

REDUCTION OF CHROMIUM LEVELS IN TANNING WASTEWATER BY PHYTOREMEDIATION METHOD: A REVIEW

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ABSTRACT

Introduction: Chromium content in tannery wastewater causes environmental health problems if the waste is not treated correctly, one of which is phytoremediation using various types of aquatic plants (water hyacinth, apu wood, horn moss, and Lemna sp.). This study aimed to find the types of aquatic plants that most reduce the levels of Cr in tannery wastewater. **Method:** research using a literature study design that uses a database, *Pubmed*, *Google Scholar*, and *Science Direct* starting in 2011 to 2021 for analysis. The keywords used Indonesian and English search keywords are degradation, wastewater, tanning, aquatic plants, phytoremediation, water hyacinth, apu wood, water spikes, fisheye, and hornworts. The inclusion criteria included the dependent variable from the study, namely the decrease in Cr levels, the independent variables inc; the types of aquatic plants, accessible full text, experimental quantitative methods, journals published with ISSN or SINTA 1-6 or Scopus, and exclusion criteria include paid and inaccessible journals in full as well as the year of publication of articles before 2011. **Result:** all journals succeeded in reducing Cr levels in tannery wastewater within a contact time of 3 hours; 5 minutes; 10 minutes; 15 minutes; 5 days; 7 days; 14 days; 15 days; 25 days; and 28 days. This research shows that this research shows lower Cr levels in tannery wastewater. **Conclusion:** the types of aquatic plants tThehe most Cr levels in leather tanning wastewater are water hyacinth plants with a contact time of 3 hours; 5 minutes; 10 minutes; 15 minutes; and 28 days. Therefore, phytoremediation needs to monitor the growth and selection of aquatic plant species adapted to the environment so that phytoremediation can provide maximum results in the absorption, removal, and reduction of heavy metals harmful to environmental health.

Keywords: chromium reduction, phytoremediation, aquatic plants, tannery wastewater

INTRODUCTION

Along with the times, various industries will also develop to increase the amount of waste produced if the waste is not processed correctly and correctly use environmental pollution. This can reduce the quality of the soil, air, and water around it. One industry that still has a lot of highlights in its waste treatment is the tanning industry (Maryudi et al., 2021). The tanning industry is famous for producing large amounts of toxic solid and liquid waste. Its potential to pollute the surrounding environment both soil, water and air (Ulfin et al., 2014). The waste when discharged directly into the environment without being appropriately handled, the waste ous diseases including itching, asthma, cancer, and various other diseases (Wardhani et al., 2012). The five countries that produce the lamost significantkin are Brazil, China, India, Ita, ly and Russia (Giaccherini et al., 2017). Indonesia

also has quite a lot of tanning industries; there are 67 (active 35 industries) and more than 100 housing industries in 2015 (Ministry of Industry, 2015).

India is one country that produces 52,500 m³/day tanning of waste (Suryawanshi et al., 2013). The tanning industry worldwide produces 40 million Cr-containing waste annually (Saranraj and Sujitha, 2013). In Bangladesh, the tanning industry involved in the chrome tanning process is about 90% because the process is simple and gives excellent results to the skin. In this process, almost large amounts of water and produce are produced. About the water used as waste (Chowdhury et al., 2013). According to Bhattacharya et al. (2016), every ton of skin in the process requires 30 m³ of water. In the process large amounts of water and chemicals are used to treat raw skin so that the wastewater produced is about 30-35 m³ per ton of processed raw skin (Islam et al., 2014). Liquid waste generated from tanning in Bangladesh amounts to 20,000 m³ (Saha and Azam, 2021).

Liquid waste from the tanning industry has a high organic content, high salinity, and other pollutants, including Cr (Ahmad et al., 2020). This wastewater is colored, very cloudy, and has a foul smell (Hu et al., 2011). The tanning industry is one of the industries that produce harmful and toxic waste. In the process it mostly uses *the chrome tanning* process that produces liquid waste containing Cr. Cr is the most commonly used chemical during tanning, staining, and surface processing (Naidansuren et al., 2017) about 85% of the world's skin is equated using Cr (Safarrida et al., 2015). Cr metal is also one of the heavy metals of a toxic nature, its toxicity level depends on its ion valence. The toxicity of Cr⁶⁺ is higher than that of Cr³⁺ which is ± 100 times (Prime et al., 2013). In addition, Cr⁶⁺ is carcinogenic and corrosive (Rahmawati and Suhendar, 2015). Although tanning uses trivalent chrome (Cr³⁺), hexavalent chrome (Cr⁶⁺) is also found in its liquid waste (Giacinta et al., 2013).

Reduction of Cr levels in tanning wastewater can be done through various effective and inexpensive methods, one of which is by phytoremediation. Phytoremediation is used as one of the alternative solutions for heavy metal remediation because it has environmentally friendly advantages based on plant utilization as a accumulation of metals in addition to cost-effectiveness and efficiency (Sumiahadi and Acar, 2018).

Plants used for phytoremediation must meet several criteria, including having a high growth speed, being able to consume large amounts of water, having high tolerance to pollutants, easily growing without care and being easy to maintain, and not being a consumable plants (Surtikanti, 2011). According to Reeves et al. (2018) the ability to accumulate much higher concentrations of heavy metals on parts of their bodies such as in leaves and roots without showing signs of toxicity. Plant characteristics that can be used as phytoremediation include fast growth rate, high biomass yield, absorption of large amounts of heavy metals, having the ability to transport metals at the top of plant-soil, and being able to tolerate metal toxicity (Ali et al., 2013). Other factors such as pH value, sunlight, nutrient availability, and salinity also greatly affect the potential for remediation and plant growth (Reeves et al., 2018; Tewes et al., 2018).

One of the plants that can be used according to the above criteria are aquatic plants, such as *Eichhornia crassipes* (hyacinth), and *Isa stratiotes* (kiambang / salad air), *Salvinia natans* (Ganepo grass), *Ipomoea aquatic* (kale) and others. According to Sulhan (2021), utilizing aquatic plants to handle the number of pollutants by absorbing, collecting and degrading certain pollutants contained in the waste, namely by phytoremediation.

Based on Wolde Michael, hyacinth plants were effective in removing Cr metal by 91% in tanning liquid waste in Ethiopia. The use of *Synechocystis salina* (*Algae* sp) plants can also remove Cr metal successfully in 15 days with excellent efficiency (Worku and Sahu, 2014). Thilakar comparing *Pistia stratiotes* (kiambang) and *Salvinia natans* to remediate the heavy metal Cr, resulting that both plants are efficient accumulators so that they are effectively

used.

Based on the description above that the Cr content in the liquid waste of tanning skin can cause environmental pollution in both air, water and soil so a further approach is needed to find the type of aquatic plants that reduce the most Cr levels. Therefore, the author is interested in conducting study literature with the title "Decreased Chromium Levels in Skin Tanning Wastewater with Fitore mediation Method".

METHODS

This type of research uses literature studies, namely research methods by analyzing, summarizing, evaluating, and synthesizing a document from various library sources to provide a more comprehensive understanding of the decrease in chromium levels in tanning wastewater and phytoremediation methods. The phytoremediation method uses different types of aquatic plants. Various types of aquatic plants include hyacinths, apu wood, kiambang, floating ferns, fish eyes, Sadak apu wood, genjer, kale, water clover, and horn moss. Search for articles using *PubMed databases*, *Google Scholar*, and *Science Direct*. Literature searches start from 2011 to 2021 for analysis.

Keywords used in the search of the article using Indonesian and English are "Chromium", "Chromium", "Decrease", "Reduction", "Wastewater", "Wastewater", "Tanning", "Tannery", "Tannery", "Tanning wastewater skin", "Tannery wastewater", "Aquatic plants", "Water plants", "Aquatic plants", "Fitoremediation", "Phytoremediation", "Hyacinth hyacines", "Water hyacinth", "Apu wood (*Pistia stratiotes*)", "Water lettuce", "Kiambang (*Salvinia molesta*)", "Floating fern (*Salvinia natans*)", "Floating fern", "Water spike", "Water fern", "Fish eyes (*Lemna minor*)", "Dadak apu wood (*Azolla pinnata*)", "Genjer (*Limnocharis flava*)", "Water clover (*Marsilea quadrifolia*)", "Water clover", "Kale (*Ipomoea aquatic*)", "Water spinach", and "Moss horns (*Ceratophyllum demersum*)", "Hornwort", using a combination of the hyphens "DAN", "AND", and "OR".

The inclusion criteria in this article search are:

1. The bound variable of the study conducted is a decrease in chromium levels.
2. Variables free from the research conducted are aquatic plants which can be in the form of hyacinths, apu wood, kiambang, floating ferns, fish eyes, dadak apu wood, genjer, water clover, kale, and horn moss.
3. Articles can be accessed *in full text*
4. The method used in journals is a type of experimental research.
5. Journals published with ISSN (*International Standard Serial Number*) or indexed SINTA 1-6 or indexed Scopus.

The exclusion criteria in the search for this article are:

1. Journals are paid accessed and cannot be accessed completely.
2. Year of publication of the article before 2011.

Literature Review Flow

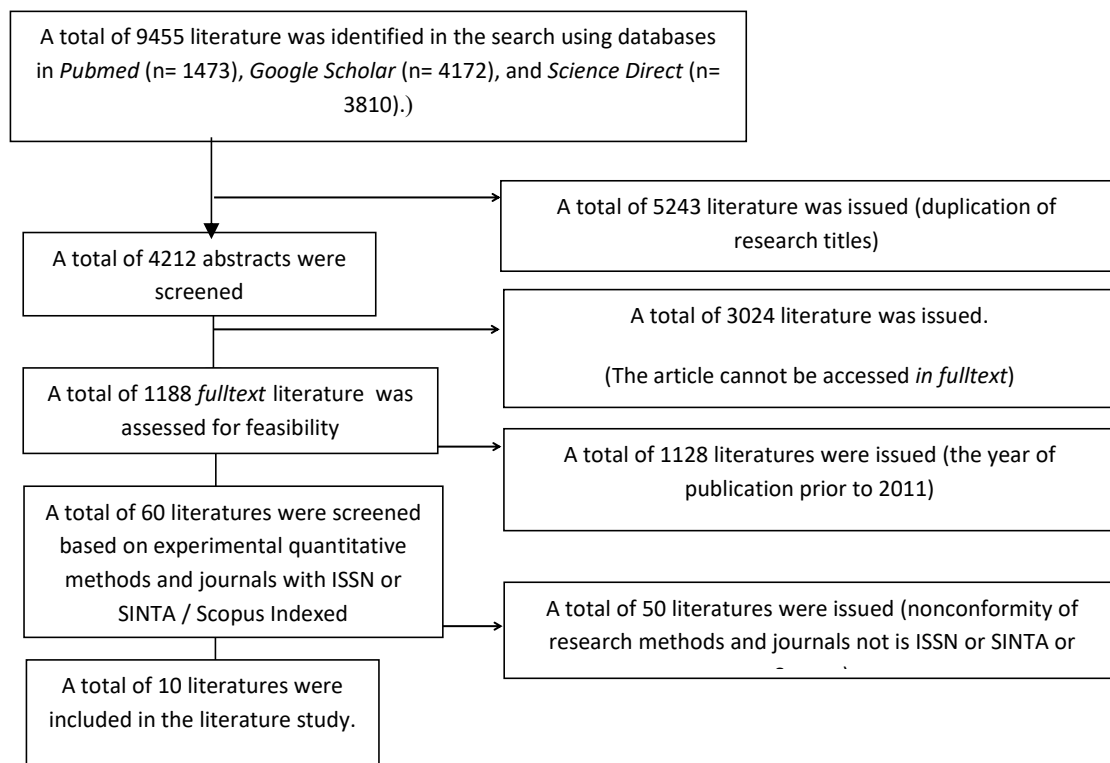


Figure 1. Literature Selection Flow

RESULTS AND DISCUSSIONS

The search results of articles with the keywords above found as much as 9455 literatures identified by *Pubmed*, *Google Scholar*, and *Science direct*. The article that has been obtained then focused on reducing chromium levels in tanning wastewater and phytoremediation methods. Here is a table of literature selection results that includes the first author of the year, title, journal name, type of aquatic plant, and results.

Table 1. Literature Selection Results

First author, year	Title	Journal, volume, and indexed	Types of aquatic plants	Result
Chakrabarty <i>et al.</i> , 2017	<i>Phytoremediation of Chromium and Some Chemical Parameters from Tannery Effluent by Using Water Hyacinth (Eichhornia crassipes)</i> . https://www.banglajol.info/index.php/RALF/article/view/35091	<i>Research in Agriculture, Livestock and Fisheries</i> , 4(3), 151-156. https://doi.org/10.3329/ralf.v4i3.35091 ISSN: P-2409-0603 ISSN: E-2409-9325	Hyacinth	Hyacinth results in a cr decrease of: a. 832.8 mg/l (32.42%) after 7 days, and b. 558 mg/l (54.72%) after 15 days. So that hyacinth has a strong ability to absorb Cr.
Hartanti <i>et al.</i> , 2014	Effect of Hyacinth Plant Density (<i>Eichornia crassipes</i>) On Chromium Metal Decline In Skin Tanning Liquid Waste https://jsal.ub.ac.id/index.php/jsal/article/view/124	<i>Journal of Natural Resources and Environment</i> , 1(2), 31-37 SINTA 5	Hyacinth	The density of hyacinth plants can lower Cr in the liquid waste of tanning so that the concentration of Cr: Plant density 6 individuals Plant density 6 individuals = 2.23 ppm Plant density 4 individuals = 2.20 ppm, Plant density 4 individuals = 2.14 ppm
Akter & Afrin, 2014	<i>Phytoremediation of Chromium (Cr) from Tannery Effluent by Using Water Lettuce (Pistia stratiotes)</i> . https://www.researchgate.net/profile/H-Zakir/publication/281272893_Phytoremediation_of_Chromium_Cr_from_Tannery_Effluent_by_Using_Water_Lettuce_Pistia_stratiotes/links/55d4dd2108ae45e825d3923a/Phytoremediation-of-Chromium-Cr-from-Tannery-Effluent-by-Using-Water-Lettuce-Pistia-stratiotes.pdf	<i>ASA University Review</i> , 8(2), 149-156. ISSN 1997-6925	<i>Pistia stratiotes</i>	Cr is efficiently reduced, from an initial value of Cr 1232.4 ppm to: - 449,57 mg/l, with reduction 782,82 mg/l (36,48%) after 7 days of phytoremediation, and - 514,28 mg/l with reduction 718,12 mg/l (58,27%) after 15 days of phytoremediation.
Suryani <i>et al.</i> , 2017	<i>Chromium Phytoremediation of Tannery Wastewater using Ceratophyllum demersum</i> https://journal.unnes.ac.id/nju/index.p	<i>BIOSAINTEFIKA (Journal of Biology Education)</i> , 9(2), 233-239. DOI: 10.15294/biosaintifika.v9i2.8716	<i>Ceratophyllum demersum</i>	<i>Ceratophyllum demersum</i> is good for remediating Cr in tanning waste at a concentration of 7.74 mg/l (1.7%) in 14 days.

	hp/biosaintifika/article/view/8716	SINTA 2			
Pamungkas et al., 2019	<i>Lemna sp. as a Chromium Heavy Metal Phytoremediator on Tannery Wastewater and its Potential Use as Fish Feed</i> https://www.journalapri.com/index.php/APRJ/article/view/30057/56402	<i>Asian Plant Research Journal</i> , 3(1), 1-7. DOI: 10.9734/APRJ/2019/v3i130057 ISSN: 2581-9992	Lemna sp.		The average decrease in Cr concentration in tenderizing liquid waste was 64.01% over 5 days.
Hashem et al., 2020	<i>Water Hyacinth Biochar for Trivalent Chromium Adsorption from Tannery Wastewater</i> https://www.sciencedirect.com/science/article/pii/S2665972720300040	<i>Environmental and Sustainability Indicators</i> , 5, 1-6. DOI: https://doi.org/10.1016/j.indic.2020.100022 ISSN: 2665-9727	Hyacinth		The maximum Cr (III) removal efficiency in tanning wastewater through adsorption was 99.14% for 15 minutes.
Sarkar et al., 2017	<i>Remediation of Chromium and Copper on Water Hyacinth (E. crassipes) Shoot Powder</i> https://www.sciencedirect.com/science/article/pii/S2212371716301585	<i>Water Resources and Industry</i> , 17, 1-6 DOI: https://doi.org/10.1016/j.wri.2016.12.003 ISSN: 2212-3717	Hyacinth		Cottonistas absorbent powder of hyacinth shoots for Cr ions was found at 98.83% each for tanning waste for 3 hours.
Woldemichael et al., 2011	<i>Potential of Water Hyacinth (Eichhornia Crassipes (Mart.) Solms) for the Removal of Chromium from Tannery Effluent In Constructed Pond System</i> https://www.ajol.info/index.php/sinet/article/view/78234	<i>SINET: Ethiopian Journal Science</i> 34(1), 49-62 ISSN: 0379-2897	Hyacinth		Hyacinth plants can potentially remove Cr from tanning waste. Highest Cr reduction efficiency at 3 mg/l concentration by 91% on day 42.
Carreño Sayago & Granada Torres, 2017	<i>Design, Development, and Evaluation of a Laboratory-Scale Phytoremediation System Using Eichhornia Crassipes for the Treatment of Chromium Contaminated Waters</i> http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1909-36672017000100007	<i>Tecciencia</i> , 12(22), 7-14 DOI: http://dx.doi.org/10.18180/tecciencia.2017.22.2 ISSN: 1909-3667	Hyacinth		The hyacinth plant lowered the concentration of Cr in tanning wastewater from 612 mg/l to 188 mg/l for 25 days. The use of hyacinths is an economical and technologically feasible solution for the tanning industry.
T & Vijayalakshmi, 2019	<i>Physicochemical Characterization of Tannery Effluent and its Treatment Using Eichhornia crassipes – A Phytoremediation Study</i> https://www.semanticscholar.org/paper/Physicochemical-characterization-of-tannery-and-its/264cd5e1648ce77fd4e42802e7e83	<i>International Journal of Engineering Development and Research</i> , 7(4), 390-395 ISSN: 2321-9939	Hyacinth		The total decrease in Cr by hyacinth plants in tanning waste is as follows: Initial Cr concentration 15.96 mg/l After treatment, the cr content in the tanning waste: Concentration of 0,6 mg/l = 2,32 mg/l Concentration of 0,8 mg/l = 1,42 mg/l Concentration of 1.0 mg/l = 0.84 mg/l

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Based on Table 1, I can be found two articles indexed SINTA 2 (Suryani et al. , 2017) and SINTA 5 (Hartanti et al., 2014) and 8 other articles indexed ISSN. In addition, it is also known from the 10 articles obtained there are similarities, namely 7 articles using hyacinth plants (*Eichhornia crassipes*) (Chakrabarty et al. , 2017) ; (Harzanti et al., 2014); (Hashem et al., 2020) ; (Sarkar et al., 2017) ; (Woldemichael et al., 2011) ; (Carreño Sayago and Granada Torres, 2017); and (T and Vijayalakshmi, 2019), while 3 other articles use apu wood (*Pistia stratiotes*) (Akter and Afrin, 2014), lumut horn (*Ceratophyllum demersum*) (Suryani et al. , 2017) , and *Lemna* sp. (Pamungkas et al., 2019) .

Based on the results of the analysis of the ten articles above, it is known that nine articles use tanning wastewater samples and one article uses artificial wastewater samples. The method used in the entire article is experimental. The experimental method is a method used to determine the influence of certain treatments (free variables) on controlled treatment (bound variables) (Sugiyono, 2011). Free variables in the article found include hyacinth, apu wood, horn moss, *Lemna* sp., length of time, plant density, wastewater concentration, adsorbent dose, pH solution, and absorbent material. Some articles have drawbacks such as not explaining the statistical test used (Chakrabarty et al. , 2017) ; (Akter and Afrin, 2014); (Carreño Sayago and Granada Torres, 2017); and (T & Vijayalakshmi, 2019). Such statistical tests can help to draw conclusions from the study, whether it relates or exerts an influence between free variables and bound variables.

Aquatic plants are often used as hyperaccumulator plants that can concentrate metals in their biomass in very high levels (Irhamni et al., 2017). Hyacinth plants in aquatic ecosystems are known as nuisance plants but can be used as heavy metal absorbers. Hyacinth ability in 24 hours can absorb cadmium, nickel, mercury, and chromium (Irhamni et al., 2017). Hyacinths are able to remove Cr and Cd from contaminated water, an average of 80.26% allowance efficiency for Cr and 71.28% for Cd while the average allowance rate is the same which is 0.2 µg / day (Satya et al. , 2011) .

A wood plants are water plants that grow quickly and have high biomass, as well as extensive rooting systems that can increase the removal of heavy metals. The moss horn plant (*Ceratophyllum demersum*) is an aquatic plant that is used as a phytoremediator where the absorption of heavy metals is carried out with its root tissue. On the research of Johnson et al. (2019), *Ceratophyllum demersum* or horn moss removes chromium (Cr) metal in industrial wastewater by 56.40%. Duckweed or *Lemna* sp. Have the ability to maintain the preservation of nature by being a hyperaccumulator plant in phytoremediation (Ali et al., 2020). *Lemna* sp. roots will absorb Cr^{3+} and Cr^{6+} , then in the cell will reduce Cr^{6+} to Cr^{3+} so that Cr toxicity is reduced (Matveyeva et al., 2013; Matveyeva and Dupliy, 2013).

Table 2. Research Method Analysis Results

First author, year	Sample	Independent Variables	Dependent Variables	Cr Analysis Method	Statistical Test
Chakrabarty et al., 2017	Air limbah penyamakan kulit di Hazaribagh Thana, Dhaka, Bangladesh.	Hyacinth and Long time (7 and 15 days)	Hyacinth and Long time (7 and 15 days)	Atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan)	Not explained
Hartanti et al., 2014	Tannerization wastewater in industry Sukun	Hyacinth and Plant Density	Decreased Cr, dissolved oxygen (DO), degree of	Spectrophotometer (Perkin Elmer 5100)	Complete Random Design (RAL),

	Subdistrict, Malang City			(2, 4, and 6) and Length of time (7, 14, 21, and 28 days).	acidity (pH), and temperature.		ANOVA, and Smallest Real Difference Test (BNT)
Akter & Afrin, 2014	Tanning wastewater in Hazaribagh Thana, Dhaka, Bangladesh	Wood apu and Length of time (7 and 15 days)		Cr's decline	Atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan)		Not explained
Suryani <i>et al.</i> , 2017	Tanning wastewater in Sukaregang, Garut Regency.	<i>Ceratophyllum demersum</i> (horn moss) and Wastewater concentration (7.74; 11.30; 17.00; and 23.73 mg/l)		<i>Ceratophyllum demersum</i> (horn moss) and Wastewater concentration (7.74; 11.30; 17.00; and 23.73 mg/l)	Atomic absorption spectrophotometer (<i>AAS</i>)		Complete Random Design (RAL) and Duncan's Multiple Range Test
Pamungkas <i>et al.</i> , 2019	Tanning wastewater in Sukaregang, Garut.	<i>Lemna</i> sp. and Length of time (5 days (days 0 to 5))		Cr's decline	Atomic absorption spectrophotometer (<i>AAS</i>)		T-pair test
Hashem <i>et al.</i> , 2020	Tanning wastewater at SAF Leather Industries Ltd., Jessore, Bangladesh	Hyacinth, absorbent doses (1, 2, 3, 4, and 5 g/70 ml of wastewater), pH of solution (5.9; 6.2; 6.5; 6.8; 7.1; 7.4; 7.7; 8.0; and 8.3) and Length of time (5, 10, 15, 20, and 25 minutes)		Cr Decline (III)	Fourier transformation infrared data spectrophotometer (FTIR 1600, Perkin Elmer)		Batch Test-wise
Sarkar <i>et al.</i> , 2017	Tanning wastewater in Hazaribagh thana.	Hyacinth adsorbent material.		Cr and Cu decline	Atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan)		ANOVA
Woldemichael <i>et al.</i> , 2011	Artificial wastewater	Hyacinth, wastewater concentration (3, 5, 7, 10, and 20 mg/l)		Cr's decline	Atomic absorption spectrophotometer (<i>AAS</i>)		ANOVA
Carreño Sayago &	Tanning wastewater in the San	Hyacinth and Length		Hyacinth and Length of	Not explained		Not explained

Granada Torres, 2017	Benito sector of South Bogota.	of time (once every 2 days for 25 days)	time (once every 2 days for 25 days)		
T & Vijayalakshmi, 2019	Tanning wastewater in Nagelkeni, Chennai, Tamilnadu	Hyacinth and wastewater concentration (0.6; 0.8; and 1.0 mg/l)	Decrease in chemical physics parameters (BOD, COD, TDS, TSS, and Total Cr)	Not explained	Not explained

Based on Table 2, it is known that 9 articles have similarities in samples, namely tanning wastewater samples (Chakrabarty et al. , 2017) ; (Hartanti et al., 2014); (Akter and Afrin, 2014); (Suryani et al., 2017) ; (Pamungkas et al. , 2019) ; (Hashem et al., 2020); (Sarkar et al, 2017) ; (Carreño Sayago and Granada Torres, 2017); and (T and Vijayalakshmi, 2019), as well as 1 article using artificial wastewater samples (Woldemichael et al. , 2011) . Variable in the obtained article includes hyacinth (Chakrabarty et al. , 2017) ; (Hartanti et al., 2014); (Hashem et al., 2020); (Sarkar et al., 2017) ; (Woldemichael et al., 2011); (Carreño Sayago and Granada Torres, 2017); and (T and Vijayalakshmi, 2019), kayuapu (Akter and Afrin, 2014), horn moss (Suryani et al., 2017), *Lemma* sp. (Pamungkas et al., 2019), length of time (Chakrabarty et al. , 2017) ; (Hartanti et al., 2014); (Akter and Afrin, 2014); (Pamungkas et al. 2019) ; (Hashem et al., 2020); and (Carreño Sayago and Granada Torres, 2017), plant density (Hartanti et al., 2014), wastewater concentration (Suryani et al. , 2017) ; (Woldemichael et al. 2011);

and (T and Vijayalakshmi, 2019), absorbent and pH doses of solution (Hashem *et al.*, 2020), as well as absorbent materials (Sarkar *et al.*, 2017) with bound variables i.e. chromium metal decline.

Another equation is 8 articles using the Cr analysis method with a Spectrophotometer (Chakrabarty *et al.*, 2017); (Hartanti *et al.*, 2014); (Akter and Afrin, 2014); (Suryani *et al.*, 2017); (Pamungkas *et al.*, 2019); (Hashem *et al.*, 2020); (Sarkar *et al.*, 2017); dan (Woldemichael *et al.*, 2011). In addition, 2 articles also have similarities in statistical tests, namely statistical tests that use ANOVA (Sarkar *et al.*, 2017) and (Woldemichael *et al.*, 2011), while the other 8 articles use different statistical tests where in Hartanti *et al.* (2014) with a complete random design, ANOVA and the smallest real difference. Suryani *et al.* (2017) article with a complete random design and Duncan multiple distances. Article Pamungkas *et al.* (2019) with t-paired test, Hashem *et al.* (2020) article with batch test, as well as other articles do not explain the statistical test in detail.

Industry tanning skin produces liquid waste in a fairly large volume. Tanning 1 ton of wet skin requires $\pm 40 \text{ m}^3$ and is disposed of as liquid waste mixed from the remaining chemicals of the process with components dissolved during tanning (Paul *et al.*, 2013). Characteristic waste liquid tanning skin is blackish brown, cloudy and foul-smelling. The waste also has a fairly high temperature of 25.8°C and a low dissolved oxygen value of 0.87 mg/l . In addition, the degree of acidification of the tanning liquid waste is 12.48 so that it is alkaline (Hartanti *et al.*, 2014). Generally, the wastewater of the tanning industry contains Cr which comes from the tanning process using Cr sulfate compounds between 60-70%. The high content of Cr in the liquid waste of tanning skin can cause environmental pollution and adversely affect health such as disorders of the skin, respiratory tract, kidneys, and liver. In addition, Cr^{3+} waste causes problems when oxidizing to Cr^{6+} (toxic) (Ma'mun *et al.*, 2016). According to WHO drinking water guidelines, the maximum limit of total Cr and Cr (VI) allowed is 0.5 mg/l and 0.05 mg/l (Astuti *et al.*, 2022), so that using phytoremediation utilizing various types of aquatic plants can lower the level of chromium metal (Cr) in tannery wastewater according to WHO..

Cr's analysis method in the article found, using atomic absorption spectrophotometer (AAS) with wet and dry destruction. Wet destruction is the overhaul of the sample by adding strong acid reagents (oxidizing acids such as sulfuric acid, perchloric acid, nitric acid, and hydrochloric acid, or its mixture) and generally the implementation of its work by the Kjeldhal method (Kristianingrum, 2012). Hartanti research *et al.* (2014) mentioned after hyacinth inaklimatisasi 3 days, the sample weighed 5 ml added H_2SO_4 and KMnO_4 solution, boiled and homogenized with Diphenyl Carbazid. Suryani *et al.* (2017) research used the *Ceratophyllum demersum* plant which was acclimated for 7 days by cutting the tip of the stem to expand the metal absorption surface. Another study said hyacinths were separated and washed 10 times with deionized water, cut into small pieces and dried in the sun for 72 hours. After drying, it is dried at a temperature of $70 \pm 5^\circ\text{C}$ in the oven for 48 hours and ground with mortar. The leaf particles are sifted and a size of $150 \mu\text{m}$ are collected (Sarkar *et al.*, 2017). Pamungkas *et al.* (2019) research states that *Lemna* sp. is used as a culture of 180 g and then harvested after 5 days and washed with running water. After that, *Lemna* sp. weighed 1 g and put in erlenmeyer pumpkin with a sample of wastewater. Then added HNO_3 concentrated and H_2O_2 , then filtered using filter paper to the measuring tube. Finally added aquabides to the volume of a solution of 50 ml. Woldemichael *et al.* (2011) research, the leaves and roots of hyacinths weighed 0.25 g then added HNO_3 and H_2O_2 . After that, with metode Kjeldhal at 150°C for 3 hours and 30 minutes, cool 15 minutes at room temperature. After cooling, the solution is filtered with Whatman filter paper ($0.45 \mu\text{m}$) and deionized. In another study, hyacinth plants were washed with running water to remove the soil attached and selected

plants with the same root and bud area display at the same weight of about 200 g (T and Vijayalakshmi, 2019) and used 180 g of hyacinth plants (Carreño Sayago and Granada Torres, 2017).

Dry destruction is the overhaul of organic metals in samples into inorganic metals by boiling samples in *muffle furnaces* and requires a high temperature between 400-800°C but the temperature depends on the type of sample to be analyzed (Kristianingrum, 2012). Chakrabarty et al research. (2017) and Akter and Afrin (2014) mentioned after the plant is washed thoroughly, cut into small pieces then dried in the air for 2 days and finally dried in the oven at a temperature of 100°C for 4 hours. Hashem et al. (2020) research states that the roots of the hyacinth plant are removed and the front is dried in the open air. Dried hyacinth is burned in a furnace for 2 hours at a temperature of 475-500°C. After that, cooled in a desicator, ground, sifted with 80 mess.

Based on these articles, in the preparation of plants on sewage treatment is carried out by including hyacinth plants (Chakrabarty et al., 2017) or wood.

apu (Akter and Afrin, 2014) which has been acclimatized into a tub containing tanning wastewater. Another study, cultivating the *Lemna* sp plant. in a fiber tub with a size of 80 x 80 x 40 cm³ with a volume of 256 liters of tanning wastewater (Pamungkas et al., 2019). Hartanti et al. (2014) study used the number of hyacinths that have been acclimatized, namely 2 individuals (K1), 4 individuals (K2), and 6 individuals (K3).

Table 3. Results of Analysis of Decreased Chromium (Cr) Levels in Skin Tanning Wastewater Samples

First author, year	Aquatic plants	Length of time	Cr Concentration			
			Pre (mg/l)	Post (mg/l)	Decline (mg/l)	% Decrease (%)
Chakrabarty <i>et al.</i> , 2017	Hyacinth	7 days	1232,4	832,8	399,6	32,42
		15 days		558	674,4	54,72
Hartanti <i>et al.</i> , 2014	Hyacinth	28 days	2,71	2 plants = 0.57	2 plants = 2.14	78,97
				4 plants = 0.51	4 plants = 2.20	81,18
				6 plants = 0.48	6 plants = 2.23	82,28
Akter & Afrin, 2014	Wood apu	7 days	1232,4	449,57	782,82	36,48
		15 days		514,28	718,12	58,27
Suryani <i>et al.</i> , 2017	<i>Ceratophyllum demersum</i>	14 days	7,74	7,61	0,13	1,7
			11,30	11,24	0,06	0,5
			17,00	-0,918	17,918	-5,4
			23,73	-1,35	25,08	-5,7
Pamungkas <i>et al.</i> , 2019	<i>Lemna</i> sp.	5 days	0,187	0,068	0,119	64,01
Hashem <i>et al.</i> , 2020	Hyacinth	5 minutes	3190,12	47,85	3142,27	98,5
		10 minutes		6,38	3183,74	99,8
		15 minutes		27,33	3162,79	99,14
Sarkar <i>et al.</i> , 2017	Hyacinth	3 hours	10,475	0,12	10,355	98,83
Carreño Sayago & Granada Torres, 2017	Hyacinth	25 days	612	188	424,2	70
T & Vijayalakshmi, 2019	Hyacinth	Not explained	15,96	Concentration 0.6 = 2.32	13,64	85,46
				Concentration 0.8 = 1.42	14,54	91,10
				Concentration 1.0 = 0.84	15,12	94,74

Based on Table 3, it is known that there are 2 articles that have similarities, namely the length of contact time (Chakrabarty et al., 2017) and (Akter and Afrin, 2014) for 7 and 15 days but different types of aquatic plants. The longest period of contact is in the article Hartanti *et al.* (2014) for 28 days and the shortest in hashem et al. . (2020) for 3 minutes to be able to lower chromium (Cr) in tanning wastewater.

In addition, Table 3 is also known 4 articles successfully lower chromium (Cr) with a percentage decrease above 80% with various concentrations of tanning water samples used as in hartanti et al. (2014) absorbed Cr by 81.18% and 82.28% using the density of 4 and 6 plants so that the decrease in chromium (Cr) occurred by 2.20 mg/l and 2.23 mg/l. Article Hashem et al. (2020) lowered Cr by 99.14% with a decrease in chromium (Cr) by 3162.79 mg/l. Sarkar et al. article (2017) lowered Cr by 98.83% with a decrease in chromium (Cr) by 10.355 mg/l. Vijayalakshmi (2019) decreased Cr by 85.46%; 91.10%; and 94.74% at sample concentrations of 0.6 mg/l; 0.8 mg/l; and 1.0 mg/l with sequential

chromium (Cr) reductions of 13.64 mg/l; 14.54 mg/l; and 15.12 mg/l. Another similarity of the 4 articles is the hyacinth plant as the type of aquatic plant that lowers Cr the most.

Based on the 10 articles above, the results of the decrease in chromium (Cr) levels in tanning wastewater with various types of aquatic plants can be seen the final Cr concentration according to WHO standards (maximum limit cr 0.5 mg / l). In the article Chakrabarty et al. (2017) mentioned hyacinth can reduce Cr to 832.8 mg / l (32.42%) in 7 days and 558 mg / l (54.72%) in 15 days. Hartanti et al. (2014) mentioning hyacinths can be menurunkan Cr on the 28th day with a plant density of 2 individuals; 4 individuals; 6 individuals in order to 0.57 mg / l; 0.51 mg / l; 0.48 mg / l (78.97%; 81.18%; 82.28%). Akter and Afrin (2014) with apu wood lowered Cr to 449.57 mg/l (36.48%) in 7 days and 514.28 mg/l (58.27%) in 15 days. Suryani et al. (2017) with *Ceratophyllum demersum* plant showed the potential to lower Cr at concentrations of 7.74 mg/l and 11.30 mg/l to 7.61 mg/l (1.7%) and 11.24 mg/l (0.5%) in 14 days. Pamungkas et al. (2019) with *Lemna* sp. had an influence on the decline of Cr to 0.068 mg / l on the 5th day. Hashem et al. (2020) the results of a study with biochar hyacinth can lower Cr to 47.85 mg / l (98.5%) in 5 minutes, 6.38 mg / l (99.8%) in 10 minutes and 27.33 mg / l (99.14%) in 15 minutes. Sarkar et al. (2017) with a safe tanof hyacinth (leaf powder) can menurunkan Cr to 0.12 mg/l (98.83%) in 3 hours. Carreño Sayago and Granada Torres (2017) with hyacinth plants was able to reduce Cr to 188 mg/l (70%) in 25 days. Meanwhile, in the T and Vijayalakshmi study (2019) with a concentration of 0.6 mg / l; 0.8 mg / l; and 1.0 mg / l, eceng mumps can reduce Cr sequentially to 2.32 mg / l (85.46%); 1.42 mg / l (91.10%); and 0.84 mg / l (94.74%). Based on the above results it can be concluded that aquatic plants (hyacinth, apu wood, *Ceratophyllum demersum*, and *Lemna* sp.) It has the ability as a phytoremediator in degrading harmful metals (Cr) in tanning wastewater. However, the results that meet WHO standards are the article Hartanti et al. (2014); Sarkar et al. (2017); and T and Vijayalakshmi (2019).

The length of contact time used in phytoremediation with different types of aquatic plants to lower cr levels in tanning water is quite influential. Based on the above articles, the decrease in Cr levels in tanning wastewater is said to be the most with hyacinth plants at the length of contact time which is 3 hours; 5 minutes; 10 minutes; 15 minutes; and 28 days. Cr decrease efficiency in 3 hours by 98.83%, 5 minutes by 98.5%, 10 minutes by 99.8%, 15 minutes by 99.14%, and 28 days by 82.28%. This is in line with Chakrabarty et al. (2017) research on the ability to reduce Cr metal by hyacinth plants increasing with the length of contact time. The results of the study found that the 15-day treatment was more effective compared to 7 days. While the deficiency in the article T and Vijayalakshmi (2019) does not mention the length of contact time used, but the decrease in Cr levels is highest at a concentration of 1.0 mg / l.

Table 4. Results of Analysis of Chromium Levels Reduction in Various Types of Aquatic Plants

First author, year	Aquatic plants	The part of the plant that absorbs Cr	Cr Concentration in Water Plant Parts		Result
			Pre	Post	
Hartanti <i>et al.</i> , 2014	Hyacinth	Root	2,71 mg/l	Highest Cr absorption by plant density of 6 individuals on day 28.	Successfully lowered
T & Vijayalakshmi, 2019	Hyacinth	Root	15,96	Highest total Cr drop at 1.0 mg/l concentration	Successfully lowered
Suryani <i>et al.</i> , 2017	<i>Ceratophyllum demersum</i> (lumut)	Compound leaves (tissue)	7,74 mg/l 11,30 mg/l	Cr decrease was highest at a concentration of 7.74 mg/l on day	Successfully lowered

	<i>tanduk)</i>		17,00 mg/l 23,73 mg/l	14.	
Pamungkas <i>et al.</i>, 2019	<i>Lemna</i> sp.	tissue	0,187 mg/l	Cr absorption in <i>the Lemna</i> sp. network amounted to 2,314 mg / kg and an average decrease in Cr by 64.01% on the 5th day.	Successfully lowered
Woldemichael <i>et al.</i>, 2011	Hyacinth	Leaves and Roots	Leaves 5 mg/l Root 15 mg/l	Cr absorption is highest on the 42nd day and at a concentration of 20 mg/l. 1. 3 mg/l Leaves = 507 Root = 1985 2. 5 mg/l Leaves = 661 Root = 2292 3. 7 mg/l Leaves = 941 Root = 2306 4. 10 mg/l Leaves = 941 Root = 2571 5. 20 mg/l Leaves = 1011 Root = 3173	Successfully lowered
Carreño Sayago & Granada Torres, 2017	Hyacinth	Leaves and Roots	612 mg/l	Highest Cr removal on day 25.	Successfully lowered

Based on Table 4, there is an equation of results that are successfully lowering cr levels by the phytoremediation method using various types of aquatic plants in tanning wastewater. Bagian plants that absorb chromium (Cr) include roots (Hartanti et al., 2014); (T and Vijayalakshmi, 2019); (Carreño Sayago and Granada Torres, 2017) and (Woldemichael et al., 2011), compound leaves (tissue) (Suryani et al., 2017), as well as leaves (Woldemichael et al., 2011) and (Carreño Sayago and Granada Torres, 2017) . Based on the results above, it can be known that the type of aquatic plants that have the most levels of chromium (Cr) in tanning wastewater is the hyacinth plant.

According to Indah et al. (2014), hyacinth plants proved to be the best plants as fitoremediators comp

ared to apu wood and water kale plants. Alhaji et al. (2021) also stated that hyacinths have the best potential in wastewater remediation. Research results puspita et al. (2011) Finding the most hyacinth plants decreased Cr in wastewater by 49.56% compared to apu wood and *Hydrilla verticillata* plants in sequence by 33.61% and 10.84%. The ability of hyacinths to absorb nutrients is high, thus supporting hyacinths as an industrial wastewater fitoremediator (Hajama, 2014). The ability to absorb is because hyacinths have vacuoles in the cell structure. The absorption mechanism occurs in the presence of absorbed materials causing the ballooning of the vacuole, so that the cytoplasm is pushed to the edge of the cell and causes the protoplasm close to the surface of the cell. Therefore, the absorption of Cr metal becomes more efficient (Febrianingsih, 2013). Cr absorption in tanning wastewater is carried out by the roots of hyacinth. Hyacinth root can bind Cr because the root type is a type of fiber root (Hartanti et al., 2014). This is in line with Herdina et al. (2018) which mentions the decrease in Cr because it is absorbed by the root of hyacinth where the root has fine feathers submerged in water, so that water seeps into the root tissue diffusively through the root feathers on the cell wall so that positive ions from high concentrations to hyacinth root cells have a lower concentration. Djo et al. (2017) and Tangio (2015) also mentioned the decrease in cr heavy metal levels in waste using the phytoremediation method with hyacinth occurs because at the root of hyacinths contain microorganisms (*rhizosphere*) that can decompose organic, non-organic, and heavy metals so as to convert inorganic Cr into organic Cr. In addition to the root part of the hyacinth, the leaf part will also accumulate heavy metals (Cr). The process of the mechanism of channeling Cr metal to the leaves, namely after Cr enters the root cell will be transported through xylem and phloem to other parts of the plant. However, the hyacinth plant moves more Cr metal to the stalk than the leaf part. This is done as an effort to protect plant tissues used for photosynthesis from interfering (Herdina et al, 2018). While in the research Purnamawati et al. (2020), apu wood is better at scapegoating Cr (III) than hyacinth.

Apu wood plants or watercress show efficiency in lowering Cr in tanning wastewater (Akter and Afrin, 2014). This is in line with the research of Prajapati et al. (2012) where apu wood is able to remove cr heavy metal from Cr 5 ppm solution by 100% in 72 hours. Other aquatic plants such as tanaman *Lemna* sp. can be used as an alternative fitoremediator in reducing Cr in tanning wastewater, because *Lemna* sp. has the ability to absorb and accumulate Cr in tissues. In addition, it can also reduce toxicity and convert Cr into organic Cr which can be used as fish food (Pamungkas et al., 2019). It is said to be an alternative because it is considered better at the ability to tolerate at cold temperatures than hyacinths, is easy to harvest compared to algae, and its growth is fast (Bokhari et al., 2016). Likewise, the *Ceratophyllum demersum* plant can be used as a phytorememediator. The plant absorbs heavy metals with its root tissue. However, absorbed Cr can result in decreased chlorophyll levels of *Ceratophyllum demersum* (Suryani et al., 2017). In the article Chakrabarty et al. (2017); Akter and Afrin (2014); Hashem et al. (2020); and Sarkar et al. (2017) did not describe the part of the aquatic plant that plays a role in absorbing Cr in tanning wastewater samples.

Based on the results of the analysis of the 10 articles above, a decrease in chromium (Cr) levels in wastewater shamingakan skin with the phytoremediation method was found that the type of aquatic plant can reduce Cr levels, but, the type of aquatic plants that most reduce Cr levels is the hyacinth plant. The length of contact time affected the decrease in Cr levels in tanning wastewater samples i.e. 3 hours; 5 minutes; 10 minutes; 15 minutes; 5 days; 7 days; 14 days; 15 days; 25 days; and 28 days. Phytoremediation methods with various types of aquatic plants can be said to succeed in lowering Cr levels in accordance with the WHO standard of 0.5 mg / l. Therefore, from the articles analyzed found cr levels that are in accordance with WHO standards with a length of contact time of 3 hours; 5 minutes; 10

minutes; 15 minutes; and 28 days. Therefore, in phytoremediation it is necessary to conduct some supervision of the growth and selection of types of aquatic plants tailored to the environment so that phytoremediation provides maximum results in the absorption, removal, and reduction of heavy metals harmful to environmental and human health.

CONCLUSIONS

The results of the literature study obtained that types of aquatic plants (hyacinth, apu wood, *Ceratophyllum demersum*, and *Lemna* sp.) In the journal found can lower cr levels in tanning wastewater. However, the type of aquatic plant that most reduces Cr levels in tanning wastewater is the hyacinth plant with a contact time of 3 hours; 5 minutes; 10 minutes; 15 minutes; and 28 days. Cr decrease efficiency in 3 hours by 98.83%, 5 minutes by 98.5%, 10 minutes by 99.8%, 15 minutes by 99.14%, and 28 days by 82.28%. The part of the hyacinth plant that absorbs Cr is the root. Therefore, in phytoremediation it is necessary to conduct some supervision of the growth and selection of types of aquatic plants tailored to the environment so that phytoremediation provides maximum results in the absorption, removal and reduction of heavy metals harmful to environmental and human health. Recommendations for further research are to conduct research with other types of aquatic plants or with the same aquatic plants but with different time variations or vice versa, so as to provide new results and can be used by the tanning industry to treat liquid waste produced in lowering cr content that negatively impacts the environment.

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