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Chlorine concentration-time (C-T) plot for *Eichhornia Crassipes* in water

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Abstract. *Eichhornia*, or water hyacinth represents a serious threat to potable water basins. This problem is materialized majorly in consuming large amounts of water and dissolved Oxygen that is necessary for aquatic life, and minorly in hindering water streams. Even there are limited trials to overcome such pests, none of them presents an acceptable solution economically and logically. Chlorine is a well-known biocide and broadly used in water industry. It could give a possible method to fight such weed. To investigate that, concentration-time plot should be introduced similar to any other microorganisms; especially, bacteria in water. In this work, various doses of Chlorine along various time periods were examined as an introductory to prescribe an adequate method to deal with such water disaster which can severely attack water resources.

1. Introduction

During early eighties, Egyptian labor who were working in Iraq started to bring water hyacinth upon their round trips as a memory from their homeland. Iraqi citizens reacted positively by considering it as an ornamental plant which in turn brings the economic factor as a potential for spreading such pest. The problem was magnified as the side effects of this plant was not sensible in domestic use. However, it crept slowly into water basins either with or without human interference [1].

Furthermore, Iraqi officials did not take this challenge seriously. They ignored registering it in agriculture quarantine in addition to delaying the needed combat. This ignorance continued along eighties and nineties of the past century. After that, random efforts started by the ministry of agriculture such as installing bumpers in rivers streams but they were not work effectively due to lack of maintenance and aging. In 2003, the natural history research center- University of Baghdad claimed that the bumpers of Tigris river (Qussaiba and Swaira) were obsolete and did not functioning well (50- 80 %) of their total efficiency [2]. Lack of labor is another factor; for instance, 88 kilometers of river were covered by only eight workers and two boats which considered as a weak coverage.

To overcome this challenge, a specialized directorate in The Ministry of Water Resources for *Eichhornia* fighting was established in Wasit- Iraq. Even though, the main effort was focusing on mechanical harvesting which represents a temporary and weak reaction against this pest [1].

The problems that are accompanied with water hyacinth can be figured out as in below [1],[2],[3]:

- 1- Hindering; or in sever situation, blocking water streams which makes boating, fishing, swimming and other activities nearly impossible.
- 2- Covering water surface with a shading layer which in turn prevent sun light from penetrating; hence, reducing aquatic life.
- 3- Consuming the dissolved Oxygen.



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- 4- This plant represents an ideal environment for diseases transfer creatures such as insects, worms, and shellfishes.
- 5- Water hyacinth masses supply a huge load on floating bridges and similar structures which introduce to collapse. Alzubaidya floating bridge in Wasset-Iraq is a significant example for such destruction.
- 6- Consuming a considerable amount of water may reach 5 liters daily for a single plant. This equivalent to 3.5 times the evaporation from surface water.
- 7- Attacking pumps and pipes that is used in agriculture or electrical industry.

Controlling water hyacinth can be divided into three techniques:

- 1- Mechanical, which could be implemented through manual or machine driven equipment rather than using wire mesh bumpers. This method is considered as the best available one even with its side effects and high cost.
- 2- Chemical, such as Glyphosate or 2-4 Dichloro phenoxy Acetic Acid. Those; in turn, have many defects, first is attacking other kinds of aquatic life. Second, is the hardness of controlling their effective concentration in a flowing water streams or in large water basins. For instance, Glyphosate lost effectiveness within several amounts of time, area or depth which turn the entire treatment process to uselessness. And;
- 3- Biological, which in general are insects which represent a natural enemy to water hyacinth. The known number of them is 100 kinds, the most usable are Taosa Plant Hopper and Hoppers Magamlus Plant. This kind of treatment represents the corner rock and the base of any combat process. However, this treatment strategy does not kill the plant completely as their life together is a natural balance process i.e. killing all water hyacinth will definitely kill the insects after that because of discontinuing food chain.

When thinking positively, the use of such weed economically jumps. The most interesting one was held very recently. *Eichhornia* was used as a raw material for producing biogas which represents the most mature solution in this research path [4],[5]. On the other hand, using this weed industrially is a false thinking because even making some benefits and profits from one side, the above problems will continue. Therefore, establishing any industry from ware hyacinth will fail if it is put on trade-off scale.

From technical point of view, and when thinking about fighting water hyacinth in water chemically, it will be a common sense thinking to go towards Chlorine biociding. The Chlorine is safe when dealing with water industry and widely used. Furthermore, *Eichhornia* like any other plant or creature exterminate under sever environmental conditions. Therefore, applying those conditions may limit this pest deployment. For instance, applying Chlorine.

To assist designing equipment that can treat this weed Chlorine concentration vs. time should be introduced. This work briefs that.

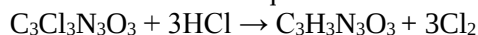
2. Materials and Methods

2.1 The water basins

24 plastic containers 50×30×25 cm each are used in this work. Every 3 containers represent 3 replicates of a single Chlorine concentration and a single time period. Besides those 3 containers there are other 3 as control. Those 24 containers divided into 4 groups every group represents a point in C-T plot.

2.2 The Chlorine tablets and solution

The Chlorine solution was prepared as described by [6]. It has been done by adding Trichloroisocyanuric acid tablets that obtained from Acti.to HCl. The reaction equation is:



The produced Chlorine solution reached 200 ppm. To produce the desired concentrations for this work, this solution was diluted with water. Also, this solution used as a makeup when Chlorine concentration decreased continuously as a result of natural exposure to air.



Figure 1. Experiments and measurements in run

2.3 Chlorine meters

In this work, two chlorine meters were used:

- 1- exact[®]Z obtained from Industrial Test Systems, Inc. (ITS).
- 2- ExStik[®] obtained from EXTECH instruments, model number of CL200. They are self-calibrated and provided with standards for external calibration.

2.4 Dissolved Oxygen measurement

The used equipment for measuring Oxygen consumption is AZ-8403 that a product of (AZ[®]). A calibration method was taken on daily basis as described in the equipment manual.

2.5 *Echhornia crassipes* plant

The weed plants are harvested from Al-Wahda water treatment plant at Tigris river in Baghdad. Figure 2 illustrates the site.

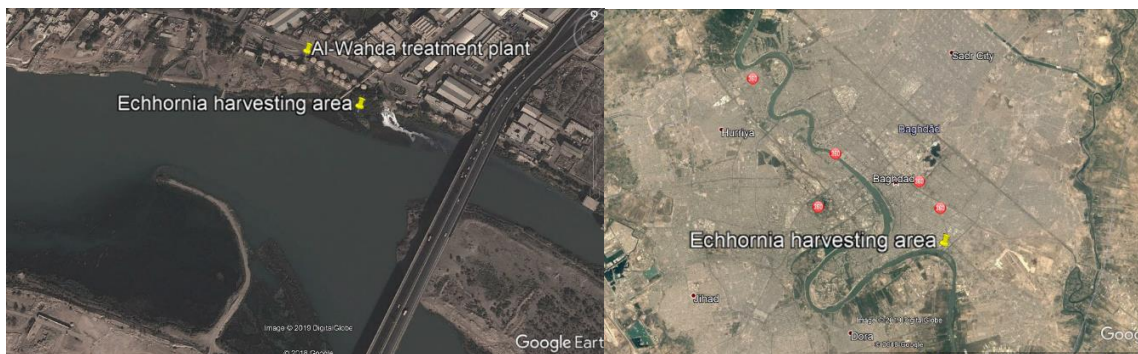


Figure 2. Echhornia Harvesting area in Baghdad, Iraq

2.6 Experimental procedure

- 1- Put 3 water hyacinth plants in 3 empty plastic containers. Beside them put 3 containers as control.
- 2- Prepare a chlorinated water by adding the high concentration chlorinated solution produced as described in 2.2 to distilled water.
- 3- Add distilled water to the 3 control containers equally. The same is done with the same quantities to the 3 water hyacinth containers but with chlorinated water.
- 4- Every Chlorine container tested hourly for Chlorine ppm content and corrected to keep the concentration and water level stable.
- 5- Water level in every container tested hourly and corrected to the original level. If the level is the same as the previous hour, this means the plant is dead.

3. Results

Chlorine was added in various concentrations and time periods. The sign of death for the plant is stopping consuming water and Oxygen. Water was compared to a control basin. Once water consumption due to evaporation was the same in the two reservoirs this means the plant is dead. On the same basis, once Oxygen level is back to its natural level, this also represents a clear sign of the weed death. Results are summarized in 3 tables, 1 points out if the weed is dead or alive. 2 represents the deference in water consumption between Echhornia's basin and its control while 3 display the same for Oxygen.

4. Discussion

Chemical control on water hyacinth represents the fastest method to deal with such pests. For instance, in Australia 80% of control processes were chemical based [7]. However, when compromising with other preventing techniques, the mechanical one is the preferred from the environmental point of view but it implies many drawbacks. That is, it is labor and time consuming; hence, cost consuming. Moreover, this technique slices the plant parts leaving some of them; especially the seeds, to regrow again.

On the other hand, biological prevention techniques represent a fairly acceptable fighting strategy [5]. This includes use of bacteria, fungus, and predators which counts up to 100 or so kind of them.

Table 1. The obtained results, green = live = fail, red = dead = successful.

		Chlorine ppm									
		20	18	16	14	12	10	8	6	4	2
Time (hr)	10										
	9										
	8										
	7										
	6										
	5										
	4										
	3										
	2										
	1										

Table 2. The plant water consumption in letters/day, every cell represents the deference in water consumption between the control and *Echhornia crassipes* basines in literes.

		Chlorine ppm									
		20	18	16	14	12	10	8	6	4	2
Time (hr)	10	0 ±2%	0 ±3%	0 ±1%	0 ±2%	0 ±2%	0 ±4%	0 ±1%	0 ±3%	0 ±1%	2.21±1%
	9	0 ±2%	0 ±2%	0 ±4%	0 ±1%	0 ±2%	0 ±2%	0 ±2%	0 ±4%	0 ±2%	2.35±2%
	8	0 ±2%	0 ±2%	0 ±3%	0 ±2%	0 ±3%	0 ±2%	0 ±2%	0 ±2%	2.55±3%	2.45±4%
	7	0 ±1%	0 ±2%	0 ±2%	0 ±3%	0 ±2%	0 ±2%	0 ±1%	2.80±2%	2.79±1%	2.77±2%
	6	0 ±3%	0 ±2%	0 ±3%	0 ±2%	0 ±2%	0 ±2%	3.12±2%	2.95±2%	2.88±3%	2.79±1%
	5	0 ±3%	0 ±3%	0 ±1%	0 ±2%	0 ±1%	3.27±2%	3.22±2%	3.15±2%	2.98±4%	2.84±2%
	4	0 ±2%	0 ±3%	0 ±1%	0 ±2%	3.45±4%	3.34±4%	3.34±2%	3.22±2%	3.12±1%	2.97±3%
	3	0 ±2%	0 ±3%	0 ±1%	3.64±2%	3.55±4%	3.46±2%	3.33±4%	3.21±3%	3.22±3%	3.11±2%
	2	0 ±2%	0 ±3%	3.77±4%	3.66±2%	3.56±4%	3.56±3%	3.45±2%	3.23±3%	3.21±2%	3.21±2%
	1	0 ±3%	0 ±2%	3.89±1%	3.78±3%	3.58±3%	3.58±2%	3.44±1%	3.22±2%	3.20±4%	3.25±2%

Table 3. Oxygen consumption due to *Echhornia crassipes*, every cell represents the deference in Oxygen concentration between control and the plant basins in ppm

		Chlorine ppm									
		20	18	16	14	12	10	8	6	4	2
Time (hr)	10	0 ±2%	0 ±2%	0 ±4%	0 ±1%	0 ±2%	0 ±2%	0 ±2%	0 ±4%	0 ±2%	3.2±2%
	9	0 ±2%	0 ±3%	0 ±1%	0 ±2%	0 ±2%	0 ±4%	0 ±1%	0 ±3%	0 ±1%	3.3±3%
	8	0 ±2%	0 ±2%	0 ±2%	0 ±3%	0 ±2%	0 ±2%	0 ±1%	0 ±2%	3.4±3%	3.3±4%
	7	0 ±2%	0 ±1%	0 ±3%	0 ±2%	0 ±3%	0 ±2%	0 ±2%	3.5±2%	3.3±2%	3.5±3%
	6	0 ±2%	0 ±3%	0 ±2%	0 ±3%	0 ±1%	0 ±2%	3.4±4%	3.6±1%	3.6±3%	3.7±1%
	5	0 ±3%	0 ±3%	0 ±1%	0 ±3%	0 ±1%	3.5±2%	3.7±1%	3.4±3%	3.3±1%	3.5±1%
	4	0 ±3%	0 ±2%	0 ±1%	0 ±4%	3.6±2%	3.7±4%	3.6±2%	3.8±1%	3.7±1%	3.6±3%
	3	0 ±3%	0 ±2%	0 ±21%	3.6±2%	3.9±2%	3.7±4%	3.6±4%	3.8±2%	3.5±4%	3.6±1%
	2	0 ±3%	0 ±2%	3.6±3%	3.6±2%	3.7±3%	3.6±3%	3.7±4%	3.8±3%	3.6±3%	3.8±3%
	1	0 ±2%	0 ±3%	3.8±2%	3.7±3%	3.6±4%	3.6±4%	3.7±1%	3.8±2%	3.5±3%	3.8±4%

More specific, all of these represent natural enemies to water hyacinth. This works by weakening and destroying the active parts of the weed [8]. The biological treatment still premature and dangerous technique as it may interact with aqua life and may destroy other kinds of water living creatures.

All of the above drive the chemical techniques in the front of the combat but when revising our view to them we find that the top used two which are Dichloro phenoxy acetic acid and Glyphosate introduce another problem; that is, affecting water quality that may be used for both irrigation and drinking [9].

Chlorine is a friendly substance and widely used. Furthermore, it is traditionally known agent and of known effects on water.

In general, CT “concentration-time” value is an important property for both biocides and microorganisms as it helps designing drinking water and other facilities. For more complicated living creatures such as plants and animals the process is different; that is, it needs more time and Chlorine to be exterminated.

In our case, water hyacinth is not an exception. The base unit of all living creatures is the cell which is the same and it is expected to follow the same behavior as single cell ones.

This fact has been approved in direction but not in value. That is, Chlorine definitely kills all water hyacinth but it consumes more time with slightly higher Chlorine concentrations.

This trend explained by two reasons. First, the dose needed to kill a single bacterium for example is less than that to kill higher numbers [10].

Moreover; and secondly, single cell microorganisms are spread in water which make them more exposed to Chlorine. On the other hand, plants and animals consist of “multi-layered” rows of cells. Therefore, to kill a cell on the surface is easier than that away towards the core.

The bright side is that in order to homicide a multi-cell body it is not necessary to attack all its cells i.e. it may be enough to biocide some outer cell layers to end the creature life. The depth “layers” to be killed vary from kind to another but at the end enough biocide concentration with enough exposure time will definitely lead to death. This puts attacking water hyacinth by Chlorine in a considerable scope.

Chlorine, as a dissolved substance could penetrate the plant with the absorbed water. The speed of water absorption through any plant was measured to be $0.25 - 0.4 \text{ mm s}^{-1}$ [11]. This suggests; theoretically, to kill a 3 meters’ height plant within less than an hour. The process seems to be slower with *Echhornia crassipes*. The reason behind that may be that the outer layers of plant cells will die faster and make a buffer layer for the Chlorine. Or, the outer cells may absorb the Chlorine and sacrifice themselves as a defensive strategy.

This leads to another hypothesis; that is, the outer layer could have exterminated due to Chlorine attack while deeper ones are died due to drought, hunger or lack of other nutrients as the outer dead layer will prevent their penetration.

On the practical and industrial level, Chlorine is a cheap and abundant agent and can be found easily in any domestic market as a bleach for example. Furthermore, its use is very easy to apply and manage. This drives towards using this chemical agent to fight *Echhornia crassipes* effectively.

On the contrary, Chlorine is a volatile substance and easy to deplete in water. Therefore, a continuous feeding equipment are needed to apply such practice. Some resources described mechanisms and implementations for applying chlorine continuously [6].

In this work, the effect of Chlorine on *Echhornia crassipes* was studied but the effect on its seed was not. The seed is a hardly part to fight because it settles in reservoirs bottoms [12]. Chlorine is high diffusive in water. So, it is expected to reach these seeds and homicide them effectively. On the other hand, the seeds are capable to resist severe environmental conditions and can build its own stronghold in water bottom and may still capable to regrowth even after 20 years [13]. Those facts are worthy to study and investigation.

Fighting water hyacinth by Chlorine could be affected by numerous environmental factors just like any other microorganisms. Temperature degree, pH, and other contaminants in water may interfere with the work of Chlorine. The followed trend in drinking water industry is to neglect the effect of those factors when dealing with this operation. Therefore, when describing the desired Chlorine dose to treat drinking water, and as a rule of thumb it is fixed as 4 ppm without mentioning any of the above variables. This means they are with negligible effect in biociding process. For water hyacinth, it may need further research to prove the same.

5. Conclusions

As the same in microorganisms and single cell living beings, water hyacinth follows the same rule of Chlorine concentration-exposure time relation. The plot is introduced and clarify that the Chlorine technique may represent a successful one to fight such pests. From industrial point of view, we have now a practical process to fight *Echhornia crassipes* chemically in stagnant water basins such as lakes,

treatment facilities, and to some extent rivers.

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