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NEW WATER CULTURE: CARE, SANITATION AND REUSE, FOR SOCIAL STABILITY, ENVIRONMENTAL AND ECONOMIC

J. Terreros-Mecalcoa
Universidad Tecnológica del Valle de Toluca, Carretera del Departamento of D.F
Estado de México

G. Velazquez-Garduño
Universidad Tecnológica del Valle de Toluca, Carretera del Departamento of D.F
Estado de México

M.C. Figueroa-Ocampo
Universidad Tecnológica del Valle de Toluca, Carretera del Departamento of D.F
Estado de México

Abstract: The challenges that we must address, has to see the implementation of existing knowledge and technology in the world around the issue of water, environmental pollution and climate change; for the preservation and conservation of our natural resources. In this research, an activated sludge system was studied for the treatment of wastewater with a high concentration of phenol for reuse, varying the hydraulic retention time and dissolved oxygen concentration. The results showed the best COD removal rate (55%) and phenol biodegradation (49%) during experiment IV, at a wastewater dilution rate of 25% (v/v), dissolved oxygen (DO) feed of 1.5 ppm, hydraulic retention time (HRT) of 2.81 days and organic load (Bv=7.5kgCOD/ $m^3 \cdot d$), once the biomass was acclimated to the presence of phenol as the only carbon source, in previous experiments.
Keywords: Water culture, Climate change, Environmental pollution, sanitation, hydric crisis

INTRODUCTION

Water is a resource that allows the development of society, contributes to equitable distribution, social justice and counteracts poverty. Hinrichsen, Robey and Upadhyay (1998) relate water management to economic development. Other authors highlight the need to analyze water, not only as a natural resource, but also in cultural, symbolic terms and as an essential element for all living beings (Velázquez, 2010; Paz, 2014). Its quality is of great relevance due to the essential ecological value for health, for economic growth, preservation and conservation of our environmental environment, which must be mutually reinforced since they are fundamental to achieve human well-being, sustainable development and social peace. worldwide (Villena, 2018).

It is estimated that there will be 31 million more inhabitants in Mexico by the year 2050, which represents close to 25% additional to the current population (INEGI, 2019), in just twenty years, the gap that was estimated between supply and demand was of 23 billion cubic meters. Its scarcity tends to manifest first in regions with high rates of demographic growth and expansion of industrial and agricultural activities (IDEAM, 2010). With population growth, economic development, changes in consumption patterns, intensification of agricultural production and expansion of cities, a substantial increase in water demand will be generated (Wada and Bierkens, 2014), while water availability becomes increasingly erratic and uncertain (FAO, 2017a; IPCC, 2018a). Global water use has increased six-fold in the last 100 years and continues to increase at a constant rate of 1% annually due to population growth, economic development and changing consumption patterns. According to current trends, feeding a largely urban population requires increasing food production by around 70% (Godfray, Beddington, Crute, Haddad, Lawrence, Muir, Pretty, Robinson, Thomas and Toulmin, 2010), which implies that water extractions would increase 55% by the year 2050 (FAO, 2011; Guijarro and Sánchez, 2015; Pérez, Leyva and Gomez, 2018).

The increase in water extraction in basins and aquifers in the country has caused a situation of overexploitation in 115 of the 653 aquifers. In approximately 69 of the 757 hydrological basins, the concessioned or assigned flow is greater than that of renewable water (deficit situation) and with climate changes, agriculture and tourism have been affected by the closure of springs and reduction of water in irrigation canals (Ortiz and Romo, 2016). Water depletion and pollution are the main causes of biodiversity loss and ecosystem degradation, which, in turn, reduce the resilience of ecosystems, making societies more vulnerable to climate and non-climate risks. Water quality not only affects economic and social well-being, but also the sustainability of vital environmental flows, ecosystems and biodiversity (WWAP, 2017).

The loss of important areas for recharge due to deforestation, change in land use, disorderly expansion of human settlements and the replacement of green areas with paved areas that prevent infiltration (CONAGUA, 2018a). Added to this, the discharge of untreated domestic, industrial, agricultural and livestock wastewater causes contamination of surface and underground water bodies, putting at risk the health of the population and the integrity of ecosystems related to the water cycle. In 2017, 2 million tons of DB05 were generated, with industries contributing the most organic pollutants and up to 340% more pollution than that generated by municipalities (CONAGUA, 2018a). Of the municipal wastewater collected in drains, 30% does not receive any type of treatment and according to a United Nations report on the Development of Water Resources in the World, 2 million tons of waste are dumped daily. natural bodies of water (sea, rivers, lakes, etc.), including industrial, household and agricultural waste (UNESCO-UN-Water, 2020). Agriculture is the economic activity that consumes the most water in the world each year, with a percentage that already reaches 70% of the total existing resources, its care is relevant. In Mexico, the area dedicated to agriculture is approximately 22 million hectares, of which 6.1 million have irrigation infrastructure and the rest is rainfed. The irrigated area is made up of 86 irrigation districts that cover 2.5 million hectares, and approximately 40 thousand irrigation units for 3.6 million hectares. Although the area under irrigation is much smaller than that of rainfed land, its productivity is significantly higher (between 2 and 3 times that of rainfed land), which is why irrigated areas generate more than half of the national agricultural production. For example; In 2018, the main basic crops were produced: rice, beans, corn and wheat, with a yield obtained in irrigated areas 3.5 times higher than that of rainfed crops (SIAP, 2018a). However, due to the use of untreated wastewater in agricultural production, it has given rise to a number of diseases. In our country, the area with the highest incidence of acute diarrheal diseases is the south-southeast; and the states of Guerrero and Chiapas register the highest infant mortality due to acute diarrheal diseases (Salud, 2016).

Water scarcity will continue to increase in the future, with around 52% of the world's population living in water-stressed regions by 2050 (Kölbel, Strong, Noe and Reig, 2018), climate change and land use change, will significantly affect natural resources and water supply sources in all regions of the country. With the increase in temperature and the alteration in rainfall, the availability and quality of water will impact the occurrence of extreme meteorological phenomena (hurricanes) classified according to the speed and damage produced (Saffir and Simpson, 1969).

The effects of climate change, ecosystem degradation, untreated urban and rural waste, oil spills and toxic discharges negatively impact biodiversity and freshwater ecosystems. Around a million animal and plant species are in danger of extinction, freshwater species are those that have suffered the greatest decline, falling by 84% since 1970. Human beings have also been affected: around 4 thousand Millions of people currently experience severe water shortages for at least one month a year, a situation that has been aggravated by the climate crisis (UNESCO-UN-Water, 2020). With appropriate management for the care and preservation of water resources, the transmission of diseases by vectors, such as viral diseases transmitted by mosquitoes, will be reduced (Kibret, Lautze, McCartney, Glenn and Nhamo, 2016). The human right to the supply of drinking water and environmental sanitation is of vital importance (WHO, 2006) to reduce the water crisis, ecological, environmental and climate change damage (WHO, 2019a). The state with the most critical situation is Guerrero, with 10%, in contrast to Nuevo León, with 95%. In urban areas a value of 64% is reached, and in rural areas it is 39%. There are 14 states with the greatest lag in access to services, in which the percentage of the population that has water every day and improved basic sanitation ranges between 10 and 58%. Which is reflected in universal access to quality water (INEGI, 2019). And take advantage of the treated wastewater for agricultural irrigation (NOM-003-SEMARNAT-1997), industrial use or artificial recharge of the aquifer via cultivation (NOM-014-CONAGUA-2003).

Among the various contaminants, there is phenol, an organic compound widely used in the industry for the production of agricultural chemicals, pesticides and pesticides (Basha, Rajendran and Thangavelu, 2010). It is used as a component of dyes, polymers, drugs and other organic substances in the production processes of industries such as: pharmaceuticals, perfumery, explosives, phenolic resins, plastics, textiles, petroleum, dyes, leather, paper, coking plants, tar distilleries, pesticides (Dargahi, Almasi, Mahmoodi and khamootian's, 2014). The concentration range of phenol in the effluents of the main industries that use or produce this substance depends on the manufacturing process of the product; However, it generally falls between 100 to 90,000 mg/L (Xiao, Zhou, Tan, Zhang, Xia, & Ji, 2006). It is reported that 73.3% of water bodies contain phenol due to its infiltration, with the possibility of being found in groundwater for human consumption (Prakash and Behari, 2004). In this context, the United States Environmental Protection Agency (EPA, 2015) has considered phenol as one of the 129 specific highly toxic priority chemicals. Under the 1977 Amendments to the Clean Water Act, it issued water quality criteria, setting a concentration of phenol in drinking and mineral water at 0.5 ppb, in surface wastewater discharges at 0.5 ppm, and for the sewer system; 1 ppm (Singh, Kumar and JN, 2013). In Mexico, a phenol concentration of 0.001 mg/L in drinking water for human consumption was established as the maximum permissible limit (MPL) (NOM-127-SSA1-1994) and 0.3 mg/L for artificial recharge of the aquifer (NOM-014-CONAGUA-2003). Its toxicity directly affects a wide variety of organs and tissues, mainly lungs, liver, kidneys and genitourinary system (Nistor, Emneús, Gorton and Ciucu, 1999). Due to the extreme toxicity of phenol and its stability, it remains for long periods of time with a tendency to bioaccumulate, causing considerable damage to ecosystems (Graca, Rychter, Staniszewska, Smolarz, Sokołowski and Bodziach, 2021). At concentrations of 0.5 mg/L, they are lethal to fish and when they bioaccumulate, their long-term effects are more serious (USEPA, 2016). The minimum dose at which the death of a human occurs is 140 mg. /kg. (USEPA, 2004).

The treatment of industrial effluents with high concentrations of phenol by activated sludge (microorganisms) is an alternative. This pathway has shown that there is a common metabolic route for this type of compound and even for those not so close to the family of phenolic compounds such as biphenyls (Autenrieth, Bonner, Akgerman, Okaygun, & McCreary, 1991). Where the acclimatization of any type of microorganism to the presence of phenol is a key factor (Terreros, Guzman and García, 2022). Various studies have been carried out to treat phenolic wastewater, due to the great contamination problem they represent, both for the environment, bodies of water, food and human health (Bevilaqua, Cammarota, Freire and Sant'AnnaJr 2002 ; Jiang, Tay and Tay (2004; Tay, Moy, Jiang and Tay 2005; Melo, Kholi, Patwardhan and D'Souza 2005; Hossein and Gordon, 2006; Bajaj, Gallert and Winter, 2008a; Contreras, Albertario, Bertola and Zaritzky, 2008; Donoso-Bravo, Rosenkranz, Valdivia, Torrijos, Ruiz-Filippi and Rolando, 2009; Ben-Youssef and Vázquez-Rodríguez, 2011).

Based on previously cited research, this study focused on evaluating the effect of hydraulic retention time (HRT) and dissolved oxygen (DO) concentration on the efficiency of phenol biodegradation and COD removal from an industrial resin effluent. polymeric, at different rates of organic load (Bv) for reuse according to the analysis of the current situation around water, with sanitation proposals, the object of this research.

MATERIALS AND METHODS

PHENOLIC WASTEWATER SAMPLING

For experiments (I to IV), 2 batches of wastewater from a polymer resin industry with a high concentration of phenol were used; transported at 4°C for preservation and subsequent characterization.

SAMPLE CHARACTERIZATION

For the characterization of raw water and process control, the following parameters were evaluated: Chemical oxygen demand (COD), Total Solids (ST) and Volatile Solids (VS) according to Standard Methods (APHA, AWWA, WPFC, 2023). The pH using a potentiometer (Corning pH/ion Analyzer 455). The determination of phenol was carried out by the 4-aminoantipyrine colorimetric method according to the Mexican Standard (NMX-AA-050-SCFI-2001).

INOCULUM

The biomass used was collected from an activated sludge reactor at the "Cerro de la Estrella" municipal wastewater treatment plant in Mexico City, with a concentration of 12.6 g/L of ST and 9.6 g/L of S.V.

AIRFLOW CONTROL

From standard dissolved oxygen curves, the concentration (mg/L) that was supplied to the system studied was determined; for this, a portable DO equipment, YSI model with a range of 0 to 20 mg/L, temperature working temperature from -5 to 45 °C, 0.1% air saturation and resolution of 0.01 mg/L, regulating the air supply through a Dwyer flowmeter manually.

UASB REACTOR OPERATING CONDITIONS

A complete mixing aerobic reactor was used, with a design volume of 4.98 L, useful volume of 4.3L, dimensions: Length: 28 cm, width of 17.5 cm and depth of 13 cm, divided into 3 sections (A, B and C). Section "A", where the biological reaction takes place, Section "B" (sludge return zone) and Section "C" (clarification zone). Equipped with fine bubble diffusers, aquakril brand recirculation pump and RESUN model air pump, AC-9602, AC 110~60Hz-5 W, Pressure: 0012MPa and capacity 3.5 L/min (figure 1).

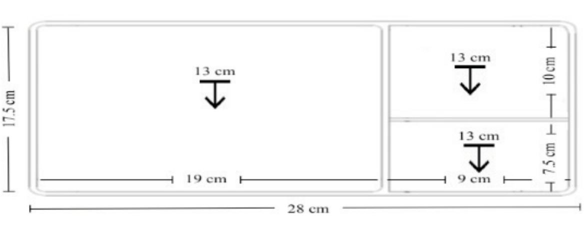

Figure 1. *Activated sludge reactor scheme.*

Table 1 shows the operating conditions of the reactor with continuous feed flow, in the different runs in which the experiment was carried out.

Experiment	I	II	III	IV
Bv (kgDQO/m^3·d)	10.9 ± 0.04	8.7 ± 0.03	13.1 ± 0.01	7.5 ± 0.1
HRT (days)	1.76	1.76	1.76	2.81
OD (ppm)	2.5	2.5	1.5	1.5

***Table 1.** Activated sludge reactor operating conditions*

Bv: organic load, TRH: hydraulic retention time, OD: dissolved oxygen

DESCRIPTION OF THE EXPERIMENTS

Before addressing the analysis of the results, Table 2 presents the averages of the main parameters evaluated in 2 batches of 10 L of phenolic wastewater, from which the activated sludge reactor feed was prepared during the experiments; I, II, III and IV, that through calibration curves, a dispersion is observed in the data, due to the variability that the phenolic wastewater presents during the different sampling periods.

Parameter	Experiment	
	M1 (I, II y III)	**M2** (IV)
DQO (g/L)	76.99 ± 2.85	84.48 ± 0.9
Fenol (g/L)	14.15 ± 4.35	15.63 ± 1.6
pH	6.56 ± 0.19	6.65 ± 0.14
ST (g/L)	0.32 ± 0.2	0.25 ± 0.1
SV (g/L)	0.19 ± 0.1	0.19 ± 0.08

***Table 2.** Characteristics of industrial wastewater samples with phenol*

M1: Residual water from which the reactor feed was prepared (experiments I to III).

M2: Residual water from which the reactor feed was prepared (experiment IV).

Table 3 shows the characteristics of the wastewater fed to the biological reactor throughout the study, according to the dilution rates tested based on the COD and phenol concentration of the wastewater samples from the polymer resin industry.

Parameter	Experiment			
	I	II	III	IV
DQO (g/L)	19 ± 0.1	15 ± 0.1	23 ± 0.2	21 ± 0.1
Fenol (g/L)	3.9 ± 0.04	3.4 ± 0.2	4.3 ± 0.4	2.7 ± 0.4
pH	6.71 ± 0.08	6.7 ± 0.11	6.7 ± 0.14	6.7 ± 0.1
ST	0.35 ± 0.3	0.57 ± 0.2	0.23 ± 0.06	0.21 ± 0.16
SV	0.21 ± 0.15	0.28 ± 0.09	0.16 ± 0.05	0.13 ± 0.07

***Table 3.** Characteristics of the wastewater fed to the biological reactor.*

RESULTS AND DISCUSSION

CHARACTERISTICS OF PHENOLIC WASTEWATER AFTER TREATMENT

Table 4 shows the averages of the main parameters evaluated for the treated water, under the reactor operating conditions tested.

Parameter	Experiment			
	I	II	III	IV
DQO (g/L)	12 ± 5	12 ± 1.6	15 ± 2.9	13 ± 3.7
Fenol (g/L)	2.5 ± 0.5	2.6 ± 0.3	2.6 ± 0.6	1.7 ± 0.4
pH	7 ± 0.12	7.23 ± 0.22	7.27 ± 0.14	7.28 ± 0.13
ST	0.82 ± 0.35	0.28 ± 0.09	1.2 ± 0.21	0.54 ± 0.34
SV	0.69 ± 0.25	1.19 ± 0.45	0.73 ± 0.13	0.52 ± 0.16

***Table 4.** General characteristics of treated wastewater (effluent).*

pH PROFILE

Figure 2 shows the pH profile of the mixed liquor from the activated sludge reactor. The black rhombuses represent the pH in the influent and the gray rhombuses represent the pH of the effluent. And it can be seen that during the first 16 days of operation (experiment I), the pH of the reactor was of the order of 7 ± 0.12. It can be seen that during the next days of operation (experiments II to IV), an average pH value of 7.26 ± 0.17 is reached; which allowed the reactor to not present any inhibitory effect or disturbance that would affect its performance on the biodegradation of phenol under the tested operating conditions.

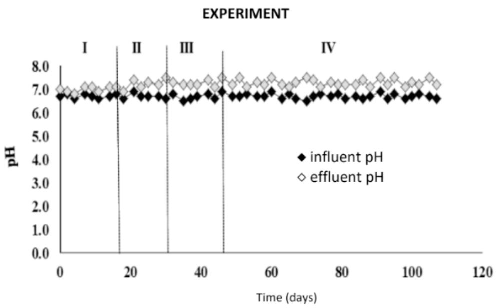

Figure 2. *pH profile of mixed liquor from activated sludge reactor.*

Influent (◆) and effluent (◇)

It is evident that the effects of pH are reflected in the enzymatic activity of microorganisms. The general ways in which pH influences microbial activity can be summarized as follows; 1) change in the hydrolyzable groups of the enzymes (carboxyl groups and amines) and 2) alteration of the non-enzymatic compounds of the system (ionization of the substrate, denaturation of the protein structure of the enzyme). To these effects of pH, the concentration of H+ must be added, which influences the different chemical, biochemical and biological reactions that occur in this system. It is reported that at extreme pH values (less than 3 or greater than 9) it can be inhibitory to the growth of microorganisms involved in the biodegradation of phenol (El-Naas et al, 2009).

COD REMOVAL EFFICIENCY

Figure 4 shows the COD removal efficiency according to the tested operating conditions (Table 1). The black diamonds represent the COD of the influent and the gray diamonds represent the COD of the effluent. And it can be seen that during the first 16 days of operation at a dilution rate of the M1 fed sample (Table 2) of 25% (v/v) with a COD of 19 ± 0.1g/L, organic load (Bv) of 10.94 ± 0.3 KgCOD/m3.d, hydraulic retention time (HRT) of 1.76 days and dissolved oxygen (DO) rate of 2.5ppm (experiment I), due to the instability of the system due to the presence of phenol in the waste water, the COD removal efficiency gradually decreased until reaching a low removal rate (15%). Reason why the feed was reduced to 20% (v/v) of phenolic wastewater to the biological reactor at the same TRH and DO conditions (experiment II) with a COD of 15 ± 0.1g/L, and organic load of 8.7 ± 0.03 KgCOD/m3.d, which improved the COD removal efficiency (40%). Based on these results, it was decided to increase the v/v ratio of M1 to 30% (COD: 23 ± 0.2 g/L and Bv: 13.11 KgCOD/m3.d) with a TRH similar to that of experiments I and II, but lower DO concentration at 1.5ppm (experiment III), and a gradual decrease in COD removal efficiency is observed (18%) during the last days of operation. In order not to affect the aerobic biomass, the dilution rate of the phenolic wastewater fed was reduced by 25% (v/v), which represented a COD of 21 ± 0.1 g/L and organic load of 7.5 KgCOD/m3.d. maintaining the DO feed at 1.5ppm, but increasing the TRH (2.81 days), in order to give sufficient time to the bacterial consortium of the reactor against phenol as the only carbon source and achieve greater COD removal efficiency. Which significantly improved the COD removal efficiency (55%).

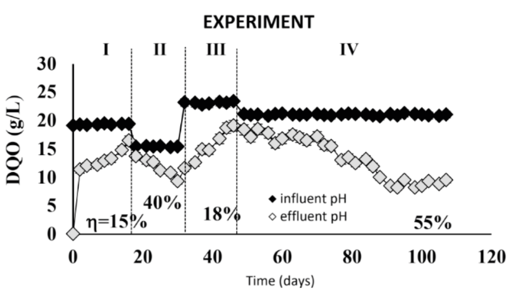

Figure 4. *COD removal in the activated sludge reactor.*

Influent (◆) and effluent (◇)

PHENOL BIODEGRADATION

Figure 5 shows the phenol degradation profile, the black diamonds represent the concentration of phenol in the influent and the gray ones, the remaining phenol in the reactor effluent. The operating conditions of the activated sludge biological reactor are shown in Table 1, and the conditions of the feed medium throughout the study are shown in Table 3. And it is observed that during experiment I, at 25% (v/v) of phenolic wastewater fed to the activated sludge biological reactor, with a phenol concentration of 3.9 ± 0.04, which during the first 14 days of operation, a phenol biodegradation efficiency (47%) is achieved that gradually decreases (eleven%). The decrease in the biodegradation capacity of phenol by the aerobic biomass of the reactor as a consequence of the toxic nature of phenol causes the biomass to be inhibited, which causes its biodegradation capacity to decrease. Based on these results, the dilution rate is reduced by 20% (v/v) of phenolic wastewater fed to the reactor (experiment II), with a lower contribution of phenol in 3.4 ± 0.2 g/L at 1.76 days of TRH and OD concentration of 2.5 ppm, which improved the phenol biodegradation efficiency (38%). As a result, it was decided to increase the dilution rate of phenolic residual water fed by 30% (v/v), which resulted in a phenol concentration in the feed of 4.3 ± 0.4 g/L (experiment III) at same TRH but different DO feed (1.5ppm). Under these operating conditions, a gradual decrease in the phenol biodegradation efficiency is observed (26%), so it is decided to reduce the dilution rate to 25% v/ v, which represented a fed phenol concentration of 2.7 ± 0.4g/L (experiment IV). During this last experimental stage, the DO supply to the biological reactor was conserved (1.5 ppm), but the TRH was increased (from 1.76 to 2.81 days). These new operating conditions of the studied system are tested for several reasons: 1) to reduce aeration costs due to energy consumption by the air blower by decreasing the DO flow from 2.5 to 1.5ppm and 2) by lengthening the TRH, The biodegradation efficiency of phenol is probably improved by increasing the contact time between the biomass and the substrate (phenol as the only carbon source), once the biomass acclimatizes to the presence of phenol throughout the experiment and 3) Evaluate which of the two variables has the greatest effect on the phenol biodegradation rate. And under these operating conditions of the system studied, a significant improvement in the phenol biodegradation efficiency (49%) is seen. To achieve adequate biodegradation efficiency of phenol from industrial wastewater through biological processes, it is recommended to acclimate the biomass of the biological reactor to the toxic compound to be biodegraded (Ba, Jones and Cabana, 2014; Terreros, Guzman and García, 2022). Under aerobic respiration conditions, phenol can be converted into a harmless compound (Ahmed, Rasul, Martens, & Brown, 2012).

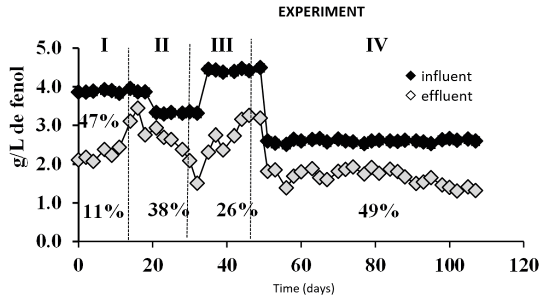

Figure 5. *Biodegradation profile of phenol in the activated sludge reactor.*

Influent (◆) and effluent (◇)

CONCLUSIONS

The challenges we must address are: promote the will, awareness, human value and desire to preserve and conserve natural resources, the environment and our planet. With clean technologies for treatment and reuse such as the one studied and contribute with this research, not only to scientific knowledge, but also as a proposal for reuse and replacement of drinking water with treated water, in those industrial processes that do not require it.

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