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Eco-Friendly Wastewater Treatment Using Orange Peels and Fish Scales: A Sustainable Adsorption Approach

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ABSTRACT

Water pollution is a growing environmental concern, and effective, low-cost treatment methods are essential for sustainable wastewater management. This study investigates the use of natural adsorbents—orange peels and fish scales—for treating wastewater from Sree Datta College. The primary objective is to reduce key pollutants such as alkalinity, hardness, total dissolved solids (TDS), and total suspended solids (TSS), while also eliminating potential pathogenic microorganisms.

The orange peels and fish scales were processed using a dehydration method and tested for their adsorption efficiency under varying conditions, including contact time, adsorbent dosage, and particle size. Results showed that orange peels were more effective than fish scales in removing pollutants. The optimal conditions for adsorption were found to be a pH range of 6-8, a contact time of 150 minutes, and an adsorbent dosage of 0.9 mg/L. The ideal particle sizes were determined to be 425μm for orange peels and 300μm for fish scales. This study highlights the potential of biodegradable waste materials as efficient and eco-friendly alternatives for wastewater treatment. By repurposing agricultural and fishery waste, this method not only reduces environmental pollution but also offers a cost-effective and sustainable solution for water purification. The study demonstrates that agricultural and fishery waste materials can be repurposed as eco-friendly and cost-effective solutions for wastewater treatment. Utilizing these natural adsorbents not only provides a sustainable alternative to chemical treatment methods but also helps in reducing organic waste. This approach aligns with circular economy principles, promoting waste-to-resource transformation while addressing environmental challenges.

1. INTRODCUTION

In many educational institutions, approximately 500 liters per day of water is used for cooking, cleaning, and other daily activities. The wastewater generated cannot be directly discharged into nearby sewage systems due to its high organic matter and total solids content. To minimize water consumption and promote sustainability, it becomes essential to treat this wastewater to a certain extent for reuse in cleaning and vegetation purposes within the institution's premises.

Educational institutions provide various facilitative services, including canteens, hostel rooms, and lunch areas. Access to proper food and refreshment facilities is crucial for students and staff to maintain their health, efficiency, and overall well-being. Without adequate facilities for food, beverages, and rest areas, productivity and efficiency may decline. Therefore, most institutions ensure the provision of canteens where food is available at reasonable or subsidized rates. Additionally, designated lunch areas may be provided for students who bring their meals from home.

2. LIETRATURE SURVEY

N. Othman [2016] as an environmental friendly method for the removal of metal from synthetic and domestic wastewater. The objectives of this study are to characterize the fish scale, determine the adsorption isotherm and biosorption kinetics in synthetic wastewater, and efficiency of fish scale in removing zinc (Zn) ion and ferum (Fe) ions in domestic wastewater.After biosorption process, scanning electron microscopy (SEM-EDX) analysis shows the presence of shiny bulky particles that indicate the appearance of Zn and Fe ion. Fourier-transform infrared (FTIR) spectrum confirmed the involvement of nitro compound, carbonyl and amine group in biosorption process. The results also show that optimum condition of Zn ion was best selected in removing heavy metal in domestic wastewater. In addition, Langmuir and pseudo-second-order models exhibited the best fit data for isotherm and kinetic study, respectively. This study highlighted that *M. tilapia* fish scale is a promising adsorbent in removing Zn and Fe ion from synthetic and domestic wastewater solution. The results prove that *M. tilapia* fish scales have high possibility and efficiency in removing Zn and Fe ions in wastewater. It is a promosing biosorbent and poses as an environmental friendly adsorbent to society and environment.

Ms.P.Sasirekha et al [2017], The carbonization method is found to be more efficient than the de-hydration method for both, orange and fish scales with high percentage removal of 50.1% and 31.25% respectively. The orange peels found to be more efficient in both methods with highest percentage removal of 50.1% and 14.3% respectively compared to the fish scales where percentage removal is found to be 31.25% & 8.2% respectively for the de-hydration method and carbonization method. The optimum pH for both methods, orange and fish scales found to be in a range between 6-8. The optimum contact time for de-hydration method of orange peel and carbonization method of fish scales is 120 min and for de-hydration of fish scales and carbonization of orange peel is 150 min. The optimum adsorbent dosage for the dehydration method of orange peel is 0.15 g and for fish scales is 0.25g. The optimum adsorbent dosage for carbonization of orange and fish scales is 0.3g and the optimum particle size for methods, orange and fish scales are 300μm.

Zhongxu Lian et al 2017 Mater, Drawing inspiration from the underwater superoleophobic surface of fish scale, we have developed the bioinspired hierarchical structure using a simple and environmentally friendly two-step method of HS-WEDM and boiling water treatment on Al alloy 5083 surfaces. The surface exhibited the ability to prevent contact with organic fluids when submerged in water. The tribological properties of underwater superoleophobic Al surfaces in aqueous environments were studied. The average friction coefficient of the surfaces was decreased compared with the polished Al surface. The average friction coefficient can be reduced from more than 0.5 to approximately 0.34 in comparison with the polished surface. The wear scar depth of underwater superoleophobic surface reduced significantly, which can effectively alleviate the wear of the surface compared with the polished surface. We believe that the research will contribute to the engineering application of underwater superoleophobic surfaces with the excellent antifriction performance in the future.

Around 71 million tons of oranges are produced annually around the world. Approximately 73% of these are consumed as fresh fruit, while 26% of the oranges are used for secondary products, primarily juice. Enormous quantities of agrifood waste are generated as a consequence of this large-scale production. In Iraq, the cultivation of oranges is one of the agro-economic activities that result in large quantities of bio-waste (orange peels). Therefore, orange peels are widely available as low-cost bio-waste. Making use of this waste for remediation would have both economic and environmental benefits. Widmer et al. (2010) indicated that a large portion of the global orange production results in waste that must be disposed of, creating environmental and economic burdens. Several researchers have utilized orange peels (OP) as economical, readily biodegradable sorbents due to their physio-chemical features. The OP consists of chlorophyll, lignin, pectin, cellulose, pigments, amid, carboxyl, and hydroxyl surface functional groups, and other lowmolecular-weight compounds. It is an abundant waste product that can be used for the adsorption of heavy metals (Pandiarajan et al., 2018).

Pandiarajan et al. (2018) used potassium hydroxide (KOH) to activate OP that was used for the adsorption of chlorophenoxyacetic acid herbicides from water. The addition of oxidizing agents can alter the surface properties of adsorbents. This indicates the feasibility of OP for the adsorption of heavy metals from aqueous solutions. Therefore, the objectives of this study were to investigate the feasibility of raw OP (ROP) and acetic acid-treated OP (TOP) in the adsorption of antimony from synthetic wastewater using a batch-mode adsorption unit and to identify the optimum remediation conditions.

Di Qin et al [2022] Fish scale is a natural renewable multi-layered composite biomaterial with highly ordered microstructure, which is mainly composed of type I collagen and hydroxyapatite. Fish scales and fish scales centered biocomposites have important application value in tissue engineering, biological fillers, sewage treatment and flexible electronics fields because of its excellent physical and chemical properties, such as biocompatibility, biodegradability, hierarchical microstructure, multiple active groups, high strength and toughness. Converting discarded fish scales into functional materials can avoid waste of resources and achieve great commercial value. In this review, we introduced the microstructure, composition and derived functional materials of fish scales, listed their potential applications in many fields, which provided important references for the application of fish scales and their derivatives in the future. Converting fish scale as byproducts of fish processing into natural biopolymers including collagen, gelatin, chitin/ chitosan and inorganic components such as bioactive hydroxyapatite, chloroapatite is a major advantage for fish scales waste management, which would not only maximize the managers profits and reduce its environmental pollutions, but they also show many advantages in medical and health care including bone tissue regeneration, oral mucosal repair, soft tissue regeneration such as skin and blood vessels and other fields such as heavy metals ion and dyes adsorption, biomass materials.

3. PROPOSED SYSTEM

The proposed system focuses on treating wastewater using low-cost, eco-friendly adsorbents orange peels and fish scales. The aim is to reduce pollutants such as TDS, TSS, alkalinity, and hardness so that the treated water can be reused for cleaning and vegetation purposes within the institution.

2. System Components

The proposed system consists of the following key components:

1. **Collection Unit** – Collects wastewater from kitchens, canteens, and cleaning activities.
2. **Pre-Filtration Unit** – Removes large debris and solid particles.
3. **Adsorption Treatment Unit** – Uses orange peels and fish scales as adsorbents to remove impurities.
4. **Settling Tank** – Allows heavier particles to settle after adsorption treatment.
5. **Filtration System** – Further filters out smaller suspended solids using filter paper or sand filtration.
6. **Storage Tank** – Stores treated water for reuse in non-potable applications such as cleaning and irrigation.

3. Working Mechanism

1. **Wastewater Collection**: Wastewater from various sources is directed to the collection unit.
2. **Pre-Filtration**: Large solid waste and floating materials are removed using mesh filters.
3. **Adsorption Treatment**:
   - The wastewater is passed through a treatment chamber containing orange peel powder (425µm) and fish scales (300µm).
   - The adsorption process occurs for 150 minutes, allowing pollutants to bind to the adsorbents.
4. **Settling & Filtration**: After adsorption, the water is transferred to a settling tank for solid separation and then passed through a filtration system.
5. **Treated Water Storage**: The purified water is stored and used for cleaning and irrigation.

4. Expected Outcomes

- Reduction in TDS, TSS, alkalinity, and hardness as per experimental results.
- Reusability of treated water, reducing overall water consumption.
- Cost-effective and sustainable wastewater treatment using biodegradable materials.
- Eco-friendly solution, preventing chemical contamination in sewage systems

4. RESULTS AND DISCUSSIONS

4.1 Waste water quality parameters

4.1.1 Alkalinity test:

It is defined as the quantity of ions in the water that will react to neutralize the hydrogen ions.

Calculation:

Table 4.1(a) Alkalinity test results with phenolphthalein

S.No	Volume of sample	Initial reading	Final reading	Volume of H_2SO_4
1	50ml	0	7.5	7.5
2	50ml	7.5	14.1	6.6
3	50ml	15	22.8	7.8

$$A = (7.5+6.6+7.8)/3 = 7.3$$

Table 4.1 (b) Alkalinity test results with methyl orange

S.NO	Volume of sample	Initial reading	Final reading	Volume of H_2SO_4
1	50ml	0	25.4	25.4

2	50ml	0	25	25
3	50ml	0	25.2	25.2

B = (25.4+25+25.2) /3 = 25.2

Total Alkalinity = ((A+B)*N*50000)/volume of sample

= ((7.3+25.2)*0.02*50000)/50

= 650 mg of CaCo3/lit

4.1.2 Hardness

Hardness of water is due to presence of certain salts such as carbonates, bicarbonates, chlorides and sulphates of calcium and magnesium dissolved in it.

Table 4.2 Hardness of water

S.NO	Volume of sample	Initial reading	Final reading	Difference
1	50ml	0	38.5	38.5
2	50ml	0	37.5	37.5

A = (38.5+37.5)/2 = 38

Ca Hardness = $\frac{100\ x\ 1000000\ x\ ml\ of\ EDTA\ X\ Molarity\ of\ EDTA}{1000\ X\ ml\ of\ water\ sample}$

Where, Morality of EDTA = 0.01M

Ca Hardness = $\frac{100\ x\ 10,00,000\ X\ 38\ \ X\ 0.01}{1000\ X\ 50}$ = 760 mg of $CaCo_3$/lit

Table 4.3 Waste water quality parameters

Test	**Result**
pH	6
EC (micro siemens)	720
TDS (mg/l)	1500
TSS (mg/l)	1250
Alkalinity (mg of CaCo3/lit)	650
Hardness (mg of $CaCo_3$/lit)	760

4.2 Treated water quality parameters

4.2.1 Effect of Contact Time

The optimum contact time was studied at pH value of 6, 0.1 g of 300 µm of adsorbent (fish scales or Orange Peels) at different contact times of 60, 120, and 150 minutes respectively.

The below graph shows that, percent removal increases gradually as the time is increased. It can be attributed to the fact that more time becomes available for the organic substances to stick with the adsorbent surface, as well as surface adsorption increases with time. However, a slight decrease on the percent removal at 150 min in orange peel and fish scales, this may be due to desorption of pollutants from the adsorbent surface due to continue stirring process.

Table 4.4 Orange peels based Treated waste water quality parameters (different contact period)

Test	Raw water	60min	120min	150min
TDS (mg/l)	1500	1200	1145	1100
TSS (mg/l)	1250	1100	1053	1021
Alkalinity (mg of CaCo3/lit)	650	450	410	380
Hardness (mg of $CaCo_3$/lit)	760	640	610	575

Table 4.5 Fish scales based Treated waste water quality parameters (different contact period)

Test	Raw water	60min	120min	150min
TDS (mg/l)	1500	1350	1300	1270
TSS (mg/l)	1250	1170	1125	1087

Alkalinity (mg of CaCo3/lit)	650	510	496	453
Hardness (mg of $CaCo_3$/lit)	760	685	641	623

Table 4.6 Treated waste water quality parameters (different contact period)

Test	% Removal Efficiency by Orange peels			% Removal Efficiency by Fish scales		
	60min	120min	150min	60min	120min	150min
TDS (mg/l)	20	23.6	26.66	10	13.3	15.3
TSS (mg/l)	12	15.76	18.32	6.4	10	13.04
Alkalinity (mg of CaCo3/lit)	30.77	36.92	41.53	21.5	23.7	30.3
Hardness (mg of $CaCo_3$/lit)	15.79	19.73	24.34	9.8	15.65	18

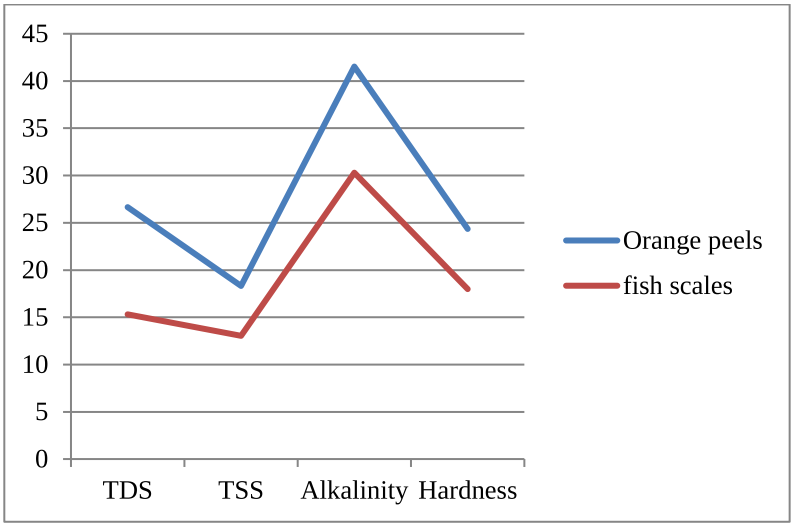

Figure 4.3: % Removal Efficiency at 150min contact period

4.2.2 Effect of Adsorbent Dosage

The optimum adsorbent dosage was studied at pH value of 6, 0.1 g of 300 µm of adsorbent (fish scales or Orange peels) at different dosages of 0.3, 0.6 and 0.9 respectively. Below graph shows that the percent removal increased as the mass of adsosrbent dosage was increased. This result indicates that more surface area was made due to increased mass of adsorbent. In some cases, the percent removal started to decrease which indicates that the adsorbent reach its optimum adsorption and desorption of the organic substances form the surface of adsorbent occurs. Then it will remove using by filter papers.

Table 4.7 Orange peels based Treated waste water quality parameters (Effect of Adsorbent dosage)

Test	Raw water	0.3mg/l	0.6mg/l	0.9mg/l
TDS (mg/l)	1500	1180	1125	1095
TSS (mg/l)	1250	1087	1023	965
Alkalinity (mg of	650	437	404	376

CaCo3/lit)				
Hardness (mg of $CaCo_3$/lit)	760	624	601	543

Table 4.8 Fish scales based Treated waste water quality parameters (Effect of Adsorbent dosage)

Test	Raw water	0.3mg/l	0.6mg/l	0.9mg/l
TDS (mg/l)	1500	1240	1210	1198
TSS (mg/l)	1250	1103	1056	996
Alkalinity (mg of CaCo3/lit)	650	505	475	432
Hardness (mg of $CaCo_3$/lit)	760	643	623	531

Table 4.9 Treated waste water quality parameters (Effect of Adsorbent dosage)

Test	% Removal Efficiency by Orange peels			% Removal Efficiency by Fish scales		
	0.3mg/l	0.6mg/l	0.9mg/l	0.3mg/l	0.6mg/l	0.9mg/l
TDS (mg/l)	21.3	25	27	17.3	19.3	20.13
TSS (mg/l)	13.04	18.16	22.8	11.76	15.52	20.32
Alkalinity (mg of	32.76	37.84	42.15	22.3	27	33.53

CaCo3/lit)						
Hardness (mg of $CaCo_3$/lit)	17.9	21	28.5	15.4	18	30.13

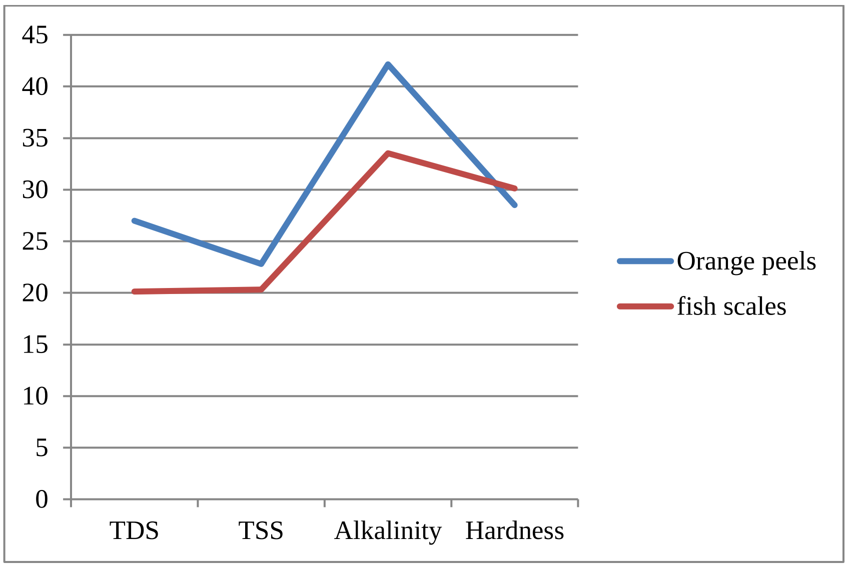

Figure 4.6: % Removal Efficiency of Adsorbent dosage of 0.9mg/l

4.2.3 Effect of Particle Size

The optimum adsorbent particle was studied at pH value of 6, 0.1 g of 300 µm of adsorbent (fish scales or Orange peels) at different particle size 300, 425, and 600 µm respectively. Below graph shows that, for orange peel 425µm particle size and fish scales 300µm particle size showing highest removal efficiency.

Table 4.10 Orange peels based Treated waste water quality parameters (Effect of Particle size)

Test	Raw water	300µm	425µm	600µm

TDS (mg/l)	1500	1080	1072	1082
TSS (mg/l)	1250	961	945	951
Alkalinity (mg of CaCo3/lit)	650	382	368	373
Hardness (mg of $CaCo_3$/lit)	760	550	532	540

Table 4.11 Fish scales based Treated waste water quality parameters (Effect of Particle size)

Test	Raw water	300µm	425µm	600µm
TDS (mg/l)	1500	1187	1193	1204
TSS (mg/l)	1250	982	994	1012
Alkalinity (mg of CaCo3/lit)	650	421	436	450
Hardness (mg of $CaCo_3$/lit)	760	526	532	515

Table 4.12 Treated waste water quality parameters (Effect of Particle size)

Test	% Removal Efficiency by	% Removal Efficiency by

	Orange peels			Fish scales		
	300µm	**425µm**	**600µm**	**300µm**	**425µm**	**600µm**
TDS (mg/l)	28	28.53	27.8	20.86	20.46	19.73
TSS (mg/l)	23.12	24.4	23.92	21.44	20.48	19.04
Alkalinity (mg of CaCo3/lit)	41.23	43.38	42.61	35.23	32.92	30.79
Hardness (mg of $CaCo_3$/lit)	27.63	30	29	30.79	30	32.23

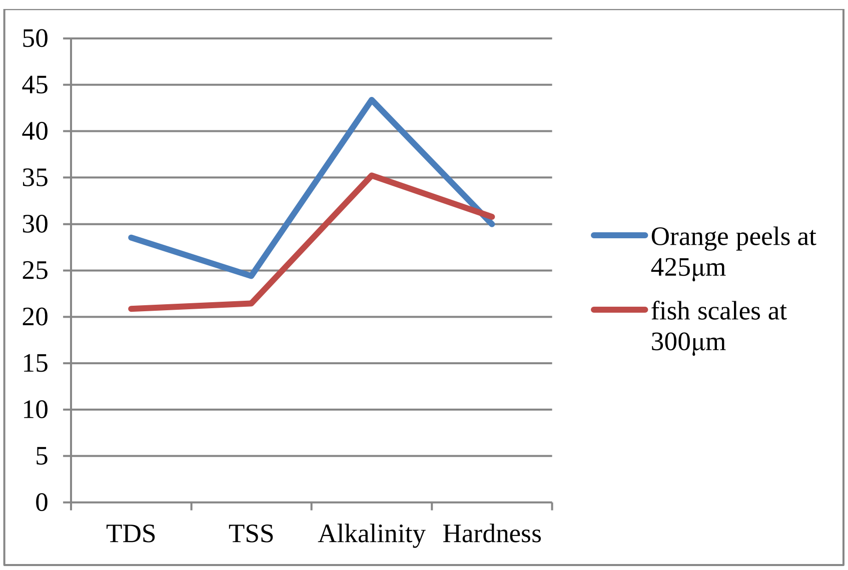

Figure 4.9: % Removal Efficiency of Effect of Particle size

4.3 Applications, advantages, and disadvantages of orange peel powder

4.3.1 Applications of orange peel and fish scales as absorbent

- ✓ To recognize a workable, easy, nearby available coagulant.
- ✓ Eco-friendly water treatment expertise is further appropriate for the earth to safeguard it from contamination affected by chemical coagulants.
- ✓ Removal efficiency is very high in orange peel powder.
- ✓ Assess the optimum doses of orange peel powder for unique concentrations to remove TDS, TSS, Alkalinity, Hardness.

5. CONCLUSIONS

The removal of organic substance from MREM canteen waste water using de-hydration method for orange peels and fish scales was studied by investigation the effect of contact time, adsorbent dosage and particle size. The Orange peels based de-hydration method is found to be more than the Fish scales based de-hydration method. This is due to the characteristics of orange peels in its content fiber which its contain more hydroxyl radicals, hence more adsorption capacity. The orange and fish scales are found to be in a range between pH 6-8. The optimum contact time for dehydration method of orange peel and fish scales is at 150 min. The optimum Adsorbent Dosage for dehydration method of orange peel and fish scales is at 0.9mg/l. The optimum Particle Size for dehydration method of orange peel is at 425µm and orange peel is at 300µm. This process is eco friendly and cost effective.

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