ADSORPTION AND MOVEMENT OF CARBOFURAN IN NONIONIC AND ANIONIC SURFACTANT AMENDED SOILS OF DIVERGENT TEXTURE: AN ANALYSIS

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Abstract:
Remediation strategies for polluted soil, sediment, and water have just recently begun to make use of surfactants. Hydrophilic or water-soluble moiety (head group) and hydrophobic or water-insoluble moiety (tail group) make up these amphiphilic compounds (tail group). Surfactants exist entirely as monomers at low concentrations. In this article, adsorption and movement of carbofuran in non-ionic and anionic surfactant amended soils of divergent texture has been analyzed.

Keywords: Adsorption, Surfactant, Carbofuran, Soils, Divergent
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INTRODUCTION:

Critical micelle concentration (CMC) is the concentration above which surfactants begin to self-aggregate (micelles). [1] Micelles of this type function as colloids, increasing the apparent solubility of hydrophobic organic compounds (HOCs) in extracting them from soils, especially those extracted with anionic and non-ionic surfactants. This apparent solubility improvement has the potential to be a useful tool for chemical and biological soil contamination clean-up. [2] Cationic surfactants are another kind of surfactant used to immobilise soil pollutants; they are retained by soil colloids and can improve HOCs/pesticides adsorption, leading to a possible increase in the creation of bound residues. [3] The availability of organic molecules to microorganisms is an important factor in microbial remediation of HOCs in soils, and surfactants may alter this. Adsorption on soils/sediments appears to have decreased the free aqueous surfactant concentration, which in turn has decreased surfactant toxicity to microorganisms involved in the degradation of pesticides.Commonly used in our nation for nematode control in soils, carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl carbamate) is a systemic non-ionic broad-spectrum insecticide/nematicide.

EXPERIMENTAL:

Chemicals and Reagents:

Carbofuran Solution, Sodium oxalate ($Na_2C_2O_4$) Solution, 1% Phenolphthalein Solution, 1 N Potassium dichromate ($K_2CrŽ0_7$) Solution, Diphenylamine Indicator Solution, 0.5 N Ferrous ammonium sulphate ($FeS0_4$ $(NH_4)2S0_4.6H_20$) Solution, % p-nitrobenzene diazoniumtetrafluoroborate Solution, 4 N Sodium hydroxide (NaOH) Solution, 0.2 % Sulphanilic acid Solution, 0.3 % Sodium nitrite (NaN02) Solution, Polyoxymethylenesorbitan monolaurate (Tween '20') Solution, Sodium dodecyl sulphate (SDS) Solution.

Apparatus:

Electrical Balance	Varanasi Balance Works, Varanasi, India.
Constant Temperature Bath	Tempo India Ltd.
Electric Oven	Tempo India Ltd.
Electric Stirrer	INL DX Magnetic Stirrer (Remo Equipments).
Sieves	British Standard Sieves
Stop Watch	Racer Swiss made.
pH Meter	Systronics India Ltd.
Centrifuge	Beckman L3-50 Ultracentrifuge.
Spectrophotometer	• T-70 UV/VIS Spectrophotometer (U.K.).

Collection of Soil Samples[4]

- Determination of the Physico-Chemical Properties of the Soils
- Mechanical Composition ofthe Soils
- Determination of the Ph of The Soils
- Determination of the Cation Exchange Capacity (CEC) of The Soils
- Determination of Organic Carbon and Organic Matter Content of the Soils
- Determination of Calcium Carbonate Content of the Soils
- Surface Area Determination of The Soils

Preparation of Standard Curve of Carbofuran:

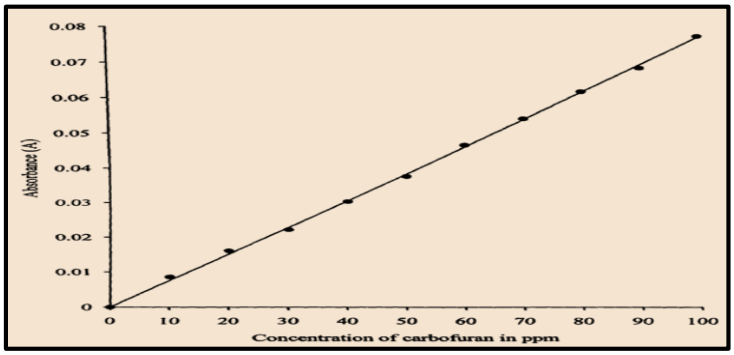

Figure: 1. Standard curve of carbofuran.

Preparation of Surfactant Amended Sous

Adsorption Studies

Soil Thin-Layer Chromatography (Soil TLC)

RESULTS AND DISCUSSION:

Carboxyfuran adsorption isotherms on surfactant-free (natural) and surfactant-amended soils are shown in Figures with data for three critical micelle concentrations (0.1 X CMC, 1 X CMC, and 10 X CMC) provided in Tables.

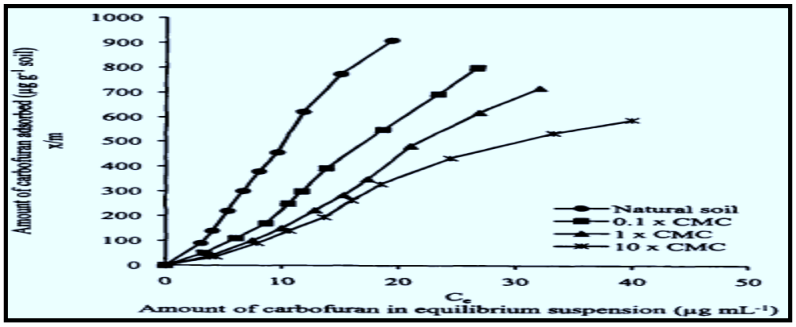

Figure 2 (a): Tween '20' amended Doiwala (I) silt loam soil

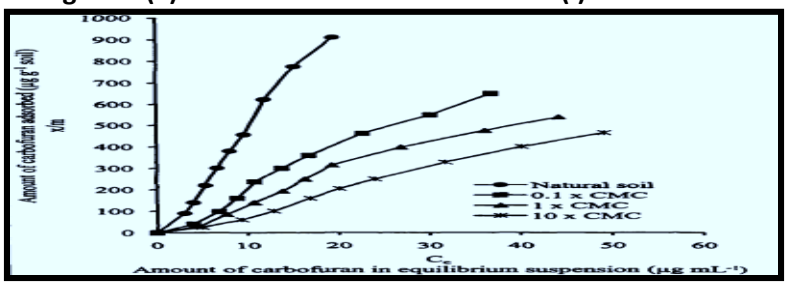

Figure 2 (b): SDS amended Doiwala (I) silt loam soil

Figure 2 (a-b): Adsorption isotherms of carbofuran on surfactant free and surfactant amended Doiwala (I) silt loam soil relative to different CMCs.

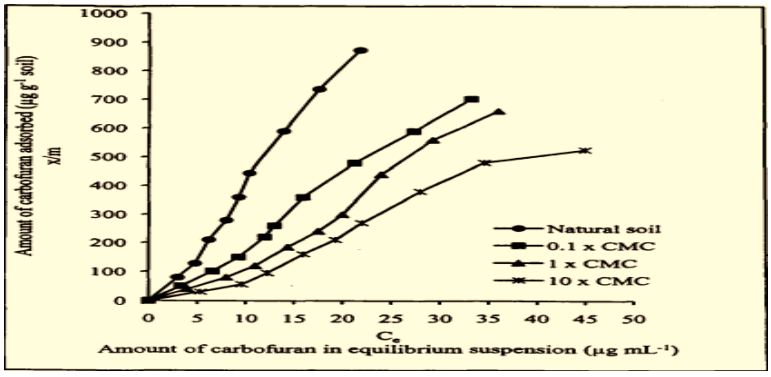

Figure 3 (a): Tween '20' amended Larhota sandy loam soil

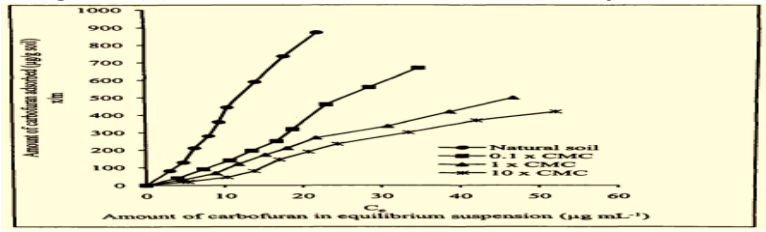

Figure 3 (b): SDS amended Larhota sandy loam soil

Figure 3 (a-b): Adsorption isotherms of carbofuran on surfactant free and surfactant amended Larhota sandy loam soil relative to different CMCs

Table 1: Adsorption of carbofuran on unamended (Surfactant Free) Doiwala (I) silt loam soil

Amount of Carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	10.00	90.00	3.00	180.00	9.00	8100.00	0.4711	1.9542
200	60.00	140.00	4.00	560.00	16.00	19600.00	0.6220	2.1461
300	80.00	220.00	5.30	1166.00	28.09	48400.00	0.7242	2.3424
400	99.00	301.00	6.60	1986.00	43.56	90601.00	0.8195	2.4785
500	120.00	380.00	8.00	3040.00	64.00	144400.00	0.9030	2.5797
600	144.00	456.00	9.60	4377.60	92.16	207936.00	0.9822	2.6589
700	177.00	623.00	11.80	7351.40	139.24	388129.00	1.0718	2.7944
800	225.00	775.00	15.00	11625.00	225.00	699625.00	1.1760	2.8893
900	289.50	910.50	19.30	17572.65	372.49	829010.25	1.2855	2.9592

Table 2: Adsorption of carbofuran on unamended (Surfactant Free) Larhota sandy loam soil

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	20.00	80.00	1.33	106.66	1.7689	6400.00	0.1239	1.9031
200	72.00	128.00	4.80	614.00	23.04	16384.00	0.6812	2.1072
300	93.00	207.00	6.20	1283.40	38.44	42849.00	0.7924	2.3159
400	120.00	280.00	8.00	2240.00	64.00	78400.00	0.9030	2.4471
500	140.00	360.00	9.33	3358.80	87.04	129600.00	0.9698	2.5563
600	156.00	444.00	10.40	4617.60	108.16	197136.00	1.0170	2.6473
700	210.00	590.00	14.00	8260.00	196.00	348100.00	1.1461	2.7708
800	264.00	736.00	17.60	12953.60	309.76	541696.00	1.2455	2.8668
900	327.00	873.00	21.80	19031.40	475.24	762129.00	1.3384	2.9410

Table 3: Adsorption of carbofuran on Tween '20' amended Doiwala (I) silt loam soil at 0.1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	50.00	50.00	3.30	165.00	10.89	2500.00	0.5185	1.6989
200	90.00	110.00	6.00	660.00	36.00	12100.00	0.7782	2.0414
300	130.00	170.00	8.60	1462.00	73.96	28900.00	0.9345	2.2304
400	150.00	250.00	9.60	2400.00	92.16	62500.00	0.9823	2.3979
500	200.00	300.00	11.70	3510.00	136.89	90000.00	1.0682	2.4771
600	207.00	393.00	13.80	5423.40	190.44	154449.00	1.1398	2.5944
700	279.00	521.00	18.60	9690.60	345.96	271441.00	1.2695	2.7168
800	350.00	650.00	23.33	15574.40	615.04	422500.00	1.3679	2.8129
900	400.00	800.00	26.66	22776.00	973.44	640000.00	1.4258	2.9031

Table 4: Adsorption of carbofuran on Tween '20' amended Doiwala (I) silt loam soil at 1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	60.00	40.00	4.00	160.00	16.00	1600.00	0.6020	1.6020
200	99.00	101.00	6.60	666.60	43.56	10201.00	0.8195	2.0043
300	150.00	150.00	10.00	1500.00	100.00	22500.00	1.0000	2.1761
400	177.00	223.00	11.80	2631.40	139.24	49729.00	1.0718	2.3483
500	230.00	270.00	15.30	4131.00	234.09	72900.00	1.1847	2.4314
600	260.00	340.00	17.33	5892.20	300.33	115600.00	1.2388	2.5315
700	315.00	485.00	21.00	10185.00	441.00	235225.00	1.3222	2.6857
800	402.00	598.00	26.80	16026.40	718.24	357604.00	1.4281	2.7767
900	480.00	720.00	32.00	23040.00	1024.00	518400.00	1.5051	2.8573

Table 5: Adsorption of carbofuran on Tween '20' amended Doiwala (I) silt loam soil at 10 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	65.00	35.00	4.30	150.50	18.50	1225.00	0.6334	1.5440
200	110.00	90.00	7.30	657.00	53.30	8100.00	0.8633	1.9542
300	160.00	140.00	10.60	1484.00	112.30	19600.00	1.0253	2.1461
400	205.00	195.00	13.60	2652.00	184.90	38025.00	1.1335	2.2900
500	237.00	263.00	15.80	4155.40	249.64	69169.00	1.1987	2.4199
600	270.00	330.00	18.00	5940.00	324.00	108900.00	1.2553	2.5185
700	366.00	434.00	24.40	10589.60	595.36	188356.00	1.3874	2.6375
800	498.00	502.00	33.20	16666.40	1102.24	252004.00	1.5211	2.7007
900	600.00	600.00	40.00	24000.00	1600.00	360000.00	1.6021	2.7781

Table 6: Adsorption of carbofuran on Tween '20' amended Larhota sandy loam soil at 0.1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	50.00	50.00	3.30	165.00	10.90	2500.00	0.5185	1.6989
200	99.00	101.00	6.60	666.60	43.56	10201.00	0.8195	2.0043
300	150.00	150.00	9.30	1395.00	86.50	22500.00	0.9685	2.1761
400	180.00	220.00	12.00	2640.00	144.00	48400.00	1.0792	2.3424
500	195.00	305.00	13.00	3380.00	169.00	93025.00	1.1139	2.4843
600	240.00	360.00	16.00	5760.00	256.00	129600.00	1.2041	2.5563
700	320.00	480.00	21.33	10238.40	454.97	230400.00	1.3289	2.6812
800	410.00	590.00	27.33	16124.70	746.93	348100.00	1.4366	2.7708
900	498.00	702.00	33.20	23306.40	1102.24	492804.00	1.5211	2.8463

Table 7: Adsorption of carbofuran on Tween '20' amended Larhota sandy loam soil at 1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	60.00	40.00	4.00	160.00	8.00	1600.00	0.6020	1.6020
200	120.00	80.00	8.00	640.00	64.00	6400.00	0.9031	1.9031
300	180.00	120.00	11.00	1320.00	121.00	14400.00	1.0414	2.0792
400	210.00	190.00	14.00	2660.00	196.00	36100.00	1.1461	2.2787
500	270.00	230.00	18.00	4140.00	324.00	52900.00	1.2553	2.3617
600	300.00	300.00	20.00	6000.00	400.00	90000.00	1.3010	2.4771
700	360.00	440.00	24.00	10560.00	576.00	193600.00	1.3802	2.6434
800	440.00	560.00	29.30	16408.00	878.50	313600.00	1.4668	2.7482
900	540.00	660.00	36.00	23760.00	1296.00	435600.00	1.5563	2.8195

Table 8: Adsorption of carbofuran on Tween '20' amended Larhota sandy loam soil at 10 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	70.00	30.00	5.30	159.00	28.09	900.00	0.7243	1.4771
200	144.00	56.00	9.60	537.60	92.16	3136.00	0.9823	1.7482
300	205.00	95.00	12.30	1168.50	151.30	9025.00	1.0899	1.9777
400	240.00	160.00	16.00	2560.00	256.00	25600.00	1.2041	2.2041
500	290.00	210.00	19.30	4059.30	373.65	44100.00	1.2855	2.3222
600	330.00	270.00	22.00	5940.00	484.00	72900.00	1.3424	2.4313
700	420.00	380.00	28.00	10640.00	784.00	144400.00	1.4471	2.5798
800	519.00	481.00	34.60	16642.60	1197.16	231361.00	1.5391	2.6821
900	675.00	525.00	45.00	23625.00	2025.00	275625.00	1.6532	2.7202

Table 9: Adsorption of carbofuran on SDS amended Doiwala (I) silt loam soil at 0.1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	60.00	40.00	4.00	160.00	16.00	1600.00	0.6020	1.6021
200	102.00	98.00	6.80	666.40	46.20	9604.00	0.8325	1.9912
300	140.00	160.00	8.80	1408.00	77.44	25600.00	0.9445	2.2041
400	162.00	238.00	10.80	2570.40	116.64	56644.00	1.0334	2.3766
500	210.00	290.00	13.70	3973.00	187.69	84100.00	1.1367	2.4624
600	249.00	351.00	16.70	5861.70	278.90	123201.00	1.2227	2.5453
700	339.00	461.00	22.60	10418.60	510.76	212521.00	1.3541	2.6637
800	450.00	550.00	30.00	16500.00	900.00	302500.00	1.4771	2.7404
900	550.00	650.00	36.66	23829.00	1343.95	422500.00	1.5642	2.8129

Table 10: Adsorption of carbofuran on SDS amended Doiwala (I) silt loam soil at 1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	70.00	30.00	4.66	139.80	21.70	900.00	0.6684	1.4771
200	115.00	85.00	7.66	651.10	58.67	7225.00	0.8423	1.9294
300	160.00	140.00	10.66	1492.40	113.63	19600.00	1.0277	2.1461
400	207.00	193.00	13.80	2663.40	190.44	37249.00	1.1399	2.2855
500	250.00	250.00	16.30	4075.00	265.70	62500.00	1.2122	2.3979
600	282.00	318.00	18.30	5819.40	334.90	101124.00	1.2625	2.5024
700	402.00	398.00	26.80	10666.40	718.24	158404.00	1.4281	2.5998
800	540.00	460.00	36.00	16560.00	1296.00	211600.00	1.5563	2.6627
900	660.00	540.00	44.00	23760.00	1936.00	291600.00	1.6434	2.7324

Table 11: Adsorption of carbofuran on SDS amended Doiwala (I) silt loam soil at 10 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	C_e.x/m	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	75.00	25.00	5.00	125.00	25.00	625.00	0.6989	1.3979
200	140.00	60.00	9.33	559.80	87.05	3600.00	0.9698	1.7782
300	200.00	100.00	12.80	1280.00	163.84	10000.00	1.1072	2.0000
400	240.00	160.00	16.80	2688.00	282.24	25600.00	1.2253	2.2041
500	290.00	210.00	19.00	3990.00	361.00	44100.00	1.2787	2.3222
600	360.00	240.00	24.00	5760.00	576.00	57600.00	1.3802	2.3802
700	272.00	328.00	31.66	10384.48	1002.35	107584.00	1.5005	2.5159
800	600.00	400.00	40.00	16000.00	1600.00	160000.00	1.6021	2.6020
900	735.00	465.00	49.00	22785.00	2401.00	216225.00	1.6902	2.6675

Table 12: Adsorption of carbofuran on SDS amended Larhota sandy loam soil at 0.1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	$C_e.x/m$	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	60.00	40.00	4.00	160.00	8.00	1600.00	0.6020	1.6020
200	110.00	90.00	7.30	657.00	53.29	8100.00	0.8633	1.9542
300	160.00	140.00	10.66	1492.40	113.63	19600.00	1.0277	2.1461
400	200.00	200.00	13.30	2660.00	176.89	40000.00	1.1238	2.3010
500	250.00	250.00	16.66	4165.00	277.55	62500.00	1.2217	2.3979
600	280.00	320.00	18.66	5971.20	348.20	102400.00	1.2711	2.5051
700	339.00	461.00	22.66	10446.26	513.50	212521.00	1.3552	2.6637
800	440.00	560.00	29.33	16424.80	860.25	313600.00	1.4673	2.7482
900	520.00	680.00	34.66	23568.80	1201.30	462400.00	1.5398	2.8325

Table 13: Adsorption of carbofuran on SDS amended Larhota sandy loam soil at 1 × CMC

Amount of carbofuran added ($\mu g\ g^{-1}$)	Amount of carbofuran in equilibrium suspension (µg/15mL)	Amount of carbofuran adsorbed per g soil ($\mu g\ g^{-1}$) (x/m)	Amount of carbofuran in equilibrium suspension ($\mu g\ mL^{-1}$) (C_e)	$C_e.x/m$	$(C_e)^2$	$(x/m)^2$	log C_e	log x/m
100	70.00	30.00	4.66	139.80	21.70	900.00	0.6684	1.4771
200	132.00	68.00	8.80	598.40	77.44	4624.00	0.9445	1.8325
300	180.00	120.00	11.80	1416.00	139.24	14400.00	1.0719	2.0792
400	222.00	178.00	14.80	2634.40	219.04	31684.00	1.1703	2.2504
500	290.00	210.00	18.00	3780.00	324.00	44100.00	1.2553	2.3222
600	325.00	275.00	21.66	5956.50	469.15	75625.00	1.3356	2.4393
700	462.00	338.00	30.80	10410.40	948.64	114244.00	1.4885	2.5289
800	580.00	420.00	38.66	16237.20	1494.60	176400.00	1.5873	2.6232
900	700.00	500.00	46.66	23330.00	2177.00	250000.00	1.6889	2.6989

Table 14: Adsorption of carbofuran on SDS amended Larhota sandy loam soil at 10 × CMC

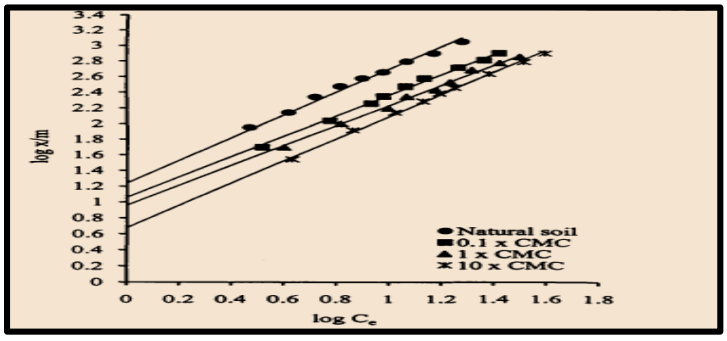

Figure 4 (a): Tween '20' amended Doiwala (I) silt loam soil

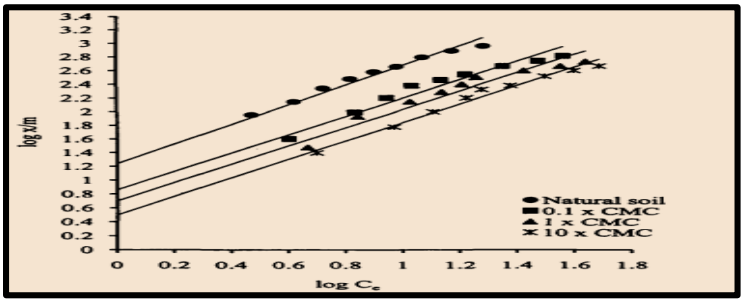

Figure 4 (b): SDS amended Doiwala (I) silt loam soil

Figure 4 (a-b): Freundlich adsorption isotherms of carbofuran on surfactant free and surfactant amended Doiwala (I) silt loam soil relative to different CMCs

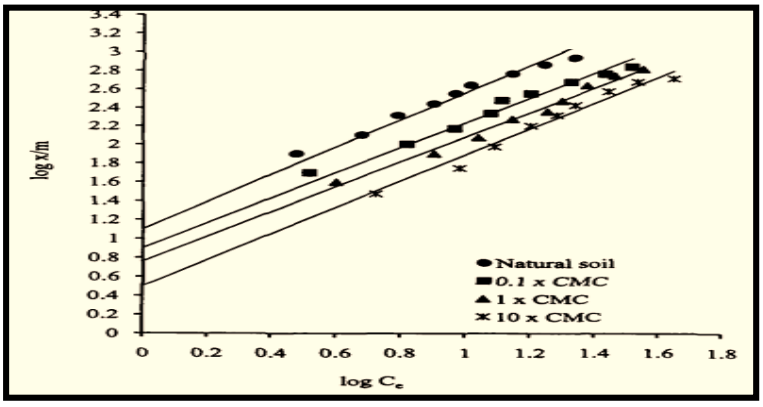

Figure 5 (a): Tween '20' amended Larhota sandy loam soil

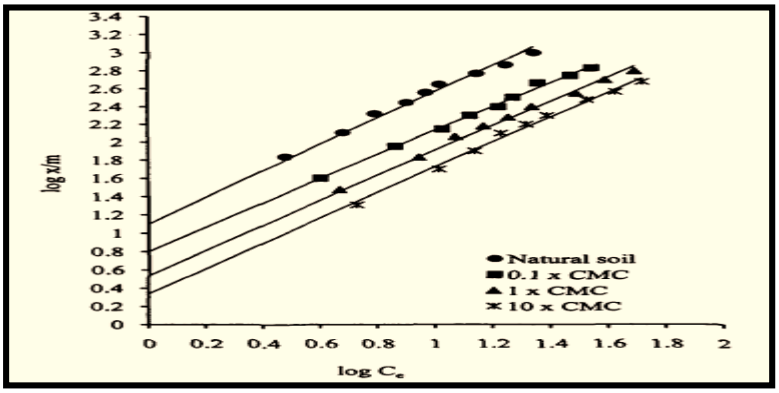

Figure 5 (b): SDS amended Larhota sandy loam soil

Figure 5 (a-b): Freundlich adsorption isotherms of carbofuran on surfactant free and surfactant amended Larhota sandy loam soil relative to different CMCs

Table 15: Carborun adsorption data on surfactant free and surfactant amended soils.

Amendment	K_F	K_D	r^2	1/n	K_{OC}	K_C	R_f
DOIWALA (I) SILT LOAM SOIL							
Tween '20'							
0.0	17.38	48.36	0.99	1.42	3868.80	261.40	0.30
Below CMC	11.48	24.91	0.91	1.40	1192.80	134.65	0.29
At CMC	9.12	21.29	0.99	1.42	1703.20	115.08	0.35
Above CMC	4.78	15.51	0.98	1.42	1240.80	83.04	0.39
Sodium dodecyl sulphate							
0.0	17.38	48.36	0.99	1.42	3868.80	261.40	0.30
Below CMC	7.24	18.80	0.99	1.40	1504.00	101.62	0.38
At CMC	5.01	13.34	0.98	1.40	1067.20	72.11	0.60
Above CMC	3.16	9.78	0.99	1.40	782.40	52.86	0.67
LARHOTA SANDY LOAM SOIL							
Tween '20'							
0.0	12.56	40.11	0.99	1.45	12154.50	573.00	0.43
Below CMC	7.94	21.12	0.97	1.45	6400.00	301.75	0.42
At CMC	5.75	17.08	0.97	1.42	5175.80	244.00	0.44
Above CMC	3.16	12.00	0.97	1.45	3636.40	171.43	0.53
Sodium dodecyl sulphate							
0.0	12.56	40.11	0.99	1.45	12154.50	573.00	0.43
Below CMC	6.31	18.45	0.98	1.42	5590.90	263.57	0.46
At CMC	3.47	10.98	0.99	1.40	3327.30	156.86	0.80
Above CMC	2.18	8.48	0.98	1.40	2569.70	121.14	0.90

Doiwala (I) silt loam soil was found to have higher Kp and KD values than Larhota (I) sandy loam soil. This verifies the preceding order for carbofuran adsorption in surfactant fi-ee and surfactant-amended soils across all CMCs tested (Figures). Furthermore, the KF and KD values show that the adsorption of carbofiiran on both soils was higher on non-ionic surfactant treated soils than on anionic surfactant supplemented soils in comparison to the various CMCs investigated.

Effect of The Non-Ionic Surfactant (Tween *20')

Adsorption isotherms of carbofiiran on Tween '20' fi-ee soil and on soil that had been treated with various CMCs are shown in Figures respectively. The Kp and KD values decreased at concentrations over O.l x CMC compared to those in soils without surfactants. KF and KD values are reduced by 36.8 and 47.3 percent, respectively, for Larhota sandy loam soil, and by 34.0 and 48.4 percent, respectively, for Doiwala (I) silt loam soil, when compared to their unamended counterparts. There is a possibility that the surfactant's ability to make the soil surface more or less hydrophobic is to blame for this decline. KF and KD values for Tween '20-amended soils were much lower than those for surfactant-free soils, indicating a significant reduction in carbofiiran adsorption. There was a decrease in KF and KD values of 54.2% and 57.4% for Larhota sandy loam soil and 47.5% and 56% for Doiwala (I) silt loam soil, respectively, when compared to the corresponding KF and KD values of surfactant-free soils at a concentration relative to 1 x CMC, and at a concentration relative to 10 x CMC, respectively.

Effect of the Anionic Surfactant (SDS)

Figures show the impact of SDS, an amonic surfactant, on the adsorption of carbofuran in comparison to other CMCs (b). Adsorption of carbofuran on SDS-amended soils was modestly reduced when compared to 0.1 x CMC, but it was significantly reduced when compared to unamended soils when surfactant was maintained at 1 x CMC or 10 x CMC during treatment. The KF and KD values were reduced by 49.8% and 54.0% for Larhota sandy loam soil and 58.3% and 61.1% for Doiwala (I) silt loam soil, respectively, as compared to surfactant-free soils, as shown in Table. When applied at a concentration of 1 x CMC, the surfactant reduced the KF and KD values by 72.4% and 72.6%, respectively, in Larhota sandy loam soil and 71.2% and 72.6%, respectively, in Doiwala (I) silt loam soil. Last but not least, when the surfactant concentration was set at 10 x CMC

value, the KF and KD values for the soils showed a drop of 82.6% and 78.9% for Larhota sandy loam soil and 81.8% and 79.8% for Doiwala (I) silt loam soil, respectively, when compared with surfactant free soils. Adsorption of carbofuran molecules by soluble spherical micelles of SDS present in the solution phase may be responsible for the drop in KF and KD values. To further understand the role that these characteristics play in the mechanisms determining the adsorption behaviour of surfactants on soil, additional studies are required.

CONCLUSION:

This research shows that the concentration and type of surfactant (anionic vs. non-ionic) both affect the behaviour of carbofuran in soil systems supplemented with micelle-forming surfactants. Surfactant adsorption to soil systems has a complicated influence on the partitioning of pesticides, even though it was typically reported to increase the apparent water solubility of HOCs. [5] As such, the results presented here are intriguing because they provide preliminary evidence for the potential application of surfactants to address the soil contamination issues raised by carbofiiran.

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