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Proximate analysis and heavy metal detection in aquatic plants of River Satluj, District Kasur

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Abstract

Present study was conducted at five study areas associated with river Satluj which includes: Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry Kasur. The triplicated samples of five species of aquatic plants (*Phragmites australis*, *Typha latifolia*, *Nymphea lotus*, *Potenderia chordata*, *Eicchornia crassipes),* soil and associated water were collected from all study areas. During the present study the proximate analysis of aquatic plants was as follows, (g/100 g of dry weight). The moisture contents of aquatic plants ranged between ($1.7\pm2.61_d$ to $7.9\pm2.61_a$). The protein contents ranged between ($2.51\pm5.57_d$ to $22.14\pm0.7_a$). The fat contents ranged between ($0.15\pm2.63_d$ to $6.9\pm2.77_a$). The fiber contents ranged between ($1.75\pm3.28_d$ to $16.14\pm4.8_a$). The ash contents ranged between ($1.62\pm8.54_d$ to $23.12\pm8.54_a$). During this study the lead limits were observed between ($0.28\pm0.001_d$ to 85.60 ± 0.09^a), Cadmium values were recorded between ($0.11\pm0.001_d$ to $9.82\pm0.05_a$) and Chromium limits were observed between ($0.04\pm0.001_d$ to 11.61±0.02a).The data obtained after heavy metal detection revealed that in roots of most aquatic plants the metal accumulation occurs in order Pb>Cd>Cr. In stems and leaves of aquatic plants the metal accumulation occurs in order Pb>Cr>Cd. The accumulation of heavy metals in different fragments of aquatic plants occurs in order Roots>Leaves>Stems.

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Introduction

The aquatic plants are a highly diverse group of plants around the globe. Aquatic plants occur in the seasonally or permanently wet surroundings. In most of the wet lands, the aquatic plants have a remarkable population sizes (Lacoul and Freedman 2006; Chambers *et al.* 2008). The growth rate of aquatic plants is very rapid in different aquatic bodies like waterways and lakes all over the world (Muhammed *et al.* 2012). Some edible aquatic plants are a good source of proteins and nutrients. During the previous few years, the research for the inclusion of aquatic plants in the animal feed is going upgraded day-by-day (Tacon *et al.* 2009).

Our environment is consisted upon a large number of natural ecosystems. The fresh water ecosystem is one of the important ecosystem in environmental stability. The fresh water ecosystem is being concentrated by the addition of heavy metals for example: lead, chromium, copper, zinc, mercury, arsenic, and cadmium, which are highly toxic when entered in to the metabolic pathway of the majority of living organisms. This situation is causing serious devastating effects on different trophic levels of food web (Garty, 2001).

The aquatic plants are able to remove contaminants like heavy metals from water. The aquatic plants are well dispersed in wetlands around the world. The waterbodies generally gathers the nutrients in them by natural processes, and by anthropogenic activities so, the aquatic plants grow there easily with efficient ability of nutrient absorption, the water bodies in this way act as a supportive medium for aquatic plants growth. The studies have shown that the aquatic plants have a remarkable capacity of absorbing the contaminants from the surrounding waters and in this way these plants can help researchers to examine the pollution levels of the environment (Jackson, 1998 and Danh *et al.* 2009).

Now-a-days one of the major environmental issues includes the heavy metal pollution, the heavy metal pollution may include air, water or soil. The soil pollution by wastewater coming from various point and non-point sources has become a major subject of concern in all industrialized ranges of many countries as well as inside the country. The emerging countries in specific have a common practice of disposing the wastes produced by various industries on the neighboring land area or in big lagoons without any management of wastewater treatment or any approved procedure of its disposal. The harmful substances from these effluents enter into the soil, leaving it unfit for agriculture. The constant seepage of these effluents into the soil also leads to the pollution of groundwater basins (Zafar *et al.* 2015).

Due to continuous and constant dumping of some pollutants containing heavy metals in natural fresh water reservoirs of the country, natural aquatic habitats are under tremendous pollution load. This situation is seriously affecting the fresh water flora and fauna. There is a dire need to explore new options like using aquatic plants to purify the polluted natural waters.

Studies on nutritional compositions and heavy metal contamination in aquatic plants have been carried out, during the previous few decades. Despite being the abundance of aquatic plants in the study area (District Kasur), not even a single study has yet been conducted. Therefore, the present study is planned with an objective to evaluate the nutritional effectiveness and status of heavy metal accumulation in aquatic plants, soil and waters of River Satluj including the surroundings of leather tanning industry in District Kasur. The data obtained from this study will help the aquaculture scientists to understand the status of heavy metals accumulation in aquatic plants, associated soils and water, being parts of freshwater ecosystem.

Aims of the study

The aims of the present study are followings:

- To analyze proximate composition and heavy metal accumulation in aquatic plants.
- To analyze physico-chemical parameters and heavy metals traces in water samples collected from study area.
- To analyze physico-chemical parameters and heavy metals traces in soil samples collected from study area.

Materials and methods

Study Area

Present study was conducted at the various sites associated with river Satluj including the surroundings of leather tanning industry in district Kasur. Following five sites of District Kasur, on River Satluj, was considered as the study sites during the present study. Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry.

Collection of Samples

Samples of aquatic plants, contaminated soil and water were collected from four study sites of river Satluj and Leather tanning industry at District Kasur. Three samples of each aquatic plant, water and soil were collected from each site.

Test Species

The aquatic plants species included in the present study are:

Phragmites (*Phragmites australis*), Cattail (*Typha latifolia*), Water Lilly (*Nymphea lotus*), Pickerel Weed (*Potenderia chordata*) and Water Hycinth (*Eicchornia crassipes*).

Aquatic plants analysis

Sample Preparation

The collected plants were thoroughly washed and then dried under the presence of sunlight for the time period of three to five days. The separation was done in the term of roots, stems and leaves. After separation the plants samples were dried in oven at a temperature of 100˚C for a time period of two days. After drying the plants were grinded into powder form. After powder formation, the plants were examined for their proximate analysis.

Proximate Composition of plants

Three samples of plants was collected from each site. These samples were analyzed to get their proximate composition in terms of, crude protein, crude fiber, crude fat, moisture contents and ash contents following (Garg *et al.,* 2008).

Heavy Metal Detection in Plants

2g of plant material was weighed and kept at 65ºC for 24 hours. 5ml of concentrated Nitric acid was included and heated for two hours, following two hours, two fold refined water was added making the volume up to 50ml. Considerable metal fixations in the consequent arrangement was settled using PERKIN-ELMER 2380 assimilation spectrophotometer (Honda *et al.,* 1982; Yaramaz 1986).

Physico-Chemical Parameters of soil

The physico-chemical parameters i.e. pH, electrical conductivity (E.C), alkalinity, total dissolved solids (T.D.S), sand, silt and clay of the soil samples from were evaluated following standard procedures (Garg *et al.,* 2008).

Physico-Chemical Parameters of water

The physico-chemical parameters i.e. temperature, pH, free Co_2, total alkalinity, calcium hardness, total hardness, chlorides, electrical conductivity (E.C), total dissolved solids (T.D.S) and salinity of the water were evaluated following standard procedures (Garg *et al.,* 2008).

Heavy Metal Detection in soil and water

Considerable metal fixations in the consequent arrangement was settled using PERKIN-ELMER 2380 assimilation spectrophotometer PERKIN-ELMER 2380 assimilation spectrophotometer (Honda *et al.,* 1982; Yaramaz 1986).

Statistical analysis

The obtained calculations were studied under Analysis of Variance (ANOVA) through SAS 9.1 statistical software and for comparing means Duncan's Multiple Range Test (DMRT) was applied (Duncan, 1955).

Results and discussions

Proximate analysis and heavy metal detection in aquatic plants of Study area 1 (Nagar village)

The data of proximate analysis and heavy metal detection in aquatic plants of study area 1 (Nagar village) was analyzed by three-way ANOVA and for comparing means DMRT was applied. The results of proximate analysis revealed significant differences ($p<0.05$) while the results of metal detection revealed non-significant differences ($p>0.05$) among the species of the study area 1. The moisture contents of aquatic plants ranged between (7.42 ± 0.9^{a} to 2.7 ± 0.7^{d})g/100g of dry weight. The highest value of moisture (7.42 ± 0.9^{a}) was observed in roots of *Nymphae lotus* while the lowest value (2.7 ± 0.7^{d}) was observed in the stems of *Potenderia chordata*. The protein contents of aquatic plants ranged between (22.14 ± 0.7^{a} to 2.55 ± 0.9^{d})g/100g of dry weight. The highest value was recorded as (22.14 ± 0.7^{a}) in stems of *Typha latifolia* while the lowest value was recorded as (2.55 ± 0.9^{d}) in roots of *Eicchornia crassipes*. The fat contents of aquatic plants ranged between (6.9 ± 0.99^{a} to 0.2 ± 0.99^{d})g/100 g of dry weight. The highest value was noted as (6.9 ± 0.99^{a}) in leaves of *Typha latifolia* while the lowest value was noted as (0.2 ± 0.99^{d}) in leaves of *Potenderia chordata*. The fiber contents of aquatic plants ranged between (15.5 ± 0.99^{a} to 2.6 ± 0.9^{d})g/100g of dry weight. The highest value of fiber was observed as (15.5 ± 0.99^{a}) in leaves of *Nymphae lotus* while the lowest value was observed as (2.6 ± 0.9^{d}) in roots of *Potenderia chordata*. The ash contents of the aquatic plants varies between (21.21 ± 0.9^{a} to 2.6 ± 0.9^{d})g/100g of dry weight. The highest value of ash contents was noted as (21.21 ± 0.9^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (2.6 ± 0.9^{d}) in leaves of *Potenderia chordata*. The accumulation of Lead (Pb) in aquatic plants ranged between (78.24 ± 0.09^{a} to 5.9 ± 0.01^{d})mg/kg. The highest value was observed (78.24 ± 0.09^{a}) in roots of *Eicchornia crassipes* while the lowest value was recorded as (5.9 ± 0.01^{d}) in stems of *Typha latifolia*. The Cadmium accumulation ranged between (8.19 ± 0.05^{a} to 0.21 ± 0.02^{d})mg/kg. The highest value was recorded as (8.19 ± 0.05^{a}) in the roots of *Eicchornia crassipes* while the lowest value was recorded as (0.21 ± 0.02^{d}) in the leaves of *Typha latifolia*. The Chromium accumulation ranged between (7.13 ± 0.02^{a} to 0.11 ± 0.02^{d})mg/kg. The highest value was observed as (7.13 ± 0.02^{a}) in leaves of *Eicchornia crassipes* while the lowest value was observed as (0.11 ± 0.02^{d}) in the leaves of *Typha latifolia*.

Table 1. Proximate analysis (g/100 g of dry weight) and heavy metal detection in aquatic plants of Study area 1 (Nagar village). *S.D (Standard deviation), *N.D (Not detectable).

Species Name	Plant Frag ments	Moisture Contents % ±S.D*	Crude protein % ±S.D*	Crude Fat % ±S.D*	Crude Fiber % ±S.D*	Ash Contents % ±S.D*	Lead (Pb)mg/Kg ±S.D*	Cadmium (Cd)mg/Kg ±S.D*	Chromium (Cr)mg/Kg ±S.D*
Eicchornia crassipes (Water hycinth)	Roots	2.8 ± 0.90^{d}	2.55 ± 0.9^{d}	4.05 ± 0.9^{b}	8.82 ± 0.9^{b}	21.21 ± 0.9^{a}	78.22 ± 0.09^{a}	8.19 ± 0.05^{a}	7.13 ± 0.02^{a}
	Stems	4.2 ± 0.7^{c}	9.92 ± 0.7^{d}	1.19 ± 0.7^{c}	2.83 ± 0.7^{d}	15.5 ± 0.7^{b}	8.07 ± 0.01^{c}	3.32 ± 0.02^{c}	4.75 ± 0.02^{c}
	Leaves	6.4 ± 0.99^{b}	12.2 ± 0.99^{c}	1.1 ± 0.99^{c}	14.2 ± 0.99^{a}	13.1 ± 0.99^{b}	32.50 ± 0.21^{b}	1.24 ± 0.02^{d}	2.12 ± 0.02^{d}
Typha latifolia (Cattail)	Roots	7.4 ± 0.90^{a}	13.2 ± 0.9^{c}	3.41 ± 0.9^{c}	6.4 ± 0.9^{c}	7.29 ± 0.9^{c}	68.23 ± 0.09^{a}	6.02 ± 0.05^{b}	5.11 ± 0.02^{b}
	Stems	6.8 ± 0.70^{b}	22.14 ± 0.7^{a}	4.42 ± 0.7^{b}	8.1 ± 0.7^{c}	5.56 ± 0.7^{d}	N.D*	1.56 ± 0.02^{d}	N.D*
	Leaves	3.4 ± 0.99^{c}	18.5 ± 0.99^{b}	6.9 ± 0.99^{a}	6.8 ± 0.99^{c}	7.1 ± 0.99^{c}	28.76 ± 0.21^{b}	0.21 ± 0.02^{d}	0.11 ± 0.02^{d}
Phragmites australis (Phragmites)	Roots	7.4 ± 0.9^{a}	12.1 ± 0.9^{c}	3.90 ± 0.9^{c}	5.6 ± 0.9^{c}	9.2 ± 0.9^{c}	67.12 ± 0.09^{a}	5.06 ± 0.05^{c}	5.13 ± 0.02^{b}
	Stems	6.4 ± 0.7^{b}	19.19 ± 0.7^{b}	4.8 ± 0.7^{b}	9.11 ± 0.7^{b}	7.1 ± 0.7^{c}	5.9 ± 0.01^{d}	N.D*	2.67 ± 0.02^{d}
	Leaves	3.9 ± 0.99^{c}	18.6 ± 0.99^{b}	4.9 ± 0.99^{b}	7.1 ± 0.99^{c}	9.8 ± 0.99^{c}	28.55 ± 0.21^{b}	0.43 ± 0.02^{d}	0.19 ± 0.02^{d}
Nymphae lotus (Water lily)	Roots	7.42 ± 0.9^{a}	13.8 ± 0.9^{c}	3.5 ± 0.9^{c}	8.2 ± 0.9^{b}	12.1 ± 0.9^{b}	77.21 ± 0.09^{a}	8.01 ± 0.05^{a}	7.11 ± 0.02^{a}
	Stems	4.2 ± 0.7^{c}	16.35 ± 0.7^{c}	3.9 ± 0.7^{c}	9.4 ± 0.7^{b}	7.0 ± 0.7^{c}	8.09 ± 0.01^{c}	3.33 ± 0.02^{c}	4.74 ± 0.02^{c}
	Leaves	6.2 ± 0.99^{b}	18.6 ± 0.99^{b}	4.4 ± 0.99^{b}	15.5 ± 0.99^{a}	13.2 ± 0.99^{b}	31.51 ± 0.21^{b}	1.26 ± 0.02^{d}	2.11 ± 0.02^{d}
Potenderia chordata (Pickerel weed)	Roots	4.6 ± 0.9^{c}	4.2 ± 0.9^{d}	0.11 ± 0.9^{d}	2.6 ± 0.9^{d}	3.8 ± 0.9^{d}	78.24 ± 0.09^{a}	7.01 ± 0.05^{a}	6.01 ± 0.02^{b}
	Stems	2.7 ± 0.7^{d}	6.4 ± 0.7^{d}	0.17 ± 0.7^{d}	6.4 ± 0.7^{c}	4.2 ± 0.7^{d}	N.D*	N.D*	4.75 ± 0.02^{c}
	Leaves	2.2 ± 0.99^{d}	4.3 ± 0.99^{d}	0.2 ± 0.99^{d}	4.1 ± 0.99^{d}	3.3 ± 0.99^{d}	30.99 ± 0.21^{b}	1.29 ± 0.02^{d}	2.12 ± 0.02^{d}

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Proximate analysis and heavy metal detection in aquatic plants of Study area 2 (Bhakhiwind)

The data of proximate analysis and heavy metal detection in aquatic plants of study area 2 (Bhakhiwind) was analyzed by three-way ANOVA and for comparing means DMRT was applied. The results of proximate analysis revealed significant differences ($p<0.05$) while the results of metal detection revealed non-significant differences ($p>0.05$) among the species of the study area 2. The moisture contents of aquatic plants ranged between (7.6±2.12^{a} to 2.2±1.83^{d})g/100g of dry weight. The highest value of moisture was observed as (7.6±2.12^{a}) in roots of *Nymphae lotus* while the lowest value was observed as (2.2±1.83^{d}) in the leaves of *Potenderia chordata*. The protein contents of aquatic plants ranged between (22.14±6.51^{a} to 2.55±5.35^{d})g/100g of dry weight. The highest value was recorded as (22.14±6.51^{a}) in stems of *Typha latifolia* while the lowest value was recorded as (2.55±5.35^{d}) in roots of *Eicchornia crassipes*. The fat contents of aquatic plants ranged between (6.9±02.77^{a} to 0.1±1.63^{d})g/100g of dry weight. The highest value was noted as (0.1±1.63^{a}) in roots of *Potenderia chordata* while the lowest value was noted as (0.2±0.99^{d}) in roots of *Potenderia chordata*. The fiber contents of aquatic plants ranged between (15.5±4.98^{a} to 2.6±2.77^{d})g/100g of dry weight. The highest value of fiber was observed as (15.5±4.98^{a}) in leaves of *Nymphae lotus* while the lowest value was observed as (2.6±2.77^{d}) in roots of *Potenderia chordata*. The ash contents of the aquatic plants varies between (21.1±6.55^{a} to 3.3±4.20^{d})g/100g of dry weight. The highest value of ash contents was noted as (21.1±6.55^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (3.3±4.20^{d}) in leaves of *Potenderia chordata*. The accumulation of Lead (Pb) in aquatic plants ranged between (79.11±0.09^{a} to 6.0±0.01^{d})mg/kg. The highest value was observed (79.11±0.09^{a}) in roots of *Potenderia chordata* while the lowest value was recorded as (6.0±0.01^{d}) in stems of *Phragmites australis*. The Cadmium accumulation ranged between (8.5±0.05^{a} to 0.24±0.02^{d})mg/kg. The highest value was recorded as (8.5±0.05^{a}) in the roots of *Eicchornia crassipes* while the lowest value was recorded as (0.24±0.02^{d}) in the leaves of *Typha latifolia*. The Chromium accumulation ranged between (7.18±0.02^{a} to 0.15±0.02^{d})mg/kg. The highest value was observed as (7.18±0.02^{a}) in leaves of *Nymphae lotus* while the lowest value was observed as (0.15±0.02d^{a}) in the leaves of *Typha latifolia*.

Table 2. Proximate analysis (g/100g of dry weight) and heavy metal detection in aquatic plants of Study area 2 (Bhakhiwind). *S.D (Standard deviation), *N.D (Not detectable).

Species Name	Plant Fragments	Moisture Contents % ±S.D*	Crude protein % ±S.D*	Crude Fat % ±S.D*	Crude Fiber % ±S.D*	Ash Contents % ±S.D*	Lead (Pb)mg/Kg ±S.D*	Cadmium (Cd)mg/Kg ±S.D*	Chromium (Cr)mg/Kg ±S.D*
Eicchornia crassipes (Water hycinth)	Roots	2.8±2.12^{d}	2.55±5.35^{d}	4.05±1.63^{b}	8.9±2.45^{b}	21.1±6.55^{a}	77.21±0.09^{a}	8.5±0.05^{a}	7.11±0.02^{a}
	Stems	4.2±1.68^{c}	9.92±6.51^{c}	1.19±2.07^{d}	2.8±2.69^{d}	15.5±4.42^{b}	8.09±0.01^{c}	3.34±0.02^{c}	4.78±0.02^{c}
	Leaves	6.4±1.68^{b}	12.12±6.31^{b}	1.11±2.77^{d}	14.1±4.98^{a}	13.1±4.20^{b}	33.50±0.21^{b}	1.26±0.02^{d}	2.14±0.02^{d}
Typha latifolia (Cattail)	Roots	7.4±2.12^{a}	13.2±5.35^{b}	3.41±1.63^{d}	6.4±2.77^{c}	7.2±6.55^{c}	68.50±0.09^{a}	6.02±0.05^{b}	5.15±0.02^{b}
	Stems	6.8±1.68^{b}	22.14±6.51^{a}	4.42±2.07^{b}	8.1±2.69^{b}	5.5±4.42^{d}	N.D*	1.58±0.02^{d}	2.69±0.02^{d}
	Leaves	3.4±1.68^{d}	18.5±6.31^{a}	6.9±2.77^{a}	6.8±4.98^{c}	7.1±4.20^{c}	28.92±0.21^{b}	0.24±0.02^{d}	N.D*
Phragmites australis (Phragmites)	Roots	7.4±2.12^{a}	12.1±5.35^{b}	3.9±1.63^{a}	5.6±2.77^{c}	9.2±6.55^{c}	69.12±0.09^{a}	5.09±0.05^{b}	5.19±0.02^{b}
	Stems	6.4±1.68^{b}	19.19±6.51^{a}	4.8±2.07^{b}	9.1±2.69^{b}	7.1±4.42^{c}	6.0±0.01^{d}	N.D*	2.70±0.02^{d}
	Leaves	3.9±1.68^{d}	18.6±6.31^{a}	4.9±2.77^{b}	7.1±4.98^{c}	9.8±4.20^{c}	29.51±0.21^{b}	0.48±0.02^{d}	0.20±0.02^{d}
Nymphae lotus (Water lily)	Roots	7.6±2.12^{a}	13.8±5.35^{b}	3.5±1.63^{c}	8.2±2.77^{b}	12.1±6.55^{b}	77.25±0.09^{a}	8.01±0.05^{a}	7.18±0.02^{a}
	Stems	4.2±1.68^{c}	16.35±6.51^{b}	3.9±2.07^{d}	9.4±2.69^{b}	7.0±4.42^{c}	N.D*	3.35±0.02^{c}	4.79±0.02^{c}
	Leaves	6.2±1.68^{b}	18.6±6.31^{a}	4.3±2.77^{b}	15.5±4.98^{a}	13.2±4.20^{b}	32.12±0.21^{b}	1.25±0.02^{d}	2.16±0.02^{d}
Potenderia chordata (Pickerel weed)	Roots	4.6±2.12^{c}	4.2±5.35^{c}	0.1±1.63^{d}	2.6±2.77^{d}	3.8±6.55^{d}	79.11±0.09^{d}	8.04±0.05^{a}	6.02±0.02^{b}
	Stems	2.8±1.68^{d}	6.4±6.51^{c}	0.17±2.07^{d}	6.4±2.69^{c}	4.2±4.42^{d}	9.06±0.01^{c}	1.32±0.02^{d}	4.71±0.02^{c}
	Leaves	2.2±1.83^{d}	4.3±6.31^{c}	0.22±2.77^{d}	4.1±4.98^{d}	3.3±4.20^{d}	31.12±0.21^{b}	1.31±0.02^{d}	2.15±0.02^{d}

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Proximate analysis and heavy metal detection in aquatic plants of Study area 3 (Ganda-Singh wala)

The data of proximate analysis and heavy metal detection in aquatic plants of study area 3 (Ganda-Singh wala) was analyzed by three-way ANOVA and for comparing means DMRT was applied. The results of proximate analysis revealed significant differences ($p<0.05$) while the results of metal detection revealed non-significant differences ($p>0.05$) among the species of the study area 3. The moisture contents of aquatic plants ranged between (7.9±2.61^{a} to 1.7±2.61^{d})g/100g of dry weight. The highest value of moisture (7.9±2.61^{a}) was observed in roots of *Nymphae lotus* while the lowest value (1.7±2.61^{d}) was observed in the roots of *Eicchornia crassipes*. The protein contents of aquatic plants ranged between

(22.2±6.32^{a} to 2.5±5.45^{d})g/100g of dry weight. The highest value was recorded as (22.2±6.32^{a}) in stems of *Typha latifolia* while the lowest value was recorded as (2.5±5.45^{d}) in roots of *Eicchornia crassipes*. The fat contents of aquatic plants ranged between (5.92±2.4^{a} to 0.19±1.34^{d})g/100g of dry weight. The highest value was noted as (5.92±2.4^{a}) in leaves of *Typha latifolia* while the lowest value was noted as (0.19±1.34^{d}) in roots of *Potenderia chordata*. The fiber contents of aquatic plants ranged between (16.11±4.85^{a} to 1.79±3.2^{d})g/100g of dry weight. The highest value of fiber was observed as (16.11±4.85^{a}) in leaves of *Nymphae lotus* while the lowest value was observed as (1.79±3.2^{d}) in stems of *Eicchornia crassipes*. The ash contents of the aquatic plants varies between (22.0±6.99^{a} to 3.11±4.52^{d})g/100g of dry weight. The highest value of ash contents was noted as (22.0±6.99^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (3.11±4.52^{d}) in leaves of *Potenderia chordata*. The accumulation of Lead (Pb) in aquatic plants ranged between (79.91±0.09^{a} to 1.58±0.02^{d})mg/kg. The highest value was observed (79.91±0.09^{a}) in roots of *Potenderia chordata* while the lowest value was recorded as (1.58±0.02^{d}) in stems of *Phragmites australis*. The Cadmium accumulation ranged between (8.9±0.05^{a} to 0.22±0.02^{d})mg/kg. The highest value was recorded as (8.9±0.05^{a}) in the roots of *Eicchornia crassipes* while the lowest value was recorded as (0.22±0.02^{d}) in the leaves of *Typha latifolia*. The Chromium accumulation ranged between (7.39±0.02^{a} to 0.40±0.02^{d})mg/kg. The highest value was observed as (7.39±0.02^{a}) in roots of *Nymphae lotus* while the lowest value was observed as (0.40±0.02^{d}) in the leaves of *Phragmites australis*.

Table 3. Proximate analysis (g/100g of dry weight) and heavy metal detection in aquatic plants of Study area 3 (Ganda-Singh wala). *S.D (Standard deviation), *N.D (Not detectable)

Species Name	Plant Fragments	Moisture Contents % ±S.D*	Crude protein % ±S.D*	Crude Fat % ±S.D*	Crude Fiber % ±S.D*	Ash Contents % ±S.D*	Lead (Pb)mg/Kg ±S.D*	Cadmium (Cd)mg/Kg ±S.D*	Chromium (Cr)mg/Kg ±S.D*
Eicchornia crassipes (Water hycinth)	Roots	1.7±2.61^{d}	2.5±5.45^{d}	3.39±1.34^{c}	8.78±2.5^{b}	22.0±6.99^{a}	79.22±0.09a	8.9±0.05^{a}	7.35±0.02^{a}
	Stems	3.9±1.43^{c}	9.9±6.32^{d}	2.12±1.81^{c}	1.79±3.2^{d}	15.92±4.44^{b}	9.11±0.01^{c}	3.41±0.02^{c}	5.01±0.02^{b}
	Leaves	6.4±2.0^{a}	12.1±6.12^{c}	0.98±2.4^{d}	4.15±4.87^{d}	13.13±4.52^{b}	34.11±0.21^{b}	1.27±0.02^{d}	2.50±0.02^{d}
Typha latifolia (Cattail)	Roots	7.6±2.61^{a}	13.4±5.45^{c}	3.36±1.34^{c}	6.4±2.5^{c}	7.2±6.99^{c}	68.70±0.09^{a}	6.02±0.05^{b}	5.55±0.02^{c}
	Stems	6.2±1.43^{a}	22.2±6.32^{a}	3.39±1.81^{c}	8.12±3.2^{b}	6.12±4.44^{d}	7.11±0.01^{d}	1.55±0.02^{d}	2.75±0.02^{d}
	Leaves	3.4±2.0^{c}	18.6±6.12^{b}	5.92±2.4^{a}	6.55±4.87^{c}	7.11±4.52^{c}	29.12±0.21^{b}	0.22±0.02^{d}	N.D*
Phragmites australis (Phragmites)	Roots	7.4±2.61^{a}	11.9±5.45^{c}	2.94±1.34^{c}	5.55±2.5^{c}	9.1±6.99^{c}	70.15±0.09^{a}	5.05±0.05^{b}	5.58±0.02^{b}
	Stems	6.1±1.43^{a}	18.5±6.32^{b}	4.9±1.81^{b}	9.6±3.2^{b}	7.8±4.44^{c}	N.D*	1.58±0.02^{d}	2.99±0.02^{d}
	Leaves	3.2±2.0^{c}	17.9±6.12^{b}	4.6±2.4^{b}	6.8±4.87^{c}	8.88±4.52^{c}	29.54±0.21^{b}	N.D*	0.40±0.02^{d}
Nymphae lotus (Water lily)	Roots	7.9±2.61^{a}	13.8±5.45^{c}	2.95±1.34^{c}	8.86±2.5^{b}	12.5±6.99^{b}	78.21±0.09^{a}	8.09±0.05^{a}	7.39±0.02^{a}
	Stems	4.1±1.43^{b}	15.5±6.32^{b}	3.9±1.81^{c}	9.7±3.2^{b}	6.9±4.44^{d}	N.D*	3.39±0.02^{c}	4.98±0.02^{c}
	Leaves	6.4±2.0^{a}	17.5±6.12^{b}	4.2±2.4^{b}	16.11±4.87^{a}	14.2±4.52^{b}	32.91±0.21^{b}	1.31±0.02^{d}	2.68±0.02^{d}
Potenderia chordata (Pickerel weed)	Roots	4.8±2.61^{b}	3.8±5.45^{d}	0.19±1.34^{d}	2.82±2.5^{d}	3.6±6.99^{d}	79.91±0.09^{a}	8.01±0.05^{a}	6.48±0.02^{c}
	Stems	2.9±1.43^{d}	6.5±6.32^{d}	0.19±1.81^{d}	6.2±3.2^{c}	4.55±4.44^{d}	9.71±0.01^{c}	N.D*	4.97±0.02^{c}
	Leaves	2.1±2.0^{d}	4.1±6.12^{d}	0.28±2.4^{d}	4.6±4.87^{d}	3.11±4.52^{d}	33.14±0.21^{b}	1.35±0.02^{d}	2.61±0.02^{d}

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Proximate analysis and heavy metal detection in aquatic plants of Study area 4 (Wallay wala)

The data of proximate analysis and heavy metal detection in aquatic plants of study area 4 (Wallay wala) was analyzed by three-way ANOVA and for comparing means DMRT was applied. The results of proximate analysis revealed significant differences ($p<0.05$) while the results of metal detection revealed non-significant differences ($p>0.05$) among the species of the study area 4. The moisture contents of aquatic plants ranged between (7.65±2.31^{a} to 2.11±1.93^{d})g/100g of dry weight. The highest value of moisture (7.65±2.31^{a}) was observed in roots of *Typha latifolia* while the lowest value (2.11±1.93^{d}) was observed in the leaves of *Potenderia chordata*. The protein contents of aquatic plants ranged between (19.11±5.98^{a} to 2.25±6.30^{d})g/100g of dry weight. The highest value was recorded as (19.11±5.98^{a}) in leaves of *Typha latifolia* while the lowest value was recorded as (2.25±6.30^{d}) in stems of *Typha latifolia*. The fat contents of aquatic plants ranged between (0.21 ± 1.91^{a} to 5.86 ± 2.53^{d})g/100g of dry weight. The highest value was noted as (0.21 ± 1.91^{a}) in stems of *Potenderia chordata* while the lowest value was noted as (5.86 ± 2.53^{d}) in leaves of *Typha latifolia*. The fiber contents of aquatic plants ranged between (9.8 ± 03.28^{a} to 1.75 ± 3.28^{d})g/100g of dry weight. The highest value of fiber was observed as (9.8 ± 03.28^{a}) in stems of *Phragmites australis* while the lowest value was observed as (1.75 ± 3.28^{d}) in stems of *Eicchornia crassipes*. The ash contents of the aquatic plants varies between (22.11 ± 8.17^{a} to 1.6 ± 8.17^{d})g/100g of dry weight. The highest value of ash contents was noted as (22.11 ± 8.17^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (1.6 ± 8.17^{d}) in roots of *Nymphae lotus*. The accumulation of Lead (Pb) in aquatic plants ranged between (81.14 ± 0.09^{a} to 3.2 ± 0.21^{d})mg/kg. The highest value was observed as (81.14 ± 0.09^{a}) in roots of *Potenderia chordata* while the lowest value was recorded as (3.2 ± 0.21^{d}) in leaves of *Typha latifolia*. The Cadmium accumulation ranged between (9.2 ± 0.05^{a} to 0.18 ± 0.02^{d})mg/kg. The highest value was recorded as (9.2 ± 0.05^{a}) in the roots of *Eicchornia crassipes* while the lowest value was recorded as (18 ± 0.02^{d}) in the leaves of *Typha latifolia*. The Chromium accumulation ranged between (8.5 ± 0.02^{a} to 1.14 ± 0.02^{d})mg/kg. The highest value was observed as (8.5 ± 0.02^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (1.14 ± 0.02^{d}) in the leaves of *Typha latifolia*.

Table 4. Proximate analysis (g/100g of dry weight) and heavy metal detection in aquatic plants of Study area 4 (Wallay wala). *S.D (Standard deviation), *N.D (Not detectable)

Species Name	Plant Fragments	Moisture Contents % ±S.D*	Crude protein % ±S.D*	Crude Fat % ±S.D*	Crude Fiber % ±S.D*	Ash Contents % ±S.D*	Lead (Pb)mg/Kg ±S.D*	Cadmium (Cd)mg/Kg ±S.D*	Chromium (Cr)mg/Kg ±S.D*
Eicchornia crassipes (Water hycinth)	Roots	2.33 ± 2.31^{d}	2.61±5.50d	3.42 ± 1.44^{c}	8.75 ± 2.11^{b}	22.11 ± 8.17^{a}	80.21 ± 0.09^{a}	9.2 ± 0.05^{a}	8.5 ± 0.02^{a}
	Stems	3.95 ± 1.51^{c}	10.11 ± 6.30^{c}	1.96 ± 1.91^{d}	1.75 ± 3.28^{d}	16.2 ± 4.40^{b}	9.25 ± 0.01^{c}	3.2 ± 0.02^{c}	6.2 ± 0.02^{b}
	Leaves	6.4 ± 1.93^{a}	11.92 ± 5.98^{b}	1.14 ± 2.53^{d}	4.22 ± 4.8^{d}	13.15 ± 4.79^{b}	36.11 ± 0.21^{b}	1.21 ± 0.02^{d}	2.98 ± 0.02^{c}
Typha latifolia (Cattail)	Roots	7.65 ± 2.31^{a}	13.5 ± 5.50^{b}	3.71 ± 1.44^{c}	6.66 ± 2.11^{c}	7.35 ± 8.17^{c}	70.70 ± 0.09^{a}	6.01 ± 0.05^{b}	5.62 ± 0.02^{b}
	Stems	6.62 ± 1.51^{a}	2.25 ± 6.30^{d}	2.32 ± 1.91^{d}	8.14 ± 3.28^{b}	7.12 ± 4.40^{c}	8.4 ± 0.01^{c}	N.D*	3.14 ± 0.02^{c}
	Leaves	3.3 ± 1.93^{c}	19.11 ± 5.98^{a}	5.86 ± 2.53^{a}	6.61 ± 4.8^{c}	7.19 ± 4.79^{c}	3.2 ± 0.21^{d}	0.18 ± 0.02^{d}	N.D*
Phragmites australis (Phragmites)	Roots	7.5 ± 2.31^{a}	11.8 ± 5.50^{b}	3.1 ± 1.44^{d}	5.78 ± 2.11^{c}	9.16 ± 8.17^{c}	$71.8\pm0.09|^{c}$	5.08 ± 0.05^{b}	6.62 ± 0.02^{b}
	Stems	6.11 ± 1.51^{a}	17.58 ± 6.30^{a}	5.1 ± 1.91^{a}	9.8 ± 3.28^{b}	7.9 ± 4.40^{c}	7.09 ± 0.01^{c}	N.D*	N.D*
	Leaves	3.5 ± 1.93^{c}	17.92 ± 5.98^{a}	5.4 ± 2.53^{a}	5.9 ± 4.8^{c}	7.9 ± 4.79^{c}	31.59 ± 0.21^{b}	0.59 ± 0.02^{d}	6.90 ± 0.02^{b}
Nymphae lotus (Water lily)	Roots	7.5 ± 2.31^{a}	14.14 ± 5.50^{b}	3.1 ± 1.44^{d}	8.9 ± 2.11^{b}	1.6 ± 8.17^{d}	80.60 ± 0.09^{a}	8.62 ± 0.05^{a}	7.75 ± 0.02^{a}
	Stems	4.6 ± 1.51^{b}	15.61 ± 6.30^{b}	4.1 ± 1.91^{b}	9.11 ± 3.28^{b}	6.9 ± 4.40^{c}	N.D*	3.41 ± 0.02^{b}	5.15 ± 0.02^{b}
	Leaves	6.3 ± 1.93^{a}	17.9 ± 5.98^{a}	4.25 ± 2.53^{b}	16.14 ± 4.8^{a}	15.1 ± 4.79^{b}	34.91 ± 0.21^{b}	1.28 ± 0.02^{d}	2.98 ± 0.02^{d}
Potenderia chordata (Pickerel weed)	Roots	5.1 ± 2.31^{b}	3.9 ± 5.50^{d}	0.15 ± 1.44^{d}	3.85 ± 2.11^{d}	2.8 ± 8.17^{d}	81.14 ± 0.09^{a}	7.98 ± 0.05^{b}	6.78 ± 0.02^{b}
	Stems	2.9 ± 1.51^{d}	6.7 ± 6.30^{c}	0.21 ± 1.91^{d}	5.55 ± 3.28^{c}	4.8 ± 4.40^{d}	9.8 ± 0.01^{c}	1.25 ± 0.02^{d}	5.99 ± 0.02^{b}
	Leaves	2.11 ± 1.93^{d}	4.9 ± 5.98^{d}	0.26 ± 2.53^{d}	5.52 ± 4.8^{c}	3.22 ± 4.79^{d}	36.16 ± 0.21^{b}	1.28 ± 0.02^{d}	3.15 ± 0.02^{c}

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Proximate analysis and heavy metal detection in aquatic plants of Study area 5 (Surroundings of leather tanning industry)

The data of proximate analysis and heavy metal detection in aquatic plants of study area 5 (Surroundings of leather tanning industry) was analyzed by three-way ANOVA and for comparing means DMRT was applied. The results of proximate analysis revealed significant differences ($p<0.05$) while the results of metal detection revealed non-significant differences ($p>0.05$) among the species of the study area 5. The moisture contents of aquatic plants ranged between (8.1 ± 2.63^{a} to 1.92 ± 2.63^{d})g/100g of dry weight. The highest value of moisture (8.1 ± 2.63^{a}) was observed in roots of *Nymphae lotus* while the lowest value (1.92 ± 2.63^{d}) was observed in the roots of *Eicchornia crassipes*. The protein contents of aquatic plants ranged between (18.91 ± 5.57^{a} to 2.27 ± 6.23^{d})g/100g of dry weight. The highest value was recorded as (18.91 ± 5.57^{a}) in leaves of *Typha latifolia* while the lowest value was recorded as (2.27 ± 6.23^{d}) in stems of *Typha latifolia*. The fat contents of aquatic plants ranged between (6.12 ± 2.63^{a} to 0.15 ± 2.63^{d})g/100g of dry weight. The highest value was noted as (6.9±0.99^{a}) in leaves of *Typha latifolia* while the lowest value was noted as (0.2±0.99^{d}) in leaves of *Potenderia chordata*. The fiber contents of aquatic plants ranged between (9.19±2.48^{a} to 1.72±3.05^{d})g/100g of dry weight. The highest value of fiber was observed as (9.19±2.48^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (1.72±3.05^{d}) in stems of *Eicchornia crassipes*. The ash contents of the aquatic plants varies between (23.12±8.54^{a} to 1.62±8.54^{d})g/100g of dry weight. The highest value of ash contents was noted as (23.12±8.54^{a}) in roots of *Eicchornia crassipes* while the lowest value was observed as (1.62±8.54^{d}) in roots of *Nymphae lotus*. The accumulation of Lead (Pb) in aquatic plants ranged between (85.60±0.09^{a} to 4.5±0.21^{d})mg/kg. The highest value was observed (85.60±0.09^{a}) in roots of *Nymphae lotus* while the lowest value was recorded as (4.5±0.21^{d}) in leaves of *Typha latifolia*. The Cadmium accumulation ranged between (9.82±0.05^{a} to 0.25±0.02^{d})mg/kg. The highest value was recorded as (9.82±0.05^{a}) in the roots of *Nymphae lotus* while the lowest value was recorded as (0.25±0.02^{d}) in the leaves of *Typha latifolia*. The Chromium accumulation ranged between (11.61±0.02^{a} to 3.60±0.02^{d})mg/kg. The highest value was observed as (11.61±0.02^{a}) in leaves of *Potenderia chordata* while the lowest value was observed as (3.60±0.02^{d}) in the leaves of *Eicchornia crassipes*.

Table 5. Proximate analysis (g/100 g of dry weight) and heavy metal detection in aquatic plants of Study area 5, Surroundings of leather tanning industry. *S.D (Standard deviation), *N.D (Not detectable).

Species Name	Plant Fragments	Moisture Contents % ±S.D*	Crude protein % ±S.D*	Crude Fat % ±S.D*	Crude Fiber % ±S.D*	Ash Contents % ±S.D*	Lead (Pb)mg/Kg ±S.D*	Cadmium (Cd)mg/Kg ±S.D*	Chromium (Cr)mg/Kg ±S.D*
Eicchornia crassipes (Water hycinth)	Roots	1.92±2.63^{d}	2.51±5.57^{d}	3.34±1.31^{c}	9.19±2.48^{b}	23.12±8.54^{a}	82.25±0.09^{a}	9.5±0.05^{a}	8.9±0.02^{b}
	Stems	4.1±1.29^{c}	11.11±6.23^{b}	2.99±2.07^{d}	1.72±3.05^{d}	15.95±4.35^{b}	9.35±0.01^{c}	3.9±0.02^{c}	8.1±0.02^{b}
	Leaves	6.21±2.04^{b}	12.12±5.57^{b}	1.19±2.63^{d}	3.39±4.36^{d}	14.62±5.38^{b}	38.15±0.21^{b}	1.50±0.02^{d}	3.60±0.02^{d}
Typha latifolia (Cattail)	Roots	7.91±2.63^{a}	13.45±5.57^{b}	2.78±1.31^{d}	6.72±2.48^{c}	8.14±8.54^{c}	72.12±0.09^{a}	7.5±0.05^{b}	7.92±0.02^{b}
	Stems	6.41±1.29^{b}	2.27±6.23^{d}	2.45±2.07^{d}	7.97±3.05^{c}	7.5±4.35^{c}	8.91±0.01^{c}	N.D*	6.14±0.02^{c}
	Leaves	6.51±2.04^{b}	18.91±5.57^{a}	6.12±2.63^{a}	6.55±4.36^{c}	4.12±5.38^{d}	4.5±0.21^{d}	0.25±0.02^{d}	N.D*
Phragmites australis (Phragmites)	Roots	7.62±2.63^{a}	11.9±5.57^{b}	3.9±1.31^{c}	4.5±2.48^{d}	8.56±8.54^{c}	82.52±0.09^{a}	5.98±0.05^{c}	9.61±0.02^{a}
	Stems	6.1±1.29^{b}	16.95±6.23^{a}	5.12±2.07^{a}	8.92±3.05^{b}	8.91±4.35^{c}	8.06±0.01^{c}	N.D*	6.15±0.02^{c}
	Leaves	3.8±2.04^{c}	17.92±5.57^{a}	5.56±2.63^{a}	4.87±4.36^{d}	7.9±5.38^{c}	32.60±0.21^{b}	0.97±0.02^{d}	8.90±0.02^{b}
Nymphae lotus (Water lily)	Roots	8.1±2.63^{a}	14.56±5.57^{b}	3.19±1.31^{c}	9.12±2.48^{b}	1.62±8.54^{d}	85.60±0.09^{a}	9.82±0.05^{a}	9.96±0.02^{a}
	Stems	4.1±1.29^{c}	16.12±6.23^{a}	5.25±2.07^{a}	8.9±3.05^{b}	5.95±4.35^{c}	10.69±0.01^{c}	3.56±0.02^{c}	9.52±0.02^{a}
	Leaves	6.9±2.04^{b}	15.97±5.57^{b}	3.92±2.63^{c}	15.15±4.36^{a}	14.12±5.38^{b}	36.96±0.21^{b}	1.92±0.02^{d}	5.55±0.02^{c}
Potenderia chordata (Pickerel weed)	Roots	4.9±2.63^{c}	4.14±5.57^{d}	0.19±1.31^{d}	3.92±2.48^{d}	2.9±8.54^{d}	83.12±0.09^{a}	8.15±0.05^{a}	9.92±0.02^{a}
	Stems	3.56±1.29^{c}	6.75±6.23^{c}	0.25±2.07^{d}	5.6±3.05^{c}	4.9±4.35^{d}	10.5±0.01^{c}	1.31±0.02^{d}	10.50±0.02^{a}
	Leaves	1.92±2.04^{d}	5.2±5.57^{d}	0.15±2.63^{d}	5.62±4.36^{c}	3.22±5.38^{d}	37.67±0.21^{b}	1.60±0.02^{d}	11.61±0.02^{a}

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Physico-Chemical parameters and metal detection in soil samples collected from the study areas

The data collected by analyzing the physico-chemical parameters of the soil samples collected from 5 study areas, Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry, was analyzed by one way ANOVA. The results of soil physico-chemical parameters revealed significant differences ($p<0.05$) in pH, electrical conductivity, alkalinity, total dissolved solids, sand, silt and clay. The level of pH in soil ranged between (5.9±0.01^{a} to 7.89±0.01^{d}). The highest value was observed as (7.89±0.01^{a}) at study area 3, Ganda-singh wala while the lowest value of pH was observed as (5.9±0.01^{d}) at study area 5, surroundings of leather tanning industry. The electrical conductivity of soil ranged between (1989±0.66^{a} to 2138±0.66^{d})uS/cm. The highest value for soil electrical conductivity was noted as (2138±0.66^{a}) at study area 3, Bhakhiwind while the lowest value was noted as (1989±0.66^{d}) at study area 4, Wallay wala. The alkalinity level of soil samples ranged between (114±0.77^{a} to 187±0.77^{d})mg/kg. The highest value was observed as (187±0.77^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of alkalinity was observed as (114±0.77^{d}) at study area 2, Bhakhiwind. The level of total dissolved solids ranged between (1810 ± 0.81^a to 2002 ± 0.81^d)mg/kg. The highest value was observed as (2002 ± 0.81^a) at study area 4, Wallay wala while the lowest value of total dissolved solids was observed as (1810 ± 0.81^d) at study area 1, Nagar village. The sand composition in soil samples collected from the study areas ranged between (92.56 ± 0.03^a to 57.21 ± 0.03^d)g/100g of dry weight. The highest value was observed as (92.56 ± 0.03^a) at study area 4, Wallay wala while the lowest value of sand was observed as (57.21 ± 0.03^d) at study area 5, surroundings of leather tanning industry. The silt composition in soil samples ranged between (22.38 ± 0.05^a to 35.77 ± 0.05^d)g/100g of dry weight. The highest value for silt composition was noted as (35.77 ± 0.05^a) at study area 1, Nagar village while the lowest value was noted as (22.38 ± 0.05^d) at study area 4, Wallay wala. The composition of clay in the soil sample collected from the study areas ranged between (2.79 ± 0.07^a to 3.67 ± 0.07^d)g/100g of dry weight. The highest value was observed as (3.67 ± 0.07^a) at study area 3, Ganda-Singh wala while the lowest value of clay was observed as (2.79 ± 0.07^d) at study area 4, wallay wala. The data collected by analyzing results of metal detection in the soil samples collected from 5 study areas, Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry, was analyzed by one way ANOVA. The results of metal detection revealed significant differences ($p<0.05$) among the study areas and metals detected, i.e. Lead (Pb), Cadmium (Cd) and Chromium (Cr). The accumulation of lead (Pb) in soil samples ranged between (0.28 ± 0.001^a to 0.56 ± 0.001^d)mg/kg. The highest value of lead (Pb) accumulation was observed as (0.56 ± 0.001^a) at study area 5, surroundings of leather tanning industry while the lowest value was observed as (0.28 ± 0.001^d) at study area 1, Nagar village. The cadmium (Cd) accumulation in soil samples ranged between (0.11 ± 0.001^a to 1.50 ± 0.001^d)mg/kg. The Highest value of cadmium detection in soil samples was noted as (1.50 ± 0.001^a) at study area 5, surroundings of leather tanning industry while the lowest value was observed as (1.50 ± 0.001^d) at study area 1, Nagar village. The chromium (Cr) detection in soil samples ranged between (0.04 ± 0.001^a to 2.0 ± 0.001^d)mg/kg. The highest value of chromium was observed as (2.0 ± 0.001^a) in the soil sample taken from the study area 5, surroundings of leather tanning industry while the lowest value was observed as (0.04 ± 0.001^d) at study area 1, Nagar village.

Table 6. Physico-Chemical parameters and metal detection in soil samples collected from the study areas. *S.D (Standard deviation), *N.D (Not detectable).

Study Area	pH ±S.D*	E.C (uS/cm) ±S.D*	Alkalinity (mg/kg) ±S.D*	TDS (mg/kg) ±S.D*	Sand % ±S.D*	Silt % ±S.D*	Clay % ±S.D*	Lead (Pb) (mg/kg) ±S.D*	Cadmium (Cd) (mg/kg) ±S.D*	Chromium (Cd) (mg/kg) ±S.D*
Nagar Village	7.71 ± 0.01^a	2130 ± 0.66^a	116 ± 0.77^d	1810 ± 0.81^d	60.44 ± 0.03^b	35.77 ± 0.05^a	3.61 ± 0.07^b	0.28 ± 0.001^d	0.11 ± 0.001^d	0.04 ± 0.001^d
Bhakhiwind	7.38 ± 0.01^b	2138 ± 0.66^a	114 ± 0.77^d	1862 ± 0.81^c	59.89 ± 0.03^c	32.75 ± 0.05^b	3.50 ± 0.07^c	0.35 ± 0.001^c	N.D*	0.68 ± 0.001^d
Ganda- singh wala	7.89 ± 0.01^a	2076 ± 0.66^b	162 ± 0.77^c	1903 ± 0.81^b	57.67 ± 0.03^d	28.45 ± 0.05^c	3.67 ± 0.07^a	0.41 ± 0.001^b	0.82 ± 0.001^a	N.D*
Wallay wala	6.8 ± 0.01^c	1989 ± 0.66^c	178 ± 0.77^b	2002 ± 0.81^a	92.56 ± 0.03^a	22.38 ± 0.05^d	2.79 ± 0.07^d	0.43 ± 0.001^b	1.23 ± 0.001^b	1.5 ± 0.001^b
Tannaries Area	5.9 ± 0.01^d	1990 ± 0.66^d	187 ± 0.77^a	1894 ± 0.81^c	57.21 ± 0.03^d	25.24 ± 0.05^d	3.65 ± 0.07^a	0.56 ± 0.001^a	1.50 ± 0.001^b	2.0 ± 0.001^a

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Physico-Chemical parameters and metal detection in water samples collected from the study areas

The data collected by analyzing the physico-chemical parameters of the water samples collected from 5 study areas, Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry, was analyzed by one way ANOVA. The results of water physico-chemical parameters revealed significant differences ($p<0.05$) among temperature, pH, free Co_2, total alkalinity, calcium hardness, total hardness, chlorides, electrical conductivity, total dissolved solids, and salinity. The level of temperature in the water samples collected form the study areas ranged between (22.2 ± 1.10^a to 20.3 ± 1.75^d)˚C. The highest value was observed as (22.2 ± 1.10^a) at study area 4, Wallay wala while the lowest value of temperature was observed as (20.3±1.75^{d}) at study area 2, Bhakhiwind. The level of pH ranged between (8.2±0.20^{a} to 6.3±0.43^{d}). The highest value was observed as (8.2±0.20^{a}) at study area 2, Bhakhiwind while the lowest value of pH was observed as (6.3±0.43^{d}) at study area 5, Surroundings of leather tanning industry. The level of free CO_2 ranged between (40±1.07^{a} to 21±3.02^{d}) ppm. The highest value was observed as (40±1.07^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of free CO_2 was observed as (21±3.02^{d}) at study area 1, Nagar village. The level of total alkalinity ranged between (146±1.11^{a} to 89±2.15^{d})mg/L. The highest value was observed as (146±1.11^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of total alkalinity was observed as (89±2.15^{d}) at study area 3, Ganda-singh wala. The level of calcium hardness ranged between (145±2.21^{a} to 79±1.42^{d})mg/L. The highest value was observed as (145±2.21^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of calcium hardness was observed as (79±1.42^{d}) at study area 1, Nagar village. The level of total hardness ranged between (228±1.23^{a} to 203±3.60^{c})mg/L. The highest value was observed as (228±1.23^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of free total hardness was observed as (203±3.60^{c}) at study area 3, Ganda-singh wala. The level of chlorides ranged between (92±3.42^{a} to 58±1.24^{d})mg/L. The highest value was observed as (92±3.42^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of chlorides was observed as (58±1.24^{d}) at study area 2, Bhakhiwind. The electrical conductivity of the water samples collected form the study areas ranged between (5.73±0.34^{a} to 4.9±0.42^{c})uS/cm. The highest value was observed as (5.73±0.34^{a}) at study area 2, Bhakhiwind while the lowest electrical conductivity was observed as (4.9±0.42^{c}) at study area 3, Ganda-singh wala. The level of total dissolved solids ranged between (1504±3.17^{a} to 310±3.32^{d})mg/L. The highest value was observed as (1504±3.17^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of total dissolved solids was observed as (310±3.32^{d}) at study area 1, Nagar village. The level of salinity ranged between (2.3±0.62^{a} to 0.8±0.47^{d}) ppt. The highest value was observed as (2.3±0.62^{a}) at study area 5, surroundings of leather tanning industry while the lowest value of salinity was observed as (0.8±0.47^{d}) at study area 1, Nagar village. The data collected by analyzing results of metal detection in the water samples collected from 5 study areas, Nagar village, Bhakhiwind, Ganda-Singh Wala, Wallay wala and Surroundings of Leather Tanning Industry, was analyzed by one way ANOVA. The results of metal detection revealed significant differences ($p<0.05$) among the study areas and metals detected, i.e. Lead (Pb), Cadmium (Cd) and Chromium (Cr). The accumulation of lead (Pb) in water samples ranged between (0.55±0.001^{a} to 0. 0.39±0.001^{d})mg/L. The highest value of lead (Pb) accumulation was observed as (0.55±0.001^{a}) at study area 5, surroundings of leather tanning industry while the lowest value was observed as (0.39±0.001^{d}) at study area 1, Nagar village. The cadmium (Cd) accumulation in water samples ranged between (1.95±0.001^{a} to 0.15±0.001^{d})mg/L. The Highest value of cadmium detection in water samples was noted as (1.95±0.001^{a}) at study area 5, surroundings of leather tanning industry while the lowest value was observed as (0.15±0.001^{d}) at study area 1, Nagar village. The chromium (Cr) detection in water samples ranged between (2.5±0.001^{a} to 0.008±0.001^{d})mg/L. The highest value of chromium was observed as (2.5±0.001^{a}) in the water sample taken from the study area 5, surroundings of leather tanning industry while the lowest value was observed as (0.008±0.001^{d}) at study area 1, Nagar village.

Proximate analysis of aquatic plants

The moisture contents of aquatic plants ranged between (1.7±2.61^{d} to 7.9±2.61^{a})g/100g of dry weight. The protein contents ranged between (2.51±5.57^{d} to 22.14±0.7^{a})g/100g of dry weight. The fat contents ranged between (0.15±2.63^{d} to 6.9±2.77^{a})g/100g of dry weight. The fiber contents of aquatic plants ranged between (1.75±3.28^{d} to 16.14±4.8^{a})g/100g of dry weight. The values of ash contents in aquatic plants ranged between (1.62±8.54^{d} to 23.12±8.54^{a})g/100g of dry weight. The results of our study shows that the moisture contents of aquatic plants recorded, are in accordance with the results observed by (Banerjee *et al,* 1990). The protein contents are almost similar with the values given by (Akmal *et al,* 2014). The observed values for fat contents are slightly greater than the fat contents noted by Mbagwu and adeniji (1988). The fiber contents of the aquatic plants samples collected during the study are related to the results described by (Linn *et al.* 1973). The values for ash contents observed by (Muhammed *et al,* 2012) are slightly higher than the values obtained in the present study.

Table 7. Physico-Chemical parameters and metal detection in water samples collected from the study areas. *S.D (Standard deviation).

Study Area	Temp. (˚C) ±S.D*	pH ±S.D*	Free CO_2 (ppm) ±S.D*	Total Alkalinity (mg/L) ±S.D*	Calcium Hardness (mg/L) ±S.D*	Total Hardness (mg/L) ±S.D*	Chlorides (mg /L) ±S.D*	E.C (uS/ cm) ±S.D*	T.D.S (mg /L) ±S.D*	Salinity (ppt) ±S.D*	Lead (Pb) (mg/L) ±S.D*	Cadmium (Cd) (mg/L) ±S.D*	Chromium (Cr) (mg/L) ±S.D*
Nagar Village	21.6± 1.18^b	7.5± 0.32^b	21± 3.02^d	96± 1.23^c	79± 1.42^d	198± 1.52^b	67± 2.16^c	5.37± 0.65^a	310± 3.32^d	0.8± 0.47^d	0.39± 0.001^d	0.15± 0.001^d	0.008± 0.001^d
Bhakhi wind	20.3± 1.75^d	8.2± 0.20^a	36± 2.71^b	107± 1.26^b	94± 2.08^c	216± 2.51^a	58± 1.24^d	5.73± 0.34^a	342± 2.76^d	1.2± 0.57^c	0.40± 0.001^c	0.63± 0.001^c	0.008± 0.001^d
Ganda-singh wala	20.7± 0.56^c	6.5± 1.20^c	32± 2.11^b	89± 2.15^d	125± 2.30^b	203± 3.60^c	71± 3.54^c	4.9± 0.42^c	456± 4.92^c	1.1± 1.02^c	0.43± 0.001^b	0.98± 0.001^c	0.12± 0.001^c
Wallay wala	22.2± 1.10^a	6.4± $0{,}92^c$	29± 1.54^c	113± 1.78^b	137± 3.0^b	196± 2.54^b	81± 1.48^b	4.6± 0.76^b	623± 2.48^b	1.9± 0.55^b	0.48± 0.001^b	1.36± 0.001^b	1.8± 0.001^b
Tanneries Area	21.7± 1.23^b	6.3± 0.43^d	40± 1.07^a	146± 1.11^a	145± 2.21^a	228± 1.23^a	92± 3.42^a	5± 0.98^a	1504 ± 3.17^a	2.3± 0.62^a	0.55± 0.001^a	1.95± 0.001^a	2.5± 0.001^a

Means sharing similar letters are statistically non-significant ($p>0.05$) and different letters in columns (abcd) are statistically significant ($p<0.05$)

Heavy Metal detection in aquatic plants, water and soil

Ingole *et al.* (2000) concluded that the huge magnitude of developing industrialization is responsible for increasing heavy metal pollution. The data obtained by heavy metal detection (Lead, Cadmium and Chromium) in aquatic plants revealed significant differences ($p<0.05$) in Pb and Cd and Cr. The data obtained after heavy metal detection shows that in roots of most aquatic plants the metal accumulation occurs in order Pb>Cd>Cr. In stems and leaves of aquatic plants the metal accumulation occurs in order Pb>Cr>Cd. The accumulation of heavy metals in different fragments of aquatic plants occurs in order Roots>Leaves>Stems.

Lead (Pb)

Singh *et al.* (2012) stated that lead is such a fetal heavy metal which can cause adverse environmental and health effect even in low concentrations. David *et al.* (2003) narrated that lead is one of the highly toxic heavy metals, as it enters and absorbs in the body directly. Lead has an ability to be stored in bones, tooth and tissues. The permissible limit in plants recommended by WHO is 2mg/kg and its maximum limit for water is 0.05mg/l. If the limit become exceeded then serious health issues like hepatitis and anemia may result. During present study the lead limits were observed between ($0.28±0.001^d$ to $82.25±0.09^a$)mg/kg in aquatic plants. In water samples collected the lead limits were observed between ($0.39±0.001^d$ to $0.55±0.001^a$)mg/L. The values observed for lead are higher than the maximum limit described by WHO.

Cadmium (Cd)

Wolverton *et al.* (1978) stated that cadmium is a highly toxic heavy metal for human life. Its exceeded limits can cause cancer, liver diseases, kidney diseases and cardiovascular issues and even very low concentrations can cause serious health issues. The permissible limit of Cadmium in plants, recommended by WHO, is 0.02mg/kg and 0.01mg/l in water. During present study the cadmium values were recorded between ($0.11±0.001^d$ to $9.82±0.05^a$)mg/kg in aquatic plants. The values observed in water samples ranged between

(0.15±0.001[d] to 0.98±0.001[c])mg/L. The observed values in water samples reflects the results given by (Nazir *et al,* 2015). The values of cadmium in aquatic plants are greater than the permissible limits recommended by WHO.

Chromium (Cr)

Chandra *et al.* (1997) stated that chromium is found naturally in animals, plants and rocks. Although chromium is required by the biological systems of animals and humans as it cause breakdown of fats, proteins and sugars. If taken in excess then it causes serious health damages. The permissible limit of Chromium for plants is 1.30mg/kg and the maximum permissible limit for Cr in water is 0.1mg/l recommended by WHO. During the present study, the values observed in water samples ranged between (0.008±0.001[d] to 2.5±0.001[a])mg/L. These limits are in accordance with the limits reported by (Zigham Hassan *et al.* 2012). The chromium limits in aquatic plants were observed between (0.04±0.001[d] to 11.61±0.02[a])mg/kg. The chromium accumulation observed during the study are higher than the maximum limits defined by WHO. These higher limits are due to the leather tanning practices in Kasur because during leather tanning process the chromium acts as an active metal ingredient.

Physico-chemical parameters of soil

Latha, (2016) concluded that water and sediment pollution has adversely affect the aquatic ecosystems by the discharge of industrial effluents in the natural water sources. The results of soil physico-chemical parameters revealed significant differences ($p<0.05$) in pH, electrical conductivity, alkalinity, total dissolved solids, sand, silt and clay. The level of pH in soil ranged between (5.9±0.01[a] to 7.89±0.01[d]). The electrical conductivity of soil ranged between (1989±0.66[a] to 2138±0.66[d])uS/cm. The alkalinity level of soil samples ranged between (114±0.77[a] to 187±0.77[d])mg/kg. The level of total dissolved solids ranged between (1810±0.81[a] to 2002±0.81[d])mg/kg. The sand composition in soil samples collected from the study areas ranged between (92.56±0.03[a] to 57.21±0.03[d])g/100 g of dry weight. The silt composition in soil samples ranged between (22.38±0.05[a] to 35.77±0.05[d])g/100 g of dry weight. The composition of clay in the soil sample collected from the study areas ranged between (2.79±0.07[a] to 3.67±0.07[d])g/100g of dry weight. The values observed after the analysis of physico-chemical parameters of soil are in accordance with the study proposed by (Nazir *et al,* 2015).

Physico-chemical parameters of water

As per recommendation by (APHA, 1995) the observation of the physico-chemical parameters can yield an overview of the overall water quality of water bodies. The indicative properties of such parameters can give a clear idea about the overall quality of the wetlands. The level of temperature in the water samples collected form the study areas ranged between (22.2±1.10[a] to 20.3±1.75[d])°C. The level of pH ranged between (8.2±0.20[a] to 6.3±0.43[d]). The level of free CO_2 ranged between (40±1.07[a] to 21±3.02[d]) ppm. The level of total alkalinity ranged between (146±1.11[a] to 89±2.15[d])mg/L. The level of calcium hardness ranged between (145±2.21[a] to 79±1.42[d])mg/L. The level of total hardness ranged between (228±1.23[a] to 203±3.60[c])mg/L. The level of chlorides ranged between (92±3.42[a] to 58±1.24[d])mg/L. The electrical conductivity of the water samples collected form the study areas ranged between (5.73±0.34[a] to 4.9±0.42[c]) uS/cm. The level of total dissolved solids ranged between (1504±3.17[a] to 310±3.32[d])mg/L. The level of salinity ranged between (2.3±0.62[a] to 0.8±0.47[d]) ppt. The data obtained by physico-chemical analysis of water shows relativeness with the data proposed by (Akmal *et al,* 2014).

Conclusions

During the present study, the results showed that natural ecosystems of country are in tremendous pollution pressures. The reason for this extremity in values is might be due to the addition of civic wastes and industrial effluents as the sewage of the city is directly discharged into the river along with the leather tanning industries which are also discharging their effluents into the river. This is in agreement with the studies (Hasan *et al,* 2012) who reported that the level of heavy metals increasing in the rivers due to discharge of industrial effluents and civic pollution of various kinds. This is in turn deteriorating the water quality making it unsuitable for both aquatic and human life. The data obtained from this study will help the aquaculture scientists to understand the status of heavy metals accumulation in aquatic plants, associated soils and water, being parts of freshwater ecosystem. The aquatic plants have proved themselves for lowering the heavy metal pollution from associated water and soil.

Recommendations

As aquatic plants are efficient in absorbing and accumulating the heavy metal traces from water. It is suggested to use the aquatic plants for lowering the heavy metal pollution from associated water and soil of freshwater ecosystems and wetlands. The proximate analysis of aquatic plants showed that these plants can also be used as animal feed supplement to decrease the protein loads from feed manufacturing industry. The industrial effluents should be treated and managed before their discharge in the rivers and natural freshwater reservoirs so that the heavy metal contents of the river remains in limitations.

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