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Effect of Phenol Loading on Wastewater Treatment by Activated Sludge Process

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ABSTRACT

The effect of Phenolon laboratory wastewater was analyzed using biological treatment. The effect of Phenol concentration, retention time and aerating time on the removal of organic matter were studied. In this case, the optimum hydraulic retention time (HRT) was 23 hours and the critical Phenol loadingwas 100 ppm. The effect of Phenol concentration was also investigated in terms of various parameters namely: chemical oxygen demand (COD), total organic carbon (TOC), suspended solids (SS), volatile suspended solids (VSS), and turbidity.
KEYWORD: S Phenol loading; Industrial wastewater; Biological treatment; Phenol removal; Removal of organic compounds.

1.INTRODUCTION

Laboratories consume great amounts of hazardous chemicals substances and consequently generate wastewater containing hazardous chemicals, for example Phenol compounds (1). Presence of Phenol and Phenolic compounds even at low concentration in the industrial wastewater adversely affects aquatic as well as human life directly or indirectly when disposed off to public sewage, river or surface water. Sometimes these form complex compounds with metal ions, discharged from other industries, which are more carcinogenic in nature than the phenolic compounds. The toxicity imparted by phenolic compounds is responsible for health hazards and dangerous to aquatic life. Phenol does not build up in fish, other animals, or plants but is expected to be toxic to aquatic life with a value for fish between 10 and 100 mg/l(2,3).Repeated or prolonged skin exposure to Phenol or vapors from heated Phenol may cause headache, nausea, dizziness, diarrhea, vomiting, shock, convulsions, and even death. Phenol affects the central nervous system, liver, and kidneys(4). Laboratory wastewater systems are increasingly being specified for academic teaching and research buildings by many environmental consultants and design engineers. While real efforts to improve the quality of wastewater are generally positive, simply installing such systems without regard to their operational setting increases capital costs, significantly increases equipment service and maintenance needs and expenses, and can potentially generate higher environmental, health, and safety risks from chemical handling exposures, spills, leaks, or uncontrolled releases to sewage (5). Phenol can be used for syntheses or analyses. Due to the application purposes, contaminated starting materials, by-products, spent solvents, and chemicals are formed, which have to be disposed off, if their recycling is not possible. In contrast to industrial wastes the waste chemicals from academic chemical laboratories are generated fundamentally by small amounts of highly complex mixtures (6). Laboratory wastewaters containing Phenols and other toxic compounds need careful treatment before discharging into the receiving waters. Biological treatment, activated carbon adsorption, surfactant-modified, solvent extraction, ozone treatment, oxidative and electrochemical methods are the most widely used processes for removing Phenol and Phenolic compounds from wastewaters(7–13).Laboratory wastewaters containing Phenols usually consist of aqueous solution which are previously neutralized to pH 6-8 and do not contain heavy metals (14). Cleaning of laboratory equipment that contain Phenolic compounds after their use in chemical experiments can also be a source for hazardous wastes which have to be disposed off according to the regulations (15). Critical to successful Phenol oxidation is the control of shock loads to the biological process. Numerous studies have shown that Phenol concentrations in excess of 500 mg/l can result in a marked decrease in efficiency of the biological treatment. The use of the biological process for removal of Phenol will attenuate the effects of shock loads, but at very high concentrations over extended periods of time will be detrimental to the process (16-19).

In this study, the feasibility of biological treatment for chemical laboratory wastewater, after Phenolloading, was evaluated, using an activated sludge process. The effect of Phenol concentration was investigated in terms of various parameters namely: chemical oxygen demand (COD), total organic carbon (TOC), suspended solids (SS), volatile suspended solids (VSS), and turbidity.

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2. MATERIALS AND METHODS

2.1.Analysis of laboratory effluent

Laboratory wastewater which is located inNorth Tehran is identified with 32 sub-laboratories. Sampling was performed for 44timesand a volume of 0.6 liter was used for each experiment during the period of 4 months (from September 2011 to December 2011). Most of the samples were taken every 72hours period. After each sampling, it was retained in clearly marked container and its source was recorded. Later on, each sample was characterized through chemical analysis in terms of pH, dissolved oxygen (DO), chemical oxygen demand (COD), total organic carbon (TOC), suspended solids (SS), volatile suspended solids (VSS) and turbidity.

2.2. Biological treatment

In order to reduce the effect of Phenol shock loading on the laboratory wastewater, aerobic biological treatment was used. The reactor designed was a pilot-plant atlaboratory scale with the dimensions of 30×25×20cm which its bottom and septum's thickness were 8 mm and 5 mm, respectively. The reactor volume was equal to 1.5 liters with a working volume of 1.2 liters. During the aerobic treatment, mixing and aerating the laboratory wastewater in the reactor was carried out by aquarium stones which was designed at the bottom of the reactor. Peristaltic pump was used to feed the waste water into the reactor. Whilst the aeration was going on, the adjustments for oxygen concentrations were adjusted at 3-4.5 mg/l. The temperature, pH, DO, Oxidation-reduction Potential (ORP) for nutrient medium and electrical conductivity (EC) monitored by each probe continuously. The output of aquarium pumps was0.6 l/min with a pressure of0.014 MPa. After filling the reactor with the laboratory wastewater, it was aerated for 23 hoursper cycle. After every cycle, the reactor was allowed to settle for one hour. During this period of time, the aeration pump was turned off, and the supernatant was decanted, and the reactor was refilled. Deposited microorganisms were used for the second treatment process. After the aeration period, and adding the laboratory wastewater to the reactor per cycle, the effect of Phenol loading was monitored to investigate the effluent biodegradability in terms of parameters: COD, TOC, SS, VSS and turbidity(NTU).

2.3. Analytical methods

Measurements of COD, TOC, SS, VSS and pH followed Standard Methods (20). Turbidity were measured by an analytical method developed by YL Instrument Company, Korea.

2.4. Source of Phenol shock medium

The Phenol removing enrichment culture used in these experiments were collected from an activated sludge unit at local laboratory waste water treatment plant near Islamic Azad University, North Tehran Branch. The culture was acclimatized in aerobic condition for the wastewater containing Phenol before being used(the contaminated wastewater used were prepared with combined wastewater, obtained from a local wastewater treatment plant and the Phenol as the contaminant by loading 10, 20, 50, 100, and 200 ppm of Phenolsource). In order to investigate the effect of Phenol loading on the effluent biodegradability, a control experiment in a free-Phenolwaste water was also carried out.

3. RESULTS AND DISCUSSION

3.1. Characterization of the laboratory wastewater

The main chemical analysis that generated in the laboratory wastewater during the period of study are given in Table 1.The results are given as mean values with 95% confidence limits. As shown in Table 1, it is observed that the level of contamination of the laboratory wastewater is significantly higher than standard values which shows the degree of contamination of the laboratory effluent.

Table1.Meanvalues of wastewater parameters (with 95% confidence limits).

Wastewater Constituent	Units	Number of Samples	Average Values
pH	-	44	8.4±0.5
BOD_5	mg/l	44	55250±50
COD	mg/l	44	69062±50
Colors	$mgPtCol^{-1}$	44	9425±25
TSS	mg/l	44	19225±50
VSS	mg/l	44	10573±50
Turbidity	NTU*	44	951.2±10
BTEX-sum	µg/l	8	399±10
Benzene	µg/l	8	1.5±0.02
Ethyl benzene	µg/l	8	88.2±2
Toluene	µg/l	8	192.2±2
Xylene	µg/l	8	118.5±2

*NTU: Noflumeterturbidity unit

3.2.Phenol shock on biological treatment

With respect to the effect of microorganisms on organic material degradation in biological treatment, and in addition to providing such effective microorganism, the effluent of the reactor was mixed with the municipal activated sludge at a local wastewater treatment plant near theuniversity,which was adequate for feeding requisite microorganisms. The reactor was then aerated continuously with three aeration pumps, during the aeration; oxygen concentration was set at 3-4.5 mg/l. The operation was carried out for 24 hours, of which 23 hours was allowed for aeration, and one hour for sedimentation in the reactor to occur. The pH of the reactor was set at 6.5-8.0 which effective microorganisms yield more during the treatment. In this case, Hydraulic Retention Time (HRT) and Sludge Retention Time (SRT) were 23 and 12 days, respectively. The systems reached the steady state within 7–8 days of acclimatization. The biological system was operated with the same sludge concentration about 4g/l. The results of COD parameter with respect to Phenol shock concentration are given in Table 2. The results are given as mean values.

Table 2.Mean values of COD parameter

Phenol Concentration (ppm)	**Parameters**			
	DO (ppm)	COD_i (ppm)	COD_e (ppm)	COD %
Blank	6	145	72	49.6
10	6	167	87	52
20	6	183	101	55.2
50	6	293	168	57.3
100	6	405	249	61.5
200	6	535	253	47.3

i: influent; e: effluent

The blank (control experiment) was used as the wastewater with free-Phenolloading. After the acclimatization process, different aeration times were investigated for the reactor throughout these experiments. As shown in Table 2,the COD increased significantly to 61.5% with increase in Phenol concentration up to 100ppm. COD dropped to 47.3% as the Phenolconcentration was increased to 200ppm, which shows 14% reduction in COD, indicating that the effluent is of difficult biodegradability, probably because of the Phenol toxic effects. The p-value in significant differences for COD_e and COD% were 0.014 and 0.738, respectively, if 0 to 200 ppm of Phenol source is considered in the calculation for p-value. However, if 0 to 100 ppm of Phenol source is considered the p-value obtained were 0.00 and 0.010, respectively, which were less than significant level (<0.05), showing that there is a correlation between the Phenol concentration and the parameters measured. A number of studies have shown that excess of Phenol concentrations can result in a marked decrease in efficiency of the biological treatment. The use of the biological process to Phenol will attenuate the effects of shock loads, but at very high concentrations over extended periods of time, Phenol can have an adverse effects on the process (16-19).The TOC,NTU, SS and VSS parameters during the biological operation are shown in Figures 1 to 4, respectively. As can be observed in Figures 1 to 4, the parameters measured were a function of Phenol concentration in the wastewater. The results of the parameters obtained are shown in Table 3. The results are given as mean values.

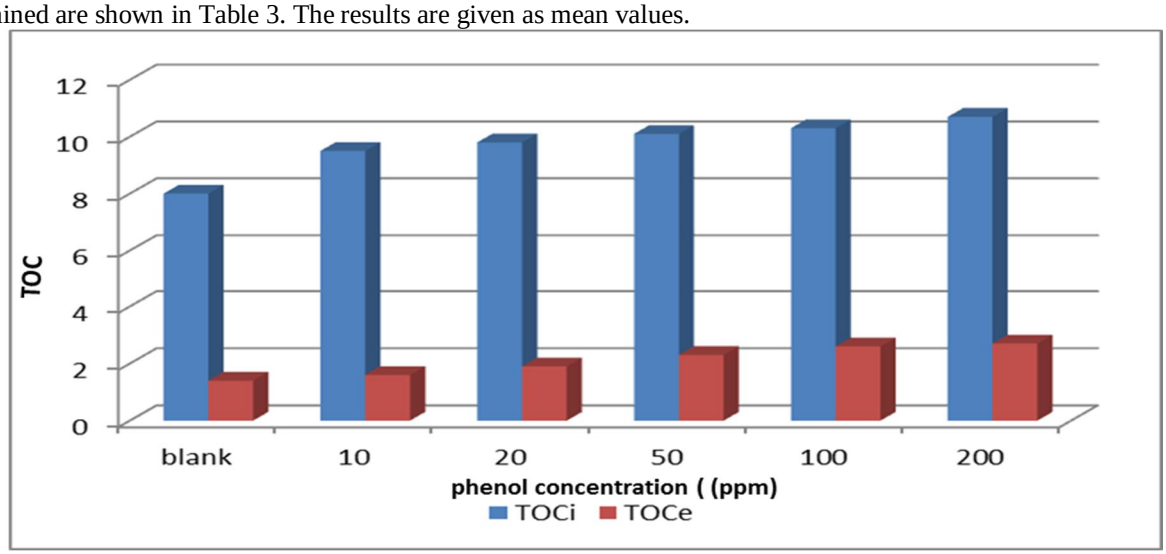

Fig 1.The effect of Phenol shock concentrations on TOC removal.

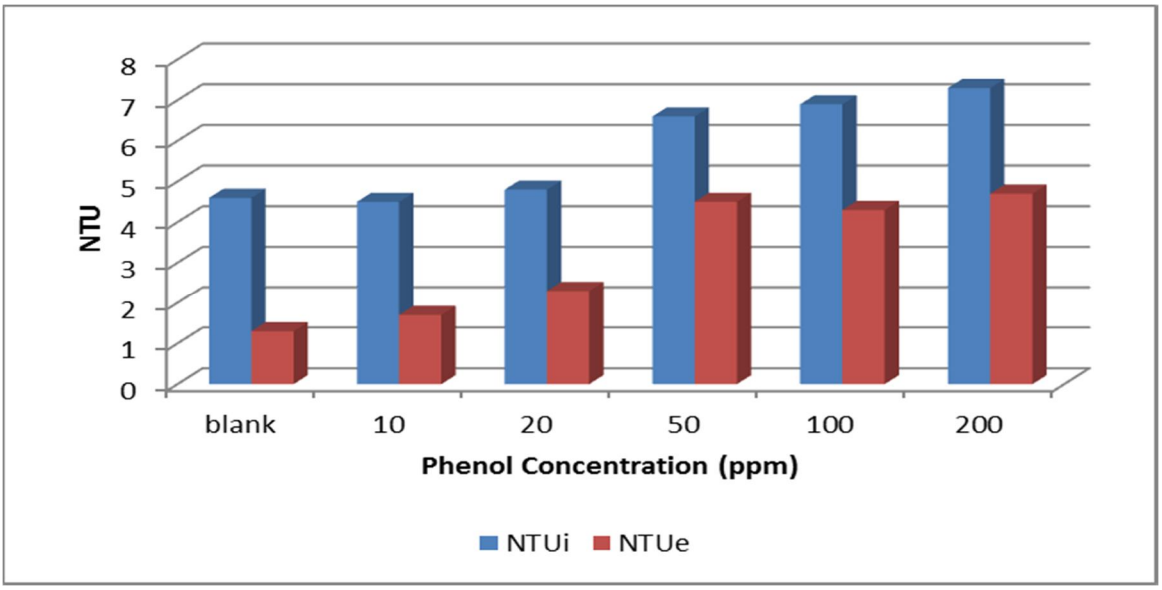

Fig 2.The effect of Phenolshock concentrations on turbidity.

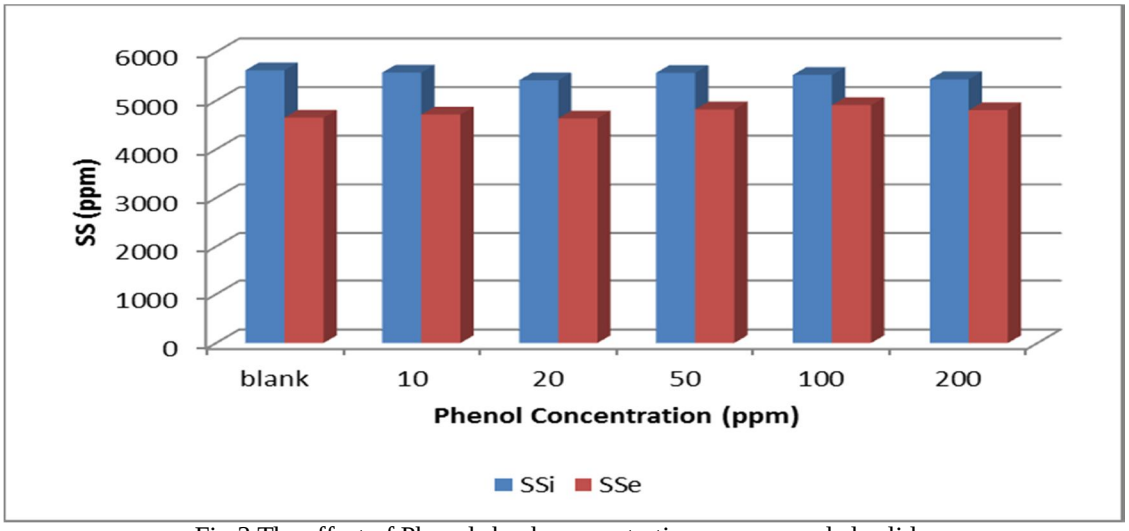

Fig 3.The effect of Phenol shock concentrations on suspended solids.

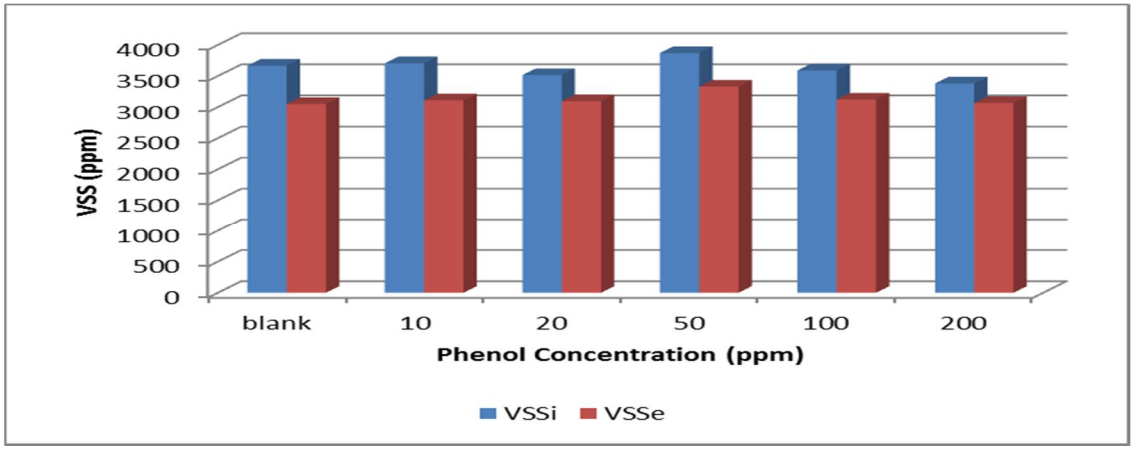

Fig 4.The effect of Phenol shock concentrations on volatile suspended solids.

Since the bio-oxidation systems for Phenol are generally aerobic, oxygen is supplied by diffused or mechanical aeration. Approximately 2.5 kg of oxygen are required per kg of Phenol at 30°C. But activated sludge systems offer better control of the process and smaller area requirements. The bio-oxidation systems represent a higher capital investment and more sophisticated operation than the low solids aerated lagoon. In either case, the major operational cost would be supplying oxygen, and the selection of oxygen transferring equipment that should be analyzed carefully. The behavior of the activated sludge was evaluated for inlet Phenol concentrations ranging from 10 to 200 ppm, corresponding to COD inlet concentrations of around 100–600 ppm at a fixed cycle time of 24 hours. Table 3 shows the effect of Phenol shock concentrations on various parameters. As can be observed in Table 3, the reactor was started by introducing the wastewater containing 10 ppmPhenol upon inoculation with the initially acclimatized biomass. As shown in Table 3, it can be seen that the values obtained for TOC and NTU parameters show similar trend which increased with increase in Phenol concentration which were found to be 37% and 45%, respectively, at Phenol concentration of 100 ppm. But as the Phenol concentration increased to 200 ppm, TOC increased to 44%, whereas that of NTU decreased to 37%.In contrast,for SS and VSS parameters, the results obtained show a significantly decreased values with increase in Phenol concentration which were found to be 11% and 9%, respectively, at Phenol concentration of 200 ppm.The p-value in significant differences for TOC_e, NTU_e were 0.003 and 0.047, respectively, and for TOC%, SS% and VSS% were 0.005, 0.027 and 0.018, respectively, if 0 to 200 ppm of Phenol source is considered in the calculation. Whereas, if Phenol concentration of 0 to 100 ppm is used the p-value for TOCe, NTUe were 0.002 and 0.024, respectively, and for TOC%, SS% and VSS%, were 0.015, 0.021 and 0.023, respectively, which were less than significant level (<0.05). Therefore, exhibiting a correlation between the Phenol concentration and the parameters measured using biological treatment.

Table3.Comparison of parameters of laboratory wastewater with Phenol shock concentrations

Phenol Concentration (ppm)	**Parameters**											
	TOC_i (ppm)	TOC_e (ppm)	SS_i (mg/l)	SS_e (mg/l)	VSS_i (mg/l)	VSS_e (mg/l)	NTU_i	NTU_e	TOC%	SS%	VSS%	NTU%
Blank	4.7	1.1	4065	5081	2662	3319	7.2	1.3	23	25	25	18
10	4.9	1.3	4272	5175	2745	3387	7.4	1.7	26	21	23	23
20	5.3	1.6	4125	4878	2623	3128	7.5	2.0	30	18	19	27
50	5.8	1.9	4379	5073	2802	3197	7.9	3.5	33	16	14	44
100	6.7	2.5	4537	5105	3010	3361	8.3	3.7	37	12	12	45
200	7.6	2.9	4485	4992	2932	3209	8.7	3.8	42	11	9	44

Conclusions

The work discussed in this study involved investigations of biological degradation of chemical laboratory wastewater using abiological treatment. The effects of Phenol concentration, retention time and aerating time on the performance of the activated sludge process are given in terms of COD, TOC, TSS, VSS, and NTU parameters. The optimum hydraulic retention time (HRT) was 23 hours. The results showed that increasing concentrations of Phenol from 0-100 ppm, the efficiency of COD increased from 49.5% to 61.5%, but as Phenol concentration was increased to 200ppm, a 14% reduction of COD was observed, showing that the effluent is of difficult biodegradability, probably because of the Phenol toxic effects. TOC and NTU parameters showed similar trend which increased with increase in Phenol concentration up to 100 ppm. In contrast, for SS and VSS parameters, the results showeda significantly decreased values with increase in Phenol concentration up to 200 ppm.The p-values calculated for the above parameters showed that using 0 to 100 ppm of Phenol source can result in values less than 0.05 significance level, indicating that there is a correlation between the Phenol concentration in the wastewater and the parameters measured.

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