1993

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Fresenius Envir Bull 2:320-324 (1993)

1018-4619/93/060320-05 $ 1.50+0.20/0

ROTATING BIOLOGICAL CONTACTORS AS AN EFFECTIVE REMOVAL SYSTEM OF WASTE PETROLEUM HYDROCARBONS FROM UNTREATED WASTEWATERS

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SUMMARY

A staged, partially submerged rotating biological disk system was assessed to determine its performance in the reduction of detectable concentrations of polynuclear aromatic hydrocarbons (PAH) attributable to waste crankcase oils (WCCO) in wastewater effluent. Results indicate that such biological systems for the removal of WCCO aromatic hydrocarbons may be a viable alternative to secondary treatment systems commonly being employed.

KEY WORDS:

POLYNUCLEAR AROMATIC HYDROCARBONS, WASTEWATER TREATMENT, ROTATING BIOLOGICAL CONTACTORS

*ALL reprint requests here.

INTRODUCTION

Considerable attention in wastewater treatment has in the past been directed toward the use of rotating biological contactors (RBCs) as an effective means of treating municipal wastewaters [1,2]. Recent work has exhibited secondary RBC system's effective ammonia nitrification and high soluble COD removal [3]. Previous investigations [4] into the PAH character of wastewaters in New York City Water Pollution Control Facilities (WPCF), attributable to waste crankcase oils (WCCO) [5] have exhibited a range of PAHs.

Several constituents of WCCO have been shown to "bioactivate" compounds into mutagens [6]. Interest in WCCO has been because of it's energy conservation use [7]. The annual influx of waste petroleum hydrocarbons to the marine environment from municipal wastewaters has been estimated at 0.7 million metric tons per year; out of a total input from all sources of 3.3 million metric tons on average [8].
The availability of these hydrocarbon pollutants to commercially/recreationally important marine/estuarine organisms is of significant concern to estuarine ecologists [9]. The chronic petroleum pollution of commercial shellfish species

may have a significant affect on the suitability of commercial seafood production in waters receiving wastewater discharges. Connell [10] estimated that sewage discharges contribute 12,775 tons of petroleum hydrocarbons per year alone to the Hudson-Raritan Estuary. Mueller, J.A., et. al. [11] has noted that urban runoff, most of which empties into combined sewage systems contains WCCO. The purpose of this work was to determine the performance of a RBC system in the reduction of initial concentrations of total detectable PAHs attributable to WCCO.

MATERIALS & METHODS

The RBC facility investigated in this study was adjunct to an activated sludge secondary treatment system serving a population of several million in the Borough of Brooklyn, New York City. The RBC system at the Jamaica Water Pollution Control Facility (WPCF) (Newtown Creek) was comprised of three main component parts: (a) ten stages of rotating discs (all plastic disks, 3' in diameter) for the removal of organics and oxidation of ammonia to nitrate, (b) six stages of illuminated rotating discs for nitrogen and phosphorus removal from the effluent of the preceding system by synthesis into attached algal cells, and (c) six packed beds of granular activated carbon columns for the adsorption of refractory organics from the preceding algal system. Sedimentation of 1.5 hours was interposed between the effluent from the stage ten unit and the algal unit. A mixed media filter preceded adsorption in carbon columns for removing the particulates, which were mainly algal cells generated on the illuminated discs. The wastewater flow rate was 28.39 liters/min.$\pm$10%, whereas the algal unit flow rate was 11.35 liters/min. Flow to the pressure downflow carbon columns was at a surface loading of 203.6 L/Min/m. Discs rotated opposite to the direction of the flow through the successive stages. The theoretical detention time was six minutes in each stage measured when the discs were devoid of slime. Actual time was somewhat less, depending upon the degree of displacement of fluid volumes by the slime.

Comparison to standard "oil and grease" and standard "petroleum extractables" in this wastewater facility were made based upon final effluent. The wastewater entering the main municipal facility is a mixture of domestic and pretreated industrial wastes. The industrial wastes contribution to organic loading is proportionately small compared to total domestic waste load.

Because of the complex chemistry of petroleum, each petroleum sample lends itself to differentiation from others. A passive-tagging approach establishes specific qualitative parameters for oil samples in the form of "profiles" or "fingerprints" to be compared to a "reference standard profile". Thus, positive correlations for RBC pilot plant effluent samples are either established or not established with reference standards depending upon those portions of the petrochemical waste that exhibit themselves in fingerprints and remain stable under physiochemical processes and environmental conditions.

Water samples were collected at successive stages along the system in 980 ml wide-mouth, glass Mason jars with Teflon-lined caps. Three individual samples were taken simultaneously from each of the raw influent, stages 1, 3, 6, 8, 10 settling tank, 13, 16 and the final effluent. Each composit sample was adjusted for pH. Each stage sample was extracted with 50 ml carbon tetrachloride (CCL_4) in separatory funnels and the bottom layer collected after settling out (a total of 150 ml CCL_4). Solvent was stripped off and the dry residue weight recorded. An infrared (IR) quantification method was used to determine total extractable hydrocarbons (mg/l) from each sample [12]. CCL_4 extracts were jet-air evaporated, concentrated, and residues weighed and brought to volume in hexanes for UV-fluorescence analysis.

Previous investigators [13] have exhibited the ability of fluorescence spectroscopy to detect trace quantities of petroleum derived hydrocarbons, particularly PAHs, in marine waters. A UV-fluorescence spectrophotometer with two independent monochromaters (150 Watt xenon-arc light source), and a constant temperature cell bath maintained a 10mm path length quartz cell at 20^0 C$\pm$0.5^0 were used for all fluorescence analyses. A synchronous excitation fluorescence spectroscopic technique was utilized for all analyses [14]. A standard reference WCCO was excited at 240 to 540 nm, generating a maxima emission profile (MEP) for that excitation wavelength. This MEP was used to correlate presence of WCCO in successive stages along the RBC system. Each stage sample as excited at successive excitation wavelengths from 240 nm to 440 nm (at 20 nm-intervals) while scanning for the maximum fluorescence emission at each excitation frequency (Figure 1). Each maximum peak was utilized as a point to be plotted graphically, generating a "fluorescence maxima profile" (FMP) for each sample. Correlation was determined by visual comparison of maxima profile plots of the WCCO reference standard to the RBC stage maxima profile plots (Figure 2).

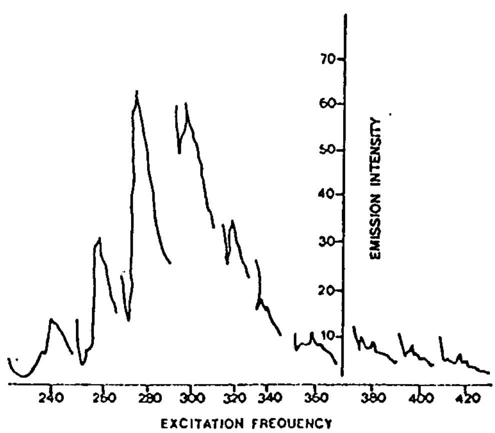

Figure 1. Fluoresence maxima profile (FMP) for WCCO.

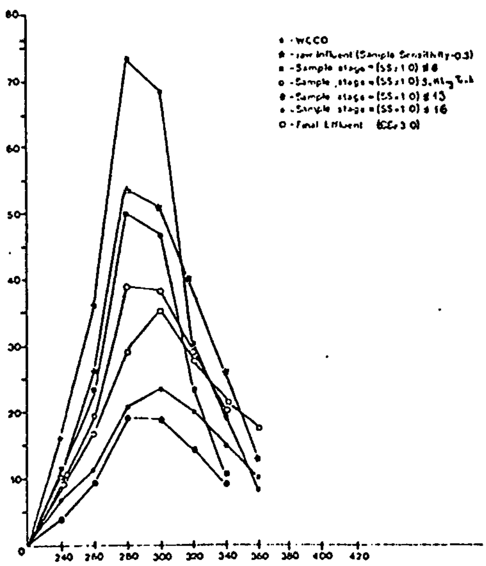

Figure 2. FMP's for RBC stages and reference standard.

RESULTS AND DISCUSSION

The total extractable organics (TEO) (including petroleum hydrocarbons) obtained from the pilot RBC system at Newtown Creek exhibited a linear decrease response after regression analysis of RBC stage and PAH removal. In addition, fluorescence profiles of RBC stages RAW to #16 positively correlates with WCCO FMP's. The final effluent sample and sample #16 at 10X over initial influent sample sensitivity setting did not reveal profiles correlating to WCCO. Results strongly indicate a reduction of total PAHs associated with WCCO in the final effluent. TEO values in this study of 0.12 mg/L in the final RBC-treated effluent are consistent with various unfiltered total hydrocarbon values. This is considerably lower than unfiltered TEO values reported by Ginger, et. al. (1976) [2.0 mg/L secondary] [15], Barrick (1982) [16.2$\pm$6.8 mg/L] [16], and in southern California wastewater treatment plants reported by Eganhouse, et. al. (1985) [range 46.5$\pm$2.1 to 899$\pm$172] [17].

CONCLUSIONS

A number of PAHs are potent carcinogens to marine organisms [18]. WCCO has been shown, along with other petroleum products, to contribute significant quantities of detectable PAHs to aquatic environments [19]. Traditional wastewater treatment facilities in major urban areas have been shown to be relatively ineffective in elimination, or providing a significant reduction of these compounds [20]. RBC systems have been successfully employed in treatment of wastewaters and have exhibited in this investigation an effective removal technology of PAHs over suspended cultures.

Further investigation is required into variations in such operational parameters as slime build-up, influent loadings, effective disc surface area, submerged disc depth, wastewater flow rates and temperature, contribution to PAH removal by activated carbon and adsorptive properties of disc materials to provide greater insight into PAH removal efficiencies by these systems.

ACKNOWLEDGEMENTS

A special acknowledgement is made to the late W. Torpey for his insight in allowing this research at his pilot RBC system at Newtown Creek. To M. Gruenfeld, U. Frank of the U.S. Environmental Protection Agency R&D Labs, Edison, New Jersey, for their comments and review. To the late G. Kupchik, Prof. Emeritus, Institute of Health Sciences, Hunter College, CUNY for this guidance and inspiration.

REFERENCES

1. Torpey, W.N., H. Heukelekian, A. Joal Kaplovsky and R. Epstein (1971) Rotating Disks with Biological Growths Prepare Wastewater for Disposal or Reuse, Jour. Water Poll. Control Fed., 43; 2181.

2. Weng, C. and Molof, A. (1974) Nitrofication in the Biological Fixed-Film Rotating Disk System, Jour. Water Poll. Control Fed., 46(7), 1674-1684.

3. Surampalli, R.Y. and E.R. Baumann (1989) "Supplemental Aeration Enhanced Nitrification in a Secondary RBC Plant, "Jour. Water Poll. Control Fed., Vol. 61, No. 2, pp. 200-207.

4. Tanacredi, J.T. (1977) "Petroleum Hydrocarbons from Effluent: Detection in Marine Environment," Jour. Water Poll. Control Fed., March: 216.

5. Hoffman, E.J., J.S. Latimer, G.L. Mills and J.G. Quinn (1982) Petroeum Hydrocarbons in Urban Runoff from a Commercial Land-Use Area, Jour. Water Poll. Control Fed., Vol. 54, No. 11, pp. 1517-1525.

6. Payne, J.F. and Martins, I. (1978) "Crankcase Oils: Are They Major Mutagenic Burden in the Aquatic Environment?," Science, 200: 329.

7. Tanacredi, J.T. (1980) "Waste Oil Recycling: Are They Any Incentives Out There?," In: Proceedings of NYSMEA 1980 Annual Conference, Dowling College; pp. 3.

8. Oil In The Sea; Inputs, Fates and Effects; National Academy of Science, National Research Council, National Academy Press: Washington, D.C. (1985).

9. World Resources: A Guide to the Global Environment: 1990-1991, World Resources Institute, Oxford University Press, New York (1990), p. 186.

10. Connell, D.W. (1982) "An Approximate Petroleum Hydrocarbon Budget for the Hudson-Raritan Estuary, New York," **Mar. Poll. Bull.**, 13: 89-93.

11. Mueller, J.A., T.A. Garrish and M.C. Casey (1982) Contaminant Inputs to the Hudson-Raritan Estuary, NOAA Technical Memorandum, OMPA-121, August 1982, pp. 191.

12. Gruenfeld, M. (1973) "Extraction of Dispersed Oils From Water for Quantitative Analysis by Infrared Spectrophotometry," **Env. Sci. and Tech**.

13. Keizer, R.D. and Gordon, D.C. (1973) "Detection of trace Amounts of Oil in Seawater by Fluorescence Spectroscopy," **Jour. Fish. Res. Brd. of Canada**, **30**, 1039.

14. Frank, U. and Gruenfeld, M. (1978) "Use of Synchronous Excitation Fluorescence Spectroscopy for In Site Quantifications of Hazardous Materials in Water," In: Proceeding 1978 Nat. Conference on Control of Hazardous Materials Spills, Miami Beach, API/USCG/USEPA. pp. 40.

15. Giger, W., M. Reinhard, C. Schaffner and F. Zurcher (1976) "Analysis of Organic Constituents in Water By High-Resolution Gas Chromatography In Combination With Specific Detection and Computer-Assisted Mass Spectrometry," In: Identification and Analysis of Organic Pollutants in Water, L.H. Keith (Ed.), Ann Arbor Publishers, Ann Arbor, Michigan, pp. 433-452.

16. Barrick, R.C. (1982) Flux of Aliphatic and Polycyclic Aromatic Hydrocarbons to Central Puget Sound From Seattle (Westpoint) Primary Sewage Effluent, **Env. Sci. & Tech.**, 16: 682-692.

17. Eganhouse, R.P., I.R. Kaplan and D.L. Blumfield (1985) "Hydrocarbons in Southern California Municipal Wastes and Their Input to Coastal Waters," In: *Wastes In The Oceans - Vol. 6 Nearshore Waste Disposal*, (Ed.) B.W. Ketchum, J.M. Capuzzo, W.V. Burt, I.W. Duedall, P.K. Park and D.R. Kester, Wiley-Interscience Series, New York, pp. 159-186.

18. GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Pollution) (1982) "**The Health of the Oceans**," UNEP Regional Seas Report and Studies, No. 16, pp.108.

19. Hoffman, E.J., J.S. Latimer, G.L. Mills and J.G. Quinn (1982) "Petroleum Hydrocarbons in Urban Runoff from a Commercial Land-Use Area," **J.Wat. Poll. Cont. Fed**., 54; (11): pp. 1517-1525.

20. Eganhouse, R.P., I.R. Kaplan and D.L. Blumfield (1985) "Hydrocarbons in Southern California Municipal Wastes and their Input to Coastal Waters," *In: Wastes In the Ocean, Vol. 6*, Eds. B.H. Ketchum, I.W. Duedall, J.M. Capuzzo, P.K. Park, W.V. Burt and D.R. Kester (J. Wiley Inter-Science Publ.) pp. 159-186.

Accepted 8 April 1993