copy sent to W.B. Papageorge 5/30/75

Monsanto

FROM (NAME & LOCATION) B. C. Bosse, W. G. Krummrich Plant

DATE : April 17, 1975

SUBJECT : RESULTS OF PLANT POLY-URETHANE FOAM TESTING

REFERENCE :

TO : Mr. W. C. Engman

cc: K. E. Boucher
H. L. Campbell
P. E. Heisler
H. J. Horner
G. L. Johnson
A. E. Leisy
D. K. Lynch
J. P. Mieure - T2B
R. H. Munch - T1B
W. R. Richard - T3A
J. R. Savage - B2SL
W. L. Smull
E. E. Stewart
S. H. Vogel

SUMMARY:

Following the success of research in using Polyurethane Foam to extract PCB's from surface waters, interest was expressed in ascertaining how well foam would remove PCB's from a waste stream on a plant scale. Tests, conducted at the Krummrich Plant, showed:

1) A single column of foam will reduce the PCB content of a waste stream from as high as 2000 ppb to $<$ 10 ppb, as will a single column of carbon.

2) The PCB content of a waste stream is not significantly reduced by passing it through a foam column after it has flowed through a carbon column.

3) Neither foam nor carbon consistently removed 1242 or 1254 perferentially.

4) The loading capacity of the foam is estimated to be $\frac{.05 \text{ lb PCB}}{\text{lb Polyurethane Foam}}$ vs. carbon loading of $\frac{0.25 \text{ lb/PCB}}{\text{lb Carbon}}$

Carbon was found to be superior to foam in:

1) Material and regeneration costs.

2) Risks involved in operating the removal system.

3) Existing technology.

As a result, it is recommended that carbon be used to remove PCB's from plant waste streams rather than foam.

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I. BACKGROUND

It was found, on a laboratory scale, that lower PCB levels could be detected by extracting the PCB's from a body of water onto Polyurethane Foam, than could be detected by adsorbing them onto carbon. As a result, interest was expressed in ascertaining how well foam would remove PCB's from a waste stream on a plant scale. Tests were conducted at the W. G. Krummrich Plant to accomplish the following objectives:

1) Find the level to which the PCB content of a plant waste stream could be reduced using a removal system containing Polyurethane Foam.

2) Obtain engineering design information.

II. TESTS CONDUCTED

Two systems were employed to accomplish the objectives of the plant testing:

1) A system in which sump water was fed to a carbon column followed by a foam column, the two columns being in series.

2) A system in which sump water was fed only to a foam column.

The following samples were taken and analyzed for PCB content:

1) The feed to each column

2) The effluent from each column

The flow diagrams on the pages that follow show the flow to and from each system and give information about the equipment and materials used in the testing.

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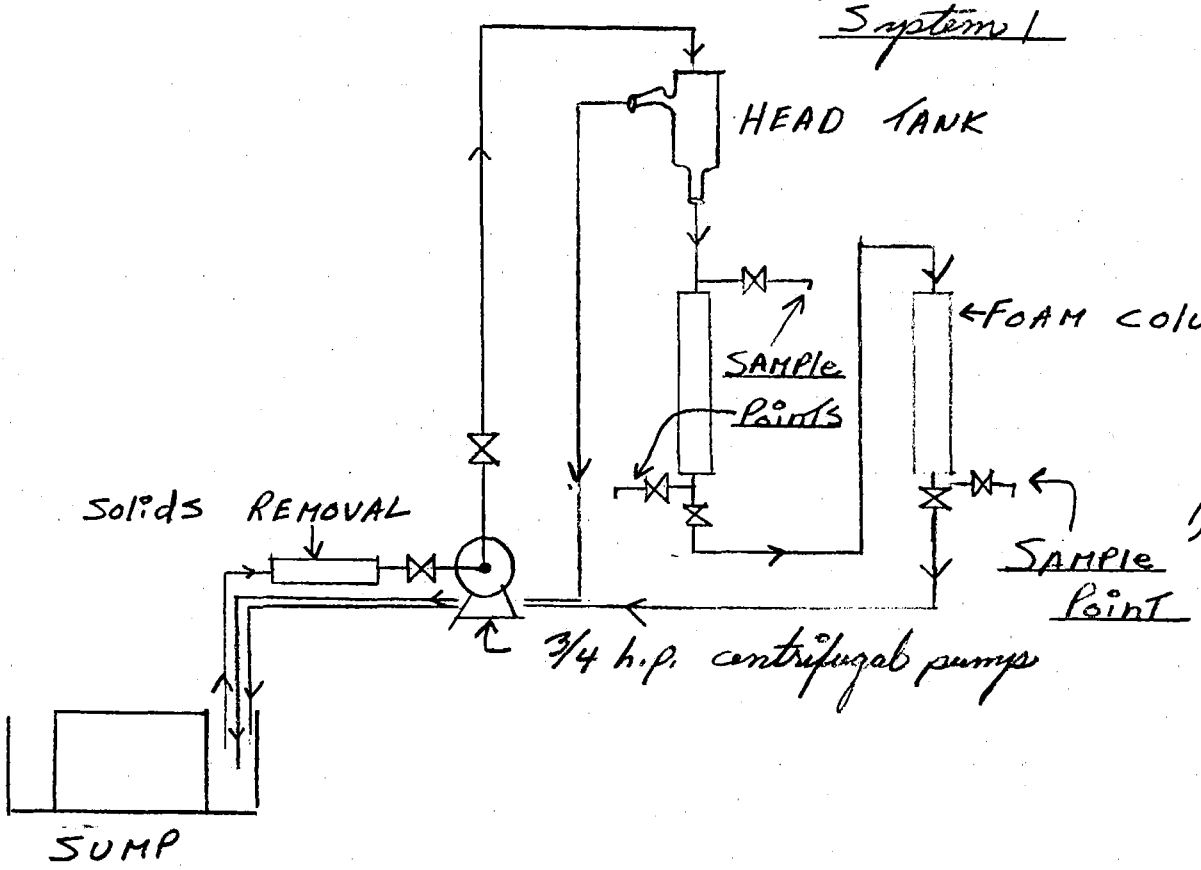
Flow Sheet #1

Carbon Column in Series with Foam Column

System 1



Glass Columns

Column	Diameter	Height
1) Head Tank	3"	17"
2) Carbon	3"	5'
4) Foam	3"	5'
5) Prefilter	2½"	11 3/4"

Material information

1) Carbon: Witco Grade 517
Apparent Density = 30 lb/ft³
Mesh Size = 20 × 40
Surface area in 3" × 5' column = 4.1×10^7 ft²
Source = Muriatic acid Department

2) Polyurethane Foam: Polyether Foam
Apparent Density: 2 lb/ft³
Porosity: 65 ppi
Surface Area in 3" × 5' column: 319 ft²
Source: = Perma Foam

3) Prefilter: normally was loosely packed with glass wool. On one day foam was used. The foam appeared to give better

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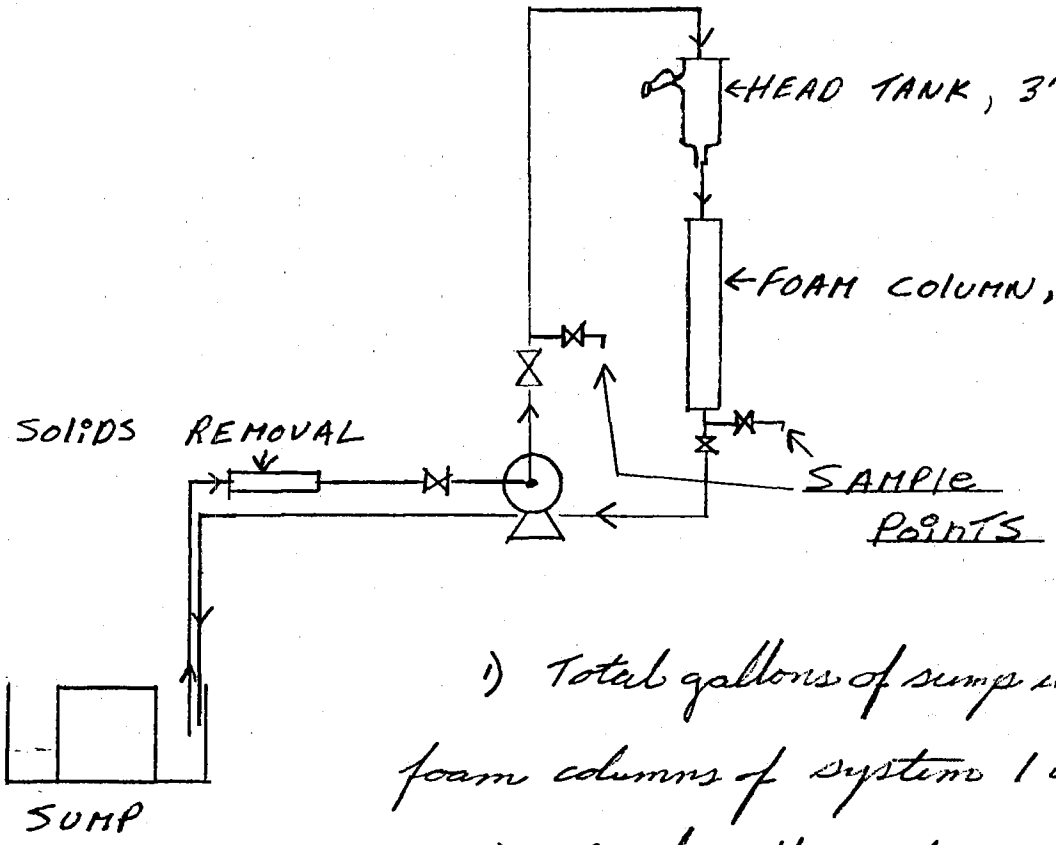
Flow Sheet #2

Foam Column Only

System #2



1) Total gallons of sump water through the carbon and foam columns of system 1 during its operation = 541 gallons

2) Total gallons of sump water through the foam column in system 2 during its operation = 1061 gall

3) Total gallons of sump water through the foam during the entire testing period = (system 1 gall + system 2 gall) = 1602 gall.

4) Average flow rate for the entire testing period = .35 gpm ≈ .95 l/min

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III. TEST RESULTS

The results of the testing are shown graphically in plots 1 and 2, PP's 6 and 7 and in table form in tables 1 and 2 on PP's 8 and 9. The plots and tables show that:

1) A single column of foam will reduce the PCB content of a waste stream to $<$ 10 ppb as will a single column of carbon.

2) The PCB content of a waste stream is not significantly reduced by passing it through a foam column after it has flowed through a carbon column.

3) Neither the foam nor the carbon consistently removed 1242 or 1254 preferentially.

The loading capacity of the foam was found to be .053 lbs PCB/lb Polyurethane Foam. The foam, the same piece being used in both systems, was cut into 3" diameter by 1" long sections and analyzed for PCB content. The results of the sectioning are presented below:

Segment of Foam	PCB loading Lbs PCb/Lb Polyurethane Foam
1st inch	.049
2nd inch	.057
3rd inch	.036
60th inch	4.32×10^{-4}

Because of the accuracy of the method of analysis used, the first two segments can be considered to have the same PCB concentration. Consequently, the first two segments are assumed to be a measure of foam loading.

Plot 1 - December, 1974 Testing

a Plot of PCB concentration vs. Bed Volume where:

1) ○ = PCB concentration of the waste stream out of the carbon column entering the foam column in series with it.

2) △ = PCB concentration of the waste stream out of the foam column in series with the carbon column.

3) □ = PCB concentration of the waste stream out of the foam column where the foam column was the only column in use.

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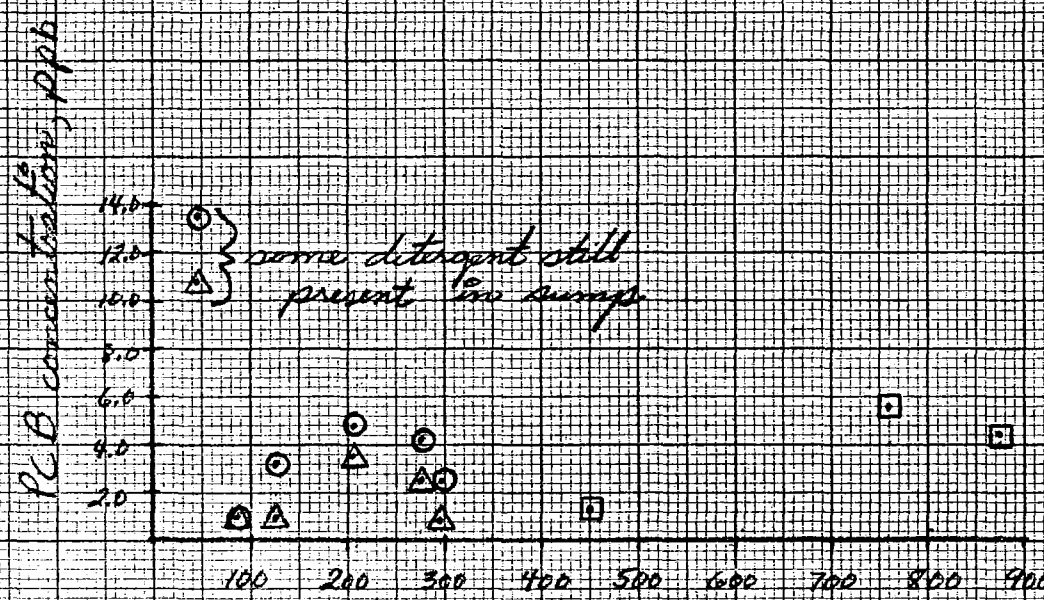

$$\frac{\text{Total Cumulative Volume of sump water through the bed}}{\text{Volume of bed}}$$

K+E 10 X 10 TO ½ INCH 46 1323
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

Plot 2

a Plot of the Percentation of the foam column effluent vs. Bed Volume. Data taken in September, 1974 testing. The Shale Stream passed only through a foam column

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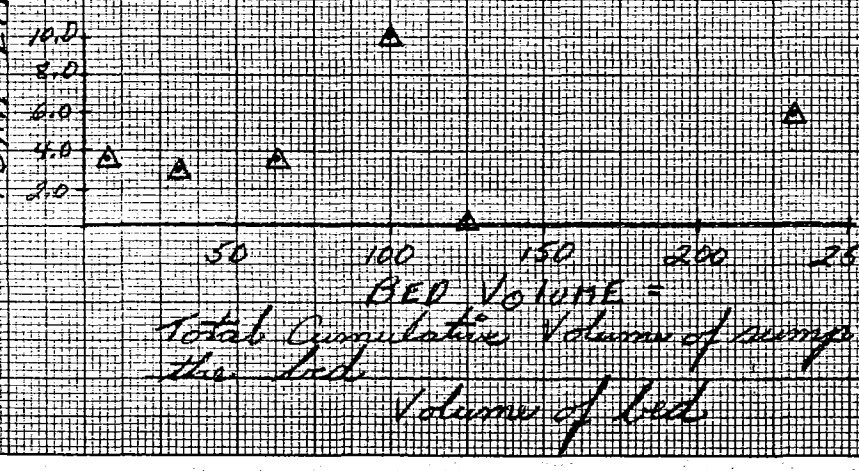

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10 X 10 TO THE CENTIMETER 46 1513
16 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

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POLYURETHANE FOAM TESTING, PART II

DATA SHEET, TABLE I

DATE	TIME	FLOW RATE GPM	TOTAL CUMULATIVE HOURS OF COLUMN OPERATION	PCB CONCENTRATION (PPB) FEED	CARBON EFFLUENT	FOAM EFFLUENT
12/23/74	2:20 P.M.	.44	5.6	800	13.5	10.9
12/31/74	11:45 A.M.	.48	9.6	1454	<1	<1
12/31/74	2:05 P.M.	.41	12.9	2038.5	3.2	1
1/3/75	1:00 P.M.	.36	17.9	289.8	4.8	3.4
1/6/75	4:30 P.M.	.26	28	333.4	4.2	2.4
1/7/75	1:10 P.M.	.12	32	227.7	2.6	.9
			OPERATION OF FOAM COLUMN ONLY			
1/7/75	8:15 P.M.	.30	38.1	390.3	----	21.5
			Considerable channeling when above data was taken			
1/8/75	4:15 P.M.	.40	44.9	701.5	----	1.3
1/9/75	5:00 P.M.	.40	49.4	604.2	----	7.7
1/10/75	5:00 P.M.	.34	73.4	725	----	6.4

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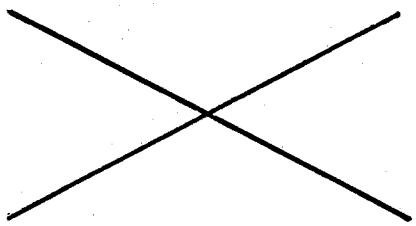
POLYURETHANE FOAM TESTING, PART II

BREAKDOWN OF PCB'S IN VARIOUS SAMPLES

TABLE II

PCB CONCENTRATIONS, PPB

DATE	Feed to system			Carbon effluent			Foam effluent		
	1221	1242	1254	1221	1242	1254	1221	1242	1254
12/23/74	--	339.3	459.9	--	3.9	9.6	--	4.2	6.7
12/31/74 (1)	--	833	621	--	<1	<1	--	<1	<1
12/31/74 (2)	554.6	596.5	887.4	--	2.4	0.8	--	1.0	--
1/3/75	61	83.9	144.9	0.9	1.5	2.4	0.9	0.8	1.7
1/6/75	--	138.1	195.3	--	0.7	3.5	--	0.8	1.6
1/7/75	--	105	122.7	--	0.7	1.9	--	0.3	0.6
			OPERATION OF FOAM COLUMN ONLY						
1/7/75	--	282	108.3				--	7.7	13.8
1/8/75	--	426.9	274.6				--	1.0	0.3
1/9/75	--	293.7	310.5				--	4.2	3.5
1/10/75	--	347.8	377.2				--	1.0	5.4



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IV. A COMPARISON OF FOAM VERSUS CARBON FOR REMOVING PCB'S FROM A WASTE STREAM

Table III, pp's 11-12, compares carbon and foam with regard to various items important in selecting a material to remove a contaminant from a waste stream. All carbon data is based on a loading capacity of 25%, a result obtained from carbon work at Anniston.

In the WGK plant testing the only way the foam could be packed into the column was by:

1) Wetting the foam with water

2) Tieing strings around both ends of the foam and pulling it into the column.

How packing would be achieved on a large scale unit is unknown.

V. RECOMMENDATIONS

It is recommended that carbon be used to remove PCB's from a plant waste stream rather than foam because:

1) The costs involved in using a carbon system are much less than those which would be incurred if a foam system was used:

   A. Material Cost:

      Foam cost/lb. PCB removed is approximatley 90 x greater than the carbon cost/lb PCB removed.

   B. Regeneration:

      1) Initial -- cost of solvent to regenerate foam is $2500/lb PCB removed. No solvent is required for carbon regeneration.

      2) Assuming 95% solvent recovery -- cost to regenerate the foam is 125 x greater than the cost to regenerate the carbon.

TABLE III - A COMPARISON OF CARBON VS. FOAM

	Item	Foam	Carbon
1)	Ability to remove PCB's	Reduces the PCB concentration of a waste stream to <10 ppb	Reduces the PCB concentration of a waste stream to <10 ppb.
2)	Initial material cost of adsorbent	$147/lb PCB removed and a $325 tooling cost to purchase the tools needed by the fabricator to fabricate the foam into a circular piece. A cost will also be incurred for tool replacement should they wear out.	$1.60/lb PCB removed
3)	Amount of adsorbent needed:	$\frac{9.4\ ft^3\ foam}{lb\ PCB\ removed}$	$\frac{.13\ ft^3\ carbon}{lb\ PCB\ removed}$
	A) Loading	.053 lb PCB/lb foam	.25 lb PCB/lb carbon
	B) Density	2 lb/ft^3	30 lb/ft^3
	C) Surface Area	$1.3 \times 10^3\ ft^2/ft^3$	$1.7 \times 10^8\ ft^2/ft^3$
4)	Cross sectional area of adsorbent per gpm flow	.14 ft^2/gpm	.14 ft^2/gpm

These figures are based on:
1) The diameter column used in the WGK plant testing, 3".

2) The average flow rate used in the WGK plant testing, .35 gpm. This may or may not be the optimum flow rate for PCB removal in the size column used.

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TABLE III - A COMPARISON OF CARBON VS. FOAM (Cont'd)

	Item	Foam	Carbon
5)	Regeneration Cost	Initial cost - $2,500/1b PCB removed. Basis: 1) Regenerating solvent = Freon TF by DuPont which costs $.60/1b when shipped in a 690 1b drum. This material is not presently shipped in tank car. 2) Volume of solvent needed to regenerate the foam -4.5 x the volume of the foam. Freon TF is not a proven solvent for regeneration but a suggested one by Dr. R.H. Munch. Freon TF can be used indefinitely. Assuming a 95% solvent recovery, the cost would be $125/1b PCB removed. This does not include the cost for the design, installation, and operation of a solvent recovery system.	Roughly $1/1b PCB removed based on furnace regeneration The exact mode of regeneration though, and whether replacement is more economical is dependent on the specific removal system.
6)	Chemical Resistance	Attacked by strong acids, caustics, and chlorine. Aliphatic hydrocarbons cause slight swelling and aromatics cause considerable swelling. This information was supplied by the Scott Paper Company.	Not attacked by strong acids, caustics, chlorine, aliphatic hydrocarbons or aromatics.
7)	Technolgoy	Much filtration work has been done by the Scott Paper Co. with air. Monsanto, for the most part would have to develop its own foam technology for PCB removal.	Technology developed

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V. RECOMMENDATIONS (Cont'd)

2) Carbon technology has been developed thereby lowering the risks involved in using a carbon system to remove PCB's.

3) Major risks would be involved in using foam to remove PCB's:

A) How to pack the foam into a large column.

B) Chemical attack of the foam by various known chemicals which may be present in the waste stream.

C) Monsanto would have to develop, for the most part, its own foam technology.

VI. ACKNOWLEDGEMENTS:

My special thanks to Steve Vogel who assisted in the plant tests. Steve's suggestions and ideas were very helpful.

Bernie Bosse

B. C. Bosse
Technical Services Department

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