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Biosorption of Metal Ions to Reduce Load on Reverse Osmosis Systems

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Abstract: *Effluent from textile industries contains a high load of total suspended and dissolved solids (5000-6000 ppm), which is sometimes much above the permitted limit. The standard treatment procedures involve removal of suspended solids followed by biological treatment and finally charcoal treatment and reverse osmosis (RO) system. Dissolved solids impose a great pressure on RO- system resulting in blinding effect. Novel operation involves addition of a cheap and effective process based on the principle of elimination of inorganic salts by adsorption on bacterial exo-polymer. Consortium prepared from cultures isolated from effluent before treatment with RO-system, was found to be efficient producer of a complex exo-polymer. It was found to be an extremely potent adsorbing agent of various metal and non-metal ions. Overall reduction in total dissolved solids along with reduction in individual ions (35.41%) was observed after passing the effluent (before RO treatment) through a bio-reactor setup containing polymer bound to a supporting basement matrix varying in surface area (beads and charcoal).*

Keywords: *Adsorption, exopolymer, dissolved salts, industrial wastes, RO-system.*

I. Introduction

The textile industry surpasses most of the industries in production of post processing wastes, both by volume and difficulty in treatment [1]. Without RO treatment such effluents are almost unusable and cause ecological damage [2]. Apart from harmful dyes, a large percentage of dissolved solids make the treatment process less efficient. These portions of the effluents pose the greatest problems when disposed off without adequate treatment [3]. The main reason for this is the difficulty in removing them from the effluent due to small size, and since most of such solids are ionic salts, they result in disruption of balance of biological life, water pollution, and deterioration of soil quality [4].

RO system is the most important part of effluent treatment that helps in removal of such dissolved solids. But this process becomes less economical with increase in TDS, since this exerts a large pressure on RO membranes, which sometimes results in problems like membrane fouling, reduction in recovery and increased RO reject [5]. Due to this, frequency of membrane replacement increases which proportionately increases the total cost of effluent treatment since the cost of replacing such membranes is very high.

Traditionally, physical and chemical methods such as ozonation and chemical coagulation [6], precipitation, adsorption by activated charcoal, ultrasonic filtration [7], nanofiltration [8], electrochemical oxidation [9], electro coagulation [10], membrane chromatography etc are used in the treatment of the textile industrial effluents [11]. Nanofiltration and electro coagulation have many short comings [12]. *In situ* processing of the effluent is a novel method under the Biological treatment procedures. In this method, the microorganisms isolated from the site of pollution are used for the treatment of the effluent [13].

Hence, present study involves formation of a consortium of bacteria selected on the basis of their ability to produce dense polymer when consolidated. Since the bacterial isolates were originated from the dye contaminated textile wastewater of local industry, so they can easily adapt to the prevailing local environment. Therefore, such bacteria can be used to develop an effective combined biological and mechanical system for TDS reduction.

II. Materials And Methods

2.1 Isolation and purification of bacteria from industrial waste sludge

Sludge obtained from a textile industry was enriched for 72 hours, and cultures were isolated on nutrient agar plates. Each of the cultures was purified by repeated streaking. Each of the pure cultures was maintained in nutrient agar slants as stock. Consortium was prepared and checked for production of dense polymer.

2.2 Testing for efficiency of the bio polymer in reducing TDS

2.2.1 Bio-reactor setup

Bio-reactors were set up using pulverized charcoal and glass beads (radii-0.5cm) as basement matrix for 2 separate reactors each containing one of them. Glass columns (30 ml) were filled with the matrix. Consortium was added to the setups and retained for 24hours. Optimum controls were set up (only matrix, consortium absent). Coating of bio polymer on the matrix was determined by microscopic examination of charcoal and glass beads. It was found that grounded charcoal accumulated more polymer than the glass beads due to greater surface area. Quantification of TDS and various inorganic ions individually was done periodically from a given effluent sample by passing it through all the reactors with zero retention periods.

2.2.2 Testing for cations

Cations were tested for by carrying out atomic absorption spectroscopic (Varian spectra AA220) analysis of the effluent passed through each of the bioreactors (test and control setups). Standards for each of the metal ions were taken in the concentration of: 0.2mg/L, 0.3mg/L, 0.4mg/L. Analysis for magnesium, lead, mercury, iron and sodium was carried out. Graphs were plotted and calculations were done to find the concentrations of the metal ions in the sample.

2.2.3 Tests for anions

Volumetric titrations were carried out for anions as per the standards given by IP 2014 (Indian pharmacopeia).

2.2.3.1 Test for chlorides

The effluent was diluted 1:10 in distilled water, 5% potassium chromate was added as an indicator, and this was titrated against 0.014N silver nitrate till reddish orange color was obtained.

2.2.3.2 Test for carbonates

The effluent was diluted 1:10 in distilled water, this was titrated against 0.02N sulphuric acid and phenolphthalein was used as an indicator.

2.2.3.3 Test for sulphates

The effluent was diluted 1:10 in distilled water; 1ml hydrochloric acid, pinch of Barium chloride and 1ml conditioning agent (to convert all less reactive sulphates to their reactive counterparts) were added. Absorptions were taken with the help of UV-vis spectrophotometer at 420 nm. Slope was calculated using standards and was found to be 0.0122. Care is taken to not add excessive barium chloride.

2.2.3.4 Determination of TDS

Total dissolved solids were filtered by vacuum filtration through Whatman filter paper. The filtrate was dried at 180°C and weighed.

2.2.4 Determination of nature polymer

The polymer was boiled in 40% hydrochloric acid and 50% sodium hydroxide separately in order to hydrolyze it. Thin layer chromatography was carried out. The solvent system used was: butanol, acetic acid and water in the ratio 4:1:5. The hydrolysate was mounted on the silica plate; iodine was used as a developing agent. Molisch's test was carried out for carbohydrates by adding alpha naphthol and sulphuric acid to sample hydrolysate. To tests for amino acids ninhydrin was added to hydrolysate.

III. Results And Discussion

3.1 Bacterial culture

Five different isolates were obtained from the sludge and purified and use in the consortium

3.2 Reduction in cation concentration

All estimations were repeated 5 times and mean was calculated and represented in the results (n=5).

Table 1: Figurative comparison of differential reduction in cation concentration

	Charcoal +polymer (mg/L)	**Charcoal (mg/L)**	**Glass beads+ polymer(mg/L)**	**Glass beads (mg/L)**
Magnesium	17.413 (SD±2.87)	55.479 (SD±4.15)	28.57 (SD±2.19)	62.335 (SD±6.09)
Sodium	77.169 (SD±5.25)	130.227 (SD±8.07)	87.614 (SD±6.17)	170.300 (SD±9.06)
Iron	1.676 (SD±0.57)	5.365 (SD±0.49)	3.626 (SD±0.67)	5.227 (SD±1.92)
Lead	N/D	N/D	N/D	N/D

Mercury	N/D	N/D	N/D	N/D

3.3 Reduction in anion concentration

Table 2: Figurative comparison of differential reduction in anion concentration

	Charcoal +polymer (mg/L)	**Charcoal (mg/L)**	**Glass beads+ polymer (mg/L)**	**Glass beads (mg/L)**
Sulphates	258.33 (SD±15.11)	333.33 (SD±17.24)	327.08 (SD±11.21)	368.75 (SD±18.16)
carbonates	16.5 (SD±2.10)	19.5 (SD±1.99)	16.5 (SD±1.24)	19.5 (SD±1.89)
Chlorides	812.24 (SD±21.17)	1624.49 (SD±27.49)	937.21 (SD±19.21)	1749.45 (SD±31.82)

3.4 Reduction in TDS

Table 3: Reduction as percentage decrease of individual ions

Chloride	60.71
Sulphate	22.4
Carbonate	15.37
Magnesium	68.61
Sodium	40.74
Iron	68.76

Mean reduction in anions was observed to be 32.66%. And that for cations was observed to be 36.50%. Therefore taking a mean of each individual reduction we can conclude that reduction in TDS was 34.358%.

Table 4: Figurative comparison of differential reduction in overall TDS (drying process)

	Charcoal +polymer (mgs)	**Charcoal (mgs)**	**Glass beads+ polymer (mgs)**	**Glass beads (mgs)**
Weight of residue (TDS)	310 (SD±30)	480 (SD±80)	360 (SD±30)	520 (SD±80)

Therefore mean reduction in overall TDS is 35.41%.

3.5 Nature of polymer

Molisch's test gave positive results suggesting presence of carbohydrates. Thin layer chromatography showed presence of glucose as the resolution factor matched with that of pure glucose, run simultaneously. Yellow coloration was observed in ninhydrin test confirming presence of proline or/and hyroxyproline residues. It was deducted from above results that the exopolymer was a glucosamine like glycoprotein.

IV. Conclusion

The present study indicated presence of bacterial cultures in waste effluent from textile industries having capability to secrete large amounts of biopolymer. Such a biopolymer may be used in a specially designed filtration system to reduce the concentrations of total dissolved solids and hence reducing the direct cost of frequently replacing RO membranes [4]. The presence of such bacteria was not detected post RO treatment suggesting affinity and adaptation in such polluted environments. Enrichment with sugars leads to fermentation and no production of the biopolymer suggesting an alternative pathway of metabolism for adaptations in such environments.

Such a filtration system has high economic potentials, as approximately 35% reduction may correspond to thousands of kilos of salts in practical situations [14]. Chloride is present in large amounts in textile waste due to addition of hydrochloric acid for neutralization of highly alkaline products present in textile wastes. Removal of such large quantity of chloride ions poses great difficulty from the economic point of view.

Since adsorption is a surface phenomenon, efficiency of the setup can be enhanced by increasing surface area and pressure; i.e. passing the effluent through several layers of such biopolymer under pressure. Lower or retentive flow rates may also be used to increase filtration efficiency, although the experiments were carried out under continuous moderately fast flow keeping in mind practical situations.

V. Abbreviation Glossary

TDS- total dissolved solids
TLC- this layer chromatography

RO- reverse osmosis
SD- Standard deviation
UV- ultra violet

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