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Potential Use of *Portulaca* Plant Species in Removing Estradiol Hormone Pollutants in the Surface Water of Bengawan Solo River

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ABSTRACT

Bengawan Solo River water is a source of drinking water and raw materials for the government of Surakarta city, but the water has been mixed with domestic, industrial, and agricultural wastes. The waste contains estradiol-17 derived from urine and feces, both from livestock and humans as well as industries around the sub-watershed Bengawan Solo River. The content of estradiol-17 in the Bengawan Solo sub-watershed is quite high. This study is the first conducted in Bengawan Solo River to look at natural estrogens that are very rarely studied in the environment, which are likely could cause several health effects in humans and wildlife due to their relatively strong estrogenic potential and high levels in wastewater and river water. Therefore, research on the elimination of these compounds using effective, energy-efficient, and low-maintenance technologies for water treatment such as phytoremediation is highly expected. The purposes of this study were to identify estradiol, to measure the estradiol levels through HPLC tests as well as to test the effectiveness of phytoremediation with Portulaca plant as biological agents. The results show that the water of Bengawan Solo River contained estradiol substances ranging from 3.88 ppm to 5.76 ppm. The Portulaca plant species was effective at eliminating estrogenic waste up to 99.89%.

INTRODUCTION

Estrogenic compounds are micropollutants, that infiltrate the environment and potentially alter human hormone response even in low doses (Maher 2020). The sources of these compounds are animals, human beings, and human estrogenic compounds that have been detected in synthetic and natural human estrogenic compounds in water and wastewater systems (Liu et al. 2015). Synthetic estrogen compounds often called environmental estrogens are persistent in the environment (Shore 2016).

The compound is a hormone that mimics the work of natural estrogens. The artificial estrogenic compound comes from various sources of pollutants namely: 1) agricultural activities (e.g. insecticides DDT, dieldrin, and endrin); 2) factory activities (e.g. dioxins, plastic constituents, and detergents); 3) medications (e.g. diethylstilbestrol (DES), ethinyl estradiol). Synthetic estrogen compounds can mimic or inhibit the activity of the hormone estrogen, so called EDC or Endocrine Disrupting Compound (Jiang et al. 2013). Estrogen is present in both lake water used for drinking and which is used for irrigation at concentrations that can affect the growth of such as alfalfa plants. Estrogen compounds are present in several compartmentalized environments, including soil and groundwater (Shore 2016).

Estradiol in urine is a natural estrogen from wastewater which is grouped in EDC because it can interfere with endocrine function in women during adulthood and causes fertility abnormalities in humans (Rattan 2017). Research with GC-MS analytical methide has been conducted for the identification of natural estrogens in waste and surface water including E1, E2, E3, 20HE1, 16a-OHE1, 40HE1, 2-hydroxy estradiol (20HE2), 4- hydroxy estradiol (40H E2), 17-epiestriol (17epiE3), 16-epiestriol (16epiE3), and 16 keto-estradiol (16 dan 20H. Most of them are detected in effluent water and rivers, where their detected concentrations were n.d-14.7 and n.d-51.7 ng.L⁻¹ respectively (Tang 2020).

The estradiol compound has two OH groups and 1 benzene ring (Fig. 1). The compound has two hydroxyl groups, one at the C3 position and the other at position 17β , and also three double bonds on the ring. Due to its



Fig. 1: Chemical structure of estradiol compounds.

two hydroxyl groups, estradiol is often abbreviated as E2. Estradiol (E2) is a steroid, estrogen, and the main female sex hormone. This hormone is functionally important in the regulation of the estrus cycle and menstrual cycle in the female reproductive cycle.

Living creatures exposed to estrogenic waste may experience various hormonal disorders, leading to their classification as Hormone Disrupting Compounds (SPH) or EDC (Endocrine Disrupting Compound). SPH can be detected in environmental media such as water and sediment, as well as in food sources like fish, shellfish, and snails. Furthermore, SPH is found in humans through various biological indicators, including blood, urine, hair, and breast milk. Continuous exposure of humans to pharmaceuticals with estrogenic properties can result in the development of conditions such as testicular dysgenesis syndrome, including testicular cancer in men and breast cancer in women. Additionally, men may experience reduced reproductive capacity, including decreased sperm count and abnormal sperm morphology, as well as an increased risk of testicular carcinoma in situ. The contributor to river water pollution generally comes from municipal wastewater disposal due to the increasing population in urban and suburban areas with a lack of wastewater treatment facilities. In contrast, the investigation of EDC events and distribution in river water is very limited (Khoiriyah 2021). Meanwhile, the condition of rivers in Indonesia is almost the same as other rivers in the world. The water discharge of the Bengawan Solo River watershed comes from domestic wastewater disposal, agriculture, and industry. If this condition is reinforced by the increasing population in urban and suburban areas and with the lack of wastewater treatment facilities, then it should be expected that the endocrine-disrupting chemicals (EDC) in the Bengawan Solo River sub-watershed are considered very important to be examined because it could cause female health problems.

Phytoremediation is a process that involves plants containing chlorophyll to reduce the pollutant content in soil, air and water. Phytoremediation is a technique that uses plants to reduce or reduce pollutant levels in the environment. Phytoremediation is a new green technology that uses plants to eliminate, degrade, or detoxify toxic chemicals (such as heavy metals, radionuclides, organic and inorganic contaminants, xenobiotics, and hydrocarbons) in soil, sediment, groundwater, surface water, and air. Phytoremediation estrogenic waste in this case estradiol compounds in this research used *Portulaca* plants. Phytoremediation is an in-situ remediation technology that utilizes the inherent capabilities of living plants (Wang et al. 2017). Phytoremediation uses plants to clean up pollution in the environment. Plants can help clean up many types of pollution including metals, pesticides, explosives, and oil. Plants also help prevent wind, rain, and groundwater from carrying pollutants from the site to other areas (Antoniadis et al. 2017).

The purposes of this study were to identify the presence of estradiol compound as EDC in the Bengawan Solo River Sub-watershed, to measure estradiol levels as EDC by employing the HPLC method, and to measure the effectiveness of *Portulaca* sp. in eliminating that substance of EDC.

MATERIALS AND METHODS

Sample Collection

Samples of estrogenic waste solution in this study were taken from upstream and downstream of the Bengawan Solo River sub-watershed at a distance of 50 meters from the outlets of four tributaries, namely: Premulung River, Pepe River, Pucangsawit River, and Kalianyar. Water samples were taken as much as 2 liters from up-stream and down-stream so that a total number of 8 (eight) samples were collected (Khoiriyah et al. 2019).

Estradiol Identification Procedure

The method of preservation of the samples was adapted from (Celic 2020, Imai 2007). Each sample was filtered up to 100 mL with nitroacetic filter paper with a pore size of 0.45 μ m to remove the solids present in the samples so that very clear samples were obtained. Filtering was assisted by vacuum suctioning to speed up the filtration process. The filtered samples were placed in labeled plastic bottles and stored in the freezer to avoid the sample biodegradation process during storage.

Standard Estradiol Test, Eluent and HPLC

The standard solution was made by diluting 0.1 g of solid estradiol standard into 1% methanol solution, making the concentration 100 ppm of estradiol standard solution with a concentration of 1-6 mg.L⁻¹ made by diluting 0.1 mL to 0.6 mL. Eluent was made from 75% acetone.



HPLC Grade Eluent Constituent Compounds

Before use, gas content in the eluent was removed or followed up with degassing by stirring with a magnetic stirrer for an hour and followed by vacuum filtration using filter paper with a pore size of 0.45 μ m to remove any solids that may be present in the eluent. Estradiol analysis was performed by HPLC with reserve phase and normal delusions. Before being used for the analyte process, the HPLC column was stabilized by draining 100 % methanol for 1 hour at a speed of 1.0 mL.min⁻¹. This treatment was also intended to clear the column from the remains of the previous analyte as well as the impactor that may still be left behind in the analytic column. Estradiol was measured at a wavelength of 230 nm in accordance with the results of wavelength optimization that has been done previously.

Phytoremediation Effectiveness Test

A phytoremediation effectiveness test was conducted by *Portulaca* plants on estrogenic waste (phenol and estradiol). The procedure of effectiveness testing used *Portulaca* plant, as a phytoremediation agent in reducing SPH (Imai 2007). It began with the preparation of *Portulaca* plants, then

Table 2: HPLC test results on pre-phytoremediation river water samples.

Table 1: HPLC test results or	4 pre-phytoremediation	river water sample
sites.		

No	Site	Estradiol Concentration (ppm)	
		Upstream	Downstream
1	Premulung River	5.76	5.19
2	Kalianyar River	5.30	3.88
3	Pepe River	4.71	4.51
4	Pucangsawit River	5.66	4.26

followed by phytoremediation and HPLC analysis. The first step was the preparation of simplisia, *Portulaca* plants as mature (flowering plants were taken from Pucangsawit, Pepe, Kalianyar and Premulung riversides). The second step was phytoremediation in which two grams of *Portulaca* was taken and incubated in 50 mL liquid SPH. *Portulaca* was then washed and extracted with methanol. Then, it was evaporated and dissolved in ethanol. In the HPLC analysis step, 2 mL of the solution after 96 hours of incubation was taken. Then, 40 μ L was taken for the phenol test and HPLC analysis on the C 18 column, and 75% of acetonitrile taken as eluent, meanwhile 400 μ L of the solution was taken for the estradiol test, and HPLC analysis on the C 18 column, and 80% methanol was taken as eluent.

No	Sample code	Estradiol (ppm)	Description	
1.	PW1	0.01	P. pillosa, Premulung River Upstream	
2.	PW2	0.76	P. pillosa, Premulung River Downstream	
3.	PK1	0.76	P. pillosa, Kalianyar Rive rUpstream	
4.	PK2	1.05	P. pillosa, Kalianyar River Downstream	
5.	PS1	1.25	P. pillosa, Pucangsawit River Upstream	
6.	PS2	1.15	P. pillosa, Pucangsawit River Downstream	
7.	PP1	2.05	P. pillosa, Pepe River Upstream	
8.	PP2	2.43	P. pillosa, Pepe River Downstream	
9.	GK1	3.42	P. grandiflora, Kalianyar River Upstream	
10.	GK2	3.82	P. grandiflora, Kalianyar River Downstream	
11.	GW1	3.53	P. grandilora, Premulung River Upstream	
12.	GW2	3.81	P. grandilora, Premulung River Downstream	
13.	GS1	5.68	P. grandilora, Pucamgsawit River Upstream	
14.	GS2	4.52	P. grandilora, Pucangsawit River Downstream	
15.	GP1	4.89	P. grandiflora, Pepe River Upstream	
16.	GP2	4.45	P. grandiflora, Pepe River Downstream	
17.	OK1	4.85	P. olleraceae, Kalianyar River Upstream	
18.	OK2	4.98	P. olleraceae, Kalianyar River Downstream	
19.	OW1	6.51	P. olleraceae, Premulung River Upstream	
20.	OW2	4.98	P. olleraceae, Premulung River Downstream	
21.	OP1	6.34	P. olleracea, Pepe River Upstream	
22.	OP2	5.27	P. olleracea, Pepe River Downstream	
23.	OS1	4.13	P. olleraceae, Pucangsawit River Upstream	
24.	OS2	5.21	P. olleraceae, Pucangsawit River Downstream	

RESULTS AND DISCUSSION

Characteristics of Estradiol in each Sample

The results of estradiol observations with HPLC reserve phase and normal delusions conducted at eight locations of Bengawan Solo River water samples appear as peaks in the chart with different levels. This indicates that all river water samples contained estradiol with varied levels.

Table 1 shows that the highest concentration of estradiol was found in the Premulung River Upstream (5.76 ppm), while the lowest was in Kalianyar River water (3.88 ppm). The average of eight samples was 4.89 ppm. The identification results indicate that the water samples from the Premulung River Upstream had a high estradiol content). Laweyan Village is a batik industrial area so more batik industrial waste flows into the river. EDC in industrial areas is higher than that in other regions. EDC, which is a micro-pollutant, generally exists or comes from various products that are used daily, such as medicines and various pharmaceutical derivative compounds (pharmaceuticals), and personal care products (Jiang et al. 2013).

According to SCHER (Scientific Committee on Health and Environmental Risks) in terms of environmental quality standard-Ethinylestradiol, the quality standard for estradiol in water is 0.035 ng.L⁻¹ or $3.5 \times 10-8$ ppm (2011). Thus, the estradiol found in the four sampling rivers exceeded the quality standard. Meanwhile, according to the Sub-Group on Review of the Priority Substances List, a member of the Common Implementation Strategy for the Water Framework Directive (2011) states that the quality standard for estradiol in water is 0.4 ng.L^{-1} . Thus, the sample water from all locations also exceeded the environmental quality standard.

The lowest estradiol content in the water sample of Kalianyar River Downstream was 3.88 ppm. The location of the river leads to the western direction of the city of Surakarta, which is in the area of the Banjarsari sub-district. The river is located in a fairly densely populated urban area. Although found in low amounts, EDC has a strong and irreversible effect. The impact on humans and animals is complex. Micro-pollutant compounds are often associated with EDC or compounds that can interfere with the endocrine system or hormonal organisms (Jiang et al. 2013). The impact of EDC on aquatic animals is mostly a feminizing effect in which it can mimic or change the activity of the hormone estrogen.

The three types of *Portulaca* namely *P.olleraceae*, *P.* grandiflora and P. pillosa give different reactions to the phyto-mediating process of phenols and estradiol in river water from eight sites (Table 2). The phytoremediation process is carried out by incubating water samples with

Portulaca plants for 96 hours. Incubation was conducted in Erlenmeyer tubes a total of 24 pieces in accordance with the design of testing experiments 3 types of *Portulaca* at 8 sites of river water sampling. After 96 hours of water samples tested HPLC and plant extracts also tested HPLC to find out how estrogenic waste absorption in Portulaca plants.

There are three phytoremediation mechanisms that can affect the mass of contaminants in soil, sediment, and water. The first is phytoextraction also called phytoaccumulation, which refers to the uptake and translocation of metal contaminants in the soil by plant roots to above-ground plant parts. The second is rhizofiltration which is mainly used to recover extracted groundwater, surface water, and wastewater with low contaminant concentrations. This research includes a rhizofiltration mechanism because it aims to conserve water exposed to estrogenic waste (estradiol). This method is a method of adsorption or deposition into plant roots or absorption of contaminants in the solution surrounding the root zone (Wang et al. 2017).

Rhizofiltration is usually exploited in groundwater (either in situ or extracted), surface water, or wastewater to remove metals or other inorganic compounds. Plants to be used for cleaning are raised or grown in a greenhouse with their roots in the water, not in the soil. To acclimate to plants and once large root systems are developed, contaminated water is collected from sewage and brought to plants to replace their water source (Gupta et al. 2013). The plant is then planted in a contaminated area where the roots take water and contaminants with them. When the roots become saturated with contaminants, the plant is removed or harvested (Gupta et al. 2013).

In one study, after one hour of treatment, sunflower reduced lead concentrations significantly (Gupta et al. 2013). The highest lead extraction accumulated in the roots of Portulaca oleracea L. was 173.39 mg.kg⁻¹, and 20.01 mg.kg⁻¹ in the shoots, respectively. The translocation factor was obtained from 0.62 to 0.12 for Portulaca oleracea L. The translocation factor was obtained to be less than one, indicating poor lead transfer from root to shoot. The ability of Portulaca oleracea L. to absorb large amounts of lead from the root zone, high crop yields and the ability to accumulate lead in harvestable organs, makes this plant very effective for remediation (Asadi et al. 2021).

The use of *Portulaca* has several advantages because it can be applied in-situ and ex-situ as well as a faster physiological mechanism. According to Jeevananthama et al. (2019), the advantage of this rhizofiltration method is the ability to use land and water plants for both in-situ and ex-situ applications. Another advantage is that contaminants do not have to be transferred to the shoots. Thus, species



other than hyperaccumulators can be used. Terrestrial plants are preferred because they have a fibrous and longer root system that increases the amount of root area (Gupta et al. 2013). Disadvantages and limitations of this method include the constant need to adjust the pH, the plants may need to be planted first in a greenhouse or nursery; there is periodic harvesting and disposal of crops; tank design must be well engineered; and a good understanding of chemical speciation/ interaction is required. (Gupta et al. 2013).

Extraction of root, stem, and leaf *Portulaca* is done to separate the estradiol component from a material or plant tissue. The initial process of extraction is by smoothing the tissue. This aims to increase the chances of dissolving the components of the desired metabolite components. Before extracting, plant tissue is dried to maintain the content of metabolites in plants that have been cut so that the metabolic process is stopped. One of the extraction stages is the maceration process which is the process of extracting samples using solvents with several times shaking or stirring at room temperature. The result of the extraction

process of *Portulaca* samples is liquid, viscous, and dry. Dry extract or powder is a solid preparation obtained by vaporizing solvents based on the content of active ingredients.

The effectiveness of phytoremediation needs to be known from the mass of elements that are expected to be transferred from contaminated soil to plant biomass, taking into account the initial level of contamination and the target value obtained after remediation (Kumar 2015). Portulaca oleracea L. commonly called purslane, has a significant phytoremediation ability (Srivastava et al. 2021). Portulaca plants have the potential as phytomediators and can lower estradiol levels in polluted water. PW1 treatment (P. pillosa to the sample water of Premulung River Upstream) is a treatment that can lower the highest estradiol levels by 5.75 ppm or 99.88%. GW1 treatment (P grandiflora to the sample water of Premulung River Upstream was able to lower estradiol levels by 2.34 pp or 40.66%. OW1 treatment (P. olleraceae to the sample water of Premulung River Upstream) was able to decrease 0.9 ppm or 15.66% (Table 3).

Table 3: Effectiveness of *Portulaca* phytoremediation against estradiol.

No.	Species	Location	Before(ppm)	After (ppm)	Difference (ppm)	Effectivness (%)
1.	P. pillosa	Premulung River Upstream	5.76	0.01	5.75	99.86
		Premulung River Downstream	5.19	0.76	4.43	85.31
		Kalianyar River Upstream	5.30	0.76	4.54	85.64
		Pepe River Upstream	4.71	1.05	3.67	77.78
		Pucangsawit River Downstream	4.26	1.25	3.01	70.71
		Pucangsawit River Upstream	5.66	1.15	4.51	79.74
		Pepe River Downstream	4.51	2.05	2.45	54.45
		Kalianyar River Downstream	3.88	2.43	1.45	37.32
2.	P. grandiflora	Premulung River Upstream	5.76	3.42	2.34	40.66
		Premulung River Downstream	5.19	3.82	1.37	26.44
		Kalianyar River Upstream	5.30	3.53	1.77	33.35
		Pepe River Upstream	4.71	3.81	0.90	19.12
		Pucangsawit Rive rDownstream	4.26	5.68	-1.43	-33.59
		Pucangsawit River Upstream	5.66	4.52	1.14	20.19
		Pepe River Downstream	4.51	4.89	-0.38	-8.43
		Kalianyar River Downstream	3.88	4.45	-0.56	-14.49
3.	P. olleraceae	Premulung River Upstream	5.76	4.85	0.90	15.66
		Premulung River Downstream	5.19	4.98	0.20	3.92
		Kalianyar River Upstream	5.30	6.51	-1.21	-22.82
		Pepe River Upstream	4.71	4.98	-0.27	-5.72
		Pucangsawit River Downstream	4.26	6.34	-2.09	-49.08
		Pucangsawit River Upstream	5.66	5.27	0.39	6.92
		Pepe River Downstream	4.51	4.13	0.37	8.24
		Kalianyar River Downstream	3.88	5.21	-1.32	-34.05

Portulaca exposed to estrogenic waste requires a special defense mechanism to survive. Plants are often exposed to natural and synthetic toxins such as heavy metals, allelochemicals, organic pollutants, and pesticides. As a result, plants must survive under adverse growth conditions (Zhang et al. 2013). One such mechanism is the ability to metabolize organic compounds derived from abiotic (xenobiotics). Extensive biotransformation is part of a strategy to address the potential negative impact of xenobiotics on plant growth and development. It is specifically proven in its metabolic detoxifying ability of herbicides (Kumar 2015).

The results of estradiol levels in plants in Portulaca show that the three types have different levels in samples of roots, stems, and leaves. P. olleraceae on the leaves was found to have the highest estradiol levels of 121.42 ppm. P. grandiflora on the stem was found at the level of 118.83 ppm, and *P. pillosa* in stem extract was found at the rate of 58.92 ppm estradiol. Estradiol level in the plant extract functions as a hint that the absorption of estradiol by plants was quite high, which is the ability to remove estradiol pollutants by the roots and to translocate them to the leaves and stems. Phytotoxicity by changing cell membrane permeability through reacting with active groups of different enzymes was involved in plant metabolism by reacting with the phosphate groups of adenosine diphosphate (ADP) or adenosine-5'-triphosphate (ATP) (Kumar 2015).

Plants can destroy or break down organic pollutants and absorb as well as stabilize metal pollutants. In this case, the organic pollutants can be cleared by the plant through a value or a combination of phytodegradation, rhizodegradation, and phytovolatilization processes. Organic pollutants such as crude oil, solvents, and polyaromatic hydrocarbons are reversible by this technique. Medium pollutants heavy metals and radioactive elements can be cleaned by plants through the process of phytoextraction/phytoaccumulation, rhizofiltration and/or phytostabilization (Mustafa et al. 2019). Pytofiltration is the process of removing metals from water contaminated by plant roots (Kumar 2015). e. The contaminants are either adsorbed onto the root surface or are absorbed by the plant roots. Plants used for rhizofiltration are not planted directly in situ but are acclimated to the pollutant first (Wuana 2018).

The Cd and Pb reduce the normalized transpiration and growth rate. The greater amount of Cd and Pb accumulate in roots relative to shoots (Lou et al. 2013). Meanwhile, phytostabilization involves the roots absorbing pollutants from the soil, storing them in the rhizosphere, and reducing the spread of pollutants (Gupta et al. 2013). In Portulaca there are absorption and translocation of contaminants,

causing toxic effects on the metabolic process. Toxic effects resulting in decreased biomass production can be prevented by the induction of various cell mechanisms. Cell mechanisms performed to reduce severe toxic effects of metal are by adsorption to cell walls, vacuole entry compartments, increased active efflux, or higher-level induction of chelated metals such as complex proteins (metallothionein and phytochelatin), organic (citrate), and inorganic complexes (sulfide) (Gupta 2013). Many heavy metals (e.g. Cd, Cu, Fe, etc.) are transition metals and can oxidize as well as reduce different biomolecules (e.g. GSH) and thus can disturb the harmony of the redox status of plant cells. These effects on the redox status of the cell may be further enhanced due to the coupling reaction of these metals with biomolecules or other transition metals that can regenerate their ionic state.

This indicates that the decrease in estradiol concentration in treatment for 96 hours was caused by not only biological decomposition but also synergy between plant root zones, microorganisms, and planting media/river sample water (Maher 2020). Organic substances that can settle are set aside through precipitation and filtration by the media. The absorption process that occurs in the media contributes to the decrease in pollutants. Organic substances filtered by the media become a substrate for microorganisms so that they grow to form a layer on the surface of the media and serve to decompose dissolved organic substances. The process in the media takes place aerobically near the water surface and around rooting (Prajapati et al. 2017). Phytoremediation, in principle, utilizes solar energy and has an extraordinary perspective for abating and assembling heavy metals. The technique of phytoremediation has developed in contemporary times as an efficient method and its success depends on plant species selection. Here in this synthesis, we are presenting a scoping review of phytoremediation, its basic principles, techniques, and potential anticipated prospects (Sabreena et al. 2022).

Microorganisms grown in Portulaca rooting also play an important role in absorbing the content of organic pollutants. Plants can absorb pollutants as far as the roots of the plant grow. Microorganisms that grow at the root are more effective in lowering the value of pollutants because the number of microorganisms is increasing and the microorganisms are increasingly able to adapt to the environment (Kumar et al. 2015). The rooting system in Portulaca is strong enough, long, and widespread so that it is very effective in expanding the area where microorganisms are attached so as to significantly lower estradiol levels. The effectiveness of the decrease in estradiol concentration is shown in Table 4, PW1 Treatment (P. pillosa against the sample water of Premulung River Upstream) is a treatment that is able to lower the highest estradiol levels by 5.75 ppm or 99.88%. GW1 treatment (*P. grandiflora* to the sample water of Premulung River Upstream was able to lower estradiol levels by 2.34 pp or 40.66%. OW1 treatment (*P. olleraceae* to the sample water of Premulung River Upstream) was able to decrease by 0.9 ppm or 15.66%.

Phytoremediation uses plants to remove pollutants naturally and sustainably. Compared with other methods such as chemical or physical remediation, phytoremediation is more environmentally friendly, more economical, and less invasive. However, phytoremediation may take longer and is not always effective for certain pollutants. Other methods tend to be quicker but can have negative environmental impacts. Phytoremediation offers proprietors and chiefs of toxic polluted locales an imaginative and financially effective choice to address headstrong natural contaminants. As it uses the plant's characteristic capacity to suck the contamination present in the dirt. Numerous plants have this regular capacity to uptake toxic contaminants and natural contaminations from air, soil, and water (Jeevanantham 2019).

CONCLUSION

The results of the above study indicate that the *Portulaca* plant has the potential as a Phytoremediation agent for water contaminated with estrogenic waste. The ability to reduce the estradiol concentration is effective up to 99.88%. Therefore, this is a very interesting finding and needs to be developed to conserve river water contaminated with estrogenic waste by using the *Portulaca* plant as a phytoremediator agent.

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