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Utilization of By-Product Materials of Building Construction and Demolition to Conserve Water and Soil in Kuwait

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Abstract: The recent boom in construction activities and the continued urban development in Kuwait have resulted in the generation of massive quantities of construction/demolition material by-products that need to be removed from construction/demolition sites in the cities to landfill areas which are limited in the country. This paper explores the possibility and benefits of utilizing by-product materials of construction/demolition activities for soil and water conservation. Procured **c**oncrete and asphalt and manually crushed sandstone mulch aggregates of size 5-10 mm (small size), 10-25 mm (medium size) and 25-50 mm (large size) at 25%, 50% and 75% density were used in the 28 treatments at the experimental sites at Sulaibiya. The control was devoid of any mulch. The results indicated no negative effects on soil pH, EC and heavy metal content due to the use of construction and demolition waste as soil mulch. All the units with mulch recorded higher moisture content than control. Units with asphalt 5-10 mm at 75% density, 10-25 mm at 50% and concrete 5-10 mm at 50% density recorded highest infiltration rate at the end of the experimental period. Units with asphalt mulch recorded highest microbial population and average annual, perennial and total plant population and diversity during spring and late spring. It can be concluded that utilization of construction and demolition waste can be used as mulch to conserve soil moisture, increase the infiltration rate and thus, promoting native plant growth. Among the soil aggregates, asphalt mulch enhanced germination and plant growth and was more efficient in retaining soil moisture and thus, supporting plant survival for a longer period than control.

Key words: Construction/demolition waste · Asphalt · Soil and water conservation · Native plant population · Mulch

INTRODUCTION

Conservation of natural resources like soil and water is essential for Kuwait due to limited water resources and rapid degradation of arable soils. The native vegetation is also rapidly disappearing. Evaporation under Kuwait's arid and dry weather is accelerated by the removal of natural gravels for construction purposes. The recent boom in construction activities and the continued urban development in the country have resulted in the generation of massive quantities of construction/ demolition material by-products that need to be removed from construction/demolition sites in the cities to landfill areas which are limited in the country [1]. Construction waste increased by 17% in 2008 (4,481,190 thousand tonnes) when compared to 2000 (3,832,740 thousand tonnes) [2]. Of the GCC countries, Oman is the pioneer in recycling by-products of demolition. Environmental concern within the GCC States as a new issue had been raised due to health problems associated with waste accumulation around the urban establishments. Alhumoud [3] estimated that solid waste averages per capita per day in Kuwait were 1.4 kg; Saudi Arabia 1.25 kg; Bahrain 1.26 kg; Qatar 1.3 kg; United Arab Emirates (UAE) 1.18 kg; and Oman 0.73 kg. Within the GCC, Kuwait produces the highest solid waste per person/ day and Oman is the lowest. Kartam *et al*. [1] emphasized the need of recycling of solid wastes in Kuwait for better

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environment, land saving and economical benefits. A technical study on increasing construction and maintenance activities by recycling the aggregates obtained from building demolition concrete revealed that asphalt concrete produced by recycling the aggregate of demolition wastes have met the requirements [4].

These waste materials have significant value for reconstruction, rebuilding and as mulch resource. Most of these by-product materials are dumped usually in desert areas, which create environmental problem and health risks. Additionally, Kuwait faces numerous environmental challenges such as the formation and displacement of sand dunes and soil erosion by water and wind. Native plants are threatened due to uncontrolled grazing and off-road movement of vehicles on the fragile desert surface. Therefore, soil and water conservation in both desert and urban regions is urgently needed to combat such challenges and improve the local environment. Recycling of construction and demolition materials in Kuwait can improve the environment, through saving of land and utilization of such materials to enhance plant growth and development by decreasing evaporation and reducing soil erosion. Potential of utilizing by-product materials of construction/demolition activities for soil and water conservation in both of these areas needs to be explored.

The presence of rock fragments modifies the soil physical properties (available water content, infiltration and runoff), soil chemical properties (carbon and nitrogen content) and agronomical characteristics like yield [5]. Cerda [6] studied the effects of rock fragments on soil infiltration, runoff and erosion under field conditions and concluded that rock fragments retard ponding and surface runoff; give greater steady-state infiltration rates and smaller interrill runoff discharges, sediment concentrations and interrill erosion rates. Scientists in Belgium compared the evaporation rate from soil containing a range of rock fragment with nonstony control soil and nonstony soil covered with rock fragment mulch. They found that evaporation rate is low in stony soils with rock fragments at field capacity than air dry soils [7]. Rock fragments affect infiltration by their presence in the soil matrix and on the soil surface. Studies show that [8], within the soil, physical properties (bulk density, porosity and water content) and hydraulic properties that affect infiltration are influenced by rock fragments. Scientists from Israel studied the effect of rock fragment size and position on top soil moisture on arid and semiarid hill slopes and concluded that the top soil moisture content under rock fragments was higher over time than that of bare soil areas [9]. Size of the rock also has a positive effect on runoff depth and negative effect on infiltration depth. The effect of rock fragment size on infiltration, runoff and erosion was found to be more pronounced than that of position [10]. A series of laboratory studies carried out on the cooling effects of crushed rock layers with different particle sizes revealed good cooling effects on the underlying soil layers [11]. Long-term effects of mulching include enhancement in soil mineral nutrients and soil aggregation [12]. Changes in soil moisture regime caused by mulch covering, increase infiltration; reduce evaporation and upward movement of Na^+ and other salts which explains the reduction in salinity and sodicity in the mulched soils. The greater dilution of soil solution through increased soil water content, increased Na^+ leaching and the dissolution of calcium salts account for the desalinization and desodication [13].

Utilizing rocks for landscape and mulching in arid environment will improve the soil moisture within the soil profile and increase the nutrient's reactions through soil solution. Cousin *et al*. [5] in France worked in rocks effect on water retention within the soil profile in the laboratory. Their conclusion revealed that rock could increase soil water retention and water percolation within the soil. Wijdenesa and Poesena [14] worked on the soil movement within the soil profile and stated that rock used as mulch can decrease soil erosion in arid soil and increase soil infiltration. In China, gravel mulching is part of the traditional concept and practices done over the last three hundred years to conserve water and increase crop production in semiarid part of China according to Xiao-Yan Li [15]. According to this author, gravel sand mulching improves soil productivities, reduces soil evaporation and decreases runoff and at the same time, improves soil infiltration. Rock is also applied in India to prevent soil erosion through controlling gully structure and it has been known to be the cheapest method of soil conservation available [16]. Meikle *et al*., [17] in Canada used rock waste materials to support plant growth and promote greenery and recycling of such products. A case study was done in Southeast Spain on variation of rock cover and size along semiarid hill slopes and concluded that rock material is the only soil stabilizer for soil conservation [18].

The objective of this paper was to explore the possibility of utilization of construction/demolition waste for soil and water conservation in Kuwait; and to improve the performance of native plants in desert.

Table 1: Treatments Used in the Mulching Experiment at KISR Sulaibiya Research Station

Treatment No.	Type	Size (mm)	Density (%)
T1	Concrete	5 - 10	25
T2	Concrete	5 - 10	50
T3	Concrete	5 - 10	75
T4	Concrete	10 - 25	25
T5	Concrete	10 - 25	50
T6	Concrete	10 - 25	75
T7	Concrete	25 - 50	25
T8	Concrete	25 - 50	50
T9	Concrete	25 - 50	75
T10	Asphalt	5 - 10	25
T11	Asphalt	5 - 10	50
T12	Asphalt	5 - 10	75
T13	Asphalt	10 - 25	25
T14	Asphalt	10 - 25	50
T15	Asphalt	10 - 25	75
T16	Asphalt	25 - 50	25
T17	Asphalt	25 - 50	50
T18	Asphalt	25 - 50	75
T19	Sandstone	5 - 10	25
T20	Sandstone	5 - 10	50
T21	Sandstone	5 - 10	75
T22	Sandstone	10 - 25	25
T23	Sandstone	10 - 25	50
T24	Sandstone	10 - 25	75
T25	Sandstone	25 - 50	25
T26	Sandstone	25 - 50	50
T27	Sandstone	25 - 50	75
Control		No Mulch	

MATERIALS AND METHODS

Various sizes of sorted and crushed aggregates (concrete and asphalt) for application as mulch were procured from a local company (Environment Preservation Industrial Company). Sandstone mulch was collected, manually crushed and sorted according to the specified sizes. A suitable site at the KISR's Agricultural Research Station, at Sulaibiya was selected and 84 experimental units, each measuring 5 m^2, were used to evaluate various test materials and to study the effects of the aggregate on soil condition, both physically and chemically and their interaction with soil. The study was conducted from December 2008 to December 2010.

Various sizes, i.e., small (5 to10 mm), medium (10 to 25 mm) and large size (25 to 50 mm) of concrete, sandstone and asphalt aggregates were distributed using the percentages on the soil surface as follows: covering 25%, 50% and 75% of total surface area. The control was devoid of any mulch. There were 28 treatments (Table 1) which were replicated thrice (3 density x 3 size x 3 structure + 1 control). Parameters like soil moisture content, pH, EC (conductivity), heavy metal content (cadmium (Cd), cobalt (Co), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo), lead (Pb), zinc (Zn), mercury (Hg)), native plant population, moisture content, biological assay and water infiltration rate were assessed periodically.

Soil Analysis: The soil analysis methods used in this study were from USDA [19]. The pH was measured in saturated soil paste using a pH meter. The EC was measured in the extract collected from the paste under vacuum using an EC meter after adjusting the temperature of the extract.

Soil Moisture Content: Soil was dried at 105°C overnight and the moisture content was determined at dry weight basis and expressed in percentage.

Heavy Metal Content: Inductively-coupled plasma- atomic emission spectroscopy was used to analyze the heavy metal content. Heavy metal content before and after each mulching treatments were measured.

Biological Assay: Composite soil samples from the site covered with concrete, asphalt and sandstone mulch were collected aseptically in sterilized biological bags. Total aerobic bacterial counts were determined using standard microbial methods [20] at the Biotechnology Department, KISR. Samples were analyzed by applying spread technology using Agar plate.

Native Plant Population: During spring (February- April) [2]; the vegetation growth was investigated using the quadrate method; i.e., each quadrate, measuring 1 m^2 was placed at the center (previously marked) of each experimental unit of 5 m^2. In each quadrate, numbers of annual and perennial species and population were studied. During late spring (April-May), as the number of plants was countable, the annual and perennial species and population were studied in all the experimental units.

Infiltration Rate: The infiltration rate of water was measured periodically in all experimental units using a double-ring infiltrometer.

Data Analysis: The data were analyzed using Duncan's Multiple Range Test to ascertain the significant differences among treatments [21]. For heavy metal content, data were analysed using paired sample 't' test for each mulch type [22] and the difference in final and initial heavy metal content of various mulching treatments were analyzed using Duncan's Multiple Range Test [21].

RESULTS

Soil Properties: There were no negative effects on soil pH, electrical conductivity (EC) and heavy metal content due to the use of construction and demolition waste as soil surface mulch. Soil remained non saline (<2 dS/m) to weakly saline (2-4 dS/m), moderately alkaline (pH 7.9- 8.4) at the end of the experimental period. Lowest bulk density (1.48) and highest porosity (43.44) were recorded in units with asphalt mulch 5-10 mm at 75% density which reflected the improvement in soil structure which led to increased infiltration rates, facilitating plant root penetration. From December 2009 to April 2010, units with concrete mulch, 10-25 mm at 50% density recorded the highest moisture content. Asphalt mulch, 10-25 mm at 50% density also recorded higher moisture content and all the units with mulch recorded higher moisture content than the control indicating the efficiency of mulch in improving the moisture retention in soil facilitating plant growth and its survival. At the end of the experimental period, the units with asphalt, 5-10 mm at 75% density, followed by units with concrete, 5-10 mm at 50% density and asphalt, 10-25 mm at 50% density recorded higher infiltration rates. Throughout the experimental period, infiltration rate in most of the units with mulch were higher than the control, indicating that mulch had improved the infiltration rate of the soil (Table 2). Significant difference in the infiltration rate was observed among the treatments when compared to control.

Heavy Metal Content: Results indicated that there was no change in Cd, Mo and Hg content in any of the experimental units, irrespective of the treatment used. Levels of Co, Cr, Cu, Fe, Mn, Pb and Zn 360 DAI were within the levels reported in the literature for a typical soil [23]. Levels of Ni were slightly above the values reported

Table 2: Infiltration Rates in the Mulching Experiment at KISR Sulaibiya Experimental Station

	Average Infiltration Rate (mm/min)				
Treatment	Initial	120 DAI	240 DAI	360 DAI	450 DAI
T1	3.56	8.67 def	7.67 de	7.00 b	9.67 a
T2	3.56	15.67 k	17.33 m	17.00 i	20.50 o
T3	3.56	11.67 j	4.67 a	20.50 i	15.67 kl
T4	3.56	10.00 hi	11.33 ij	8.67 c	13.33 ef
T5	3.56	5.00 a	6.67 bc	15.33 h	11.00 bc
T6	3.56	9.00 efg	9.33 gh	13.00 g	16.50 lm
T7	3.56	8.00 cd	8.00 def	7.67 bc	18.50 n
T8	3.56	7.00 b	17.00 m	11.67 def	12.00 d
T9	3.56	11.33 j	8.33 def	12.00 efg	16.00 kl
T10	3.56	8.00 cd	15.33 l	21.00 jk	16.00 kl
T11	3.56	8.33 cde	9.00 fgh	7.67 bc	13.67 efg
T12	3.56	11.33 j	11.00 i	16.50 i	22.50 p
T13	3.56	8.00 cd	11.67 ij	20.00 j	19.00 n
T14	3.56	11.33 j	13.33 k	20.50 j	20.00 o
T15	3.56	4.67 a	8.33 def	5.00 a	11.33 cd
T16	3.56	15.33 k	15.00 l	12.33 fg	9.67 a
T17	3.56	9.67 ghi	8.33 def	22.00 k	14.00 fgh
T18	3.56	12.00 j	20.67 o	11.00 de	17.00 m
T19	3.56	11.33 j	18.33 n	8.00 bc	14.00 fgh
T20	3.56	8.67 def	14.00 k	11.67 def	13.00 e
T21	3.56	11.67 j	12.00 j	15.00 h	10.33 ab
T22	3.56	7.67 bc	6.33 b	12.00 efg	10.67 bc
T23	3.56	8.33 cde	7.33 cd	5.67 a	14.67 hij
T24	3.56	7.67 bc	11.67 ij	16.50 i	15.50 jk
T25	3.56	8.67 def	8.00 def	10.67 d	14.50 ghi
T26	3.56	10.33 i	9.67 h	11.00 de	15.33 ijk
T27	3.56	9.67 ghi	11.00 i	12.33 fg	11.33 cd
Control	3.56	9.33 fgh	8.67 efg	8.33 c	10.30 ab
Significance	NS	**	**	**	**

DAI - Days after initiation of experiment. Data were analyzed using analysis of variance procedure and Duncan's Multiple Range Test. ** = Significant at P $\leq$ 0.01 level. NS–Not Significant.

The means followed by the same letter within the column are not statistically different at p$\leq$ 0.05.

Table 3: Heavy Metal Content in Soils in the Mulching Experiment at KISR Sulaibiya Research Station

	Cd		Co		Cr		Cu		Fe		Mn	
	mg/kg											
Treatment	Initial	Final [i]	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	<0.01	<0.01	4.1 a	6.3 b	25.9 a	31.5 b	4.6 a	6.3 b	8419.9 a	10075.0 b	67.3 a	133.3 b
2	<0.01	<0.01	4.1 a	8.3 b	25.9 a	44.0 b	4.6 a	9.8 b	8419.9 a	13200.0 b	67.3 a	193.5 b
3	<0.01	<0.01	4.1 a	8.8 b	25.9 a	47.5 b	4.6 a	10.3 b	8419.9 a	13525.0 b	67.3 a	227.3 b
4	<0.01	<0.01	4.1 a	6.5 b	25.9 a	35.3 b	4.6 a	7.3 b	8419.9 a	10575.0 b	67.3 a	143.0 b
5	<0.01	<0.01	4.1 a	8.0 b	25.9 a	45.3 b	4.6 a	9.5 b	8419.9 a	12475.0 b	67.3 a	173.5 b
6	<0.01	<0.01	4.1 a	7.5 b	25.9 a	40.0 b	4.6 a	8.5 b	8419.9 a	12225.0 b	67.3 a	188.0 b
7	<0.01	<0.01	4.1 a	7.0 b	25.9 a	42.0 b	4.6 a	8.0 b	8419.9 a	11075.0 b	67.3 a	152.0 b
8	<0.01	<0.01	4.1 a	7.5 b	25.9 a	39.8 b	4.6 a	12.3 b	8419.9 a	11875.0 b	67.3 a	182.5 b
9	<0.01	<0.01	4.1 a	6.8 b	25.9 a	38.5 b	4.6 a	7.5 b	8419.9 a	11275.0 b	67.3 a	166.5 b
10	<0.01	<0.01	4.1 a	5.5 b	25.9 a	29.3 b	4.6 a	6.3 b	8419.9 a	9400.0 b	67.3 a	102.3 b
11	<0.01	<0.01	4.1 a	9.0 b	25.9 a	47.8 b	4.6 a	11.0 b	8419.9 a	13700.0 b	67.3 a	221.0 b
12	<0.01	<0.01	4.1 a	5.8 b	25.9 a	34.8 b	4.6 a	6.3 b	8419.9 a	9700.0 b	67.3 a	123.5 b
13	<0.01	<0.01	4.1 a	8.3 b	25.9 a	44.3 b	4.6 a	10.5 b	8419.9 a	12175.0 b	67.3 a	191.3 b
14	<0.01	<0.01	4.1 a	5.5 b	25.9 a	31.3 b	4.6 a	6.3 b	8419.9 a	9675.0 b	67.3 a	113.8 b
15	<0.01	<0.01	4.1 a	9.0 b	25.9 a	44.8 b	4.6 a	10.3 b	8419.9 a	13150.0 b	67.3 a	204.5 b
16	<0.01	<0.01	4.1 a	5.8 b	25.9 a	30.8 b	4.6 a	7.8 b	8419.9 a	9600.0 b	67.3 a	126.5 b
17	<0.01	<0.01	4.1 a	7.3 b	25.9 a	39.8 b	4.6 a	8.3 b	8419.9 a	11550.0 b	67.3 a	181.8 b
18	<0.01	<0.01	4.1 a	6.0 b	25.9 a	33.3 b	4.6 a	7.0 b	8419.9 a	10200.0 b	67.3 a	127.0 b
19	<0.01	<0.01	4.1 a	6.3 b	25.9 a	35.5 b	4.6 a	7.0 b	8419.9 a	10250.0 b	67.3 a	124.5 b
20	<0.01	<0.01	4.1 a	7.5 b	25.9 a	40.5 b	4.6 a	8.3 b	8419.9 a	11675.0 b	67.3 a	182.3 b
21	<0.01	<0.01	4.1 a	6.8 b	25.9 a	35.5 b	4.6 a	7.3 b	8419.9 a	10925.0 b	67.3 a	174.5 b
22	<0.01	<0.01	4.1 a	8.0 b	25.9 a	46.3 b	4.6 a	9.3 b	8419.9 a	12475.0 b	67.3 a	190.8 b
23	<0.01	<0.01	4.1 a	9.3 b	25.9 a	48.3 b	4.6 a	11.0 b	8419.9 a	13675.0 b	67.3 a	223.0 b
24	<0.01	<0.01	4.1 a	6.5 b	25.9 a	35.5 b	4.6 a	8.0 b	8419.9 a	10650.0 b	67.3 a	144.5 b
25	<0.01	<0.01	4.1 a	7.8 b	25.9 a	47.8 b	4.6 a	9.8 b	8419.9 a	12925.0 b	67.3 a	192.5 b
26	<0.01	<0.01	4.1 a	8.3 b	25.9 a	43.8 b	4.6 a	9.0 b	8419.9 a	12475.0 b	67.3 a	201.8 b
27	<0.01	<0.01	4.1 a	7.5 b	25.9 a	38.3 b	4.6 a	8.5 b	8419.9 a	11625.0 b	67.3 a	172.8 b
Control	<0.01	<0.01	4.1 a	7.3 b	25.9 a	37.3 b	4.6 a	8.3 b	8419.9 a	11200.0 b	67.3a	168.3 b
Typical Soil	< 1		9.1		54		25		26000		550	
Significance [ii]	NS		NS		NS		NS		NS		NS	

Cd - Cadmium; Co - Cobalt; Cr - Chromium; Cu- Copper; Fe - Iron; Mn - Manganese; Mo - Molybdenum; Ni- Nickel; Pb - Lead; Zn - Zinc; Hg - Mercury; The initial and final values followed by different letter within each row for each element are statistically different at $p \leq 0.05$. [i] - The initial and final value of each element were analyzed using paired sample t test, [ii]- Difference in final and initial values for each element was analyzed using Duncan's Multiple Range Test.

in the literature for a typical soil in all the experimental units including control. There was significant variation in Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn content after the experimental plots were treated with concrete, asphalt and sandstone mulches (Table 3). However, when the difference in the final and initial levels of the heavy metals was analyzed, there was no significant variation between various mulch types except the level of Pb (Table 4). The Pb content was significantly lower in experimental units with asphalt mulch than control. The results indicated no negative effects due to the use of construction and demolition waste as soil surface mulch.

Biological Assay: Microbial population of the soil samples collected from experimental units with asphalt mulch was higher than that of samples from units with sandstone and concrete mulch and control at the end of the experimental period (Table 5).

Native Plant Population: Presence and growth of plant population in each treatment were studied during spring. During spring, maximum numbers of plant population were found in units with 10 to 25 mm concrete mulch at 75% density, followed by units with 25 to 50 mm asphalt mulch at 75% density (Table 6). Maximum plant diversity was observed in units covered with 25 to 50 mm concrete

Table 3 (Cont'd.)

	Mo		Ni		Pb		Zn		Hg	
	mg/kg									
Treatment	Initial	Final	Initial	Final [i]	Initial	Final	Initial	Final	Initial	Final
1	<0.01	<0.01	21.19 a	32.00 b	1.38 a	4.00 b	10.88 a	23.00 b	<0.001	<0.001
2	<0.01	<0.01	21.19 a	46.50 b	1.38 a	4.50 b	10.88 a	25.50 b	<0.001	<0.001
3	<0.01	<0.01	21.19 a	47.25 b	1.38 a	5.50 b	10.88 a	31.75 b	<0.001	<0.001
4	<0.01	<0.01	21.19 a	33.75 b	1.38 a	4.00 b	10.88 a	24.00b	<0.001	<0.001
5	<0.01	<0.01	21.19 a	39.75 b	1.38 a	5.75 b	10.88 a	24.00 b	<0.001	<0.001
6	<0.01	<0.01	21.19 a	37.50 b	1.38 a	5.50 b	10.88 a	23.50 b	<0.001	<0.001
7	<0.01	<0.01	21.19 a	34.75 b	1.38 a	7.50 b	10.88 a	28.25 b	<0.001	<0.001
8	<0.01	<0.01	21.19 a	37.25 b	1.38 a	4.00 b	10.88 a	27.50 b	<0.001	<0.001
9	<0.01	<0.01	21.19 a	34.75 b	1.38 a	5.25 b	10.88 a	24.25 b	<0.001	<0.001
10	<0.01	<0.01	21.19 a	34.75 b	1.38 a	3.25 b	10.88 a	21.50 b	<0.001	<0.001
11	<0.01	<0.01	21.19 a	47.00 b	1.38 a	4.50 b	10.88 a	31.00 b	<0.001	<0.001
12	<0.01	<0.01	21.19 a	27.50 b	1.38 a	2.75 b	10.88 a	23.25 b	<0.001	<0.001
13	<0.01	<0.01	21.19 a	43.75 b	1.38 a	5.25 b	10.88 a	29.25 b	<0.001	<0.001
14	<0.01	<0.01	21.19 a	27.50 b	1.38 a	2.75 b	10.88 a	22.00 b	<0.001	<0.001
15	<0.01	<0.01	21.19 a	47.75 b	1.38 a	5.25 b	10.88 a	30.75 b	<0.001	<0.001
16	<0.01	<0.01	21.19 a	28.00 b	1.38 a	2.75 b	10.88 a	24.50 b	<0.001	<0.001
17	<0.01	<0.01	21.19 a	36.25 b	1.38 a	4.75 b	10.88 a	28.25 b	<0.001	<0.001
18	<0.01	<0.01	21.19 a	32.00 b	1.38 a	3.75 b	10.88 a	23.75 b	<0.001	<0.001
19	<0.01	<0.01	21.19 a	30.00 b	1.38 a	5.75 b	10.88 a	24.75 b	<0.001	<0.001
20	<0.01	<0.01	21.19 a	38.25 b	1.38 a	3.75 b	10.88 a	27.00 b	<0.001	<0.001
21	<0.01	<0.01	21.19 a	31.75 b	1.38 a	3.75 b	10.88 a	25.00 b	<0.001	<0.001
22	<0.01	<0.01	21.19 a	41.25 b	1.38 a	4.00 b	10.88 a	31.75 b	<0.001	<0.001
23	<0.01	<0.01	21.19 a	48.00 b	1.38 a	6.25 b	10.88 a	31.25 b	<0.001	<0.001
24	<0.01	<0.01	21.19 a	30.25 b	1.38 a	4.00 b	10.88 a	25.75 b	<0.001	<0.001
25	<0.01	<0.01	21.19 a	44.25 b	1.38 a	4.00 b	10.88 a	29.25 b	<0.001	<0.001
26	<0.01	<0.01	21.19 a	41.50 b	1.38 a	3.25 b	10.88 a	29.25 b	<0.001	<0.001
27	<0.01	<0.01	21.19 a	39.00 b	1.38 a	4.25 b	10.88 a	27.25 b	<0.001	<0.001
Control	<0.01	<0.01	21.19 a	36.25 b	1.38 a	6.00 b	10.88 a	25.00 b	<0.001	<0.001
Typical Soil	2		19		19		60		<1	
Significance [ii]	NS		NS		*		NS		NS	

Cd - Cadmium; Co - Cobalt; Cr - Chromium; Cu- Copper; Fe - Iron; Mn - Manganese; Mo - Molybdenum; Ni- Nickel; Pb - Lead; Zn - Zinc; Hg - Mercury; The initial and final values followed by different letter within each row for each element are statistically different at $p \leq 0.05$; * Significant at $p \leq 0.01$.[i] The initial and final value of each element were analyzed using paired sample t test, [ii] Difference in final and initial values for each element was analyzed using Duncan's Multiple Range Test.

Table 4: Mean Difference in Heavy Metal Content in Various Mulching Treatments in Sulaibiya

	Mean Difference in Heavy Metals							
Mulch Type	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Concrete	3.26	14.54	4.18	3391.24	106.03	16.98	3.74 ab	14.88
Asphalt	2.76	11.43	3.54	2596.79	87.36	14.87	2.51 a	15.15
Sandstone	3.40	15.38	4.04	3432.90	111.25	17.06	2.96 a	17.04
Control	3.13	11.38	3.63	2780.13	101.00	15.06	4.63 b	14.13
Significance [i]	NS	NS	NS	NS	NS	NS	*	NS

Co - Cobalt; Cr - Chromium; Cu- Copper; Fe - Iron; Mn - Manganese; Ni- Nickel; Pb - Lead; Zn - Zinc; Data were analyzed using analysis of variance procedure and Duncan's Multiple Range Test. The means followed by the same letter within the column are not statistically different at $p \leq 0.05$.

Table 5: Microbial Population in Soils in the Mulching Experiments at KISR Sulaibiya Research Station

	Cell Count (CFU/g)		
Sample	Initial	Mid	Final
Concrete	2.5×10^{9}	4.2×10^{5}	3.0×10^{4}
Asphalt	2.5×10^{9}	2.1×10^{5}	3.2×10^{4}
Sandstone	2.5×10^{9}	1.2×10^{5}	2.0×10^{4}
Control	2.5×10^{9}	2.4×10^{5}	1.2×10^{4}

CFU - Colony forming unit

Table 6: Distribution of Native Annual and Perennial Plants Recorded in the Mulching Experiment at KISR Sulaibiya Experimental Station during Spring

Treatment No.	Total No. of Annual Species	Total No. of Perennial Species	Total No. of Species	Total No. of Plants
T1	16	3	19	63
T2	11	2	13	98
T3	13	2	15	66
T4	12	10	22	85
T5	15	5	20	90
T6	13	5	18	165
T7	20	4	24	103
T8	20	3	23	117
T9	19	2	21	118
T10	13	4	17	84
T11	12	6	18	111
T12	15	3	18	115
T13	17	4	21	83
T14	17	4	21	84
T15	13	2	15	110
T16	16	3	19	122
T17	16	3	19	106
T18	16	5	21	162
T19	16	4	20	93
T20	14	3	17	96
T21	15	4	19	62
T22	12	8	20	77
T23	18	4	22	99
T24	15	4	19	79
T25	9	3	12	114
T26	14	3	17	116
T27	11	4	15	106
Control	8	2	10	60
Significance	NS	NS	NS	NS

Data were analyzed using analysis of variance procedure. NS - Not Significant.

Table 7: Comparison of Native Plant Population in Various Mulching Treatments During Spring in Sulaibiya

Type of Mulch	Average No.of Annual Species	Average Population of Annuals	Average No. of Perennial Species	Average Population of Perennials	Average Plant Population
Concrete	7.67 b [i]	30.67 b	1.74 b	2.85 ab	33.52 b
Asphalt	7.52 b	32.48 b	2.00 b	3.70 b	36.19 b
Sandstone	6.70 b	27.89 b	2.00 b	3.30 b	31.19 b
Control	3.67 a	18.00 a	1.00 a	2.00 a	20.00 a
Significance	**	*	**	*	**

Data were analyzed using analysis of variance procedure and Duncan's Multiple Range Test.

[i]The means followed by the same letter within the column are not statistically different at $p \leq 0.05$.

**,* = Significant at $P \leq 0.01$ and 0.05.

mulch at 25% density. Highest number of annuals was recorded in units with 25 to 50 mm concrete mulch at 25% and 50% densities. Perennial plant diversity was highest in units with 10 to 25 mm concrete mulch at 25% density. Control unit documented the least number of annual and perennial plant species, plant diversity and total plant population. Annual species *Plantago boissieri* dominated in all the treatment units except T2 (Concrete mulch 5-10 cm, 50% density).

There was no significant variation among the treatments in annual and perennial plant population and diversity. However, when the data were analyzed considering various mulch types, there was a significant variation among the treatments compared to control in the average annual, perennial plant population and diversity and total plant population (Table 7). Units with asphalt mulch recorded the highest average annual, perennial and total plant population and perennial plant diversity during

Table 8: Distribution of Native Annual and Perennial Plants Recorded in the Mulching Experiment at KISR Sulaibiya Experimental Station in Late Spring

Treatment No.	Total No. of Annual Species	Total No. of Perennial Species	Total No. of Species	Total No. of Plants
T1	2	5	7	52
T2	2	6	8	39
T3	3	7	10	57
T4	2	7	9	38
T5	3	7	10	52
T6	1	6	7	29
T7	3	9	12	50
T8	2	6	8	31
T9	3	7	10	45
T10	3	7	10	68
T11	5	7	12	48
T12	3	9	12	60
T13	4	7	11	60
T14	3	8	11	91
T15	6	6	12	34
T16	2	8	10	57
T17	4	8	12	65
T18	2	6	8	54
T19	6	7	13	57
T20	3	7	10	65
T21	4	6	10	74
T22	0	8	8	46
T23	4	5	9	57
T24	4	7	11	52
T25	1	6	7	31
T26	3	6	9	46
T27	1	7	8	24
Control	0	2	2	15
Significance	NS	NS	NS	NS

Data were analyzed using analysis of variance procedure. NS - Not significant.

Table 9: Comparison of Native Plant Population in Various Mulching Treatments in Late Spring in Sulaibiya

Type of Mulch	Average No. of Annual Species	Average Population of Annuals	Average No. of Perennial Species	Average Population of Perennials	Average Plant Population
Concrete	0.78 b [i]	1.41 b	3.93 bc	13.15 b	14.56 b
Asphalt	1.48 c	2.78 b	4.41 c	17.19 b	19.96 c
Sandstone	1.00 bc	2.04 b	3.56 b	14.67 b	16.70 bc
Control	0.00 a	0.00 a	1.33 a	5.00 a	5.00 a
Significance	**	**	**	**	**

Data were analyzed using analysis of variance procedure and Duncan's Multiple Range Test.
[i] The means followed by the same letter within the column are not statistically different at $p \leq 0.01$.
** = Significant at $P \leq 0.01$ level.

spring. Units with concrete mulch recorded the highest annual plant diversity. This implies that the type of mulch plays a significant role in the native plant population and diversity. Size and density of mulch did not affect them significantly and there was no significant variation among the mulching treatments.

During the late spring, units with 5 to 10 mm sandstone at 75% density topped the list for total plant population (Table 8). Units with 5 to 10 mm sandstone mulch at 25% density recorded the highest number of annuals and plant diversity, while highest number of perennials was found in units with 10 to 25 mm sandstone mulch at 25% density. There was no significant variation among the treatments in annual and perennial population and diversity. However, when the data were analyzed considering various mulch types, there was significant variation among the treatments compared to control in average annual, perennial plant population and diversity and total plant population (Table 9). Among the various mulch types, units with asphalt mulch recorded the highest average annual and perennial plant population and diversity and total plant population. There was a significant variation among the treatments compared to control at $p \leq 0.01$ level; however, there was no significant variation based on size and density of mulch. Mulch increased soil moisture retention thereby providing favorable environments for annual and perennial seeds to germinate and grow. Among the soil aggregates, asphalt mulch enhanced germination and plant growth and retained soil moisture better than other mulches and thus, supporting plant survival for a longer period than control.

DISCUSSION

The soil remained alkaline and non-saline to slightly saline indicating that there were no negative effects in pH, EC and heavy metal content of the soil due to the use of construction and demolition wastes as soil mulch. The fact that, there was no significant variation in changes in heavy metal content between the treatments indicate the absence of any negative effect on soil due to the utilization of construction and demolition waste as mulch.

Significant difference in the infiltration rate was observed among the treatments when compared to control. At the end of the experimental period, units with asphalt 5-10 mm at 75% density, 10-25 mm at 50% density and concrete 5-10 mm at 50% density recorded higher infiltration rates. Higher infiltration rate in experimental units with various mulches when compared to control may be due to the fact that mulch can increase infiltration rates by intercepting and absorbing water and also by impeding lateral flow of excess surface water and reduces runoff. Thus mulch holds excess water in contact with the soil surface longer and allows more infiltration [24]. As well as intense rainfall and topography, the rate of surface runoff is also influenced by the extent of infiltration, which in turn, is controlled by the soil type and vegetation cover [25].

Results showed that both concrete and asphalt mulch conserved moisture during September, facilitating the plant germination and growth. While concrete mulch of 5-10 mm size succeeded in preserving more moisture during September, bigger-sized concrete mulch (10-25 mm) was effective during the rest of the experimental period. Lower moisture content recorded in the control unit demonstrated the positive effect of utilization of construction and demolition waste as soil mulch to conserve moisture. This supports the previous research findings by Li [15].

Vegetation provides a physical barrier to surface runoff, decreasing its velocity and thus slowing the rate of discharge. In addition, vegetation increases the soil impermeability and infiltration by loosening the soil. The results indicated that there was significant variation in annual and perennial native plant population, diversity and total plant population among various mulch types and control during and late spring. However, mulch size and density did not have significant influence on the same. Asphalt mulch was found to be effective in supporting the annual and perennial native plants. During spring, when the annuals were prevalent, units with concrete mulch recorded highest plant diversity Placement of mulching materials on the surface normally prevents the removal of top soil by wind. This could have led to retention of seeds in the top layer. Availability of viable seeds and a favorable soil moisture regime may have led to increase in the composition and frequency of native plant population in the experimental plots. Mulch acts as a one-way water valve for the soil, thus water remains in the soil longer and benefits growing plants [25].

Microbial population of the soil samples collected from experimental units with asphalt mulch was higher than that of samples from units with sandstone and concrete mulch and control at the end of the experimental period. Results indicated higher soil moisture levels in plots that were mulched with construction by-products compared to the control. Increased moisture levels may have led to greater microbial activities in the soil. Zaady *et al*., [26] found that stones and rocks provided moderate micro-niches for soil biota. Lahav and Steinberger [27] reported that stone cover and distribution greatly affected the intensity and duration of biological activity.

CONCLUSION

It can be concluded that utilization of construction and demolition waste can be used as mulch to conserve soil moisture, increase the infiltration rate and thus, promoting native plant growth. Asphalt mulch of smaller size (5-10 mm) at higher density (75%) increased infiltration rate and porosity and asphalt mulch of bigger size (25-50 mm) at lower density (25%) improved the moisture retention. Asphalt was found to be the best material among soil aggregates for retaining soil moisture and for supporting plant survival and growth for longer period. The findings of the study is a clear evidence of the benefits attained by the utilization of building and construction waste which in turn contributes towards management of environmental pollution and prevention of landfills caused by the recent boom in construction and unethical disposal of the construction and demolition wastes. A systematic recycling and reuse of these waste materials can provide additional resources for improving the soil properties and sustaining native plant diversity and thus assist the government initiatives for the rehabilitation and restoration of Kuwait's desert ecosystem.

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