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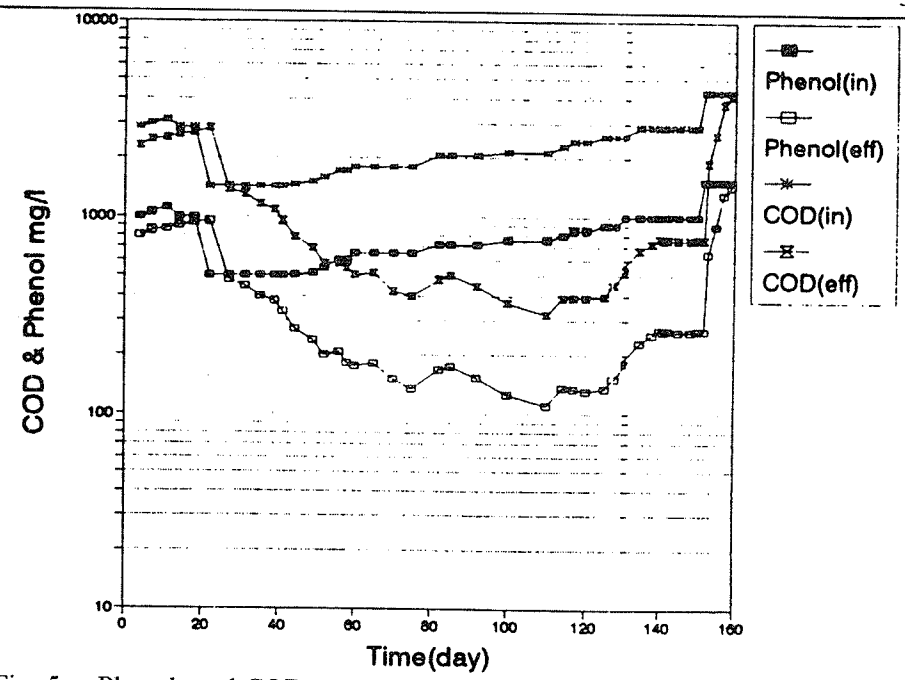

Fig. 5 - Phenol and COD removal in reactor with sand medium in stage 4 .

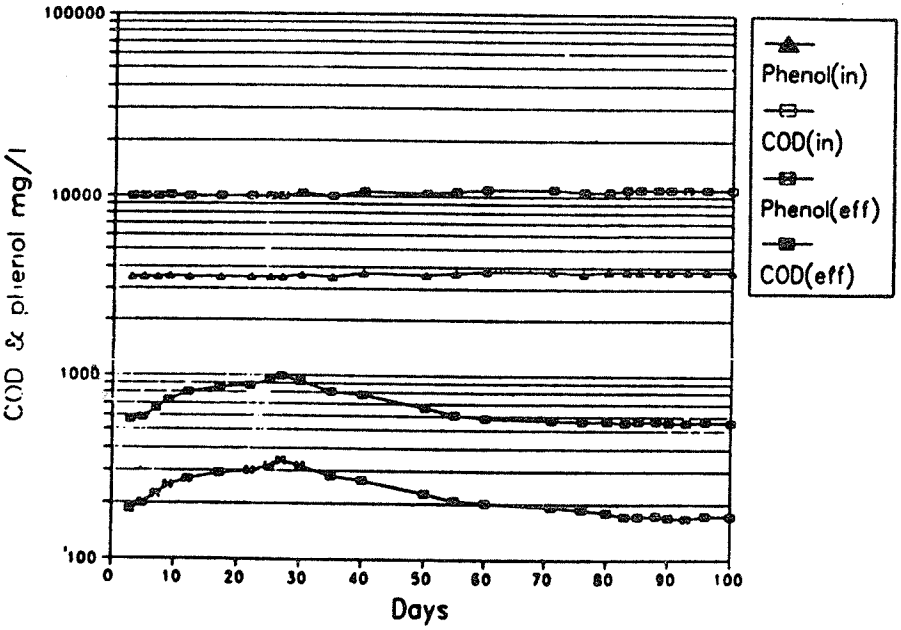

Fig. 6 - Infulent and effluent phenol and COD variations for reactor with GAC medium in stage 5.

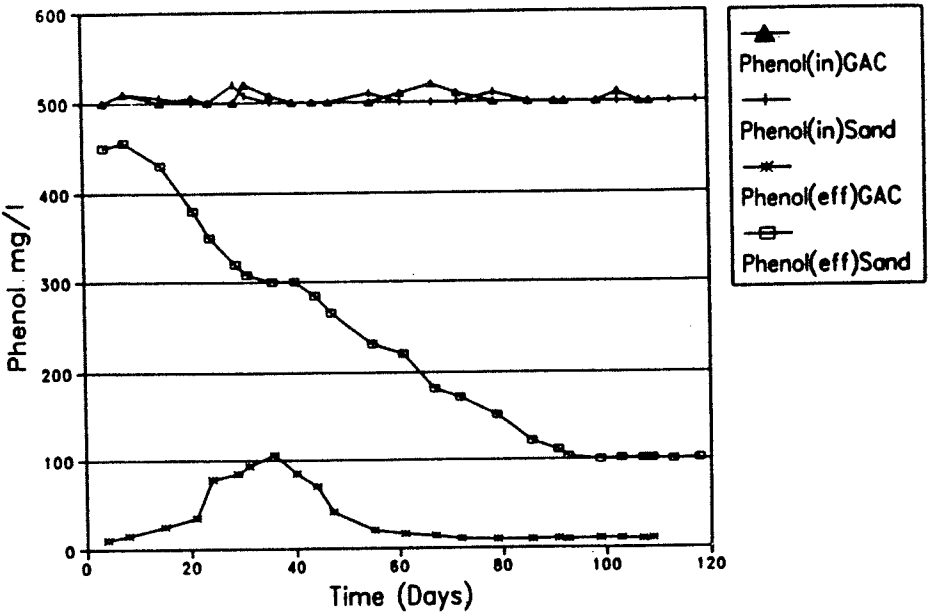

Fig. 3 - Comparison of Phenol removal in reactor with GAC and sand media in stage 3 .

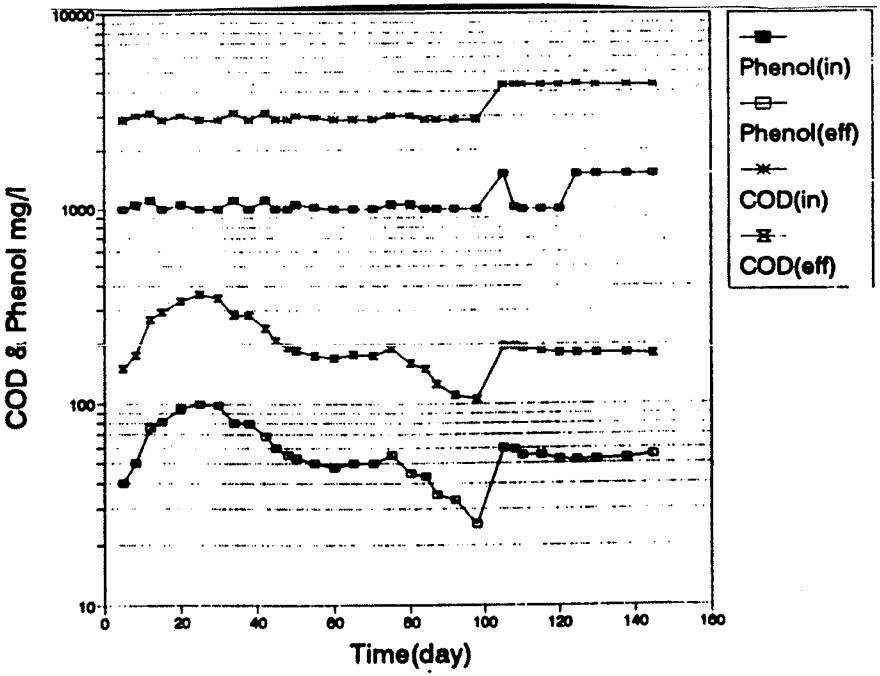

Fig. 4 - Phenol and COD removal in reactor with GAC media in stage 4.

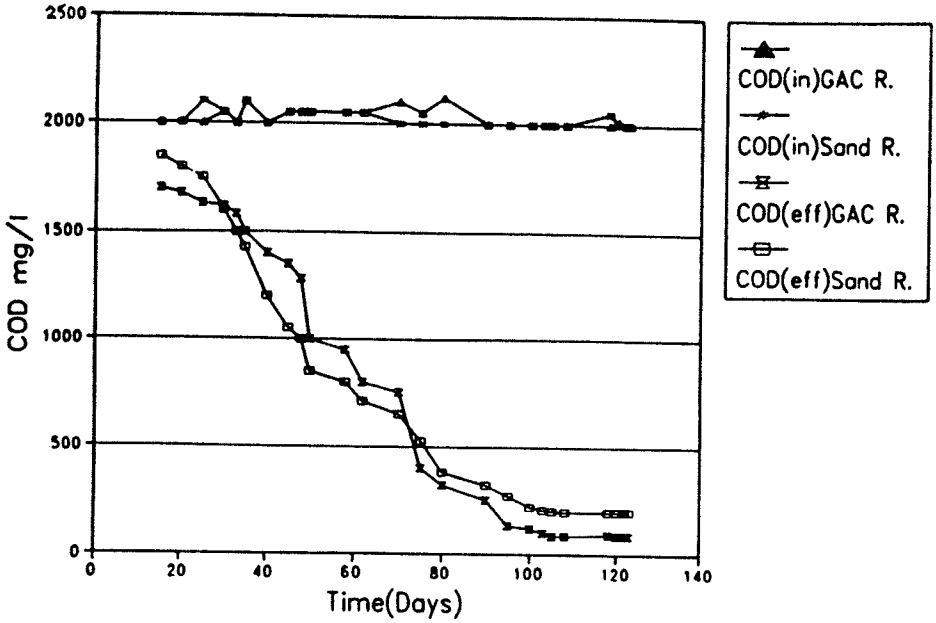

Fig. 1 - Comparison of COD removal in reactor with GAC and sand media in stage 1

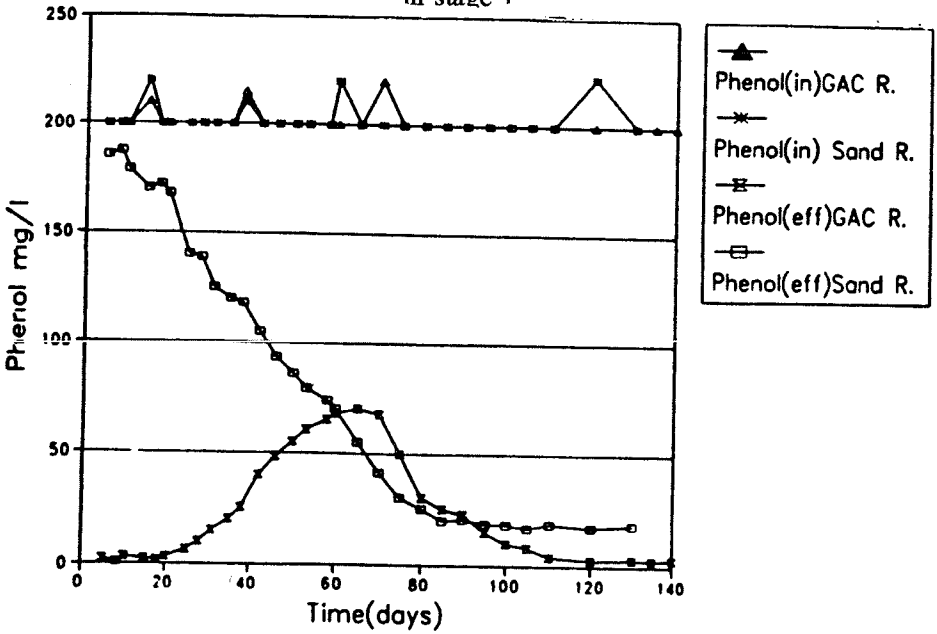

Fig. 2 - Comparison of phenol removal in reactor with GAC and sand media in stage 2.

achieved , and through stepwise phenol increase up to 1500 mg/L , system performance was ceased again.

In the GAC reactor , upon inflluent phenol increase up to 1000 mg/L, then to 1500 mg/L , the rate of phenol in the effluent was measured low. System performance on phenol removal was very desirable, in such a manner that under stable condition , a rate of phenol removal of 97.7% was achieved.

In diagrams 4 and 5 , a comparison of phenol variations in the effluents of both reactors are presented.

5) In the fifth stage , upon sudden increase in influent phenol concentration upto 3500 mg/L , then to 4000 mg/L , the GAC reactor performed very well , in such a way that the rate of phenol concentration in the effluent was gradually increased until the thirtieth day of the operation and reached a maximum of 320 mg/L. Thereafter , the outlet phenol rate began to reduce , gas generation condiserably increased , stable condition in the system was achieved after about 50 days , the rate of effluent phenol reached 170 mg/L on average and phenol removal efficiency of more than 95% was gained. Diagram 6 shows system's influent and effluent and outflow phenol variations in this stage.

Discussion

The main results of the study can be stated as follows :

- Fluidized bed reactor with either sand medium or GAC medium under varying COD loadings is capable of highly efficient COD removal. However, the reactor with GAC medium has a higher efficiency becuase of activated carbon characteristics.
- For phenol removal , fluidized bed reactor with sand medium shows different efficiecy with regard to the rate of influent phenol concentration or the rate of phenol loading.

Moreover , for acclimation to phenol loading increase , a rather longer time is required , and with influent phenol loading increase to 1500 mg/L (2.4 gr phenol. L^{-1} . day $^{-1}$) , the system performance faced disturbance.

- The performance of the fluidized bed reactor with GAC medium in phenol and COD removal was much higher and more desirable than that of the reactor with sand medium. In particular , such capability was more tangible with phenol loading rate increase. The important result gained from the GAC reactor performance was that the system stood well aginst shocks resulting from phenol loading increase, in such a way that the system performance faced no distrubance in phenol removal and its impact was little.
- Upon studying and comparing the rates of gas generation in both reactors, it was found that , under stable conditions , phenol and COD removal in GAC reactor took place nearly a hundred percent biologically. However , under shocks resulting from loading increase , the adsorption mechanism on GAC was also effective in phenol removal. With the continuation of the operation under new loading condition , biological removal of phenol previously adsorbed by activated carbon also took place by bacterial population , and the regeneration of activated carbon was done biologically.

2) In the second stage , after addition of phenol at a rate of 200 mg/L to th influent , the reactors showed different performances. Such a rate of pheno concentration was selected with regard to the examination of previous works o phenol removal in anaerobic systems and the possibility of system acclimation.

During the first 20 days of the stage , phenol concentration in th effluent of the reactor with GAC was measured as minor whose reason is seemingl the strong adsorption of phenol by activated carbon.

After that period , phenol concentration in the effluent gradually bega to reduce and gas generation increased. Under stable condition which started fron the hundredth day of the stage , the rate of phenol in the effluent was measure 3 mg/L on average , and the rate of gas generation showed that the removal too place biologically under such condition.

In this stage , the reactor with sand medium showed a differen performance. Upon the entrance of phenol to the reactor with sand medium, the rat of gas generation reduced and COD concentration in the effluent increased. Then gas generation gradually increased and it took about 100 days of reach the stabl condition. Under the stable condition , phenol was measured 18 mg/L on average

Diagram 2 shows a comparison between phenol removal in the reactor wit sand and GAC media in the second stage.

Phenol removal rates of 98.5% and 91% were achived in the reactor with GA and sand media respectively.

3) In the third stage , upon inffluent phenol concentration increase up to 50 mg/L and glucose removed from the influent of the reactor with GAC medium, the rate of gas generation decreased ; but the rate of phenol in the effluent showed no increase , whose reason was phenol adsorption by activated carbon. During subsequent period (from the twentieth day on), gas generation increased , but the rate of phenol in the effluent growingly increased to reach a maximum of 105 mg/L and thereafter , the rate of gas generation steadily increased . In this period, gas generation increase was so much that indicated the degradation of the previously adsorbed phenol onto the activated carbon surface by bacterial population. From about the 120 th day on , gas generation reached a constant limit which was almost equivalent to the removed organic carbon in the system.

In the reactor with sand medium in this stage , in the beginning the rate of phenol in the effluent increased , then gradually decreased, then it took about 90 days to reach the stable condition. Digram 3 shows a comparison between phenol removal in both reactors in this stage. The rates of phenol removal under stable conditions in the reactor with GAC and sand media were 97% and 80% respectively.

4) In the fourth stage , the rate of the influent phenol to the reactors was dramatically increased to 1000 mg/L. Under this condition , the shock resulting from phenol increase led to the ceasing performance of the reactor with sand medium. Thus , the reactor was first fed with glucose , then with phenol , and finally the system performance improved again, under which condition the rate of influent phenol was increased gradully step by step to reach 1000 mg/L. Under this condition , in the stable state , the rate of phenol removal of 74% was

Fluidized bed columns were made of plexyglass with a height of 150 cm , ner diameter of 7.5 cm and volume of 5.7 L.

The reactors had inlets from the bottom , effluent outlets from the top, nd they were also equipped with sampling valves and locations for placing in naterials , medium and other supplements.

Main flow of wastewater entered each reactor from the bottom through osing pumps (adjustable flow pumps) , and exited from outlet pipes assembled on ne upper part of the reactor's surface area. The reactors were all equipped with ffluent sedimentation system , gas direction , collection measurement system and emperature control system (within the limits of mesophyllic digestion). ffluent circulation to produce bed fluidity was done by adjustable discharge iruclation pumps. GAC was introduced to one reactor as the medium , and sand to nother one , in a manner that the height of non-fluidized bed in each reactor qualled 35 cm. The rate of the recycled flow was adjusted in such a way that the luidity height in both reactors was 100 cm , and reactor volume of 3.84 L based n fluidized bed was attained. Reactors influents were artificially prepared at ne laboratory , and in addition to glucose and phenol as the substrate , nutrient naterials including micro - neutrient and macro - nutrients were added at equired values to the influent. In all stages , the reactors influents were onsidered 6.15 L/day , and retention time of 15 hours based on fluidized bed olume in each reactor was achieved.

The study was performed in 5 stages , lasting more than 500 days [from arly 1374 (A.H.) to late 1375 (A.H.)]. In the first stage , putting into peration of the reactors , getting them to the steady state and comparison of COD emoval were performed ; during the second to the fourth stages , comparison of henol removal in both reactors with varying loadings was conducted and , in the ifth stage , phenol removal with high loading in GAC reactor was examined.

The measured parameters in each stage consisted of pH , temperature , COD, nfluent and effluent phenol concentrations , and the rate of gas generation in ach stage was also monitored. All tests were performed according to the methods ndicated in standard methods book. (1)

Results

The results , gained from the study , in the order of stages of precesses performed , are as follows :

1) In the first stage , the performances of both reactors in COD removal showed no considerable difference. Diagram 1 shows a comparison between COD removal in both reactors. Under stable conditions , the rate of COD removal in the reactor with GAC medium is higher. COD removal rates of 95% and 90% were achieved in the reactor with GAC medium and sand medium respectively.

Moreover , the variation of gas generation variations in the period of the study showed that COD removal mechanism in the reactor with GAC medium was almost biologicall during the whole period.

Biological treatment of wastewaters containing phenol has been performed through common biological processes such as activated sludge with extended aeration , trickling filters and aerated lagoons , but there exists some problems with such processes (3,8).

The first study on phenolic compounds removal in anaerobic medium was reported in 1977 (4). Employing fermentation tubes , they proved that phenol and catechol (O - Hydroxy phenol) could be degraded to methane and carbon dioxide under anaerobic condition.

Activated carbon containing anaerobic filter reactors were examined for the treatment of phenol - bearing wastewater (6). They achieved 90% phenol removal with the use of three reactors in series. In the study , the concentration of influent phenol was as much as 400 mg/l.

It was found to be possible to turn phenol stoichiometrically into methane and carbon dioxide with the use of the sludge existing in anaerobic digesters of municipal wastewater treatment plants (12).

Moreover , it was shown that phenol was degradable under anaerobic condition (7).

Another study was carried out on anaerobic biodegradation of phenol by fixed bed reactor biofilms (11).

Phenol biodegradation was examined by anaerobic processes (5). It was stated that the acclimation of bacteria in anaerobic processes was difficult in phenol - bearing wastewaters. In the study , a new method for acclimation was employed. The study showed that the sludge resulting from aerobic treatment plants treating phenol - bearing wastewater might be directly used for anaerobic processes.

A research on the treatment of phenol bearing wastewater was conducted in upflow anaerobic sludge blanket reactor (UASB) (2). In the study , with a retention time of 12 hours and different COD loading rates, promising results were gained. The percentage of the removal of phenol of 1260 mg/l concentration was above 95%. However , the system acted unsuccessfully against acclimation to varying loadings , and long time was required for returning to stable conditions.

The present study was also conducted for phenol removal in anaerobic fluidized bed reactors with GAC and sand media.

The reason for selecting anaerobic fluidized bed reactors in this study was their positive characteristics for wastewater treatment.

In the present study , with regard to the type of system being utilized, good phenol adsorbability on th GAC, appropriate features of GAC as a medium for microorganims growth and biomass formation on to it , system performance for COD and phenol removal will be more desirable and better results will be gained.

Materials and Methods

To conduct the study , laboratory scale pilot units were constructed : Two identical systems were employed as anaerobic completely mixed fluidized bed systems.

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COMPARISON OF PHENOL REMOVAL IN ANAEROBIC FLUIDIZED BED REACTORS WITH SAND AND GAC MEDIA

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Key words : *Anaerobic Treatment , COD removal , Phenol , Fluidized bed reactor , Granular Activated Carbon (GAC)*

Abstract

In this study two identical anaerobic compeletly mixed fluidized bed reactors with GAC and sand media were employed for COD & phenol removal. At loading rate of 1.6 gr phenol $L^{-1}d^{-1}$, the efficiency of phenol removal in GAC & sand reactors were 97.7% & 74% respectively. At high loading rate of phenol (6.09 gr phenol $L^{-1}d^{-1}$) the efficiency of phenol removal in GAC reactor was better than 95%.

In GAC reactor , the main mechnism for phenol removal at steady state condition was biological process ; this was concluded through balance of gas production and COD removal.

Better efficiency of GAC reactor comparing with sand reactor was because of risistance to fluctuations , higher surface for biomass growth and adsorption capacity of activated carbon.

Introduction

After chlorination of water containing phenol , chlorophenols are formed which , at low concentrations , produce odour and tastes in water. Therefore , chlorophenols or phenol alone must not be present in water at a rate of more than 0.1 ug/l (10).

Phenol and some of its derivatives , at concentrations of 5-25 mg/l , have toxic (enzyme activity reduction) and fatal effects on the fish, and are also suspected of carcinogenic activity in animals and human beings (9).

Phenol is also known as a disinfective and germicidal agent. It is considered as a raw material for many industrial products , and it may be present at low to high concentrations in many industrial wastewaters.

Due to the environmental and health impacts of phenol , its removal from industrial wastewaters is very important. Although activated carbon adsorption and chemical oxidation are two good and efficient processes for the removal of phenol, they are considered difficult and noneconomic processes for the treatment of wastewater containing high phenol content.

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