents of topsoil sampled from Shahrab and Farahan river sites, it was lower in salty soils sampled from Shahrab river site (0.98 %). Especially TOC was significantly low (0.35 %) in salty soil sampled from the release site of wastewater of sodium sulfate plant. The response of subsoil TOC to soil sampling site was low. The means of TOC had no significant differences in the subsoil of municipal wastewater, Shahrab and Farahan river sites. The means of TOC in the topsoil of each site was higher than that in its subsoil but only the response of TOC to soil depth was significant for anthropogenic influenced soils in municipal wastewater site and sodium sulfate plant wastewater site. The response of TOC to soil sampling time was significant only for topsoil of non-salty sites.

**Table 5:** Mean test of heavy fraction (HF) value (mg OC g<sup>-1</sup> soil) and total organic carbon (TOC, %) values in topsoil and subsoil of 4 sampled soils from Meyghan lake in spring and fall #

		HF				TOC					
Sampling time		Spring		Fall		Mean	Spring		Fall		Mean
Site		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Site 1	Topsoil	3.27bcd	0.10	4.05b	0.79	<b>3.66B</b>	1.62a	0.10	1.21b	0.21	<b>1.41A</b>
Site 2		3.78b	0.50	5.51a	0.85	<b>4.64A</b>	0.98cd	0.02	0.98cd	0.20	<b>0.98B</b>
Site 3		3.79b	0.33	5.31a	0.50	<b>4.55A</b>	0.88de	0.02	1.24b	0.11	<b>1.06B</b>
Site 4		2.04efg	0.15	2.54def	0.20	<b>2.29D</b>	0.36hi	0.01	0.33hi	0.05	<b>0.35D</b>
	<b>Mean</b>	<b>3.22B</b>		<b>4.35A</b>			<b>0.95A</b>		<b>0.93A</b>		
Site 1	Subsoil	3.07b-e	0.25	3.25bcd	0.77	<b>3.16BC</b>	0.88de	0.02	1.07bc	0.10	<b>0.98B</b>
Site 2		2.63c-f	0.19	3.72bc	0.85	<b>3.17BC</b>	0.60fg	0.15	0.51gh	0.07	<b>0.55B</b>
Site 3		2.15efg	0.32	3.38bcd	1.24	<b>2.76CD</b>	0.55fg	0.08	0.72ef	0.14	<b>0.63B</b>
Site 4		1.16g	0.37	1.89fg	0.49	<b>1.53E</b>	0.20i	0.07	0.25i	0.05	<b>0.22E</b>
	<b>Mean</b>	<b>2.25C</b>		<b>3.06B</b>			<b>0.56B</b>		<b>0.64B</b>		

#- 1) Municipal Wastewater, 2) Shahrab River, 3) Farahan River and 4) Sodium sulfate Factory Wastewater; Means with the small same letter are not significantly different; Means with the capital same letter in each column are not significantly different.

The soil sampled from the eastern sites of the lake compared to the soils sampled from the western sites, had higher CWEOC and HWEOC. These finding may be related to the higher moisture content of soils around the lake in the eastern parts. In addition, the soil texture was finer in these parts of the lake. The importance of soil texture on TOC and moisture contents was reported by many researchers (von Lu<sup>tz</sup> et al., 2007). Burke *et al.* (1990) found that soil

clay content and TOC was positively correlated in the Great Plains (Burke *et al.*, 1990). The protection of SOM against microbial attack due to the organo-mineral complex formation is an effective phenomenon for carbon sequestration especially in finer textured soils (Campbell *et al.*, 1991; Juma, 1993; von Lu<sup>tz</sup> et al., 2002). So, in clayey soils, MBC recycling rate is slow (Brookes, Wu, and Ocio, 1990; Gregorich, Voroney, and Kachanoski, 1991). In

addition to those reports, our previous incubation study on the plant residue treated soil revealed that MBC had coherence with CWEOC and HWEOC (Safari and Afzalpour, 2014). The response of CWEOC to soil depth compared to the response of HWEOC was lower. In the most cases, the HWEOC was markedly and significantly higher in topsoil of the sampled soils. The different response of CWEOC and HWEOC to soil depth may be related to their different solubility's in soil water and distribution in soil profile. The CWEOC may be more solubilized in soil water and moved from topsoil to subsoil layer. So its response to soil depth was lower than the response of HWEOC. In addition, the HWEOC mainly originated from microbial exo-polysaccharides and plant mucigels (Safari Sinegani, 2015). The means of CWEOC and HWEOC increased from spring to fall but only the increase of CWEOC in topsoil was significant. These findings may be depended on higher biodegradability of HWEOC. In an incubation study, Gregorich et al. (2003) reported that the HWEOC is more biodegradable than CWEOC. The amount of biodegradable OC in hot water extracts was more than that in cold water extracts. They were up to 80% and 50–60%, respectively. The responses of FPOM to anthropogenic and natural influences was noticeable. The anthropogenically influenced soils in the release site of municipal wastewater and in the release site of wastewater of sodium sulfate plant had the highest and the lowest contents of FPOM respectively. This shows the responsibility of FPOM to anthropogenic activities is high. The water analysis revealed that municipal wastewater had low soluble salt (EC, 2.92 dS m<sup>-1</sup>), Na (151.67 mg l<sup>-1</sup>) and K (17.92 mg l<sup>-1</sup>) and high N (68.33 mg l<sup>-1</sup>) and P (5.72 mg l<sup>-1</sup>) contents which can improve aquatic plant growth. In contrast, wastewater of sodium sulfate plant had high soluble salt (EC, 49.54 dS m<sup>-1</sup>), total suspended solids (427.58 g l<sup>-1</sup>), total solid (552.62 g l<sup>-1</sup>), Na (100356.7 mg l<sup>-1</sup>) and K (105.73 mg l<sup>-1</sup>) and low N (30.80 mg l<sup>-1</sup>) and P (0.46 mg l<sup>-1</sup>) contents which can decline plant growth. The response of FPOM in the top layer of naturally influenced soils was also significant. The higher FPOM in the topsoil of Farhan river site may be due to its lower soluble salt and better plant growth, but Shahrab River had lower FPOM due to higher soluble salts (EC, 52.87 dS m<sup>-1</sup>). The study of SOM fractions in response to cover crops showed that TOC was not significantly changed by the cover crops, but cover crops increased LF and the active pools in all of the studied soil layers (Oliveira, Oliveira, and Xavier, 2016). It shows the high sensitivity of FPOM and low sensitivity and response of TOC to natural and anthropogenic influences. Similar to the other fractions, the means FPOM were significantly higher in the topsoils and in fall. Soils with higher moisture

and clay contents sampled from the eastern part of the lake had higher OPOM means, similar to CWEOC and HWEOC fractions. The response of these fractions to anthropogenic activity was relatively lower than that of FPOM. The response of OPOM to soil sampling time was higher than the response of the other fractions. Similar to CWEOC, it accumulated in the soils during plant growth season. So, the biodegradability of OPOM may be lower than the biodegradability of HWEOC and FPOM. The FPOM is an active pool and OPOM is a slow or moderate pool (Safari, 2015). The slow turnover rate of OPOM compared to FPOM may be related to occlusion of POM by clay particles and aggregate formation (Baisden, Amundson, Cook, and Brenner, 2002; Golchin et al., 1997; von Lu<sup>tzow</sup> et al., 2007). Janzen et al. (1992) found a meaningful correlation coefficient between the rate of soil respiration and the light fraction (Janzen, Campbell, Brandt, Lafond, and Toenley-Smith, 1992). However in some soils especially in burned forests and rangelands, the light fraction may contain recalcitrant and passive OC. So in these soils the fast pool would be overestimated by LF and the stable pool would be underestimated by HF (Safari Sinegani, 2015; Skjemstad et al., 1990; von Lu<sup>tzow</sup> et al., 2007). Here burning of soil organic matter because of low plant cover on soil have not been occurred so far and FPOM may be a good index for estimating the active pool. Our statistical analysis confirmed that this fraction is the most responsive fraction. It can explain the anthropogenic and natural influences on SOC and C input/output balance in this region of the world. Similar to the other fraction, the highest HF was measured in the eastern parts of the Meghan Lake. Expectedly the response of this fraction to anthropogenic activity was relatively low. It had higher content in soils with higher clay and moisture contents. The response of HF to soil sampling time is similar to the response of OPOM and accumulated in topsoil and subsoil during plant growth season. So the biodegradability of HF similar to OPOM and CWEOC is lower than the biodegradability of HWEOC and FPOM. The HF is a too heterogeneous organic matter mainly includes in the passive pool (von Lu<sup>tzow</sup> et al., 2007). But, this heterogeneity is higher in TOC (Safari, 2015). The heterogeneity of TOC in soils makes it not responsive to the factors. In soil, one fraction may have a positive response and one another a negative response which complicate the response of TOC. Here the effect of soil sampling site, depth and time interaction was significant on TOC while the simple effect of time was not significant. The response of TOC to agricultural and environmental practices is not always meaningful in the short-term study (Xavier et al., 2013). So, soil organic matter fractionation is necessary to readily detect short time changes in soil



in response to changes in management practices (Blanco-Moure et al., 2013; Sequeira et al., 2011). This study showed less biodegradable fractions like CWEOC, OPOM, and HF shows a meaningful response to soil sampling time. They can accumulate in topsoil and subsoil during plant growth season. On the other hand, the active and labile fractions of SOM like HWEOC and FPOM may be more responsive indices for assessing the effects of anthropogenic and natural influences on soil and water quality (Carter, 2001; Marques et al., 2015; Souza, Figueiredo, Madeira, and Alcântara, 2014).

**Conclusions:** The study showed that municipal wastewater of Arak had significantly increased TOC in the soil around the Meyghan Lake. Against it, the wastewater of sodium sulfate processing plant has markedly decreased TOC and its fractions compared to ephemeral natural Shahrab and Farahan rivers. So mixing of the wastewaters and discharging them into the Meyghan Lake may be suggested for inhibiting the drying up of this wetland. The ratio of mixing, the treatments and the method of discharging of the new mixed wastewater needs a special study. Soil organic carbon includes active, slow and passive pools with different degradation rates causing the response of TOC to soil sampling site, depth and especially time more complicated. The response, retention and biodegradation of TOC largely depend on its fractions. The responses of HWEOC and FPOM as active pools to anthropogenic and natural influences were markedly clearer than that of TOC. Their contents in soils were more governed by the soil properties which affecting microbial activity (output rate) and plant growth (input rate). So the HWEOC and FPOM as active pools, are good indexes for assessing soil and water management practices even in short period of time because of no black C in these unburned soils. The response of CWEOC, OPOM and HF as slow pools to anthropogenic and natural influences was also better than that of TOC because of their higher homogeneity. Their accumulation in soils was more governed by the soil properties which affecting retention and biodegradation (output rate) by microbial activities. Thus they may not show the direct and short-term effects of soil and water management practices in non-agricultural lands.

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