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Electro coagulation for the pathogenic and microorganism removal from Oued El-Harrach, Algeria wastewater

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ABSTRACT

This study was carried out to investigate in the pathogenic and indicator microorganism of Oued El-Harrah wastewater removal by electro coagulation. Three microorganisms groups were studied, namely protozoa, helminth eggs, and bacteria. In the untreated water, the helminth eggs presence was found as follow: 2,310 eggs/l of Nematoda, 440 eggs/l of Cestoda and 90 eggs/l of Trematoda. The helminth eggs concentration found exceeds the standards recommended by the World Health Organization (i.e., ≤1 viable Nematoda egg/liter). The best treatment efficiency was recorded for helminth eggs, especially for *Ascaris* (100% removal after only 5 min of treatment). The efficient electric current was about (3A) in removing pathogens, the eggs destruction mechanisms were also discussed. The obtained results were sat is factory for wastewater reuse in irrigation.

Keywords: Bacteria; Electro coagulation; Helminth eggs; Oued El Harrach; Wastewater treatment

1. Introduction

With the increase of domestic, industrial, and agricultural water use, conventional water resources have been seriously depleted [1]. In Algeria, the wastewater controlled reuse should be considered as a valuable potential resource. The treatment of such unconventional resources would protect the environment and have significant potential value [2]. The practice of discharging wastewater into water bodies causes considerable damage to the ecosystem, waterfront inhabitants, swimmers, and fishermen [3,4].

Oued El Harrachis a large river characterized by its high pollution degree. The Oued El Harrach's water quality deterioration is caused by domestic and industrial liquids discharge. In addition, wastewater is an important biological agent's vehicle such as bacteria, viruses, and parasites, endangering public health and the environment [5–9].

Particular attention should be paid to characterizing parasites, especially helminths, which are the agents presenting the highest disease transmission risk in raw wastewater. This is mainly due to their long persistence in the environment and their low infectious dose [10,11]. Various studies have focused on the removal of helminth eggs and protozoan parasites by different methods (lagoons, settling basins, etc.) and have contributed to the intestinal parasites presence decrease, without totally eliminating pathogenic micro organisms and parasites [12–14]. It is important to consider the survival of the eggs, larva,and adult parasites when designing wastewater treatment. The WHO [15] recommends that the helminths presence, mostly intestinal Nematoda (i.e., *Ascaris, Trichuris, Ancylostoma*), must be lower than one nematode egg per liter.

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EC is an electrochemical technique in which aluminum and iron "sacrificial" electrodes are dissolved, generating in situ coagulant agents, which destabilize the colloidal particles. The main difference from chemical coagulation is the addition of metalcations in situ rather than via external dosing. Simultaneously electrolytic gases (typically hydrogen) are generated at the cathode. Depending on the reactor operating conditions and the pollutant, these bubbles (gases) may float some portion of the coagulated pollutant to surface [45–48].

In our previous works the COD and BOD_5 were considered as the main pollution indicators, the bacteria and parasite were not taken into account. This work focused on the parasitological characterization and the helminth species determination from OuedElHarrach wastewater before and after using an electro coagulation treatment process. The electro coagulation process efficiency in the elimination of parasite eggs and protozoan cysts by the electric current was also studied.

Electro coagulation is an efficient method for the treatment of wastewater and it could improve the elimination of parasite eggs and protozoan cysts. Moreover it has recently gained more interest for biological and waste water treatments and prevents the formation of secondary pollutants [49–53].

2. Materials and methods

2.1. Site description

Oued El Harrach is considered as an important river, which is located in the central Atlas south of Algiers as shown in Fig. 1. It is formed by the confluence of two main rivers: Oued Akacha and Mekka. Its area is estimated to be of about 1,270 km^2 and it drains an area of 51 km from north to south and 31 km from east to west [16]. Oued El Harrach city has a population of 1,125,300; they produce about 259,000 m^3 of wastewater per day, which is discharged into the river without any prior treatment [16].

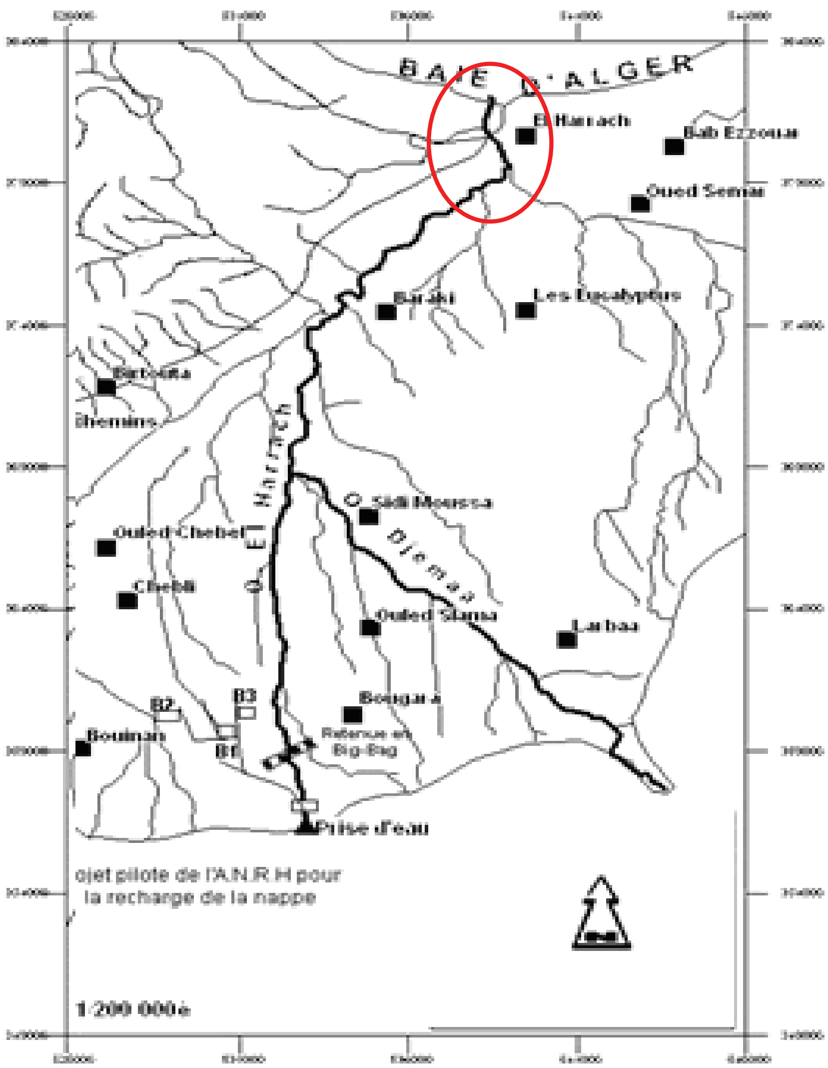

Fig. 1. Oued El Harrach wastewater sampling station.

2.2. Samples collection

Wastewater samples were collected monthly from the surface upstream of the Oued El Harrach to its mouth in the Bay of Algiers. After the addition of 10% of formaldehyde (2 ml/L) the samples were placed in sterile plastic containers and transported to the laboratory for analysis. One of these 2-L samples was placed in a test tube and decanted after 24 h for parasitical analysis.

2.3. Electrolyte treatment

The electrolyte cell consisted of two electrodes made of aluminum (Al/Al) or iron (Fe/Fe) as presented in Fig. 2.

The 3 A electric current was supplied by a current generator. Every 5 min, a volume of 100 ml was sampled into every six conical tubes. The same experimental conditions, namely temperature (25°C), conductivity (1 mS/cm), initial pH (7.5) and the distance between electrodes (1.5 cm) were used to reduce the bacteria numbers.

The parasitological analysis was used as an enrichment technique for the parasite density determination. As the value found by direct microscopic examination [17] proved to be too low, the WHO [18] strongly recommends the Baillenger technique – for its application simplicity, low cost and reliability, and also for its efficiency and reproducibility due to the constant characteristics of its nontoxicreagents [19].

The intestinal helminth eggs concentration and identification in wastewater were performed using the modified Bailenger method [20,21]. Briefly, the sediment was transferred to several tubes and centrifuged at 1,000 G for 15 min. The pellet was suspended in an equal acetoacetic buffer volume (pH 4.5). Then, 2 ml of ether was added and the suspension was mixed in a vortex mixer. The samples were again centrifuged and resuspended in 5 ml of zinc sulfate solution (33%, density = 1.18). Three slides were prepared. The full slide after 5 min was examined under a microscope at 10× and 40× magnification. All the eggs seen were counted and the average for the 3 slides was also recorded.

The eggs per liter number (N) of wastewater were calculated by the following equation:

$$N = A \cdot X / P \cdot V \quad (1)$$

where N = eggs per liter number of sample; A = eggs number counted on the three slides; X = the final product volume (ml); P = three slides capacity (0.15 ml); V = initial sample volume (2 L).

The helminth eggs microscopic observation was based on the eggs size, shape, and content and was in accordance with descriptions in the literature.

The parasites removal percentage was calculated according to Eq. (2):

$$\% \text{ removal} = (Nw - Nt) \times 100/Nw \quad (2)$$

where Nw = parasite eggs number in the original wastewater, Nt = parasite eggs number in the treated wastewater.

The computer software Statistical software (version 7) was used for the data statistical analysis, and Wilcoxon's signed Ranks Test was used to compare the wastewater before and after treatment. The 95% confidence interval was used to calculate and compare the average concentrations of parasite eggs and cysts in the samples.

3. Results

The helminth eggs quantification in treated and untreated wastewater is presented in Table 1. Microscopic examination before treatment showed that the helminth eggs found in the wastewaters belonged to the following groups: Protozoa, Nematoda, Trematoda, and Cestoda.

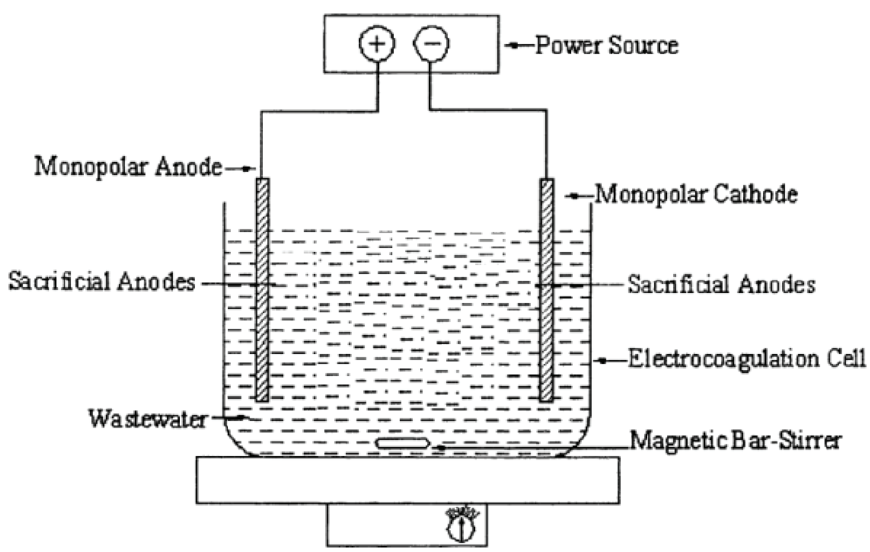

Fig. 2. Bench scale electrocoagulation (EC) reactor with monopolar electrode.

Table 1
Parasite eggs concentration in Oued El Harrach wastewater

	Species	Eggs/L in wastewater	Total
Protozoa	*Giardia sp* *Entomeba coli Entomeba histolytica*	ND	ND
Helminths	Nematoda:		
	Ascaris sp	2,040	
	Enterobius vermicularis	120	
	Trichuris trichura	40	2,310
	Ankylostoma duodenale	60	
	Trichostrongylus sp	40	
	Toxocana sp	10	
	Trematoda:		
	Schistosoma haematobium	90	90
	Cestoda:		
	Taenia sp	240	440
	Hymenolepis nana	200	
		Total of all eggs	2,840

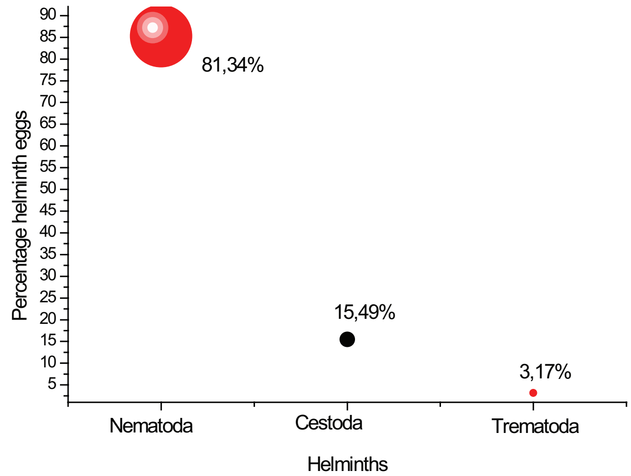

Fig. 3. Distribution of Helminths three classes: Nematoda, Cestoda and Trematoda in Oued El Harrach wastewater.

3.1. The parasite load quantitative characterization of the wastewater before treatment

Table 1 shows that the samples contained different helminths groups: *Nematoda, Cestoda* and *Trematoda*. Among protozoan cysts, the species *Giardia sp* and non-pathogenic amoebae such as *Entomebacoli* and *Entomebahistolytica* were highlighted. According to Strauss [22]; Faby and Brissaud [23] and Thompson [24], amoebic cysts and *Giardia sp* can survive in the environment for several months and eggs of *Taenia sp* and *Ascaris sp*, can survive from 9 months to more than 1 year, respectively.

Parasitic helminth eggs microscopic observation from Oued El Harrach wastewater highlighted three parasites classes, which are presented in Fig. 3. The *Nematoda, Cestoda,* and *Trematoda* rates corresponded to 81.3%, 15.5% and 3.2%, respectively. The highest rate was observed for *Nematoda*. The similar result has been obtained and reported by several authors (Stien and Schwartzbrod [25]; Alouini [26]; Belghyti et al. [27]; Bouhoumet al. [28]. However, Guessab et al. [29], Alouini et al. [30], Bouhoum, and Schwartzbrod and Banas [31] reported that the intestinal Nematoda eggs were more resistant than those of Cestoda. This was related to the strength of their eggs and their transmission mode (direct cycle) [32]. In addition, the parasitic nematodes eggs shown in (Fig. 4) are spread across several species, namely *Ascaris sp, Deodunel hookworm*, *Enterobius vermicularis*, *Strongyloides sp, Toxocara sp* and *Trichiuris sp.* The Cestodes found were *Teaniasaginata and Hymenolepis nana*.

The Table 1 demonstrates that a total of 2,840 eggs per liter were counted. The highest values (2,310 eggs/L) were observed for nematode eggs, 440 eggs/L for cestodes and 90 eggs/L for trematodes. It is noted that all-pervading *Ascaris* eggs were found in the wastewater analysis. However, *Ascaris sp* parasite pathogen was accounted for the highest eggs/liter number (n = 2,040; 71.8%) and *Enterobius vermicularis* (n = 120; 4.2%), *Taenia sp* (n = 240; 8.5%), *Hymenolepis nana* (n = 200; 7.0%). *Schistosomahaematobium* had the lowest eggs/liter numbers (n = 90; 3.2%). These different concentrations found in wastewater were mainly caused by various climatic and socio-economic systems. The *Ascaris* prevalence is related to their high resistance to environmental factors and their enduring survival [33]. Another important fact is that *Ascaris* eggs can survive in septic tanks for 2–3 months at 20°C to 22°C and even longer at lower temperatures. The *Cestoda* tape worm's eggs were represented by *Teania sp* and *Hymenolepis nana* with a concentration of 240 and 200 eggs/L, respectively. On the other hand, Trematoda eggs were represented by *Schistosoma duodunel* at low concentration (10 eggs/L). Numerous pathogenic parasites were detected, so the authorities must remain vigilant about their release into the environment or the possible waste reuse containing them.

3.2. The helminth eggs treatment by electro coagulation(EC)

Wastewater treatment commonly aims to eliminate pathogens and putrescible materials. The results presented in Fig. 4 indicate that no differences can be observed between aluminum and iron electrodes during the EC experiment. Indeed in terms of efficiency these electrodes allowed the helminth eggs complete destruction (100%) in only 5 min. The iron electrode will be chosen for its ability to be used in agriculture irrigation and its non-toxicity contrarily to aluminum.

The parasite eggs removal was statistically significant (z = 2.665; p = 0.007). Thus, parasite eggs cannot withstand the electric current. Foam and flocs were formed during the treatment, which was probably due to the helminth eggs destruction. For that reason, foam and flocs were recovered

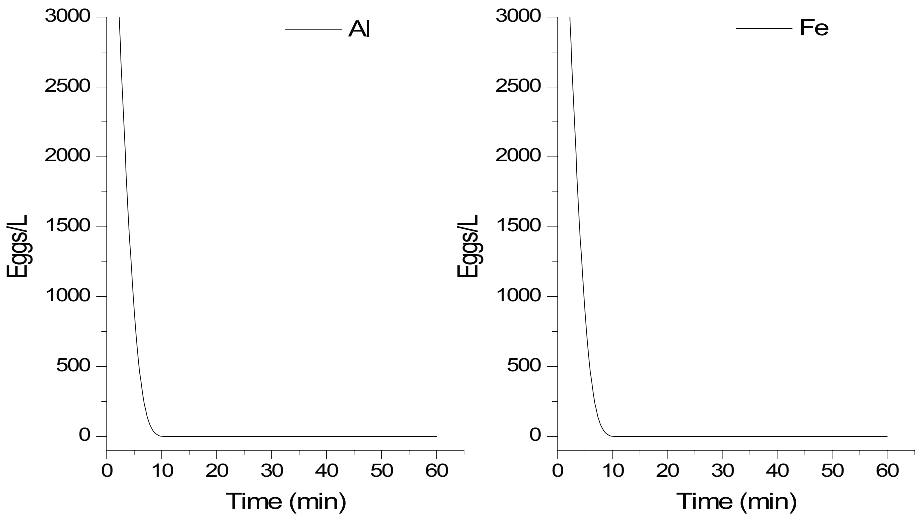

Fig. 4. Helminth eggs concentration (*Ascaris sp*) in Oued El Harrach wastewater during the EC treatment using aluminum and iron electrodes (current intensity I = 3A).

for substantial analysis in order to confirm our hypothesis. The results showed that helminth eggs were eliminated neither in the flocs nor in the foam. The explanation for this may be that the electric current plays an important role in the helminth eggs removal during the electro coagulation process.

4. Discussion

According to El Guamri and Belghity [2], the high helminths concentration is strongly related to demographic factors. Other authors, such as Nsom-Zamo et al. [34], Bouhoum [35], explain that human population growth is responsible for the increase in the helminth eggs concentration according to the environmental conditions: temperature, humidity; oxygen and the solar radiation, which are favorable to their maturation. Encysted organisms are extremely resistant to environmental stress and persist for a longer time than the conventional indicator. Bacteria are able to survive in water for several weeks depending on the temperature, physicochemical characteristics, sunlight, etc., [36–38].

The helminth eggs elimination followed the same mechanism as the bacteria destruction. It should be noted that the parasites eggs are more perceptible than those of bacteria. *Ascaris* eggs are protected by a protein cocoon. The electric current could denature the proteins, thus releasing the blastomeres present inside the eggs. Consequently, this treatment stopped cocoon maturation. In addition, the infestation eggs cycle was not completely reproduced despite helminth eggs having high resistance to various environmental conditions such as temperature and UV radiation. Thus, unfavorable conditions were created for the helminth eggs emergence and strength. This caused the helminth egg walls collapse, which is weaker than those of bacteria [39].

4.1. Mechanism of helminth egg removal

The helminth eggs removal was mainly caused by the electric current effect on the egg wall. The wall is composed of three layers of different chemical compositions: an outer protein layer, an inter mediate chitins layer, and an inner lipid layer.

Two possible mechanisms have been proposed for the helminth eggs removal by electro coagulation. The first involves helminth eggs adsorption onto the biological flocs. This mechanism is improbable, however, since no eggs presence was observed on the flocs. The second mechanism involves the protozoan pathogens and helminths removal through the electric current action and can be explained by three steps presented in Fig. 6. First, the electric current sensitizes the outer layer by disrupting the protein fibers arrangement that gives the *Ascaris* egg its rigidity. Second, when the electric current perforates the egg wall, the chitins layer, which is extremely hard and gives high resistance to the egg, is disturbed. Thus, the egg's resistance decreases. The current destroys some of the Ascaroside A,B, and Diascaroside polymer chains of the chitin-based layer (Fig. 5).

The electric current can overcome this thin layer resistance (3–4 microns) by changing the layout and distorting the helical chitin fibers structure as observed in Fig. 6.According to Wharton [40], this polymer fiber has a helical structure which is responsible for the resistance of the egg to strong acids and bases as well as various specific enzymes. The third step concerns the lipid layer that allows gas exchanges between the external environment and the eggs, unlike the previous layers, which have protective functions. Finally, we can say that the electric current causes a wall permeability disturbance. Several factors, such as temperature, have been reported to affect the pathogenic microorganism removal in a wastewater treatment system [41].

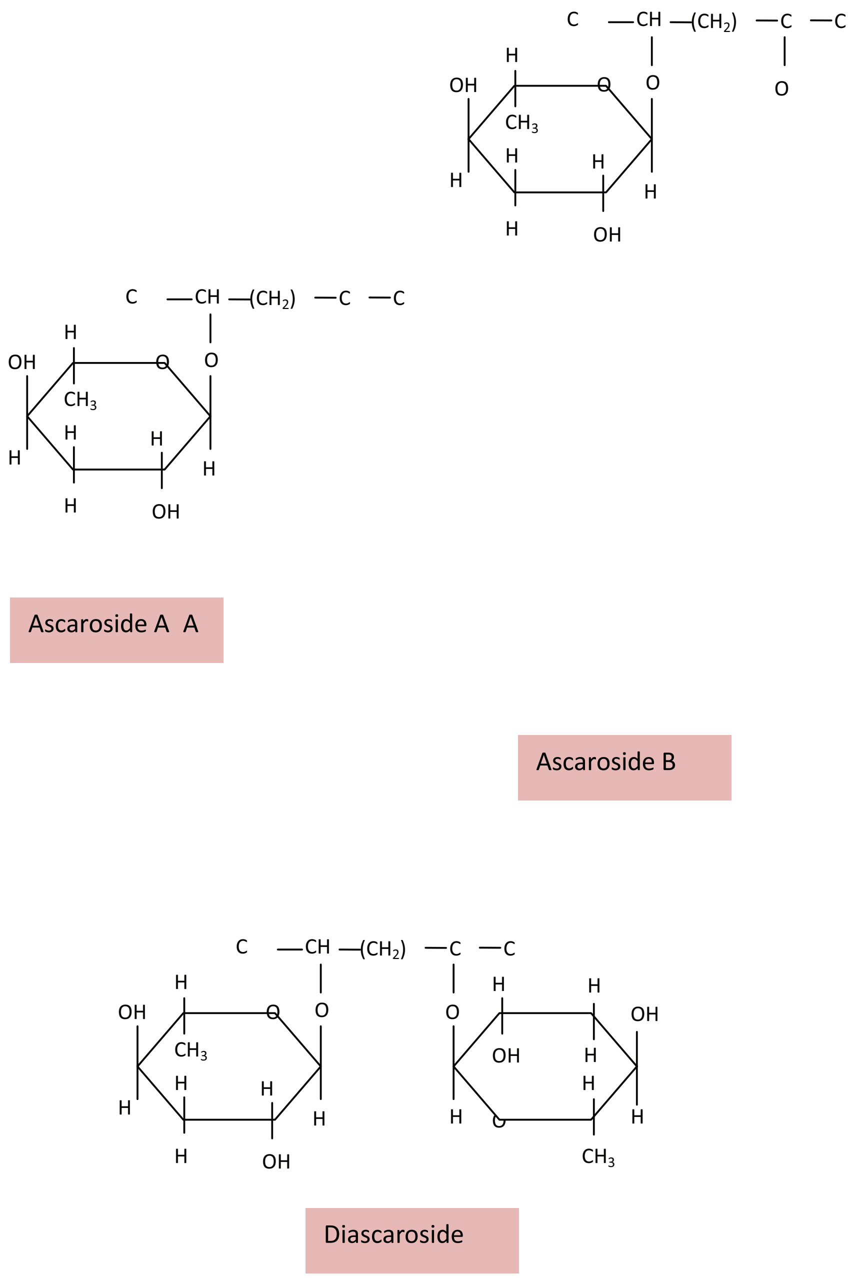

Fig. 5. Polymer chains of *Ascaris* eggchitin-based layer (Wharton, 1980).

4.2. Comparison with the usual techniques for the helminth eggs removal

The conventional processing methods generally involve the helminth eggs removal and the chemical contaminants effect. Fig. 4 shows the concentration variation during the EC treatment using iron electrodes and aluminum electrodes. In this study, a total abatement (100%) was recorded in a very short time. This treated wastewater can be reused, for instance, in non-limited crop irrigation without leading to any contamination or infectious parasitic diseases [42,43]. Others studies reported a decrease of about 50%–90% in helminth eggs has been observed after primary settling [23,30] reported a reduction of 76% when eggs and cysts had enough time to settle, showing the significantly better efficiency of this treatment. Studies on lagoons showed a reduction between 85 and 100% in helminth eggs and protozoan cysts[44].

The conventional treatments disinfection processes (sedimentation, activated sludge treatment, biological filtration, aeration lagoon and oxidation ditch treatment) do not respect the bacterial quality standards recommended

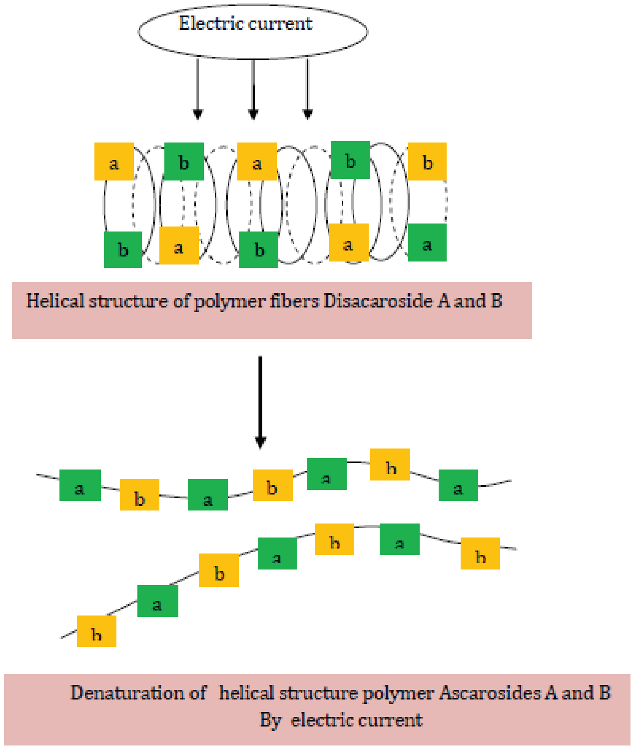

Fig. 6. Removal mechanism of *Ascaris* egg by electric current: (a) Ascaroside A, (b) Ascaroside B.

by the WHO (<1,000 UFC/100 ml fecal coliforms) for crop irrigation in Category A (irrigation of cultures intended to be consumed raw, sports grounds and public gardens) [21]. The bacteria analysis of Oued El Harrach wastewater revealed high total coliforms concentrations, *E. coli*, fecal coliforms and *Clostridium perfringens*. After treatment, the bacterial quality was 10 UFC/100 ml and was within the recommended standards (<1,000 UFC/100 ml) [39]. The electro coagulation process can be considered as the most appropriate way tore move pathogens in a short time (i.e., 30 min for bacteria and 5 min for helminth eggs. Microbiological analysis is indispensable if treated wastewater is to provide benefits without any negative consequences.

5. Conclusion

This study indicates and develops a more efficient process to eliminate the helminth eggs and bacteria (pathogens) from Oued El Harrach wastewater by using electro coagulation treatment.

The results indicate that EC process was able to destroy helminth eggs, especially for *Ascaris* after only 5 min. Further works using the electro coagulation pilot will be realized, then a wastewater treatment plant will allow the directly treated water discharge into the sea without causing environmental and health hazards. In Algeria, Oued El Harrach wastewater must be taken into consideration as a water resource that can be reused for different applications such as crop irrigation or agriculture.

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