Environment Protection Engineering

Vol. 29 2003 No. 2

L.E. ARIRIATU*, N.C. EWELIKE*

A LOW-COST FILTRATION SYSTEM FOR THE TREATMENT OF WASTEWATERS

A filtration unit fabricated from local raw materials was used for the treatment of industrial wastewater. The system produced a clarified effluent which was odourless, colourless and stable.

Microbiological analysis of the effluent after filtration showed that the unit was capable of providing 96.6% reduction in the microbial load of effluents. Spectrophotometric analysis of the filtered effluent revealed the ability of the filter system to provide 99.3% reduction in turbidity. Further analysis of the effluent after filtration showed a considerable reduction in the concentration of the following physicochemical properties of the effluent: ammonia nitrogen was reduced by 98.5%, grease by 98.3%, TOC by 79.3%, chloride by 95.8%, carbonate by 98.8%, sulphate by 84.4%, nitrate by 84.4%, BOD_5 by 98.6% and COD by 99.1%. A high efficiency of the filter system and the availability of the raw materials for its fabrication makes it easily adaptable to a wide range of applications in environmental management and control.

1. INTRODUCTION

Filtration is one of the principal unit operations used in the treatment of water and wastewaters. Filtration in addition to eliminating particulate matter removes microorganisms and has been considered to have relatively low cost in capital equipment compared to chemical treatment. Filtration processes involving the use of sand, multimedia, diatomaceous earth and carbon filters are extensively used in removing impurities and objectionable properties such as turbidity, suspended matters, organic matter, odour and colour from water. A potable porcelain water filter made of clay and sand that produced odourless and colourless filtrate has been reported [3]. Sand and cloth filters were recommended by UNICEF for the control of guinea worm and other waterborne diseases in rural endemic areas.

Generally biological systems have also been used successfully in the control of volatile organic compounds [6], [8] and for the treatment of odorous air from wastewater facilities [5]. In most of these systems, readily available substances such as

* Department of Biological Sciences, Federal University of Technology, Owerri, Nigeria.

compost, soil, peat moss or other porous media capable of adsorbing gaseous compounds were used. The mixture of these materials with chips of wood branches and other sundry items help to create a loose structure for gas passage while preventing clogging [2]. Biological treatment has also been extensively used in Europe for the removal of nitrates from wastewater [4]. A process combining biological denitrification and ion exchange is also in use for the removal of nitrates from wastewater. However biological nitrate removal from water was found to be cost effective in comparison to ion exchange [10]. Filtration has also been used to remove chemically precipitated phosphorus, iron and manganese among other metals from wastewater.

The ability to design filters and to predict their performance must be based on an understanding of the variables that control the process and knowledge of the pertinent mechanisms responsible for the removal of particulate matter from a wastewater. The aim of this project is to design a low-cost, high-performance filter system from local raw materials that would otherwise constitute waste.

2. MATERIALS AND METHODS

Several packing materials, montmorillonite clay, illite clay, kaolinite clay, different wood chips, wood dust and paper pulp of different grades were tested to determine their ability to adsorb odour and reduce turbidity of industrial wastewater. Based on the preliminary findings of this investigation, a filter unit was fabricated with white wood dust obtained from a wood-processing factory located at Owerri, pure white paper pulp from Star Paper Mill, Owerrenta, and montmorillonite clay obtained from Okigwe Clay Depot. The clay was activated by heating at 200 °C for 24 hrs, cooled, ground to fine powder, then sieved using a set of standard sieves. The packing materials, clay, pulp and wood dust in the ratio of 4:6:1 (wt/wt/wt) were laid in a column of 4.5 cm diameter and 60 cm height. Fine clay was laid at the bottom, pulp was at the middle and the wood dust was placed on the top. One cubic decimetre of distilled water was allowed to drain out through the packed column to displace air bubbles, leaving a height of 2:2:1 cm for each layer. The effluent used was untreated industrial wastewater from offshore, which comes along with crude oil during the process of exploration and production activities. The effluent was collected in 2 dm^3 plastic containers, at 9.00 a.m. and 5.30 p.m. daily, placed in ice cooler to maintain temperature before filtering. Effluent samples to be analysed for ammonium nitrogen (NH^+_4) and oil were preserved with 2 cm^3 of concentrated sulfuric acid. The effluent samples were analysed before and after filtration. Each filter unit was run, 4 hrs per day for 14 days.

Microbial determination was limited to bacterial content only. The method used was pour plate, in nutrient or plate count agar plates incubated at 37 °C for 24 hrs. Coliform determination was done by the membrane filtration method. The physicochemical characteristics analysed were: COD, BOD_5, grease, total organic carbon, total suspended solids, ammonium nitrogen, detergent, chloride, carbonate, sulphate and nitrate. These determinations were done using standard methods for the examination of water and wastewaters [1].

3. RESULTS

Preliminary results showed that various packing materials had the ability to reduce the turbidity and microbial content of the industrial effluent used in this study (table 1). White wood dust of the least reduction potential reduced the turbidity of industrial effluent by 13.3% and the microbial load (bacterial content) by 70.5%. Pure paper pulp reduced the turbidity of the effluent by 95.3% and the microbial load by 91.6%, while activated montmorillonite clay reduced the turbidity by 98.7% and the microbial load by 94.0%. The filter unit designed and fabricated from the materials reduced the turbidity of the same industrial effluent by 99.3% and the microbial load by 99.8%. The filter system also reduced the coliform content of the effluent from 1800/100 cm^3 to 4/100 cm^3, a reduction of 99.8%.

Table 1

The effect of the different packing materials
on the turbidity and microbial content of industrial effluent

Packing material	Initial turbidity	Final turbidity	Reduction (%)	Initial microbial count (CFU/cm^3)	Final microbial count (CFU/cm^3)	Reduction (%)
Wood dust	1.5	1.3	13.5	1.9×10^5	5.6×10^4	70.4
Paper pulp	1.5	1.07	95.3	1.9×10^5	1.6×10^4	91.6
Clay	1.5	1.02	98.7	1.9×10^5	1.4×10^4	94.0
Combination of wood/paper clay	1.5	1.01	99.3	1.9×10^5	1.0×10^4	96.6

The results of the physicochemical analysis of the effluent before and after filtration are shown in table 2. The results show a reduction between 79.3 and 99.9% in the parameters analysed. The BOD_5 and COD of the effluent were reduced from 1452 and 3226.7 mg/dm^3 to 20 and 30 mg/dm^3, respectively, after filtration. Ammonia nitrogen was reduced from 680 to 10.5 mg/dm^3 and grease was reduced from 34.7 to 0.76 mg/dm^3. Other parameters reduced included total organic carbon (TOC) reduced from 1052.7 to 218.4 mg/dm^3 and total suspended solids (TSS) reduced from 490 to 3.3 mg/dm^3. The filter system produced a clarified effluent that was relatively colourless and odourless.

Table 2

Physicochemical analysis of effluent before and after filtration through the filter unit

Parameters analysed	Concentration before filtration	Concentration after filtration	Reduction (%)
pH at 29 °C	6.8	6.0	99.9
Ammonia nitrogen	680	10.5	98.5
Grease	43.7	0.8	98.3
Total organic carbon	1052.7	218.4	79.3
Chloride	6833.8	289.7	95.8
Carbonate	3142	33	98.8
Sulfate	2288.4	358	84.4
Nitrate	18.0	0.8	95.6
Phosphate	28.4	2.9	89.8
Total suspended solids	490	3.3	99.3
Detergent	40.1	0.2	99.5
BOD_5	1452	20	98.6
COD	3226.7	30	99.1

All concentrations are in mg/dm^3 unless otherwise stated.
Coliform initial count = 1800/100 cm^3; final count = 4/100 cm^3; % reduction = 99.8.

4. DISCUSSION

Effluent filtration using various granular media appears to be one of the most commonly adopted methods for the removal of residual solids. Filtration is accomplished by passing the wastewater to be filtered through a filter bed composed of granular materials with or without the addition of chemicals. Within the granular filter bed a complex process involving one or more removal mechanisms, such as straining, interception, impact sedimentation and adsorption, accomplish the removal of suspended solids contained in the wastewater. The filter unit employed in this investigation not only removed odours and colours due to organic compounds, but it reduced the turbidity and the microbial load of the industrial effluent. The turbidity of the effluent was reduced by 99.3%, while the microbial load was reduced by 99.4% (table 2). Similar observations were reported by other investigators [7], [11]. The ability of the filter unit to reduce turbidity and to remove colour and odour is attributed to the adsorptive property of the composite materials such as the cellulose material present in pulp. In addition, the filter system achieved a considerable reduction in BOD_5, suspended solid and ammonia nitrogen. BOD_5 was reduced by 98.6%, total suspended solid by 99.5% and ammonia nitrogen by 98.5%. The reduction in microbial load achieved with the filter unit reached 99.4%. The mechanism by which microorganisms were eliminated from the filter unit is likely to be the process of microbial antagonism. This simply means that the stressed microorganisms in the primary effluent were outcompeted by the indigenous microflora of the filter materials. The antimicrobial properties of peaty soils and other similar filtration units are well established in scientific literature. The antimicrobial properties of the Puraflo Peat system have also been described [7]. The treatment mechanisms which occurred in the filter unit described here include physical filtration, adsorption, chemical adsorption/ion exchange and biological transformations.

5. CONCLUSION

The results obtained by the operation of this filter system have conclusively shown that it can produce a high-quality treated effluent which can be disposed of at the subsurface without any adverse effects on groundwater, subsurface water quality or associated human health risks. This could be a very efficient and natural method of recycling wastewater.

REFERENCES

[1] American Public Health Association (APHA), *Standard Method for the Examination of Water and Waste Water* (19th ed), Washington D.C., 1995.

[2] DEVING J.S., HODGES D.S., MEDINA V.F., *Bench testing of fuel vapour treatment by biofiltration*, [in:] *Proceedings of the International Society of Environmental Protection*, 1991, Vienna, Austria, 85–103.

[3] ETTE A.O., AMADI O., KUCH E.I., OGO D.U.I., *Production of drinking water*, African Journal of Science and Technology, 2002, Vol. 1, 1, 1–6.

[4] GAYLE B.P., BOARDMAN G.D., CHERRAND J.H., BENOIT R.E., *Biological denitrification of water*, Journal of Environmental Engineering, 1992, 115 (5), 930–943.

[5] GÖSCHL R., *Odor stabilization in waste disposal sites*, [in:] *Insitu Aeration, Air Sparing, Bioventing and Related Remediation Processes*, edited by R.E. Hinchee, R.N. Miller, P.C. Johnson, 1995, Columbus OH. Battele Press, 289–295.

[6] HODGE D.S., MEDINA V.F., *Modelling removal of air contaminants by biofiltration*, Journal of Environmental Engineering, 1995, 121 (1), 121–131.

[7] HUGH H., NAMONA B., *Treatment of Septic Effluent Using Puraflo Peat Biofiltration System*, http;//plymouth.ces.state.nc.us/septic/puraflo.html cyber | pc 17.

[8] LESSON G., WINER A.M., *Biofiltration. An innovative air pollution control technology for VOC emissions*, Air and Water Management Association Journal, 1991, 41 (8), 1045–1054.

[9] METCALF and EDDY, *Waste Water Engineering Treatment Disposal and Reuse*, 3rd edition, McGraw-Hill, New York, 1991, 56–127.

[10] RICHARD Y.R., *Operating experiences of full scale biological and ion-exchange denitrification plants in France*, J. Inst. Water Envir. Mgt., 1989, 3 (2), 154–167.

[11] SMITH C.D., SMITH J.F., *Comparison of Biological, Chemical and Physical Iron Removal*, Proceedings of the 1994 National Conference on Environmental Engineering, edited by J.N. Ryan and M. Edwards, ASCE, New York, 1994, 74–81.

TANI SYSTEM FILTRACYJNY DO OCZYSZCZANIA ŚCIEKÓW

Urządzenie filtracyjne zbudowane z lokalnych surowców służyło do oczyszczania ścieków przemysłowych. System taki dawał sklarowane ścieki pozbawione zapachu i koloru.

Mikrobiologiczna analiza ścieków po filtracji wskazuje, że urządzenie umożliwia 96,6-procentową redukcję mikrobiologicznego ładunku ścieków, a spektrofotometryczna analiza przefiltrowanych ścieków potwierdza, że pozwala ono zredukować mętność o 99,3%. Kolejna analiza przefiltrowanych ścieków wykazuje, że nastąpiła znaczna redukcja wartości następujących fizykochemicznych parametrów: azotu amonowego – o 98,5%, smarów – o 98,3%, całkowitego węgla organicznego – o 79,3%, chloru – o 95,8%, węglanów – o 98,8%, siarczanów – o 84,4%, BZT_5 – o 98,6% i ChZT – o 99,1%. Duża efektywność systemu filtracyjnego i dostępność surowców potrzebnych do jego budowy sprawia, że może on być łatwo dostosowywany do różnych warunków zarządzania środowiskiem i jego kontroli.