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EVALUATION OF ACTIVE SLUDGE AND AQUATIC FERNS USAGE FOR REMOVAL OF ZINC IN A BIOLOGICAL WASTEWATER TREATMENT SYSTEM

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Abstract
In this research capability of biological treatment method via active sludge and aquatic fern evaluated in different operating conditions and they were optimized in order to remove Zn (II). A simple reactor performance for treatment of model and real wastewater on laboratory and semi-industrial scale was investigated. This refining process proceeded with special attention to the effect of solution pH-value, pollutant concentration, absorbent concentration and reaction time. The batch semi-industrial scale reactor represented over 90 % removal efficiency under pH-value of 6 and 5-5.5 for aquatic ferns and active sludge, respectively. Effective reaction times represented various durations for aquatic ferns and active sludge with respect of 120 minutes and 90 minutes. The two biological masses had the best performances with 6 g/l for aquatic ferns and 5 g/l for active sludge. In the presence of 5 ppm of Zn (II) as the objective heavy metal, both absorbents had over 93.2 % removal efficiencies. While obviously laboratory-scale attempts introduced higher acceptable reduction efficiencies via this economic applicable treatment method. Additionally, economic considerations clarified feasibility of this recommended simple method.

Keywords*: active sludge, aquatic ferns, wastewater treatment, zinc*

Introduction
Increasing worldwide population and variety of industrial means as well as decreasing natural resources of water and soil and climate change problems have risen international concerns. Unfortunately, industrial growth has a deep adverse effect on environmental conditions while it improves human welfare. Different categories of industries discharge various contaminants which are recalcitrant and non-biodegradable in most cases such as phenols, aromatics, dyes, nitrates and etc. These pollutants can change environmental characteristics of natural resources that fresh up applications of modern environmentally friendly approaches for treatment strategies (Amir 2017, Amir & Gevorg 2014).
There are fateful criteria namely health, hygiene, economy and food safety which are affected wildly by lack of water resources. Besides reuse of polluted waters after treatment methods face difficulties while they are contaminated with recalcitrant heavy metals and their derivatives in various chemical and industrial processes which cannot be removed effectively (Helmseresht & Delpisheh 1997, Allah-Qoli 2007). Heavy metals have been identified as the most poisonous compounds (Allah-Qoli 2007) with different categories of Al, Zn, Co, Cu, Pb, Mn, Ni, Ti, Sn, Fe and etc. while they have represented deep poisoning characteristics in high dose values

in human food chain (Karamad 2010, Erfani-Manesh & Afuni 2006). Also surface and underground water resources can be in danger easily by heavy metals compounds (Allah-Qoli 2007). In the case of treatment of heavy metals from wastewater, different refining methods introduced like chemical sedimentations, reverse osmosis, ion exchange, solvent extraction and etc. These foregoing methods could lead to some undesirable results similarly to great initial investment, special operating conditions, expensive initial apparatus and specially production of hazardous chemical sludge in some cases. Biological absorbents can overcome most of these unfavourable outputs while represent great performance capabilities. The importance of these methods was recommended wildly because of high efficiency and low volume of biological and chemical sludge, revival of biological mass and recovery of heavy metals (Fouladi-Fard et al 2004). Although their removal efficiency is definitely affected by reactor structure, wastewater properties and type of absorbent. It should be mentioned that acceptable quality levels of water in any industry refer to the one that has the lower treatment costs with respect of remedy costs because of its impurity effects (Mansour-Panah & Kakanezhadie-Kherad 2015).

On the other hand, lack of adequate research studies is sense wildly and still needed for more clarifications in this field of research especially in semi-industrial scale (Marchioretto 2003). This article expounded real operational characteristics of aquatic fern and active sludge for treatment. Aquatic fern grows naturally in lagoons as an aggressive spice with suitable capability of refining properties in its living and non-living states.

Materials and Methods

As it was mentioned followings are the two categories of attempts; laboratory and industrial experiments for model and real effluents.

Laboratory scale: Applying a jar testing apparatus was the first attempt in laboratory scale and optimization of four different factors by a routine procedure was the further goal. So industrial attempts built on the optimizing of aforementioned parameters. There are pH-value, reaction time, and absorbent and pollutant concentration that had to be evaluated and optimized. All experiments arranged based on Table 1 for optimization and data provided for industrial part. All experiments carried out in 13 cylindrical vessels of 1000 ml by volume and fed with absorbent, a contaminant (Zn (II)) and wastewater. Both ferns and active sludge had prepared before experiments carried out. In the case of ferns, fresh ferns were collected from lagoons then they were dried and grinded for 2mm by diameter particles. Thereafter it had to be washed and refluxed by sulphuric acid 0.2 normal and then by NaOH 0.1 normal. By drying ferns under 60 ˚C, specific weight of absorbent achieved. It is necessary to mention that optimization carried out step by step as shown in Table 1. Each parameter optimized and set for further factors' optimization. Further more active sludge was supplied in the required content. It was dried and grinded as well as the ferns. However, in the case of treatment of real effluent the ferns and active sludge charged 6 g/l and 5 g/l, respectively. This sample contained 1.5 mg/l contaminant with initial pH-value of 6.8. It was agitated for 120 minute and 90 minute, respectively in the case of the fern and active sludge. All collected samples analysed via spectrophotometer apparatus.

Table 1. Parameters operational levels in laboratory scale

Factors	Understudying ranges	Optimum value
Ferns		
pH	2-8	3.5
Time(min)	30-240	120
Absorbent concentration (g/l)	2-7	6
Pollutant concentration (ppm)	50-230	200
Active sludge		
pH	2-8	3.5
Time(min)	30-240	90
Absorbent concentration (g/l)	2-7	5
Pollutant concentration (ppm)	50-230	200

Semi-industrial scale: In these experiments all models and real effluents agitated via 30, 50, 100 and 150 rpm by the pilot system which was designed. For the model, wastewater pH-value and pollutant concentration arranged on 5 and 2 ppm, respectively for the two absorbents. But the ferns fed 500 grams and agitated 120 minutes versus active sludge charging of 600 grams with reaction time of 90 minutes. Treatment of real wastewater carried out with 500 grams of active sludge while contaminated with 1.5 ppm of pollutant under residence time of 90 minutes. But in the case of the ferns, 600 grams of absorbent was charged and the reaction carried out in 120 minutes. As it was mentioned earlier all optimized parameters of earlier stage arranged in this part and absorbents performance was evaluated.

Results and Discussion

Individual Effect of PH-Value: Incrementing trend of removal efficiency by increasing of pH-value raised by availability of negative charge groups as PO_4^{-3} on the cellular surface of the absorbent. Accordingly, Zn^{+2} was absorbed via negative charge functional groups on the absorbent surface. At low values of pH, removal efficiency decreased because of excess amount of H^+ ions and intense acidic environment. Because there is a deep competition between Zinc cation ions and H^+ ions in connection with negative charge functional groups.
However, it was not possible to increase pH-value more than 7 for this heavy metal while it was removed by sedimentation in the form of hydroxide and the effect of biological absorbent could not be surveyed (Shokoohi et al. 2009), similar to all metal cations for pH-values more than 5 with different rates (Wu et al. 2012). However higher values of pH represented better results since production of OH^- and Zn^{+2} enhanced removals, so ferns had removal efficiency of 98.8 % at pH-value of 6 and active sludge showed 90.8 % efficiency at pH-value of 5-5.5.

Individual Effect of Absorption Time: As it is depicted, optimum reaction time was 120 minutes and 90 minutes for the ferns and active sludge, respectively. But it can be seen that for the ferns, reduction phenomenon reached to equilibrium values faster and in the case of active sludge it was reduced at latter times. Influence of type and size of heavy metal ions, active group structures on the absorbent surface and number of collisions between heavy metal and absorbent on removal time and efficiency could not be negligible. Sharp slop of reduction in the first minutes could be explained via existence of active functional groups on the cellular surface of the absorbent. While after a specific time it saturated and removal efficiency faced reduction (Wu et al 2012).

Individual Effect of Absorption Concentration: There is a direct relationship between removal efficiency and absorbent concentration. But at high values of biomass, undesirable coalescence happens and inhibits availability of absorbent active sites (Khosravi et al 2005). In the case of the ferns, efficiency of 98.8 % attained at 6 g/l and for active sludge 5 g/l of absorbent removed heavy metal up to 93.2 %. There was a sharp ascending trend for the ferns at concentrations above 4 g/l, but in the case of active sludge absorbent concentration did not have any particular effect on removal.

Individual Effect of Pollutant Concentration: It was found that Zn (II) concentration was generally low even in real plating wastewaters as in the range of 10-20 ppm (Zhao et al 1999). So in this research low concentrations were evaluated. Increasing initial concentration of the heavy metal could enhance production of metal ions in the solution so competition for absorption increased between ions.
Furthermore, all active sites on the absorbent surface activated and removal efficiency increased. In the case of both absorbents there were not any significant changes in the aforementioned evaluated ranges and it was observed that removal efficiency decreased by rising pollutant concentration. 5ppm showed the best results for the ferns and active sludge by 99.6 % and 93.2 % removal efficiency, respectively.

Absorbent Removal Capabilities in Real Wastewater for Laboratory Scale: Evaluation of absorbents capabilities for real wastewater treatment conducted while all previous parameters optimized and method efficiency investigated in the presence of 1.5 ppm of Zinc ions in pH-value ranges of 6.5-7. Also repeatability of results evaluated three times. In the case of real wastewater treatment, removal efficiency obviously deceased while active sites of absorbents were interfered by other pollutants unless selectivity of objective contaminant occurred (Amiri 1999). Some interfering ions inhibited absorption of Zinc ions, so efficiency descended to 93.6 % and 90.1 % for the ferns and active sludge, respectively.

Absorbent Removal Capabilities in Real and Model Wastewaters for Industrial Scale: In this part of the study, first of all agitation speed optimized in laboratory scale as 150 rpm for 1 litre of solution and in the case of industrial scale determinations carried out by Reynolds calculations. By the following graphs, Fig. 1 & Fig.2, it can be seen that agitation speed of 50 rpm indicated the best results and lower speeds could not provide suitable dispersion. Also higher speeds were definitely led to weaken great absorption and provided negative breakage on the fluid surface. By the ferns absorbent, zinc ions removed over 93.2 % in model wastewater and 88.5 % for real fluent. However active sludge provided weaker performance of 89.5 % and 85.6 % for model and real effluent, respectively. In fact, for both absorbents removal performance decreased in the case of real effluent as it was expected.

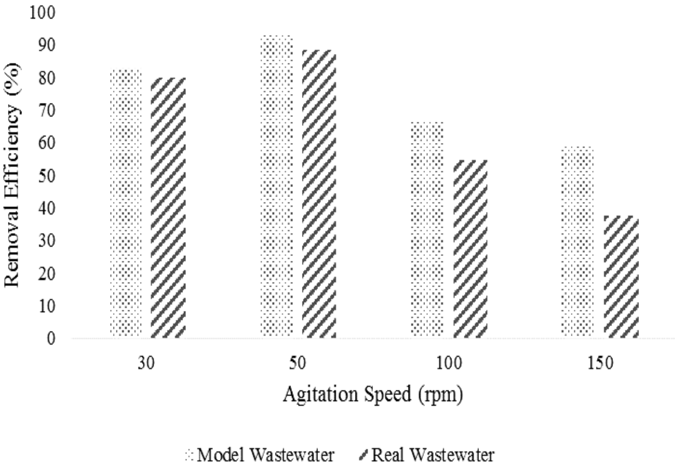

Figure 1. Zn (II) removal efficiency by fern absorbent in industrial scale

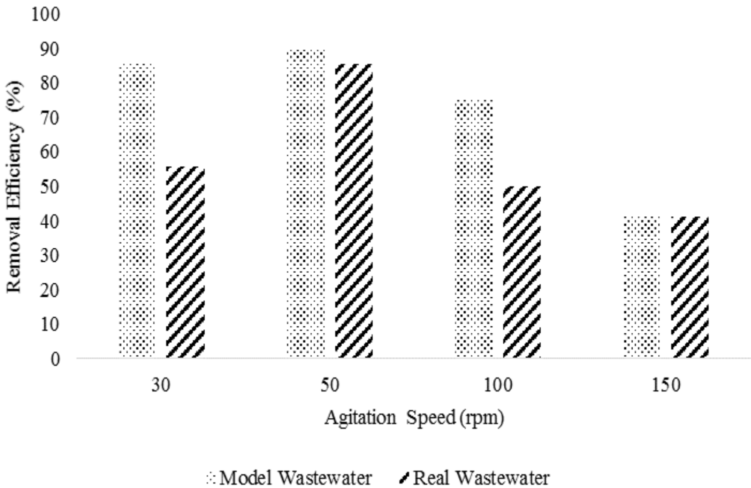

Figure 2. Zn (II) removal efficiency by active sludge absorbent in industrial scale

Conclusions

Overcoming to many dangerous effects of introducing heavy metals to the environment can be carried out by applying different applicable treatment methods as done in this research. Hence, capabilities of two biological absorbents, aquatic ferns and active sludge investigated and optimized. By the industrial results, zinc could be removed effectively in a more time consuming process by 6 g/l of ferns under agitation speed of 50 rpm (88.5 %) -better results were attained in comparison with active sludge- and active sludge represented a bit weaker performance which had pollutant removal by 85.6 % from the real effluent. Finally, it can be mentioned that the two biological absorbents had suitable efficiencies while they were economic environmentally friendly approaches.

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