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Reuse of wastewater for irrigation purposes

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Abstract

At present no Macrophyte WSP system under study in many of developing countries like Pakistan, so for promotion of macrophytes based WSP system, detailed pilot scale studies is needed for treating wastewater that can be used for irrigation purposes. In near future, water scarcity is expected all over the world so efforts should be made to address this issue, as most of economy of our country is dependent on agriculture. The aims of this study is to reduce and evaluate the different parameters of domestic wastewater by treating it with macrophtes WSP system with different Hydraulic Retention Times (HRT) so that wastewater can be used for irrigation purposes as per FAO Irrigation Water Quality Guidelines. A macrophytes WSP system model was designed /operated for five experimental runs with each run comprising of different HRT i.e. 3, 5, 7 and 10 days. For treating wastewater, locally available Macrophyte specie Duckweed was used. The different parameters used in this study were; EC_w , TDS, SAR, Sodium, Chloride, Boron, Nitrate, Bicarbonate, pH and F Coliform. The average reduction in values of different parameters of wastewater at the start of each run was 31.96%, 31.96%, 42.51%, 31.00%, 22.86%, 34.52%, 30.23%, 50.23%, 20.02% and 41.39% for EC_w, TDS, SAR, Sodium, Chloride, Boron, Nitrate, Bicarbonate, pH and F Caliform respectively. After treating wastewater with 10 days HRT, the values of different parameters of wastewater was within the range of FAO guidelines with slight to moderate degree of restriction on use.

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Introduction

In many of developing countries like Pakistan currently no Macrophyte WSP system initiated, thus for uplifting of macrophytes based Wastewater Stabilization Pond system, a comprehensive pilot scale studies is required for treating wastewater which can be used for irrigation purposes. Water scarcity is expected all over the world in near future, thus efforts should be made to reuse this wastewater for irrigation purposes, because most of economy of our country is relying on agriculture.

The prime intention of this research study is to reduce and evaluate the different parameters of domestic wastewater by treating it with macrophtes Waste Stabilization Pond (WSP) system at different Hydraulic Retention Times (HRT) that can be used for irrigation purposes in line with Irrigation Water Quality Guidelines of Food and Agriculture Organization (FAO). The mandatory quality of treated wastewater will base on crop selection, soil conditions and system of distribution chosen for irrigation. The health hazards can be reduced through proper crop selection and selection proper irrigation system.

Pakistan is an agricultural country which is located in severe water shortage region and its population is likely to be increase from 152 million (2005) to 208 million (2025), [Population Census of Pakistan (2017), GOP]. Conversely, in similar water accessibility condenses as shown below in Fig. 1. At that juncture, about 50% of total population will live in cities. The clean water shortage will increase due to rise of population and untreated disposal of domestic and industrial wastewater of the region in the water bodies and other disposal points. This pollutes both ground and surface water. Because of removal of unprocessed domestic and industrial wastewater from certain area into water bodies (i.e. lakes streams and rivers) not only demolish the water ecosystem but also become the cause of several water borne diseases and whenever used for irrigation purposes the contaminants in wastewater taken up by the different crops could also cause different dangerous diseases to users.

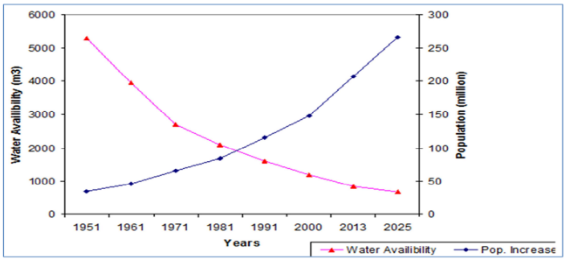

Fig. 1. Water Availability vs Population.

Wastewater Evaluation for a city in Pakistan was studied for Characterization and Agricultural Reuse. Under this characterizes 154 WW samples were collected from 11 disposal stations. These samples were analyzed for 23 parameters related to organic matter, nutrients, inorganic matter, and pathogens to determine pollution extent distribution, agricultural reuse potential, and WW treatment database. The results showed that average values of BOD and COD were 2.7 and 3.8 times higher than the permissible limits while microbiological parameters like total coliform and E-Coli were 10.6 and 36 times higher than the permissible limits. But heavy metals and nutrients were found within the permissible limit except phosphorus. It was found that selected WW parameters showed the direct or indirect relationship among WW constituents and the impact of different sources of pollution on WW characteristics [Khan *et al.,* 2019]. A study was carried out on Municipal Wastewater Treatment of The cloaca maxima, the "biggest sewer" in Rome. This sewer and others similar to it were collected wastes and discharged them into the nearest lake, river, or ocean. These convenient made cities more habitable, but their success relied on transferring the pollution problem from one place to another. Though this worked sensibly well for the Romans but it does not work well today [Gerba, C. P., & Pepper, I. L., 2019].

A wastewater reclamation and reuse trend in Turkey was investigated to know its Prospects and contests. This study was targeted to give an overview of water reuse activities of the country and the opportunities and challenges in increasing reclaimed water reuse. This review precisely presents the research trends performed in different institutes to meet the wastewater reuse goal along with the wastewater treatment plants currently working in the country [Maryam, B., & Büyükgüngör, H., 2019].

Effect of wastewater treatment on the growth of selected leafy vegetable plants (Coriander and Lettuce) was studied. The study was also aimed to know the influence of wastewater treated plants on human health. Vegetative growth parameters such as height, number of leaves, weight of fresh, dry leaves and rate of germination of seed were measured to know the impact of waste water treatment. A significant effect on the growth of leafy plants was found by the usage of Wastewater treatment water. Relatively good results were found in plant treating with wastewater rather than fresh water. The practice of municipal wastewater for irrigation could be a rich resource of the nutrients essential for plant's growth. But as for health hazards, edible crops irrigated with this untreated waste water should not be grown in spite of its positive impact on the physical parameters of some plants [Ali et. al., 2019].

A thorough review of Wastewater irrigation was done with it's past, present, and future prospects. This study discussed the major challenges linked with wastewater irrigation and its future use to help improve wastewater irrigation practices around the world. As a main alternative water resource, wastewater could be used in agriculture to meet water shortages. Wastewater irrigation had a long expansion history and had undergone different phases in developing and developed countries. Untreated wastewater irrigation could come with numerous environmental problems. Strong management practices, such as the application of suitable treated and irrigated technologies, could be used to reap substantial benefits while minimizing risks [Zhang, Y., & Shen, Y., 2019].

Biotechnological approach of greywater treatment and reuse for landscape irrigation in small communities was studied to describe the risks related to GW reuses and to select an appropriate treatment. Three lawn plots were irrigated with raw GW, treated GW and tap water respectively. The risk analysis performed had shown that no significant difference between the lawn plots irrigated with treated GW combined with UV disinfection and the one irrigated with tap water, Contrary to the lawn plot irrigated with raw GW. On the whole, UV disinfection treated GW produced from the horizontal sub-surface flow constructed wetland (HSSF CW) reactor developed was considered to be an effective and feasible alternative for agricultural reuse [Laaffat *et al.,* 2019].

Treatment efficiency of a hybrid constructed wetland system (HCWS) for municipal wastewater and its suitability for crop irrigation was investigated. Treatment efficiency percentages found in HCWS reclaimed water quality parameters were, i.e., EC (56.68), TDS (56.86), alkalinity (39.67), chloride (39.68), sulfate (46.73), Na (28.80), Mn (65.24), Cr (78.07), Ni (81.02), BOD (68.74), total hardness (19.56), Fe (70.09), phosphate (55.40), Pb (80.48), COD (63.64), Mg (17.24), K (60.05), Co (100), Cu (67.73), Zn (59.97), Cd (100), and Ca (21.47) respectively. Wastewater treatment in HCWS was due to aquatic plants (Phragmites australis Cav. Trin. ex Steud., Canna indica L. Typha latifolia L., and Hydrocotyle umbellata L.), microbial activities and substrate based wetland processes. The HCWS treated water was well under irrigation standards and suggested for safer crop production in water scarce regions [Ali *et al.,* 2018].

Effect of Domestic Wastewater as Co-Substrate on Biological Stain Wastewater Treatment using Fungal/Bacterial Consortia in Pilot Plant and Greenhouse reuse was studied. The post-treated effluent was used as irrigation water. Lolium perenne plants were watered during 60 days with post-treated effluent. The results of root weight showed that there were significant differences between the initial water and the effluent obtained after the operational cycles ($p = 0.00470$).

In plants irrigated with water got from the last treatment cycle, maximum root weights (1-1.12g) were found [David *et al.,* 2018].

An effect of Treated Wastewater Irrigation of Sfax, Agareb and Mahres Stations on Olive Plants grown in three soil types was studied. The experiment was done in a greenhouse under controlled conditions, with regular observing of plant morphology, followed by physic-chemical soil parameters. It was found an observable increase in soil alkalinity. An accretion of nutrients (mainly P and K) and salts (Na) in soils 10 months after the application of four types of treated wastewater were observed in comparison to tap water [Bakari *et al.,* 2017]. Reclaimed municipal wastewater for forage production was studied to know its usage possibility for agricultural purpose. The results showed that reclaimed municipal treated wastewater (TWW) increased plant growth, producing taller plants with respect to tubewell water (TW). It was suggested that TWW could be used as a valid alternative to freshwater for irrigation of fodder species [Ines *et al.,* 2017].

Mineral and biological contamination of soil and Capsicum annuum irrigated with recycled domestic wastewater was studied to know; suitability of recycled wastewater contaminated by trace minerals and pathogens for irrigation, impact of differently treated wastewaters on soil and fruits, and marketable yield of the harvest as a function of mineral and biological contamination risk. Results showed that small to enough zinc contamination were traced in some vegetables. Potassium accumulation in the yield showed the highest values followed by zinc. But, conclusions show that vegetables receiving wastewater treated with wetlands could be taken as safe compared to those getting only preliminary treated wastewater. In terms of economic return High yields were linked with an organic growth medium, a wetland with a small aggregate size and a low contact time [Almuktar, S. A. A. A. N., & Scholz, M., 2016].

Biological treatment of drippers clogged by the use of treated domestic wastewater was investigated to recover the flow rate of clogged drippers with different doses and permanence times of the product MaxBio. The flow rate of the drippers and the relative flow rate reduction were investigated to express the unclogging levels after application of MaxBio product. There was major effect of T2 (without biological treatment) and T3 (2nd application of the product) on the recovery of the flow rate of the drippers were observed while for reduction of relative flow rate, the doses of the product did not show statistical difference with regard to types of drippers [Costa *et al.,* 2016]. A Study was conducted on domestic wastewater treatment using new-type multi-layer artificial Wetland. The results showed, when hydraulic loading reaches approximately $0.44m^3/(m^2 d)$ and hydraulic retaining duration reaches 3 days, the effect of removing COD_{Cr}, BOD_5, NH_3–N, TN and TP from the wetland is relatively good, and the average removing rate achieves 90.6%, 87.9%, 66.7%, 63.4 and 92.6% respectively, and the effluent COD_{Cr} reaches approximately 14.1~30.8 mg/L, BOD_5 reaches approximately 8.2~13.1 mg/L,NH_3–N reaches approximately 9.9~19.6mg/L, TN reaches approximately 17.3~28.7mg/L and TP reaches less than 1.2mg/L. In general if temperature is higher than 24°C, the higher planting density and lower contaminant concentration reaches, the better effect of the treatment would be grasping [Shibao *et al.,* 2015].

To overcome the shortage of water in developing counties like Pakistan, where agriculture is major source of income, it is essential to reuse the wastewater for irrigation purposes after proper treatment.

So the study was conducted with the objectives; to determinate the percentage reduction in different parameters of wastewater like Total Dissolved Solids (TDS), Electrical Conductivity (EC_w), Sodium Absorption Ratio (SAR) Sodium, Chloride, Boron, Nitrate, Bicarbonate, pH and F Coliforms, so that, wastewater can be used for irrigation purposes with slight to moderate or no degree of restriction on use as per recommended standards. In addition to that to analyze and compare different samples for their initial raw water value, 3 days treatment value, 5 days treatment value, 7 days treatment value and 10 days treatment value and find out the required Hydraulic Retention Time (HRT) for wastewater to be used for irrigation purposes.

Material and methods

To study the removal efficiency of different parameters of wastewater by treating it with macrophytes (Waste Stabilization Ponds) so that wastewater can be used for irrigation purposes according to FAO Irrigation Water Quality Guidelines. A small bench scale model was constructed and designed for study. The domestic wastewater was collected from Nallah. The specie used for the treating wastewater was Duckweed.

Construction of Model

In the first step a bench scale model for treating wastewater was to design. The material used for the construction of model was tempered glass with the wall thickness of 25mm. Steel frame was used to protect the outer surface of model.

Tempered glass was attached to steel frame with the help of silicone sealant. The model is illustrated in Fig. 2. Overflow rate of model was fixed. After the design of model a prototype was prepared. The prototype was placed at suitable place after construction for testing purpose.

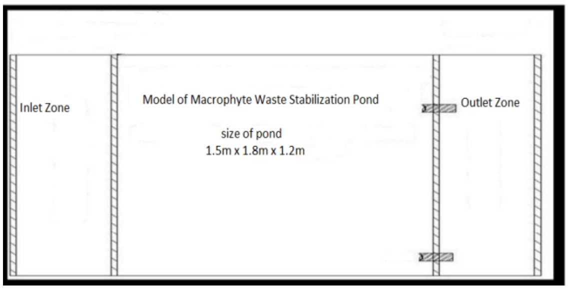

Fig. 2. Plan of Model.

Treatment Materials

In balancing of Lake Ecosystem, macrophytes plays very important role. The plants macrophytes have tendency to develop the water quality of wastewater through absorbing nutrients by the use of their efficient root system. The usefulness of plants macrophytes in reducing the harmful parameters was accessed so that wastewater can be used for irrigation. Under this work, one of the free floating macropyhtes Species Lemma commonly called Duckweed (Fig. 3) was selected /used.

Fig. 3. Macrophyteic Species Lemma (Duckweed).

Sampling Plan

The removal efficiency of treatment of wastewater was studied so that it can be used for irrigation purposes according to FAO Irrigation Water Quality Guidelines, a comprehensive sampling plan was formed which consists of five experimental runs with each run consists of 0, 3, 5, 7 and 10 days Hydraulic Retention Times (HRT). At each HRT, Wastewater samples were collected from Nallah (Fig. 4) and testing on sewer water was done for getting initial values for wastewater and preserved as per standards guidelines. The model was run with different detention times as mentioned above.

Fig. 4. Nallah (Wastewater).

Standards of Sampling and Preservation

For preservation and testing of all samples Standard Methods for Preservation and Examination of Water and Wastewater (American Public Health Association) and World Health Organization (WHO) Guidelines for drinking water quality were followed. Sampling for testing of bacteriological study was done in such a way that no external contamination occur in the samples.

For analysis of bacteriological contamination, Plastic Poly Ethylene (PET) containers with capacity of half liter were used, then containers were washed and cleaned with care, and given a last wash with distilled water, and uncontaminated at 120°C for 10 to 15 minutes, according to directions given in section 9030 and 9040 of standard methods for the examination of water and wastewater (American Public Health Association). For analysis of physicochemical parameters of wastewater, samples were collected in Poly Ethylene containers with the capacity of one and half liter then accurately washed and cleaned. During collection of samples, a sufficient space of about 25mm was kept left for proper shaking before test. Sample containers were kept clogged until packed (without washing) and caps were substituted immediately. Then Comparison and Analysis of results were performed.

Quality of water

Water becomes contaminated because of many natural or man-made sources, and it is hard to recognize and separate both of them. Contaminations are generally due to significant man made activities to water bodies like stream or lakes and contaminate them. A contaminated water body must be distinct with respect to its unaffected human condition activity relative to its absolute terms.

Similarly, tolerability of given intensities of pollution depends on reuse of waster afterwards.

Testing of collected samples

The percentage reduction in different parameters of wastewater (TDS, EC_w, SAR, Chloride, Boron, Nitrate, Bicarbonate, pH and F Coliforms) as per FAO Irrigation Water Quality Guidelines [15] with slight to moderate or no degree of restriction on use were determined, analyzed and compared different samples for their initial raw water value, 3 days treatment value, 5 days treatment value, 7 days treatment value and 10 days treatment value and find out the required Hydraulic Retention Time (HRT) for wastewater to be used for irrigation purposes.

Result and discussions

The samples of wastewater were collected from the Nallah (domestic sewer of Tehsil Gujjar khan, District Rawalpindi) and tested in laboratory. The result of untreated samples before the start of each trial is given in the Table 1 and descriptive statistical data of the experimental raw municipal wastewater sample is given in Table 2.

Table 1. Raw water composition of different parameters during five experimental runs.

SN	Parameter	Unit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
01	EC_w	ds/m	4.325	3.943	2.832	4.123	3.566
02	TDS	mg/L	2768	2524	1812	2639	2282
03	SAR	No.	6.59	5.73	5.39	5.01	5.47
04	Sodium	meq/L	12.90	11.40	12.17	10.28	11.83
05	Chloride	meq/L	10.96	9.67	11.75	9.34	10.30
06	Boron	mg/L	4.32	3.97	4.58	2.87	3.89
07	Nitrate	mg/L	38.18	31.86	25.12	39.54	36.98
08	Bicarbonate	meq/L	17.33	15.88	11.22	13.76	15.84
09	pH	No.	8.56	8.78	8.37	8.18	8.23
10	F Coliform	No./ 100mL	1248	1387	1154	1136	1435

Table 2. Statistical Data of different Parameters.

SN	Parameter	Unit	Average value	Standard Deviation
1	EC_w	ds/m	3.76	0.59
2	TDS	mg/L	2405	377
3	SAR	No.	676.20	0.59
4	Sodium	meq/L	10.404	0.97
5	Chloride	meq/L	1.164	0.98
6	Boron	mg/L	3.926	0.65
7	Nitrate	mg/L	34.336	5.91
8	Bicarbonate	meq/L	14.80	2.37
9	pH	No.	8.42	0.25
10	F Coliform	No./100mL	1272	135

The results of untreated wastewater depicts that wastewater is of strong strength (FAO Irrigation water Quality Guidelines). All the samples of wastewater which were collected from the municipal sewer was first of all sent to primary settling tank and after screening through tank, it was distributed into lagoon having macrophytes. The specie of macrophte taken was Duckweed. The wastewater was retained for 3, 5, 7 and 10 days in model during each experimental run, and total of five runs were performed to check reduction in values of different parameters so that it can be used for irrigation purposes as FAO Irrigation Water Quality Guidelines. After completion of treatment from each Hydraulic Retention Time (HRT), treated wastewater samples were collected from aquatic model and tested for determination of percentage reduction in different parameters. The plants in model were yielded 2 to 3 times per week. All analysis of parameters was performed accordingly with Standard Methods for Preservation and Examination of Wastewater (American Public Health Association). The average temperature during whole study was between 20°C and 25°C with an average of 23°C. The surface area maintained by the plants was 85% to 95%.

The average reduction of different parameters of wastewater against different Hydraulic Retention Time (HRT) during five experimental runs is given in Table 3, Table 4, and Table 5 respectively.

Table 3. Results of Sample 1.

SN	Parameter	Unit	Raw Wastewater Values	Result of 3 days HRT	Result of 5 days HRT	Result of 7 days HRT	Result of 10 days HRT	% reduction after 10 days HRT
1	EC_W	ds/m	4.325	3.877	3.476	3.124	2.876	33.48%
2	TDS	mg/L	2768	2482	2225	2000	1841	33.48%
3	SAR	No.	6.59	5.93	4.88	4.35	3.67	44.32%
4	Sodium	meq/L	12.90	11.51	11.09	9.68	8.71	32.45%
5	Chloride	meq/L	10.96	10.43	9.80	8.90	8.17	25.45%
6	Boron	mg/L	4.32	4.19	3.80	3.33	2.72	36.87%
7	Nitrate	mg/L	38.18	34.36	32.45	31.30	25.37	33.56%
8	Bicarbonate	meq/L	17.32	13.00	12.30	11.61	8.00	53.78%
9	pH	No.	8.56	7.96	7.70	7.19	6.72	21.45%
10	F Coliform	No./ 100mL	1248	1148	1011	849	717	42.56%

Table 4. Results of Sample 2.

SN	Parameter	Unit	Raw Wastewater Values	Result of 3 days HRT	Result of 5 days HRT	Result of 7 days HRT	Result of 10 days HRT	% reduction after 10 days HRT
1	EC_W	ds/m	3.943	3.578	3.365	2.904	2.746	30.34%
2	TDS	mg/L	2524	2291	2154	1859	1758	30.34%
3	SAR	No.	5.73	5.27	4.58	3.90	3.28	42.73%
4	Sodium	meq/L	11.40	10.37	9.34	8.55	7.95	30.21%
5	Chloride	meq/L	9.67	9.17	8.34	7.26	6.98	27.82%
6	Boron	mg/L	3.97	3.78	3.37	2.18	2.66	33.12%
7	Nitrate	mg/L	31.86	29.00	26.76	25.85	21.84	31.45%
8	Bicarbonate	meq/L	15.872	11.90	10.80	10.32	7.80	50.87%
9	pH	No.	8.78	8.25	7.73	7.29	6.93	21.12%
10	F Coliform	No./ 100mL	1387	1234	1082	929	766	44.78%

The results show the removal efficiencies of different parameters of wastewater by stabilization pond system expressed as percentage of untreated raw wastewater. The test results of the first experiment after treatment with 10 days HRT shows a reduction of 33.48% in Electrical Conductivity (EC_W), 33.48% in Total Dissolved solids (TDS), 44.32% in Soil Absorption Ratio (SAR), 32.45% in Sodium, 25.45% in Chloride, 36.87% in Boron, 33.56% in Nitrate, 53.78% in Bicarbonate, 21.45% in pH and 42.56% in F

Coliform respectively. The test results of the second experiment after treatment with 10 days HRT shows a reduction of 30.34% in Electrical Conductivity (ECw), 30.34% in Total Dissolved solids (TDS), 42.73% in Soil Absorption Ratio (SAR), 30.21% in Sodium, 27.82% in Chloride, 33.12% in Boron, 31.45% in Nitrate, 50.87% in Bicarbonate, 21.12% in pH and 44.78% in Coliform respectively.

Table 5. Results of Sample 3.

SN	Parameter	Unit	Initial Wastewater Values	Result of3 days HRT	Result of 5 days HRT	Result of 7 days HRT	Result of 10 days HRT	% reduction after 10 days HRT
1	ECw	ds/m	2.832	2.625	2.335	2.127	1.927	31.57%
2	TDS	mg/L	1812	1680	1494	1361	1240	31.57%
3	SAR	No.	5.39	4.74	4.20	3.72	3.07	43.12%
4	Sodium	meq/L	12.17	11.56	10.46	9.37	8.32	31.58%
5	Chloride	meq/L	11.75	11.33	10.63	10.02	9.20	21.67%
6	Boron	mg/L	4.58	4.21	3.94	3.38	2.96	35.43%
7	Nitrate	mg/L	25.12	21.60	19.58	18.56	17.70	29.55%
8	Bicarbonate	meq/L	11.22	8.64	8.30	7.62	5.66	49.50%
9	pH	No.	8.37	7.62	7.11	6.86	6.66	20.43%
10	F Coliform	No./100mL	1154	1016	877	831	673	41.65%

Table 6. Results of Sample 4.

SN	Parameter	Unit	Initial Wastewater Values	Result of 3 days HRT	Result of 5 days HRT	Result of 7 days HRT	Result of 10 days HRT	% reduction after 10 days HRT
1	ECw	ds/m	4.123	3.903	3.660	3.198	2.653	35.65%
2	TDS	mg/L	2639	2499	2343	2047	1698	35.65%
3	SAR	No.	5.01	4.46	3.76	3.36	2.91	41.85%
4	Sodium	meq/L	10.28	9.45	8.63	7.71	6.98	32.11%
5	Chloride	meq/L	9.34	8.94	7.95	7.61	7.40	20.77%
6	Boron	mg/L	2.87	2.70	2.32	2.00	1.82	36.50%
7	Nitrate	mg/L	39.54	37.56	34.80	32.82	28.29	28.45%
8	Bicarbonate	meq/L	13.76	9.90	9.65	8.94	7.61	44.67%
9	pH	No.	8.18	7.53	7.20	7.03	6.66	18.58%
10	F Coliform	No./100mL	1136	988	863	727	680	40.12%

The test results of the third experiment after treatment with 10 days HRT shows a reduction of 31.57% in Electrical Conductivity (ECw), 31.57% in Total Dissolved solids (TDS), 43.12% in Soil Absorption Ratio (SAR), 31.58% in Sodium, 21.67% in Chloride, 35.43% in Boron, 29.55% in Nitrate, 49.50% in Bicarbonate, 20.43% in pH and 41.65% in FColiform respectively.

The test results of the fourth experiment after treatment with 10 days HRT shows a reduction of 35.65% in Electrical Conductivity (ECw), 35.65% in Total Dissolved solids (TDS), 41.85% in Soil Absorption Ratio (SAR), 32.11% in Sodium, 20.77% in Chloride, 36.50% in Boron, 28.45% in Nitrate, 44.67% in Bicarbonate, 18.58% in pH and 40.12% in F Coliform respectively.

Table 7. Results of Sample 5.

SN	Parameter	Unit	Initial Wastewater Values	Result of 3 days HRT	Result of 5 days HRT	Result of 7 days HRT	Result of 10 days HRT	% reduction after 10 days HRT
1	ECw	ds/m	3.566	3.272	3.162	2.722	2.540	28.76%
2	TDS	mg/L	2282	2094	2024	1742	1626	28.76%
3	SAR	No.	5.47	4.65	3.83	3.61	3.25	40.54%
4	Sodium	meq/L	11.83	10.28	9.93	9.46	8.44	28.66%
5	Chloride	meq/L	10.30	9.70	9.11	8.67	8.39	18.58%
6	Boron	mg/L	3.89	3.54	3.08	2.84	2.70	30.66%
7	Nitrate	mg/L	36.98	31.80	29.60	27.74	26.57	28.14%
8	Bicarbonate	meq/L	15.84	12.04	9.82	8.71	7.55	52.34%
9	pH	No.	8.23	7.65	7.41	7.0	6.70	18.54%
10	FColiform	No./100mL	1435	1234	1076	963	892	37.84%

The test results of the fifth experiment after treatment with 10 days HRT shows a reduction of 28.76% in Electrical Conductivity (EC_W), 28.76% in Total Dissolved solids (TDS), 40.54% in Soil Absorption Ratio (SAR), 28.66% in Sodium, 18.58% in Chloride, 30.66% in Boron, 28.14% in Nitrate, 52.34% in Bicarbonate, 18.54% in pH and 37.84% in F Coliform respectively. The Table No.8 clearly shows that for each sample maximum HRT required to achieve FAO Irrigation Water Quality Guidelines is 10 days.

Table 8. Different HRT required for using wastewater for Irrigation purposes.

SN	Parameter	Unit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
01	EC_w	ds/m	10 days	07 days	0 days	10 days	07 days
02	TDS	mg/l	10 days	10 days	0 days	10 days	10 days
03	SAR	No.	0 days	0 days	0 days	0 days	0 days
04	Sodium	meq/l	0 days	0 days	0 days	0 days	O days
05	Chloride	meq/l	5 days	0 days	10 days	0 days	3 days
06	Boron	mg/l	10 days	10 days	10 days	0 days	7 days
07	Nitrate	mg/l	10 days	3 days	0 days	10 days	5 days
08	Bicarbonate	mg/l	10 days	10 days	7 days	10 days	10 days
09	pH	No.	3 days	3 days	0 days	0 days	0 days
10	Facial Coliform	No. /100ml	7 days	7 days	5 days	3 days	7 days

Conclusion

The results show the removal efficiencies of the Waste Stabilization Pond system expressed as percentage of initial concentration and then values were compared with Food and Agriculture (FAO) Irrigation Water Quality Guidelines. The result clearly shows that if domestic wastewater is to be reused for irrigation purposes, it must be treated by macrophytes Waste Stabilization Ponds with HRT of 10 days with slight to moderate restriction on use as explained in Table No.8. The initial values of wastewater were in the range of severe degree of restriction on use according to FAO guidelines. The results indicate that average reduction in values of different parameters of wastewater was 31.96%, 31.96%, 42.51%, 31.00%, 22.86%, 34.52%, 30.23%, 50.23%, 20.02% and 41.39% for EC_w, TDS, SAR, Sodium, Chloride, Boron, Nitrate, Bicarbonate, pH and F Coliform respectively. The results show higher removal efficiency for EC_w, TDS, SAR, Boron, Bicarbonate and F Coliform. The results show after three days of detention there is not much reduction in pollutant values but as the detention time increase the reduction of pollutant in the sewage also increase.

Rate of growth of Duckweed is very important. In the project trial session, it is noticed that temperature has a great influence on the growth of Duckweed. The average temperature during research work was in range of 20C^o to 25C^o. Winter season at low temperature growth of water hyacinth is less as compare to summer season at high temperature. Extra Duckweed should be removed to provide sufficient free space to penetrate sunlight.

Recommendations

- The macrophytes wastewater stabilization ponds system should be encouraged for the treatment of domestic wastewater in developing countries like Pakistan as it decreases the major toxic wastewater pollutants to a large extent and wastewater can be used for irrigation purposes as per FAO Irrigation standards. On the other hand, this is Eco-friendly, maintenance free and self-sustained also.
- The cost of harvesting and frequency of macrophytes need to be considered while selecting the type of macrophyte in the regions where growth rates are high to get efficient results regarding reuse of wastewater for Irrigation purposes.
- Different types of wastewater has different concentrations and has effect on performance of Macrophyte, therefore the initial conditions and initial values should be considered while designing the waste stabilization ponds.
- It is recommended that awareness should be made in farmers to utilize wastewater for Irrigation purposes after proper treatment instead of using it in polluted form.

- Parameter testing expenses are very high in this project. It is recommended to Government of Pakistan to establish more laboratories for testing wastewater quality so that this methodology can be applied frequently.

Abbreviations

EC_W: Electrical Conductivity
BOD: Bio Chemical Oxygen Demand
COD: Chemical Oxygen Demand
FAO: Food and Agriculture Organization
HRT: Hydraulic Retention Time
ppm: Parts per million
TDS: Total Dissolved Solids
WSP: Waste Stabilization Ponds
HCWS: Hybrid Constructed Wetland System
HSSF CW: Horizontal Subsurface Flow Constructed Wetland
GW: Gray Water
SAR: Sodium Absorption Ratio
TWW: Treated Wastewater
TW: Tubewell

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