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PCB Removal by Conventional Water Treatment: Effect of Chemical Coagulation and Chlorination

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Polychlorinated biphenyls (PCBs) are one of the most persistent and Widespread environmental pollutants. (Edwards,1971; Kpekata,1975; Nadaau and Davis,1976; Skea et al,1977; El-Dib and Badawy,1985). PCBs are accused to create health hazards lead to marked changes in the aquatic environment (EHRC,1976; Hesse and Powers 1978).

Previous studies (El-Dib and Badawy,1985) revealed that residue levels of PCBs in the drinking waters in Egypt tend to exceed the permissible levels (WHO,1980). This study evaluated the efficiency of coagulation and chlorination for removal of PCBs from drinking water.

MATERIALS AND METHODS

Solutions of PCBs of known concentration(2.0-2.2 ug/l) were prepared in River Nile water having pH value in the range of 7.5-7.8. One litre portions of each Acroclor solution was placed in a suitable container of the "Jar Test" apparatus. The solutions were then treated with increasing doses of either aluminium sulphate or ferric chloride (25,50 and 100 mg/l). In a separate experiment, three doses of Nalco (0.1,0.5 mg/l) were added, as a coagulant aid, to the Aroclor solutions and then treated with 50 mg/l aluminium sulphate or ferric chloride. Addition of the coagulant was followed by flash mixing for one minute, floc conditioning for 15 minutes and settling for 15 minutes. Residual concentrations of PCBs were finally determined according to U.S. EPA methods (1974).

Aqueous solutions of chlorine were prepared and their concentrations were determined by the iodometric method (Standard Method,1982). Oxidation was studied at pH values ranged between 7.5 and 7.8 which is the dominated pH in river Nile water. Chlorine was added to PCBs solution to give an active concentrations of 5 and 10 mg/l. A known volume (500 ml) of the treated

solutions were periodically withdrawn and analyzed for PCBs.

A varian 3700 GLC, equipped with Ni^{63} electron capture detector and a glass column (4m m I.D. and 2 m length) was used. The column was packed with 4% SE 30+6% Q F on 80/100 chromosorb W. The column, injector,and detector temperatures were 200°C, 250°C and 300°C,respectively. Nitrogen was used as the carrier gas at a flow rate of 40 ml/min.

RESULTS AND DISCUSSION

Results given in Table 1 show that conventional treatment with coagulants has relatively limited effect on the removal of PCBs. In general, ferric chloride was less effective in the removal of PCBs as compared with aluminium sulfate. Percentage removal ranged between 10% and 40% depending on the dose of coagulant. Increasing the dose of coagulant from 25 to 50 mg/l result in considerable removal while a slight or no increase in percentage removal was observed as the dose of coagulant was increased to 100 mg/l. The addition of increasing dose of coagulant aid (Nalco) to a fixed dose of both aluminium sulphate and ferric chloride improved the coagulation and hence the removal of PCBs. Maximum percentage removal was obtained with 50 mg/l of aluminium sulphate and 0.2 mg/l Nalco, which tends to be the optimum doses for the coagulation. It was observed that PCBs with the low molecular weight(1221, 1232 and 1242) were removed better than the high molecular Aroclors (1248, 1254 and 1260). Available results in the literature indicate that organic pollutants are hardly affected by coagulants even in the presence of coagulant aids such as hydrated lime,activated silica or polyelectrolytes (Aly and Faust, 1964; Robeck et al, 1968). However, with PCBs removal may be caused by the coagulant and by the adsorption of PCBs on clay minerals and suspended matter (Karichhoff et al, 1979; Wildish et al, 1980). The sequence of the removal process is first the adsorption of PCBs on clays and suspended matter and then these adsorbents, containing PCBs precipitate by the effect of coagulation which results in a relative increase in the percentages removal from water.

Chlorine is widely used for disinfection of water. Hence,the effect of chlorination on raw river water samples containing 2 ug/l of different PCBs was studied and results are shown in Table 3. Samples were analyzed after one hour to investigate the variations in the percentages of different isomers. Although some isomers disappeared an increase in the number of isomers was observed after treatment with chlorine due to the

Table 1. Effect of chemical coagulation with aluminum sulphate and ferric chloride on the removal of PCBs.

Arocolr	Coagulant	% Removal of PCBs Using 24 mg/l	50 mg/l	100 mg/l
1221		23.1	31.4	38.9
1232		25.0	36.6	39.4
1242	$Al_2(SO_4)_3$	23.6	32.7	37.7
1248		13.5	23.5	27.0
1254		16.1	26.8	27.8
1221		15.0	22.5	33.9
1232		13.9	25.9	30.1
1242	$FeCl_3$	18.0	25.7	29.3
1248		9.9	14.4	17.3
1254		14.3	22.0	25.8
1260		6.4	17.2	20.2

Table 2. Percentage removal of PCBs using different dose of coagulant aid (Nalco) and 50 mg/l of coagulant.

Arocolr	Coagulant	% Removal of Arocolr Using 0.1 mg/l	0.2 mg/l	0.5 mg/l of Nalco
1221		36.2	40.0	40.9
1232		37.9	40.3	40.7
1242	$Al_2(SO_4)_3$	36.9	39.2	40.2
1248		13.4	16.9	18.8
1254		27.3	31.2	32.6
1260		20.1	30.4	33.8
1221		25.1	32.8	33.3
1232		30.1	33.3	33.3
1242	$FeCl_3$	27.6	32.7	33.6
1248		28.1	31.0	31.0
1254		22.3	26.2	27.2
1260		22.9	29.3	32.1

Table 3. Effect of chlorination on percentages isomers of Arocolr 1221 after 1 hour*.

Peak No	Retention time (minutes)	% of isomers in untreated sample	% of isomers after 1 hour	
			5 mg/l Cl_2	10 mg/l Cl_2
1	0.59	29.48	23.25	28.31
2	1.62	2.39	-	-
3	1.82	17.71	2.83	0.91
4	1.95	-	-	0.15
5	2.13	11.34	1.77	-
6	2.37	2.03	-	-
7	2.57	15.92	1.64	0.43
8	3.03	6.33	-	-
9	3.31	8.52	0.88	0.27
10	3.75	2.99	-	1.20
11	4.39	2.67	0.42	1.22
12	4.49	-	-	1.16
13	4.55	-	0.19	-
14	6.36	-	26.37	25.15
15	10.05	-	23.78	10.27
16	12.00	-	17.31	29.12
17	14.50	-	-	0.67
Total %	-	99.38	98.44	98.86
Number of isomers	-	10	10	12

* Aroclors 1232,1242,1248,1254 and 1260 were not affected by chlorine.

formation of new isomers. For instance,the chlorination of Aroclor 1221 (Table 3) resulted in the disappearance of isomers measured at retention times: 1.62,2.37 and 3.03 minutes, while seven new isomers were formed at different conditions of chlorination at retention times: 1.95, 4.49,4.55, 6.36, 10.05, 12.00 and 14.50 minutes. These isomers belong to higher molecular weight PCBs, e.g. Aroclor 1242 or 1254, which indicates the transformation of PCBs isomers containing less chlorine atoms to those containing more chlorine atoms by an addition reaction. It seems that the dose of chlorine and contact time have an effect on the formation of the new isomers and the concentration of isomers. Results obtained clearly indicated that the chlorination of Aroclors 1232, 1242, 1254 and 1260 were not effected by chlorination. However, the appearence of the additional chlorinated by products, at retention times of 1.07, 5.6, 7.5, 8.6, 10.8, 14.0 and 23.3 is possibly the

result of chlorination of aromatic hydrocarbons liable to be found in Nile Water. Such finding are in agreement with the results of Gaffney, 1977,where biphenyls were reported to give PCBs derivatives on chlorination.

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