

Full Paper

Water Hyacinth Roots as Economic Potential Biomass for the Removal of Organic Pollutants in Wastewater via Application of Coated Wire Electrodes

Safa'a M. Riad^{1,*} and Nouruddin W. Ali²

¹*Pharmaceutical Analytical Chemistry Department, Faculty of Pharmacy, Cairo University, Kasr El-Aini St., 11562, Cairo, Egypt*

²*Pharmaceutical Analytical Chemistry Department, Faculty of Pharmacy, Beni-Suef University, Alshaheed Shehata Ahmad Hegazy St., 62514, Beni-Suef, Egypt*

*Corresponding Author, Tel.: +2-01068802592; Fax: +2-35635145
E-Mail: s.mohany02@gmail.com

Received: 18 September 2012 / Accepted: 14 October 2012 / Published online: 30 October 2012

Abstract-The applicability of Water Hyacinth (*Eichhornia crassipes*) as an important aquatic weed plant in sub-tropical regions of the world makes it a useful bio-accumulator and bio-sorbent for some organic pollutants including phenolic pollutants and some nitrogenous organic pollutants from wastewater. The experimental conditions upon using the investigated biomass were optimized to achieve a reduction of the chemical oxygen demand (COD) and the total organic carbon (TOC) by about 90%. Also the sorption of the reported pollutants was examined as a function of its initial concentration in wastewater, pH, weight of roots and contact time. The concentration of phenolic pollutants and nitrogenous organic compounds in influent and effluent of wastewater and in the collected water samples were monitored using several coated wire ion selective electrodes (ISEs). Each ion selective electrode is designed specifically to monitor one type of pollutants. The results obtained using the dried roots of water hyacinth is compared to that obtained when a granular activated carbon (GAC) is used. Preliminary results show that the outlet of the purification biomass meets most of the regulator's limits for discharge of treated wastewater in Egypt. Therefore, the treated effluents can be used safely in different applications such as irrigation of golf course, green way or park. If it is sufficiently clean it can also be used for ground water recharge, in recharging of batteries or in some industrial use. Moreover, such water hyacinth roots can be used as an effective tool for the treatment and reuse of wastewater as they have been shown to adsorb and accumulate toxic elements.

Keywords- Water Hyacinth roots, Ion-Selective Electrodes, Phenolic Pollutants, Nitrogenous Organic Pollutants

1. INTRODUCTION

During the decade, there has been growing concern that the world crisis, such as desertification. The greatest warnings were that upcoming conflicts and wars in the region might be over water and live hood. Water reuse has been dubbed as the greatest challenge of the 21st century, and a paradigm shift from effluent disposal to water reuse is needed. Egypt is a water scarce area facing the dilemma of limited water and growing population; forcing the need for agricultural expansion to insure food security. Thus; it is imperative to develop sustainable water resources for agricultural expansion, protect underground water from pollution and reuse of treated water for some industries like manufacturing of batteries. Parallel to that we are facing in our society a big problem from the dense populations of Water hyacinth (*Eichhornia crassipes*) which is an important aquatic weed plant of sub-tropical regions of the world [1]. It renders water ways unavailable, reduce water flow and restrict commercial fishing. On the positive side, it was reported that nonliving dried roots of water hyacinth can be used as an adsorbent (without pretreatment) for the removal of methylene blue and Victoria blue [2]. Also it successfully absorbs and accumulates toxic elements from aqueous solutions [3-8]. It was also used as a scavenger of heavy metal pollutants in the Lake Chivero and its associated rivers in Zimbabwe [9]. The sorption mechanisms of these elements occur via the root system in substrate water that was contaminated and via the leaves that were exposed to atmospheric deposition [8].

Ranking pollutant according to their severity to public health and the environment put pathogenic microorganisms at the top. This is followed by organic compounds; including phenolic and nitrogenous organic compounds which biodegrade and depletes dissolved oxygen, rendering water unsuitable for many purposes [10].

The aim of this work is to investigate *Eichhornia crassipes* roots as a candidate bioaccumulator and biosorbent for the removal of the stated pollutants in the collected wastewater samples and its applicability as a cheap commercial tool for wastewater treatment.

Furthermore, the concentrations of nitrogenous organic pollutants were determined for the first time using a specific coated wire ion selective electrode in the collected wastewater samples. In addition, phenolic pollutants were also determined in the samples. Moreover, the results obtained using the dried roots of water hyacinth is compared with that obtained when a granular activated carbon (GAC) is used. By the usage of this plant as a bio-sorbent one have the benefit of removing various pollutants from wastewater also limiting its previously mentioned problems.

2. EXPERIMENTAL

2.1. Equipments and Instruments

-Ionic total organic carbon analyzer 15555B. Hamilton syringe 100 μ L. (For TOC measurement)

-Schimadzu, UV-1601 PC, UV-Vis spectrophotometer, Digestion vessels, oven and Bandelin sonrex, RX5105, magnetic stirrer. (For COD measurement).

-Thermostatic shaker Schutzart DIN 40050-IP 20, 1 Nenn temp: 100 °C, Type: WB 14.

-Potentiometric measurement at 25°C were made with an Orion digital ion-analyzer model 720A using membrane sensors in conjunction with an Orion 90-02 Ag/AgCl double junction reference electrode containing 10% (w/v) KNO₃ solution in the outer compartment. Adjustment of pH was made with an Orion 91-20 combination glass electrode.

2.2. Reagents

All chemicals were of analytical reagent grade (AR) unless otherwise stated, CO₂ free water and deionized water was used throughout. A phenanthroline-iron (II) sulphate solution was prepared by dissolving 100 mg of 1,10-phenanthroline in 20 ml of 2×10^{-2} M ferrous (II) sulphate solution, followed by drops of ethanol or water to keep the solution clear. Sodium tetraphenylborate (NaTPB) 99.5%; Aldrich, Tetrahydrofuran 99%; Adwic, Poly (vinyl chloride) high molecular weight (10,000); dibutyl phthalate (DBP), dioctyl phthalate (DOP), dioctyl sebacate (DOS) and tricresyl phosphate (TCP) were used as received from Aldrich .

2.3. Procedures

2.3.1. Procedure for TOC and COD

The combustion- infrared method [11] was used for the evaluation of TOC for the collected water samples. On the other hand, the WHO standard methods for the examination of water and wastewater [11] were used for the determination of COD using dichromate in sulphuric acid medium.

2.3.2. Preparation of phenol ion association complex and Aniline ion association complex

5 mL aliquots of 1.0 M aqueous phenol and aniline were separately mixed with 5 mL of 1,10-phenanthroline-iron (II) solution and NaTPB solution after mixing with 0.5 mL of 0.1 N NaOH and HCl; respectively and shaking for 5 min. The precipitates formed were filtered off on Whatman No. 42 paper, washed with cold water, dried at room temperature and ground to a fine powder.

2.3.3. Preparation of microcoated wire sensors

Ten mg portion of each of the previously named ion pair was mixed with 350 mg of DOP plasticizer and 190 mg of PVC powder and dissolved in 5 mL of THF. The solution was poured into Petri dishes (5 cm diameter) and then the following procedure was followed:

The Petri dishes were covered with filter paper and left to stand for one hour to allow slow evaporation of the solvent, producing the master thick PVC solution. The covers were removed for a length of about one cm at both ends of an insulated platinum wire. One end of the wire was immersed in the previously prepared PVC solution and was left to stand for 10 min to allow complete air drying, forming a thin membrane around the wire end.

Immersing and air drying of the wire were repeated until a globular membrane of about 3 mm diameter around the wire end was formed. The resultant coated wire membrane sensors had to be conditioned by soaking in 1.0×10^{-2} M of the previously named pollutant solution for 3 h and had to be stored in the same solution when not in use [12].

The potential readings of stirred 1.0×10^{-2} - 1.0×10^{-7} M of the previously named pollutant solutions were measured at $25 \pm 1^\circ\text{C}$ and recorded after stabilization to ± 0.2 mV. A calibration graphs were constructed and used for subsequent measurements of the corresponding pollutants in the collected wastewater samples.

2.3.4. Sampling

More than fifteen sites distributed around almost all the industrial facilities located along the Nile River were selected for sample collection covering the upstream Nile branch Also effluents from these industrial facilities were collected. Table 1 shows the collected water samples located along the studied area. The method followed for the collection of these samples was a grab sampling using manual sampling [13].

2.3.5. Water samples

Two liters were collected in clean polyethylene screw caps containers acidified with 2 ml concentrated sulphuric acid/L to prevent the adsorption of the pollutants on the walls of the container. Then, the samples were stored in a refrigerator at 4°C until the time of analysis.

2.3.6. Sample preparation

Upon using ISE method, the e.m.f of the collected water samples was determined without previous preparation. The corresponding concentrations of these water samples were determined from the calibration curve of phenol and aniline and the total phenolic and nitrogenous organic pollutants contents were calculated as phenol or aniline in ppm; respectively as shown in Fig. 1.

Table 1. Location of the collected water samples

Sample Number	Location
Sample 1	Collected from the industrial effluents of Misr for production of spinning and weaving machinery (Helwan).
Sample 2	Collected from the industrial effluents of Misr Helwan spinning and weaving company.
Sample 3	Collected from the industrial effluents of paint and industrial chemical company (El Ameeria).
Sample 4	Collected from the industrial effluents of Cairo Company for dyeing and preparation (Ghamra).
Sample 5	Collected from the industrial effluents of Esco Textile Company (Shubra El Khema).
Sample 6	Collected from the industrial effluents of El Nasr Company for spinning, weaving and dyeing (El Mahalla).
Sample 7	Collected from the industrial effluents of Paint and Industrial Company (Alex.)
Sample 8	Collected from the industrial effluents of Dye Stuff and Chemicals (El Behara).
Sample 9	Collected from the industrial effluents of Middle Egypt Spinning and Weaving Company (El Menia).
Sample 10	Collected from the industrial effluents of National Plastics Company (Giza).
Sample 11	Collected from the industrial effluents of El Nasr Company for Rubber Products (Ghamra).
Sample 12	Collected from the industrial effluents of National Plastics for Batteries (Giza).
Sample 13	Collected from the industrial effluents of Abu Zaabal Company for fertilizers and Chemicals (Cairo).
Sample 14	Collected from the industrial effluent of EL-Nasr Company for manufacturing Coke & Basic chemicals in Helwan (before treatment).
Sample 15	Collected from the industrial effluents of Egyptian Leather Tanning Company (El Basteen).

2.3.7. Water hyacinth roots

Water hyacinth roots were collected from the River Nile at Rosette City, Egypt. The roots were cleaned thoroughly to remove dirt and the unhealthy parts were discarded. The roots were then rinsed in bidistilled deionized water and dried in oven at 80°C overnight, grounded and passed through a sieve of 1 mm size. The pulverized roots were then boiled using bidistilled deionized water to remove any soluble compound. Air dried samples were used throughout the experiments [9].

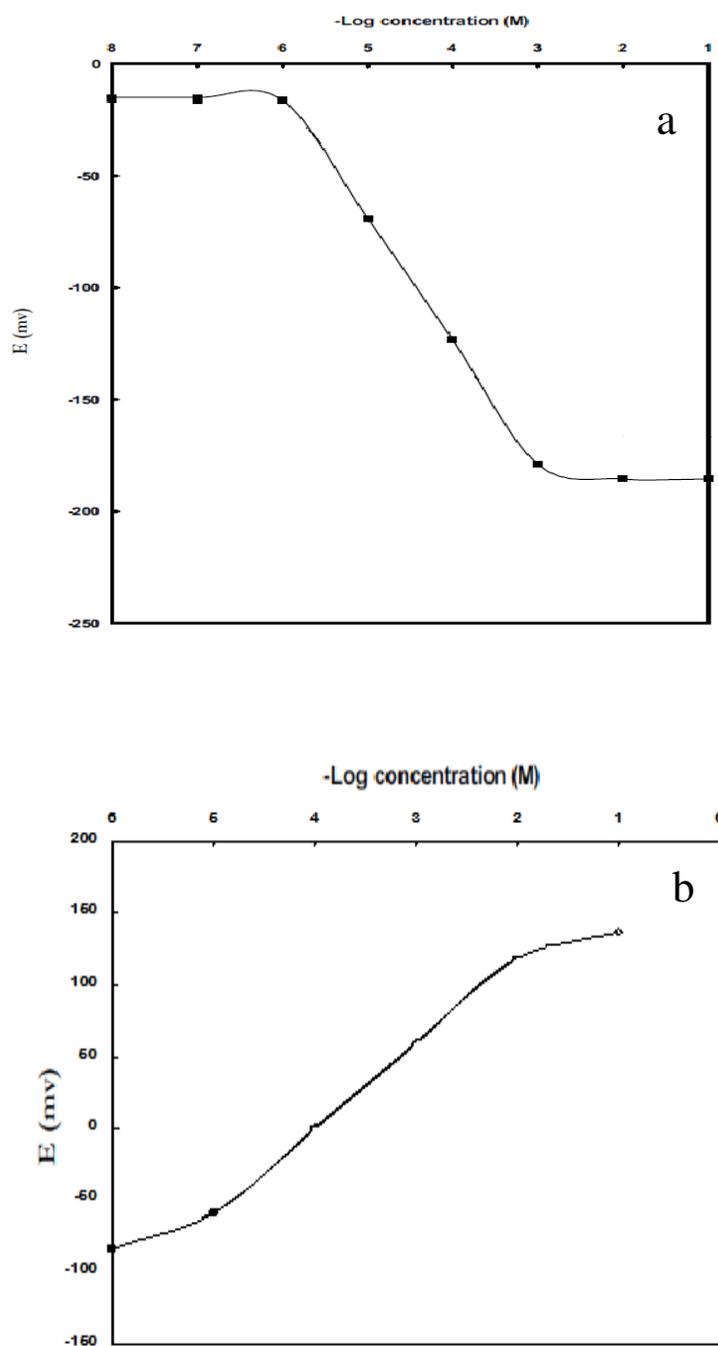


Fig. 1. Profile of the potential in mV vs. $-\text{Log concentration}$ of the determined phenolic pollutants [a] and nitrogenous pollutants [b] using the proposed sensors

2.3.8. Sorption experiments

The sorption of the investigated pollutants on roots was studied by the batch technique. One g of the roots was equilibrated with 20 ml of the pollutants aqueous solutions of known concentration in a stoppered Pyrex glass flask at 25 °C in a thermostated shaker water bath for 2 h. After sorption, the roots were separated by filtration and then the residual pollutants concentrations in the filtrates were determined using their corresponding sensor.

2.3.9. Effect of pH

The effect of pH on the sorption of either the phenolic pollutants or nitrogenous organic pollutants was investigated over the range from 2-12. One g of the dried roots was equilibrated in 20 ml of 100 ppm aqueous pollutants solutions and shaken for 2 h at (25±2°C) with oscillation rate 500 osc/min and the phenol or aniline concentration was determined using their respective coated wire ISE.

2.3.10. Effect of adsorbent weight

The effect of water hyacinth roots mass on the amount of removal of the studied pollutants was obtained by contacting 100 ml of 100 ppm aqueous pollutants solutions with different weighed amount (0.2-2 g) of water hyacinth roots in stoppered flask and the previous procedure was followed and the pollutants concentrations were determined by their respective ISE.

2.3.11. Effect of pollutants initial concentration

The effect of pollutants initial concentration on the amount of removal of the studied pollutants were obtained by contacting different concentrations of the pollutants solutions in the range of 20-100 ppm with 1.0 g of water hyacinth roots in stoppered flask and the previous procedure was followed and the pollutants concentrations were determined by their respective ISE.

2.3.12. Effect of contact time

The effect of contact time between studied pollutants and water hyacinth roots were investigated over the time range from 0-300 min. The previous procedure was followed and the pollutants concentration was determined by their respective ISE.

2.3.13. Adsorption equilibrium study

Equilibrium studies were carried out by contacting 1.0 g of water hyacinth roots with 20 ml of aqueous pollutants solutions of different initial concentrations (10, 20, 30, 40, 50, 60, 70, 80, 90, 100 ppm) in stoppered flasks. The samples were then shaken for 2 h at (25±2°C) with oscillation rate 500 osc/min and the phenol or aniline concentration was determined using their respective coated wire ISE.

3. RESULTS AND DISCUSSION

3.1. Development and optimization of the potentiometric method

Many sophisticated techniques were used for the evaluation of pollutants in wastewater such as chromatographic methods and others but we are concerned with clean environment and clean chemistry. All of the previous techniques require the use of hazardous solvents, but on the other hand, the performance of ion selective electrodes gives them important advantages over other techniques [14].

The advantages of the usage of ion selective electrodes include the ease of construction, rapid manipulation, low cost, fast response, wide concentration range, and applicability to turbid and colored solutions. Also sensor parameters look promising for the employment of the sensor in highly sensitive screening of the studied pollutants in field of analysis without delay time between sampling and measuring. The latter is an important aspect in view of the well known alteration of polluted water samples during storage. Moreover, the chemical design of the electrodes has been developed to give superior selectivity and response [14]. The investigated coated wire sensors consists of membrane of PVC/sensing system/mediator in ratios 34:2:64, without an internal reference system as there is a confident view that the coated wire sensors have an inbuilt reference system which is attributed to the permeability of PVC to both water and oxygen that sets up an oxygen electrode at the wire membrane interface to function as an internal reference system [15].

The potentiometric responses of the proposed electrodes at their respective optimum pH range at $25\pm 2^\circ\text{C}$ were linear with constant slopes over their corresponding concentration ranges. Typical calibration plots of the proposed sensors were shown in Fig. 1a&b. Applying the suggested sensors for the determination of studied pollutants showed near Nernstian responses about 60 and the results are shown in Table 2.

The potentiometric selectivity coefficients of the proposed sensors were calculated in the presence of related organic and inorganic substances using the separate solution technique [16]. The results given in Table 3 reveal that the proposed sensors can be successfully applied for the determination of either phenolic or nitrogenous organic pollutants in the presence of other anions, cations and related substances either organic or inorganic, which are commonly present in wastewater samples as pollutants.

3.2. Adsorption studies

In this work we studied the usefulness of water hyacinth as a bioaccumulator and biosorbent for the mentioned pollutants in wastewater samples.

Several factors which influence the studied organic pollutants sorption such as pH, pollutant concentration, contact time and weight of adsorbent were studied to investigate the removal process of these pollutants from the collected wastewater samples.

Table 2. Response characteristics for phenol and Aniline sensors

Parameter	Phenol sensor	Aniline sensor
Slope (mv.decade ⁻¹)	59.20	59.15
Response time (min)	1	1
Working range (pH)	9–10	4-6
Stability	4 weeks	4 weeks
Conc. (ppm)	0.94–94.11	1.296-129.59
Average recovery ^a (%)	99.74	98.79
RSD	0.29	0.427
Correlation coefficient	0.999	1

^aResults of five determinations

3.3. Effect of pH

The pH of the adsorption medium is one of the most important parameters affecting the adsorption process. Fig. 2 shows the effect of pH on the adsorption of phenol and aniline. From the figure, it was observed that the uptake of phenol by water hyacinth roots was almost constant in the pH range 2.5-5.0. Then the adsorption decreased with increasing pH and it was decreased from 8.0 ppm at pH 5 to 5.7 ppm at pH 9. The opposite is observed with aniline where the aniline adsorption on water hyacinth roots increases as the pH increase up to pH 4.5 where after the adsorption of aniline remains constant.

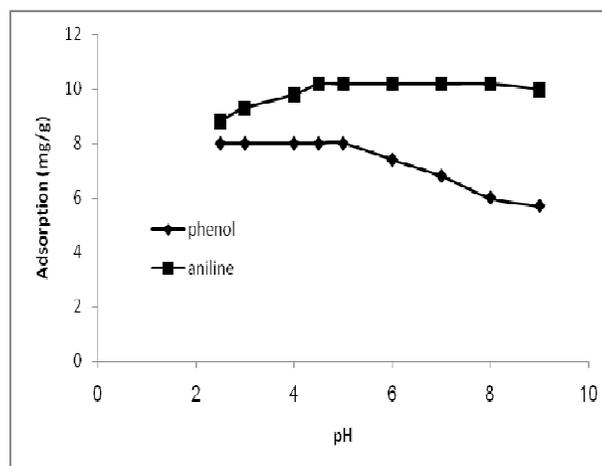


Fig. 2. Effect of pH on the adsorption of phenol and aniline on water hyacinth roots

Table 3. Potentiometric selectivity coefficients a (K pollutants, Interferent) for the proposed sensors

Interferent ^b	Phenol sensor	Aniline sensor
Ammonia	7.76×10^{-3}	4.89×10^{-3}
Urea	2.41×10^{-3}	1.01×10^{-3}
Pyridine	4.51×10^{-3}	2.01×10^{-3}
Methylamine	7.95×10^{-3}	8.61×10^{-3}
Ethylamine	2.90×10^{-3}	3.92×10^{-3}
Butylamine	3.19×10^{-3}	1.09×10^{-3}
Formaldehyde	3.11×10^{-2}	2.31×10^{-2}
Phenol	1	2.98×10^{-3}
Aniline	6.25×10^{-3}	1
<i>o</i> -toluidine	4.23×10^{-3}	3.34×10^{-1}
<i>p</i> -toluidine	5.30×10^{-3}	2.69×10^{-1}
2,5-Dimethyl aniline	1.08×10^{-3}	3.99×10^{-1}
2-chloroaniline	2.64×10^{-3}	1.96×10^{-1}
Nitrate	3.21×10^{-3}	2.11×10^{-3}
Sulphate	2.79×10^{-3}	3.75×10^{-3}
<i>p</i> -chlorophenol	3.46×10^{-1}	3.90×10^{-3}
Naphthol	4.51×10^{-1}	2.36×10^{-3}

^a Average of three measurements^b 10^{-3} M aqueous solutions were used

3.4. Effect of the weight of dried roots

The effect of root weight on the sorption of pollutants was investigated between 0.2 and 2 g of the dried roots. As shown in Fig. 3 a&b, the % removal of phenol and aniline increases by increasing the weight of the root from 0.2 to 1 g, due to the greater availability of the sorption sites at the roots. Then it remains constant up to 2 g due to the saturation of all available sites. This curve is similar to the sorption of methylene blue by water hyacinth roots [2]. On the contrary, the amount of phenol and aniline adsorbed per unit mass of water hyacinth roots decreases with the increase in adsorbent weight.

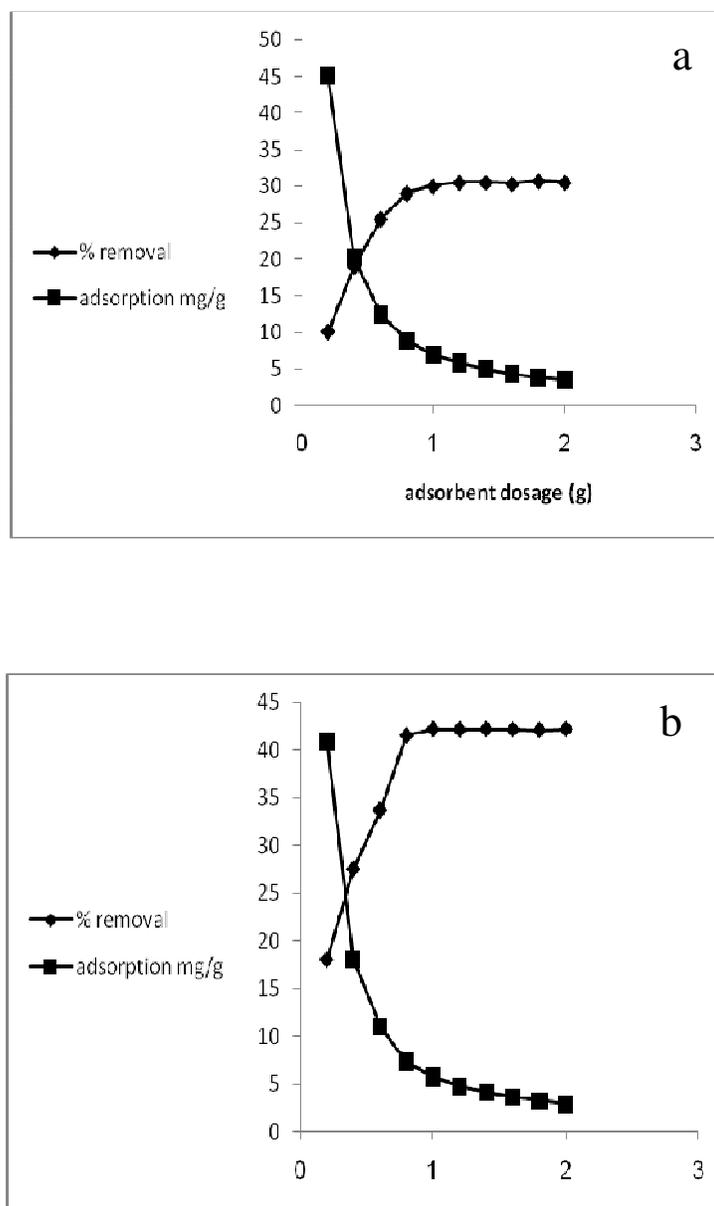


Fig. 3. Effect of adsorbent dosage on the adsorption of phenol [a] and aniline [b] on water hyacinth roots

3.5. Effect of the contact time and initial pollutant concentration

Fig. 4 a&b shows the adsorption data for the uptake of phenol and aniline vs. contact time at different initial pollutant concentrations. The obtained results indicate that an increase in initial pollutant concentration resulted in increase in the sorption over the investigated range (20–100 ppm.). The figures also show that equilibrium time required for the adsorption of pollutants on water hyacinth roots is almost 60 min (1 h). However, the samples were let for

2 h to ensure equilibrium in further experiments. The sorption of phenol and aniline from solution is fairly rapid. It almost reached a maximum after 30 min, and almost remained constant up to 300 min. A similar pattern of sorption was also noted in the sorption of copper by water hyacinth [17].

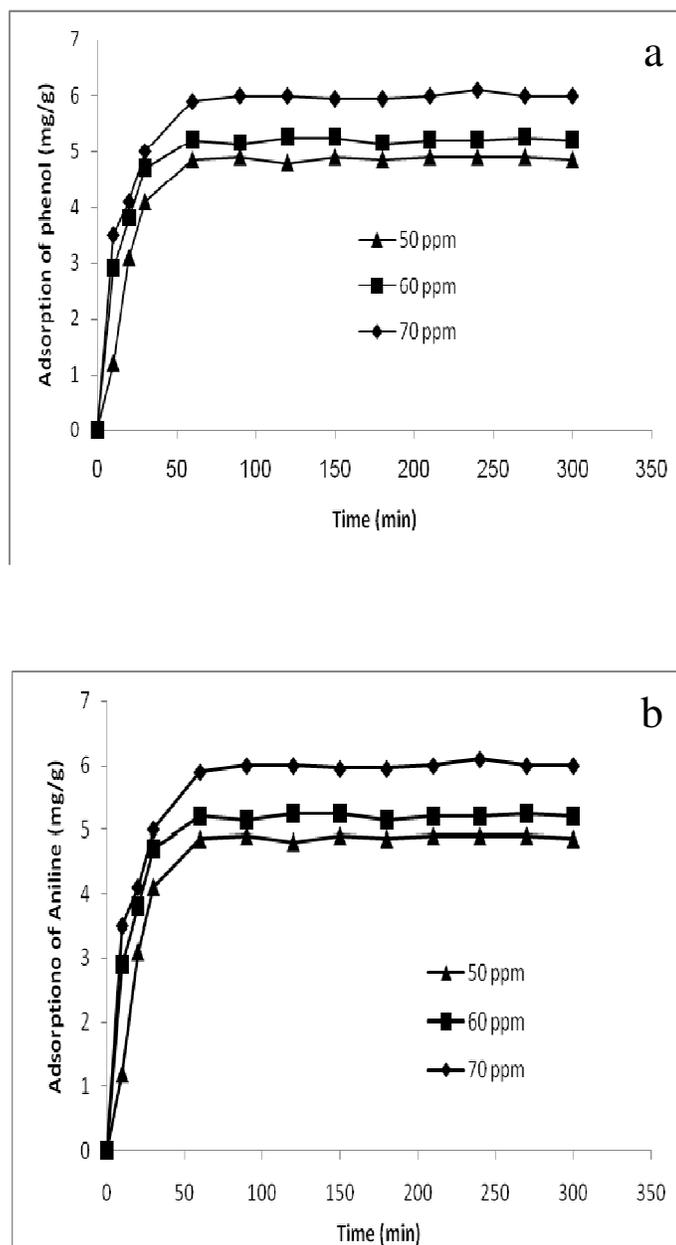


Fig. 4. Effect of contact time and initial concentrations on the adsorption of phenol [a] and aniline [b] on water hyacinth roots

These results indicate that up to 90-95% of the total amount of pollutants uptake was found to occur rapidly in the first 30 min, then thereafter the sorption rate decreases. This may be attributed to an increased number of vacant sites on the adsorbent available at the initial stage; as a result there exist increased concentration gradients between adsorbate in solution and adsorbate on adsorbent surface. This leads to an increase in pollutants sorption at the initial stages. As time precedes this concentration gradient decreases due to the saturation of the vacant sites with pollutants particles leading to a decrease in the sorption rate at the later stages from 30-300 min [18].

3.6. Adsorption Equilibrium

Equilibrium study on adsorption provides information on the capacity of the adsorbent. An adsorption isotherm is characterized by certain constant values, which express the surface properties and affinity of the adsorbent and can also be used to compare the adsorptive capacities of the adsorbent for different pollutants. Equilibrium data can be analyzed using commonly known adsorption isotherms, which provide the basis for the design of adsorption systems. The most widely used isotherm equation for modeling of the adsorption data is the Langmuir equation, which is valid for monolayer sorption onto a surface with a finite number identical site and is given by the following equation:

$$q_e = \frac{q_0 K_L C_e}{1 + K_L C_e}$$

Where q_0 and K_L are Langmuir parameters related to maximum adsorption capacity and free energy of adsorption, respectively. C_e is the equilibrium concentration in the aqueous solution and q_e is the equilibrium adsorption capacity of adsorbent. The linearized form of Langmuir equation can be written as:

$$\frac{1}{q_e} = \frac{1}{q_0} + \frac{1}{q_0 K_L} \cdot \frac{1}{C_e}$$

The Langmuir constants q_0 and K_L can be calculated by plotting $1/q_e$ vs. $1/C_e$. The Freundlich model is an empirical equation based on sorption on heterogeneous surface. It is given as:

$$q_e = K_f C_e^{\frac{1}{n}}$$

Where K_f and n are the Freundlich constants that indicate adsorption capacity and adsorption intensity, respectively.

The linearized form of Freundlich isotherm can be written as:

$$\ln q_e = \ln K_f + 1/n \ln C_e$$

The value of K_f and n can be calculated by plotting $\ln q_e$ vs. $\ln C_e$.

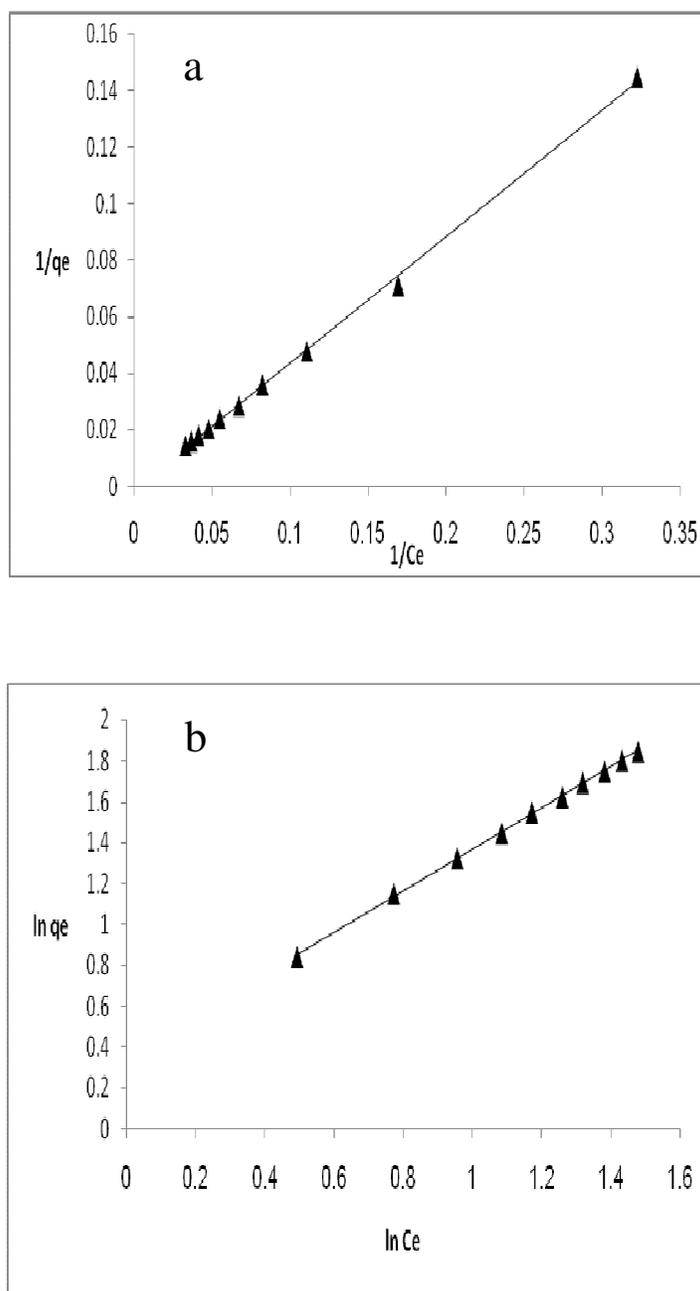


Fig. 5. Langmuir isotherm [a] and Freundlich isotherm [b] for phenol adsorption on water hyacinth roots

Fig. 5 a&b and Fig. 6 a&b show the Langmuir and Freundlich curves for phenol and aniline adsorption onto water hyacinth roots, respectively. The isotherm constants and correlation coefficients are shown in Table 4.

Table 4. Equilibrium constants for phenol and aniline adsorption on water hyacinth roots

Component	Langmuir isotherm parameters			Freundlich isotherm parameters		
	q_0 (mg/g)	K_L	r^2	K_f	n	r^2
Phenol	704.23	0.0032	0.9993	1.4241	1.0849	0.9997
Aniline	562.96	0.0020	0.9997	1.4177	1.0957	0.9998

From Fig. 5 and Fig. 6, it was observed that the equilibrium data were very well represented by the Langmuir as well as the Freundlich equation. The sorption equilibrium data fitted Langmuir and Freundlich equations with correlation coefficients values of 0.9993 & 0.9997 and 0.9997 & 0.9998 for phenol and aniline, respectively. The best fit of equilibrium data in the Langmuir isotherm expression predicted the monolayer coverage of both phenol and aniline onto water hyacinth roots. From Table 4 it was also observed that the maximum sorption capacity of phenol and aniline for water hyacinth roots was found to be 704.23 mg/g and 562.96 mg/g for phenol and aniline, respectively.

Table 5. Comparison between the results obtained upon using Water Hyacinth Roots and Granular Activated Carbon (GAC) for pure pollutant samples

Taken (ppm)	Water Hyacinth Roots				Granular Activated Carbon (GAC)			
	Phenol		Aniline		Phenol		Aniline	
	Found ^a (ppm)	Recovery%	Found ^a (ppm)	Recovery%	Found ^a (ppm)	Recovery%	Found ^a (ppm)	Recovery%
50	14.80	98.67	20.70	98.86	9.85	98.50	24.58	98.33
100	29.80	99.33	41.80	99.52	19.85	99.25	29.70	99.00
200	58.80	98.00	83.20	99.05	39.10	97.75	68.48	97.83
Mean± R.S.D	98.67±0.665		99.14±0.339		98.58±0.878		98.39±0.578	

^a Average of five determinations

Table 6. Determination of pollutants Content in the Collected Waste Water Samples a upon Using Water Hyacinth Roots and Granular Activated Carbon (GAC)

Sample No.	Water Hyacinth Roots Recovery (%) ^b RSD		Granular Activated Carbon (GAC) Recovery (%) ^b RSD	
	Phenol sensor	Aniline sensor	Phenol sensor	Aniline sensor
1	.....	99.23±0.43	.....	99.81±0.99
2	.....	99.25±0.51	.....	100.05± 0.33
3	99.45±0.43	97.16±0.31	99.51±0.11	99.51±0.11
4	101.31±0.51	99.72±0.63	99.01 ±0.25	98.41 ±0.20
5	.....	98.52±0.72	.....	99.96±0.63
6	97.35±0.26	98.31±0.16	100.41± 0.32	98.41± 0.09
7	97.04±0.44	97.11±0.12	97.60±0.66	98.11±0.82
8	98.06±0.95	97.99±0.38	100.01±0.15	99.35±0.78
9	.....	99.80±0.66	.....	99.63±0.17
10	98.20±0.74	.....	99.00±0.86	.....
11	98.48±0.29	.....	100.06±0.05	.....
12	98.08±0.22	.....	97.93±0.26	.....
13	.....	.....	.....	.....
14	100.11±0.66	.....	100.19±0.28	.....
15	99.84±0.50	98.52±0.71	98.66±0.39	98.96±0.49

^a The samples collected from the industrial effluents of different factories mentioned in Table 1

^b The results of at least three determinations

The results obtained using the dried roots of water hyacinth is compared with that obtained when a granular activated carbon (GAC) is used; Tables 5 & 6. As we can notice from these tables that GAC having greater sorption power than WH roots; about 80% and 70% for phenolic and nitrogenous pollutants, respectively. Activated carbon is the most widely used adsorbent. It has the advantage of high adsorption capacity for organic compounds, but its use is usually limited due to its high cost [19,20]. This fact and the increasing demand for naturally occurring Low-Cost Adsorbents (LCAs) makes the studies on WH of great interest. As shown in this study, WH roots have proven to be effective adsorbent comparable to GAC but of much lower cost, solving its national problem in our society and offer promise for the future.

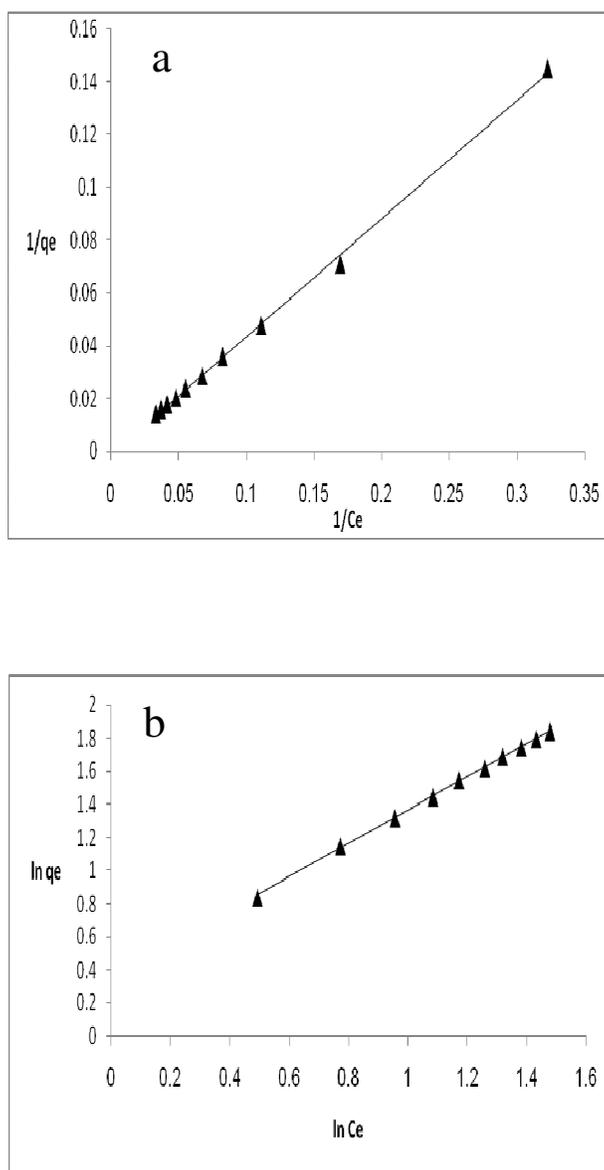


Fig. 6. Langmuir isotherm [a] and Freundlich isotherm [b] for aniline adsorption on water hyacinth roots

4. CONCLUSIONS

The described sensors offer advantages such as fast response and determination of organic pollutants in wastewater samples without pretreatment or separation steps. They can therefore, be successfully used for highly sensitive monitoring of the studied pollutants without delay time between sampling and measuring. Also the use of non-living water hyacinth roots offers sorption and accumulation of relatively large amounts of the studied pollutants from aqueous solution. Moreover water hyacinth roots can be considered as a type

of Low Cost Adsorbents (LCAs) and their use for water treatment and pollution control can contribute toward the economic and social development of communities and solves a big problem facing our society. They should therefore be considered as valuable components of national and local programs for the implementation of sustainable development policies.

REFERENCES

- [1] V. Ramachandran, and T. J. D'Souza, *J. Nucl. Agr. Biol.* 27 (1998) 73.
- [2] K. S. Low, C. K. Lee and K. K. Tan, *Bioresour. Technol.* 52 (1995) 79.
- [3] A. T. Lee, and J. K. Hardy, *Environ. Sci. Health.* 22 (1987) 141.
- [4] M. Lenka, K. K. Panda, and B. B. Panda, *J. Environ. Pollut.* 66 (1990) 89.
- [5] T. D. Turnquist, B. M. Urig, and J. K. Hardy, *J. Environ. Sci. Health.* 25 (1990) 897.
- [6] G. Akcin, N. Guidede, and O. Saltabas, *J. Environ. Sci. Health.* 28 (1993) 1727 .
- [7] R. Sadhna, M. S. Narayanswami, S. H. Hassan, D. C. Rupainwae, and C. Y. Sharma, *Int. J. Environ. Stud.* 46 (1994) 251.
- [8] H. Chua, *Sci. Total Environ.* 214 (1998) 79.
- [9] S. Shawky, M. A. Geleel, and A. Aly, *J. Radioanal. Nucl. Ch.* 265 (2005) 81.
- [10] A. A. El Refaey , and M. A. Fathi; *Colloque Eau, Déchets et Développement Durable*, Alexandrie, Egypte (2010).
- [11] APHA, AWWA and WPCF; "Standard Methods for the Examination of Water and Wastewater", 13th Ed, American Public Health Association, New York (1989).
- [12] S. M. Riad, *Egypt. J. Biomed. Sci.* 25 (2007) 234.
- [13] J. Wang, F. Lu and and D. Lopez, *Biosens. Bioelectron.* 9 (1994) 9.
- [14] E. Ballesteros, M. Gallego, and M. valcarcel, *J. Chromatogr. A* 518 (1990) 59 .
- [15] G. Moody, J. Thomas, *Ion-Sel. Electrode Rev. I*, 1 (1979) 8.
- [16] G. Moody, J. Thomas, *Selective ion sensitive electrodes*, Merrow Technical Library (1971).
- [17] K. S. Low, and C. K. C. H. Tai, *J. Environ. Sci. Health.* 29 (1994) 171 .
- [18] V. Vadivelan and K. V. Kumar, *J. Colloid. Interf. Sci.* 286 (2005) 90.
- [19] G. McKay, G. Ramprasad and P. R. Mowli, *Water Air. Soil Poll.* 29 (1986) 273.
- [20] B. K. Singh and N. S. Rawat, *J. Chem. Technol. Biotechnol.* 61 (1994) 307.