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ORIGINAL ARTICLE

A Statistical analysis of organic carbon of olive mill waste water and olive mill solid waste & its effects on soil properties

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ABSTRACT

Olive oil production is the main activity of Mediterranean countries. Olive oil production is a new emerging sector in India. Olive oil refinery, Lunkaransar has been producing olive oil since 2015. After oil extraction, huge amount of waste is generated-Olive mill waste water & olive mill solid waste. These wastes are dumped in soil which affects soil environment. Olive oil waste main component is total organic carbon. In our research paper organic carbon of olive mill waste effects on soil properties are evaluated. Soil parameters such as pH, EC, Bulk Density, water holding capacity & TOC are analysed. Statistical Analysis of soil parameters showed that soil properties pH, bulk density was reduced & water holding capacity was increased. Olive mill wastes improved soil quality but it also contaminated organic carbon in soil. Our research study provides an idea to recycle olive mill solid waste as an organic fertiliser or making compost to manage olive mill waste disposal.
***Key words**- Bulk density, EC, Soil pH, Total organic carbon.*

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INTRODUCTION

Waste are the unwanted and undesirable products which are generated after main primary activity. Agriculture industrial waste is the left-over materials produced by manufacturing process. Many Agriculture processing industries like food processing, diaries industries, oil processing mills, sugar mills are generated waste in large scale. These crop residues are full of nutrients rich compounds, which can be recycles or reuse. Generally, these Agro wastes are used as compost or animal feeding. In India, olive oil production mill is located at Lunkaransar, Bikaner, Rajasthan state. In refinery, Olive oil is produced by two phase centrifugation technique. In this process, olive fruits are washed, crushed, malaxation & centrifuged. Olive oil is separated & mixture of solid residue- olive mill solid waste & effluent water- olive mill waste water is left over. These waste products are dumped into open land area behind the refinery. The waste products are generated in large amount in a short period of time. The wastes are collected every year.

Olive mill waste water is an acidic dark brown liquid effluent with high electric conductance [1]. It is a polluting effluent because of consists of organic compounds, especially polyphenols. Earlier investigation showed that this waste water is rich in organic matter with high BOD & COD value [2]. Our previous research study investigated that Olive mill waste water contains high concentration of macronutrients potassium and notable level of nitrogen and micronutrients iron, copper, zinc [3].

Olive mill solid waste is a semi solid waste which called olive pomace or alperujo [4]. It consists olive pulp, olive skin & olive stones. According to earlier researcher, Olive mill solid waste has high toxic organic loads, high COD & BOD and low pH [5]. Previous studies shown that olive mill waste water is mainly constituent of organic carbon, macronutrients Nitrogen & potassium, micronutrients- iron, copper, zinc & manganese [6]. Our previous research study showed that olive mill solid waste is a nutrient rich compound- specially potassium, organic carbon & micronutrients [7].

Earlier research author reported in their studies that long term application of olive mill solid pomace in soil, improved soil chemical, physical and biological properties [8]. The work of previous researcher indicated that olive mill solid waste's compost significantly increased availability of macronutrients and

organic matter in soil [9]. The similar result was found in previous study that wet pomace of olive mill solid waste improved soil fertility [10]. Research author investigated that soil treated with olive mill waste water showed increase of availability of potassium, it enhanced soil fertility no negative effects were observed [11]. Unlike previous studies, some researchers reported that untreated olive mill waste water increased soil salinity and reduced plant growth, while treated olive mill waste water improved plant growth but soil pH was decreased [12].
In recent years, composting has become useful approach to recycle and manage the olive mill agricultural waste disposal [13]. Although olive mill waste reuse offers significant benefits, but no previous studies have investigated of olive mill waste utilization and management in India. No prior studies have been conducted on the waste disposal of olive mill refinery Lunkaransar. The main component of olive mill waste is total organic carbon [7]. For recycling and reuse this waste as organic fertilizer or compost, it is important to know the effect of organic carbon of olive mill solid waste on soil properties. Therefore, the aim of present study is to report and analyse olive mill waste water and olive mill solid waste organic carbon & its effects on soil properties.
Main objectives of our study are-

1. Analysis of total organic carbon of olive mill solid waste.
2. Analysis of total organic carbon of olive mill waste water.
3. Analysis of soil parameters at two different sites–
   Soil parameters- pH, EC, Bulk density, water holding capacity & Total organic carbon.
   Two different sites of soil- soil at waste disposal site & soil at Nearby from disposal site.
4. Statistical Analysis- Effect of total organic carbon of OMWW & OMSW on soil parameters.

MATERIAL AND METHODS

(A) **Sampling of Olive mill waste water-** Olive mill waste water samples were collected from olive oil refinery, Lunkaransar. In refinery, waste products are dumped into open land area. Samples were collected from waste water disposal site in sterile & labelled plastic bottles. Samples were immediately transported to laboratory & stored in refrigerator at -4^0C. Total 12 samples were collected for analysis.

(B) **Sampling of olive mill solid waste-** Olive mill solid waste samples were collected from olive oil refinery, Lunkaransar. Samples were collected from disposal site at depth of 10-15 am using auger. The samples were carried out in sterile & labelled polythene bags. Samples were immediately transported to laboratory and stored in refrigerator at -4^0C. Total 12 samples were collected for analysis.

(C) Sampling of soil- Soil samples were collected from two different site- at waste disposal site & nearby from waste disposal site. All samples were collected at the depth of 10-15 cm using shovel. Samples were placed in sterile & labelled polythene bags & transported to laboratory. Total 24 soil samples were collected, 12 from waste disposal site & remaining 12 were taken from nearby disposal site.

(D) Experimental Methodology of Analysis of OMWW, OMSW & Soil –

1. **OMWW-** Total organic carbon – TOC of olive mill waste water was determined by Dry Combustion Method (APHA, section 5310B).
2. **OMSW-** Total Organic carbon**-** Olive mill solid waste total organic carbon was analyzed by Walkely Black Method. (IS 2720, part 22, 1972)
3. **Soil Analysis-**

1. pH- Soil pH was determined by potentiometric method. (IS 2720, part 26:1987)
2. Electrical Conductance – Soil EC was determined by conductimetry method using EC meter. (IS 14767:2000)
3. Bulk Density – Soil bulk density was measured by cylinder method. (IS:2720-28:1974)
4. Water Holding Capacity- Soil WHC was analyzed by Gravimetric saturation drainage method. (IS 2720, part 21:1977)
5. Total organic carbon- Soil TOC was determined by Walkley Black method. (IS 2720, part 22:1972)

RESULT AND DISSCUSION

Table1: Analysis of total organic carbon of olive mill waste water & olive mill solid waste

Sample no.	TOC (OMWW)	TOC (OMSW)
1.	21.20	57.80
2.	21.40	59.20
3.	21.00	54.23
4.	20.80	55.75
5.	19.20	57.20
6.	20.40	57.59
7.	18.50	50.77
8.	20.10	52.55
9.	20.10	49.49
10.	18.40	48.70
11.	18.30	51.84
12.	19.50	50.84

Table 2: Physico-chemical Analysis of Soil at disposal site)

Sample No.	pH	EC (mS/cm)	BD (gm/cc)	WHC (%)	TOC (%)
1.	8.01	0.2000	1.23	55	0.80
2.	8.01	0.2100	1.21	54	0.89
3.	8.01	0.1855	1.27	55	0.85
4.	8.02	0.2700	1.28	55	0.80
5.	8.01	0.2200	1.30	52	0.80
6.	8.03	0.2500	1.30	55	0.88
7.	8.04	0.2100	1.30	52	0.75
8.	8.04	0.2100	1.34	51	0.70
9.	8.10	0.1850	1.33	51	0.75
10.	8.10	0.2500	1.34	50	0.70
11.	8.07	0.2100	1.32	52	0.70
12.	8.04	0.2150	1.30	50	0.70

Table 3: Physico-chemical Analysis of Soil at Nearby from disposal site

Sample No.	pH	EC (mS/cm)	BD (gm/cc)	WHC (%)	TOC (%)
1.	8.25	0.1304	1.53	47	0.27
2.	8.20	0.1300	1.50	46	0.21
3.	8.20	0.1280	1.51	45	0.30
4.	8.20	0.1500	1.51	45	0.28
5.	8.25	0.1300	1.50	44	0.28
6.	8.25	0.1500	1.50	42	0.28
7.	8.20	0.1380	1.50	40	0.29
8.	8.20	0.1340	1.50	40	0.21
9.	8.20	0.1200	1.52	35	0.29
10.	8.20	0.1600	1.5	35	0.28
11.	8.25	0.1400	1.51	38	0.28
12.	8.25	0.1400	1.50	40	0.27

Table 4: Mean value of TOC

Mean value TOC (OMWW)	Mean value TOC (OMSW)
19.9	53.83

Table 5: Mean value of soil parameters

Sr. No.	Parameter	Soil at disposal site	Soil at nearby disposal site
1.	**pH**	8.04	8.22
2.	**EC (mS/cm)**	0.2179	0.1375
3.	**Bulk Density (gm/cc)**	1.29	1.50
4.	**Water holding capacity (%)**	52.66	41.41
5.	**Organic carbon (%)**	0.77	0.27

Total organic Carbon of OMWW & OMSW-From table 1 represents, total organic carbon of olive mill waste water and olive mill solid waste. The range of olive mill waste water TOC was 18.30-21.40 g/l and olive mill solid waste was 48.70-59.20 %. The experimental data showed that organic carbon was very high in waste water & olive pomace. The mean value of organic carbon was 19.9 g/l in waste water & 53.83 % in solid waste (table 4). The high concentration of organic compounds can pollute soil environment. Research author also reported that olive mill waste major component was organic carbon [14].
The presence of high amount of total organic carbon makes this waste useful for preparing compost and it becomes good organic fertiliser. But without proper treatment it will show harmful effect on soil. Previous

Physico chemical Analysis of Soil at disposal site & nearby disposal site-

Table 2 and table 3, reveals that-

1. **pH-** The result data indicated that Soil pH range at disposal site was 8.01-8.10. Soil pH at nearby site was in the range of 8.20-8.25. The mean value of soil pH at disposal site was 8.04 and at nearby site was 8.22 (table 5). Soil pH of disposal site was slightly low compared to nearby site. It is due to the disposal of olive mill solid waste. Olive mill waste water & solid waste are acidic in nature [3,7]. Our experimental analysis data showed that the major component of olive mill waste was organic carbon. This high level of organic compounds lowered soil pH at disposal site. Soil has buffering capacity, so soil pH was not much lowered. Researcher also found olive mill waste water decreased soil pH [15].
   According to FAO guidelines for agriculture soil, soil pH mean value of both sites are in the alkaline zone.[16]
2. **EC-** Analysis revealed that soil EC at disposal site & nearby site was in the range of 0.1850-2700 mS/cm & 0.1200-0.1600 mS/cm respectively. Mean value of EC at disposal site was 0.2179 mS/cm and nearby site was 0.1375 mS/cm (table 5). A marked variation was noted between both sites. Soil at disposal site has higher EC value. Olive mill waste disposal increased soil EC at disposal site. Olive mill waste contains high concentration of soluble and suspended salts. These waste water & solid waste increased soil salinity.
   According to FAO guidelines for agriculture soil, EC of both sites are in the normal zone. [16]
3. **Bulk Density-** The result data showed that soil bulk density at disposal site & nearby site was in the range of 1.21-1.34 gm/cc & 1.50-1.53 gm/cc respectively. The average value of bulk density at disposal site was 1.29gm/cc and nearby site was 1.50 gm/cc (table 5). A significant decrease in bulk density was observed at disposal site soil. Due to the disposal of olive mill waste, soil bulk density was decreased. This result suggests that olive mill wastes improved soil bulk density. Such results are consistent with earlier researcher study [17].
4. **Water holding capacity**-Study data showed that soil water holding capacity at disposal site was in the range of 50-55 % and soil at nearby site water holding capacity range was 35-47%. The mean value of WHC of soil at disposal site & nearby site was 52.66 % & 41.41% respectively (table 5). The analysis revealed that soil water holding capacity was higher at disposal site compare to nearby site. The observation data suggested that olive mill waste improved soil water holding capacity. This result findings are similar with the finding of previous research literature [18].
5. **Total Organic carbon-** It was observed that soil total organic carbon at disposal site was in the range of 0.70-0.89 % & nearby site was in the range of 0.21-0.30%. The average value of soil total organic carbon at disposal site was 0.77% & nearby site was 0.27%. A significant increase in soil total organic carbon was observed at waste disposal site. Soil organic carbon of disposal site was very high compare to nearby site. Olive mill solid waste disposal improved soil carbon content. But this high level of organic carbon pollutes soil at disposal site.
   According to FAO guidelines for agriculture soil, Soil organic carbon at disposal site is in high & nearby site is in low carbon content category zone. [16]

We can recycle olive mill waste as organic fertilizer to enhance soil fertility. By composting, utilization of this waste can be solved its disposal problem also. Olive mill waste compost improved soil properties.

Statistical analysis

Multiple Regression analysis & linear regression analysis are performed to show combined & individual effect of olive mill waste water and solid waste on soil properties. Three regression models are developed-

Table 6: Multiple regression analysis of OMWW & OMSW (TOC) v/s Soil parameters

Statistical parameter	Soil pH	Bulk density	Water holding capacity
Multiple R	0.831971	0.870537	0.842043
R Square	0.692176	0.757835	0.709037
Significance F	0.004982	0.001692	0.003866
Pearson r for OMWW	-0.59907	-0.70568	0.716627
P value for OMWW	0.809792	0.248674	0.190232
Pearson r for OMSW	-0.83071	-0.8467	0.802588
P value for OMSW	0.012287	0.012566	0.036219
Intercept	8.469026	1.87998	23.60723
Cofficient TOC of OMWW	-0.00187	-0.00972	0.6066
Coefficient TOC of OMSW	-0.00728	-0.00736	0.3164

Effect of TOC of Olive mill waste water and olive mill solid waste on soil pH at disposal site-

Regression equation-

$Soil_{pH}=8.469-0.00187(TOC_{OMWW})-0.00728(TOC_{OMSW})$

- Multiple regression analysis is performed on olive mill waste water & solid waste total organic carbon & soil pH. The analysis result showed that a significant negative decreasing effect of olive mill waste water & solid waste total organic carbon on soil pH is observed. Soil pH was decreased as increase in waste total organic carbon. An inverse relationship is analyzed in this model.
- Significant F was found <.05(Combined effect of OMWW & OMSW TOC). For olive mill waste water TOC, P value >0.05 & For olive mill solid waste TOC p value <0.05, showed that olive mill solid waste TOC is highly significant, it truly affects soil pH more than olive mill waste water TOC. $R^2=0.6921$ showed that 69.21% of pH variance of disposal site is explained by olive mill waste water & solid waste TOC.
- Pearson coefficient r for olive mill waste water was found -0.59907 negative relationship was found.
- Pearson coefficient r for olive mill solid waste was found -0.83071 negative relationship was found.
- The linear regression analysis for separately olive mill waste water TOC and soil pH was –
  Regression equation- $Soil_{pH}= -0.0179(TOC_{OMWW})+8.3958$
  It showed negative relationship of soil pH and TOC of olive mill waste water. $R^2=0.3589$, only 35.89% of soil pH variation is explained by TOC of OMWW.
- The linear regression analysis for separately olive mill solid waste TOC and soil pH was-
  Regression equation- $Soil_{pH}=-0.0077(TOC_{OMSW})+8.453$
  It showed negative relationship of soil pH and TOC of OMSW. $R^2=0.6901$, 65.01% soil pH variation is explained by OMSW TOC.

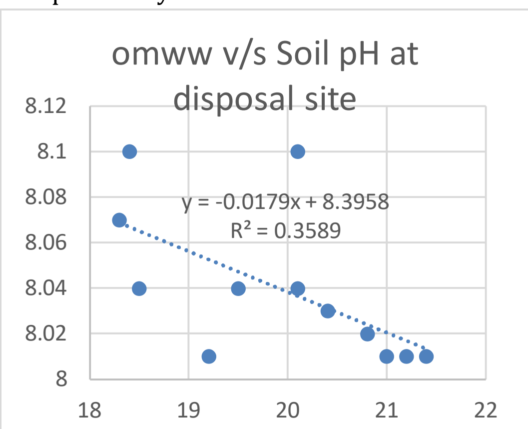

Fig :1, linear regression graph of omww TOC v/s soil pH

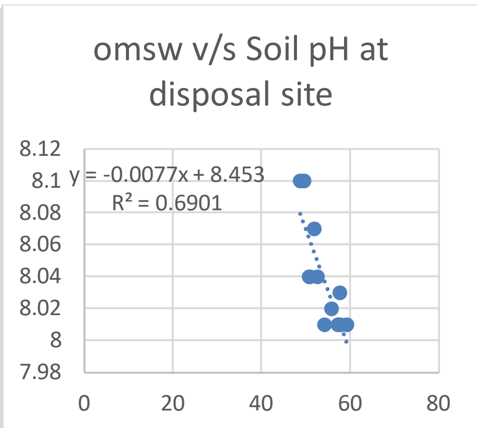

Fig :2, linear regression graph of omsw TOC v/s soil pH

Effect of TOC of Olive mill waste water and olive mill solid waste on soil Bulk Density.

Regression equation-

$Soil_{BD}$=1.87998-0.00972(TOC_{omww})-0.00736(TOC_{omsw})

- Multiple regression analysis is performed on olive mill waste water & solid waste total organic carbon & soil bulk density. The analysis result showed that a significant negative decreasing effect of olive mill waste water & solid waste total organic carbon on soil bulk density is observed. Soil bulk density was decreased as increasing in waste total organic carbon. An inverse relationship is analyzed in this model.
- Significant F was found <.05(Combined effect of OMWW & OMSW TOC). For olive mill waste water TOC, P value >0.05 & For olive mill solid waste TOC p value <0.05, showed that olive mill solid waste TOC is highly significant, it truly affects soil bulk density more than olive mill waste water TOC. R^2=0.7578 showed that 75.78% of disposal site soil bulk density variance is explained by olive mill waste water & solid waste TOC.
- Pearson coefficient r for olive mill waste water was found -0.70568 negative relationship was observed.
- Pearson coefficient r for olive mill solid waste was found -0.8467 negative relationship was observed. It is highly significant effect of OMSW is observed on soil bulk density.
- The linear regression analysis for separately olive mill waste water TOC and soil bulk density was –
  Regression equation- $Soil_{BD}$= -0.0258(TOC_{OMWW})+1.8079
  It showed negative relationship of soil bulk density and TOC of olive mill waste water. R^2=0.5014, only 50.14% of soil bulk density variation is explained by TOC of OMWW.
- The linear regression analysis for separately olive mill solid waste TOC and soil bulk density was-
  Regression equation- $Soil_{BD}$=-0.0087(TOC_{OMSW})+1.7594
  It showed negative relationship of soil Bulk density and TOC of OMSW. R^2=0.5868, 58.68% soil bulk density variation is explained by OMSW TOC.

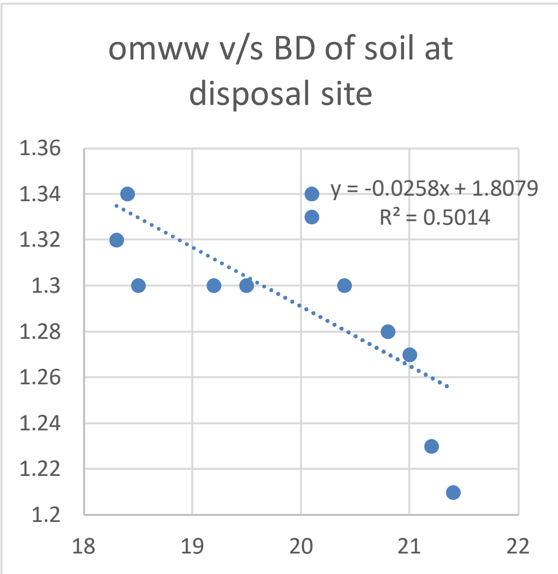

Fig :3, linear regression graph of omww TOC v/s soil bulk density

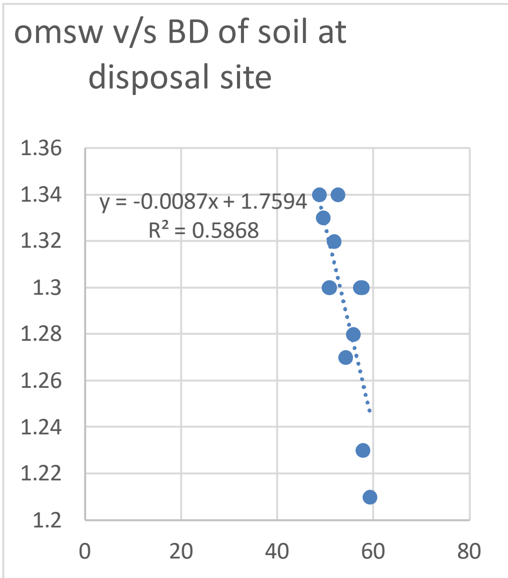

Fig :4, linear regression graph of omsw TOC v/s soil bulk density

Effect of TOC of Olive mill waste water and olive mill solid waste on soil Water holding capacity.

$Soil_{WHC}$=23.607+0.6066(TOC_{OMWW}) +0.3164(TOC_{OMSW})

- Multiple regression analysis is performed on olive mill waste water & solid waste total organic carbon & soil water holding capacity of disposal site. The analysis result showed that a significant positive effect of olive mill waste water & solid waste total organic carbon on soil WHC is observed. Soil WHC is increased as increase in waste total organic carbon. Soil WHC is directly proportional to waste TOC.
- Significant F was found <.005(Combined effect of OMWW & OMSW TOC). Model is highly significant.
- For olive mill waste water TOC, P value >0.05 & For olive mill solid waste TOC p value <0.05, showed that olive mill solid waste TOC is highly significant, it truly affects soil water holding

capacity more than olive mill waste water TOC. $R^2=0.7090$ showed that 70.90 % of WHC variance of disposal site is explained by olive mill waste water & solid waste TOC.

- Pearson coefficient r for olive mill waste water was 0.7166, positive relationship was observed.
- Pearson coefficient r for olive mill solid waste was found 0.8025, positive relationship was observed.
- The linear regression analysis for separately olive mill waste water TOC and soil water holding capcaity was –
  Regression equation- $Soil_{WHC}= 1.2935(TOC_{OMWW})+26.914$
  It showed positive relationship of soil WHC and TOC of olive mill waste water. $R^2=0.5136$, only 51.36% of soil at disposal site water holding capacity variation is explained by TOC of OMWW.
- The linear regression analysis for separately olive mill solid waste TOC and soil water holding capacity was-
  Regression equation- $Soil_{WHC}= 0.4388(TOC_{OMSW})+29.044$
  It showed positive relationship of soil WHC and TOC of OMSW. $R^2=0.6165$, 61.65% of soil at disposal site water holding capacity variation is explained by OMSW TOC.

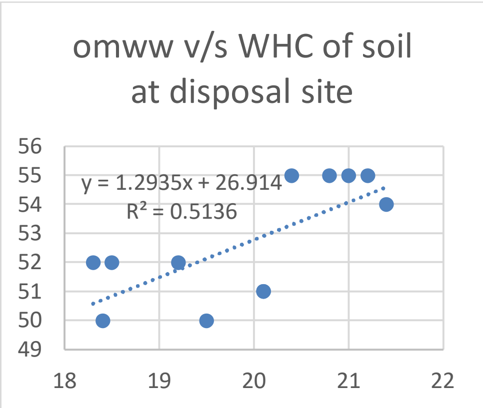

Fig :5, linear regression graph of omww TOC v/s WHC

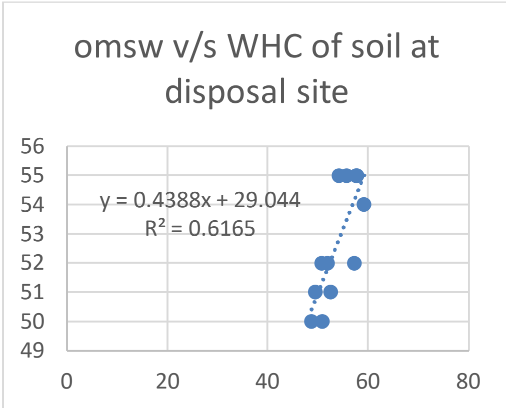

Fig :6, linear regression graph of omsw TOC v/s WHC

From the statistical analysis model, it is proved that soil bulk density & water holding capacity was improved at disposal site. It is due to the disposal of olive mill waste. Soil bulk density & WHC is highly influenced from olive mill solid waste, rather than OMWW. Soil pH was decreased, but it is not much altered.

CONCLUSION

The Experimental study showed that olive mill waste disposal improved soil at disposal site. Soil pH was slightly decreased; soil EC was increased but it lied in normal limit. Soil bulk density was decreased & water holding capacity was increased at disposal site. Soil of nearby site has low carbon content. Olive mill waste increased high soil organic carbon. It pollutes soil environment. The statistical analysis result showed that olive mill solid waste is highly influenced soil pH, bulk density & water holding capacity compare to olive mill waste water. Soil bulk density & water holding capacity is improved by olive mill waste at disposal site. Our previous study [3,7] & current study suggested that olive mill solid waste has potential to be an organic fertilizer. Through composting, we can recycle it in valuable compound. We cannot direct use of olive mill solid waste because organic carbon contamination in soil is observed. After making compost, olive mill solid waste negative effects will decrease. The soil area of study site is alkaline & poor in organic carbon. The highly organic carbon contain olive mill solid waste compost will effective in agriculture use in this area. By recycling this organic agro-industrial waste may provide a solution for the management of this waste.

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