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***Research Article** (Open Access)*

USE OF *MORINGA OLEIFERA* SEEDS AS A NATURAL ADSORBENT FOR TREATMENT OF DAIRY AND PETROLEUM EFFLUENTS

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ABSTRACT
Population growth, rapid urbanization, and industrial growth have all contributed to the escalation of pollution levels across the globe. Companies that treat water employ synthetic or natural coagulants. The polymers used in the manufacture of synthetic coagulants contain contaminants that are harmful to human health. However, naturally occurring coagulants are primarily considered safe for human. Dairy and Petroleum industries are considered to be major contributors to environmental pollution. Hence, an effort was made to remediate the effluents from the dairy and petroleum industries with *Moringa oleifera*. Petroleum and Dairy effluent samples were collected and treated with seed extract of *M.oleifera*. Standard techniques were used to analyze treated and untreated samples (APHA, 2012). Following *M.oleifera* treatment, TS, TSS, TDS, phosphate, alkalinity, turbidity, hardness, ammonia, nitrate, chloride, phosphate, and heavy metals all drastically decreased among various physico-chemical characteristics. As *M. oleifera* seeds are easily accessible, affordable, sustainable, renewable, and eco-friendly, they can be used for the treatment of water in developing countries.

Keywords: *Moringa oleifera, Seed Extract, Dairy Effluents, Petroleum Effluents, Bioremediation*

INTRODUCTION
The increasing amount of industrial activities has led to the release of enormous amounts of effluents into the environment, posing a severe threat to human health and ecosystem integrity and has become one of the major environmental concerns worldwide. Among these, the Dairy and petroleum industries are two major contributors. Dairy and petroleum industries generate a significant amount of effluents that contain high concentrations of organic and inorganic pollutants that can cause severe damage to aquatic life and ecosystems when discharged into water bodies.

Whey, a by-product of dairy processing operations, is the most polluting effluent due to its high organic load (Shete & Shinkar, 2013). Raw sewage generated from the dairy industry can contain high values of Chemical Oxygen Demand (COD) of about 40–60 g/L (Vieira *et al*., 2010) and Biological Oxygen Demand (BOD) sometimes up to 1000 mg/L (Shivsharan *et al*., 2013). Dairy wastewater is considered extremely polluting mostly because of its organic load, and high concentrations of nutrients and solids (Kushwaha *et al*., 2010), which promote eutrophication (Shete & Shinkar, 2013).

Petroleum effluents from industries and refineries mainly contain oil, organic matter, and other compounds produced during crude oil processing, manufacturing fuels, lubricants, and petrochemical intermediates. This includes various pollutants such as phenolic compounds, dissolved and dispersed oil, heavy metals, and hydrocarbons, including benzene, toluene, and xylene. Phenolic compounds in petroleum effluents pose a significant risk to the environment and human health due to their extreme toxicity, persistence, bioaccumulation, ability to remain in the atmosphere for a long time, and carcinogenic properties (Aljuboury *et al*., 2017, Rahi *et al*., 2021). Further, the discharge of Dairy and petroleum effluents into the environment without treatment results in decreased dissolved oxygen, displeasing colors and odors in receiving water.

Typical approaches for treating these effluents involve the utilization of chemicals like aluminum sulfate (alum), synthetic organic polymer, synthetic polymeric derivatives, and inorganic coagulants (Sulaiman *et al*., 2017). While the effectiveness of these chemicals as coagulants are well acknowledged, they have some downsides related to their usage, such as high cost of the process, operation and maintenance, as well as generation of significant quantities of sludge (Dehghani & Alizadeh, 2016). Research has shown several serious disadvantages of using aluminum salts in water and wastewater treatment, such as the possibility of Alzheimer's disease and other health issues linked with residual aluminum in treated water, production of large amounts of sludge, reaction of alum with natural alkalinity in the water which can lower the pH, and low efficiency in coagulating cold water (Ndabigengesere & Narasiah, 1998).

Therefore, the need to develop cost-effective, sustainable and eco-friendly methods for the treatment of dairy and petroleum effluents is crucial to mitigate their negative impacts on the environment. One promising solution is the use of plant-derived natural adsorbents. Recently, there has been growing interest in using natural adsorbents derived from plant sources as an alternative to conventional treatment methods.

Moringa oleifera (MO), also known as drumstick tree or horseradish tree (Sulaiman *et al*., 2017), is a rapidly growing (Ndabigengesere & Narasiah, 1998), drought-resistant plant. It is widely cultivated in tropical and subtropical regions and has been traditionally used for both its medicinal and nutritional properties (Vieira *et al*., 2010). It is a medium-sized tree that typically reaches a height of 20 to 25 meters. The roots are smooth, fissured, soft, and tuberous, while the seeds range in length from 9.12 mm to 16.21 mm. MO seeds are biodegradable, safe for the environment and human consumption and possess the ability to treat a wide range of ailments such as rheumatism, urinary tract infections, sexually transmitted diseases (STDs), epilepsy, and gout. Traditional Ayurvedic practitioners have extensively documented the medicinal qualities of these seeds. Moreover, the tree has earned the title "Miracle Tree" due to the numerous beneficial properties found in nearly all of its parts (Dehghani & Alizadeh, 2016; Sulaiman *et al*., 2017).

The seeds in diverse extracted and purified forms have been found to possess remarkable adsorbent properties, making them an ideal option for treating various effluents. Studies have shown that these seeds are effective in removing suspended material, and the high concentration of proteins in them acts as cationic polyelectrolytes, reducing the turbidity, COD, and total dissolved solids (TDS) of treated wastewater. As a result of this water-soluble cationic coagulant protein, they are commonly used as primary coagulants. In addition, the sludge produced by coagulation with MO is innocuous and four to five times less in volume than the chemical sludge produced by alum coagulation. MO also softens hard water and acts as an effective adsorber of cadmium. The benefits of using MO as a coagulant include cost-effectiveness, water treatment without changing the pH level significantly, and high biodegradability (Vieira *et al*., 2010; Dehghani & Alizadeh, 2016). Industrial-scale studies have confirmed the effectiveness of MO seed coagulation for treating wastewater from various industries, such as palm oil mills, and have reported high effluent reduction rates (Sulaiman *et al*., 2017). Overall, utilizing natural adsorbents, such as MO, to treat industrial effluents is an effective approach to protect the environment and ensure sustainable development for these industries (Dehghani & Alizadeh, 2016). Therefore, using Moringa oleifera seeds as a natural adsorbent for treating dairy and petroleum effluents could provide a low-cost and environmentally friendly approach to mitigating the pollution caused by these effluents.

This research aims to explore the potential use of MO seeds as a natural adsorbent for the treatment of dairy and petroleum effluents and to evaluate the adsorption capacity of the seeds in removing different pollutants present in these effluents. This study examines various physicochemical parameters of effluent before and after treatment by coagulation using Moringa oleifera seed powder. The findings of this study could contribute to the development of cost-effective, sustainable, and environmentally friendly solutions for the treatment of dairy and petroleum effluents, reducing the impact of these industries on the environment.

METHODS AND MATERIALS

Collection of effluents

The dairy effluent samples were collected from the Aavin Milk Factory, Madhavaram while the petroleum effluent samples were collected from Chennai Petroleum Corporation Limited (CPCL), Manali. The collected samples were then transported to the laboratory and stored at 20±2°C for further analysis.

Preparation of MO seed suspension

MO seeds used in the study were obtained from trees in Chennai and their wings and coating were manually removed and discarded. The seeds were dried in an oven at 50°C for 24 hours. A domestic food blender was used to grind the dried seeds into powder, and the resultant powder was sieved to obtain an adsorbent with homogenous particles of known size. 100 mg of the MO seed powder was then mixed with 1000 ml of distilled water for 2 minutes. Fresh solutions were prepared daily to avoid any aging effects.

Treatment of Effluent

In a jar apparatus, the resulting powdered seed suspension was mixed with 2 liters of effluent samples and a paddle was inserted. The magnetic stirrer was set at 100 rpm for 30 minutes to ensure proper mixing. All batch experiments were conducted at room temperature.

Analysis of physicochemical parameters

Standard methods outlined by APHA (2012) were used to analyze both the raw and treated effluent samples. The physical parameters, such as pH, electrical conductivity, turbidity, total solids (TS), total dissolved solids (TDS), and total suspended solids (TSS), were measured. The chemical parameters, such as alkalinity, total hardness, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, chloride, and phosphate, were determined. Heavy metals, such as Copper, chromium, and zinc were also analyzed using an atomic absorption spectrophotometer (AAS, Perkin Elmer Analyst, 300).
Furthermore, the removal efficiency of each parameter was calculated using the formula:
Removal efficiency = (Ci - Cf / Ci) x 100, where **Ci** and **Cf** are the initial and final concentrations, respectively, for each parameter (Mateus *et al*., 2017).

RESULTS AND DISCUSSION

The present study investigated the efficacy of MO seeds as a natural adsorbent for the treatment of dairy and petroleum effluents. The physicochemical parameters analysis results showed that MO seeds were effective in removing pollutants from both types of effluents. The results indicate that the application of MO seed powder as a coagulant led to significant removal of turbidity, TS, TDS, TSS, copper, zinc, chromium, electrical conductivity, ammonia, nitrate, chloride, and phosphate content from both types of effluents. The physicochemical parameters analysis results are summarized in table 1 and 2.
The removal of turbidity from dairy and petroleum effluents was found to be 84.3% and 69.2%, respectively, after coagulation with MO seed powder. This finding corroborates with that of Dehghani & Alizadeh (2016) which indicated that MO at 70 mg/L and under optimum conditions could remove 63.70% of turbidity. Mohammad *et al*., (2009) revealed that the removal of turbidity was 50%-87.5% by MO coagulant protein.
Muthuraman & Sasikala (2014) demonstrated that MO seed extracts at 250 mg/L had the highest performance in turbidity removal (99%), among 3 natural coagulants (*M. oleifera, Strychnos potatorum and Proteus vulgaris*). However, the reported 99% turbidity removal efficiency is higher than the current finding which is most likely due to their usage of higher dose (250 mg/L) in comparision to the present study.
The treatment process resulted in significant removal of total suspended solids (TSS), total dissolved solids (TDS), and total solids (TS) from both types of effluents. Removal rates of 58.4%, 52.6%, and 53.8% for TSS, TDS, and TS respectively were observed in the dairy effluent sample, whereas removal rates of 36.8%, 43%, and 42.9% for TSS, TDS, and TS respectively were observed in the petroleum

effluent sample. Jar test experiment carried out by Dehghani & Alizadeh (2016) showed that M. oleifera could remove 62.05% of total suspended solids (TSS)

MO seeds had minimal effect on the pH value of the effluent and they acted as a pH. This finding aligns with that of Lester-Card *et al*., (2023) who proposed that MO seed extract can slightly increase the final pH when applied to an acidic solution and slightly decrease the final pH when applied to an alkaline solution, thereby providing a pH buffering effect. This amphoteric characteristic may be due to the ability of its amino and carboxyl groups to interact with H+ and OH- ions. Having this buffering effect would be advantageous in actual industrial wastewater treatment since there would be no need to adjust the pH using chemicals.

Following treatment with MO seed suspension, both effluents showed a significant decrease in alkalinity indicating that MO seeds have the ability to reduce the alkalinity. In contrast to the current findings, Araújo *et al*., (2022) demonstrated an increase in alkalinity when MO in 1M and 1.5 M NaCl solution was used for the treatment of cosmetic industry wastewater. However, this increase may be attributed to the high concentration of saline solution they used in the preparation of MO suspension.

The study also investigated the removal efficiency of heavy metals in the effluent samples. The results indicated that MO treatment resulted in the eradication of 99.9% of copper and zinc, and 97.1% of chromium from the dairy effluent sample, whereas in the petroleum effluent sample, removal rates of 40.5%, 27.1%, and 51.4% were observed for copper, zinc, and chromium respectively. Furthermore, the treatment process led to significant reductions in the electrical conductivity of both the dairy and petroleum effluent samples, with reductions of 39.9% and 41.7%, respectively. MO treatment was also found to eradicate 90.2% of ammonia, 58.1% of nitrate, 32.0% of chloride and 96.1% phosphate content in petroleum effluent sample, while in the dairy effluent sample, the removal of ammonia, nitrate, chloride, and phosphate was 52.5%, 65.4%, 26%, and 64%, respectively.

The BOD and COD levels of the raw petroleum effluent sample were found to be 640 mg/L and 1984 mg/L, respectively, while those of the dairy effluent sample were 930 mg/L and 2989 mg/L, respectively. However, after treatment with Moringa oleifera seed powder, the BOD and COD levels dropped to 110 mg/L (82.8% reduction) and 345 mg/L (82.6% reduction), respectively, in the petroleum effluent sample and to 450 mg/L (51.6% reduction) and 1760 mg/L (41.1% reduction), respectively, in the dairy effluent sample.

These accords with the findings of Thanki *et al*., (2022) which showed that MO seed powder removed approximately 38% of COD and 73% BOD in municipal wastewater. Bhuptawat *et al*., (2007) revealed 50% COD removals at both 50 and 100 mg/L MO doses and with a supplementation by 10 mg/L of alum to 50 and 100 mg/L MO doses, COD removals further increased to 58 and 64%, respectively. Furthermore, Rifi *et al*., (2022) presented that in olive oil mill wastewater treatment, the COD removal efficiency of MO was 88% under optimum conditions.

The high adsorption capacity of MO seeds for dairy and petroleum effluents can be attributed to their unique chemical composition, including proteins, polysaccharides, and polyphenols, which been shown to have adsorption properties. Preliminary studies have suggested that the coagulant property of the MO seeds is due to the presence of water-soluble cationic proteins composed of two positively charged peptide units (Mateus *et al*., 2017). These peptides have relatively low molecular weight (6–16 kDa) (Bhuptawat *et al*., 2007), an isoelectric pH value of 10 and play a role in the adsorption of organic compounds on the surface of the seeds (Vieira *et al*., 2010). The main mechanisms of coagulation is likely due to adsorption and charge neutralization (Beltrán-Heredia and Sánchez-Martín, 2009, Mateus *et al*., 2017), which are likely facilitated by the electrostatic attraction between the negatively charged pollutants in the effluent and the positively charged active compounds in the seeds.

Although, Ndabigengesere & Narasiah (1998) suggested that in order to use MO seeds as a coagulant in water and wastewater treatment systems, adequate purification of the active proteins a is necessary, as the organic matter in the seeds can exert a chlorine demand and act as a precursor of trihalomethanes (carcinogen) during disinfection process with chlorine.

Table 1: Physicochemical parameters analysis of petroleum effluent sample before and after treatment by coagulation with MO seed suspension and its removal efficiency of each parameter

Physicochemical parameters	**Raw petroleum effluent**	**Treated petroleum effluent**	**Removal efficiency in %**
Turbidity (NTU)	117	36	69.2
TS (mg/L)	3252	1856	42.9
TDS(mg/L)	3214	1832	43.0
TSS(mg/L)	38	24	36.8
Electrical conductivity (μmho/cm)	4302	2510	41.7
Ph	4.91	7.23	-
Alkanity (mg/L $CaCO_3$)	396	124	68.7
Total hardness (mg/L)	780	400	48.7
Ammonia (mg/L)	28	2.74	90.2
Nitrate (mg/L)	31	13	58.1
Chloride (mg/L)	1089	740	32.0
Phosphate (mg/L)	14.25	0.55	96.1
BOD (mg/L)	640	110	82.8
COD (mg/L)	1984	345	82.6
Copper (mg/L)	3.7	2.2	40.5
Zinc (mg/L)	5.9	4.3	27.1
Chromium (mg/L)	7.2	3.5	51.4

The primary concern when employing natural seed extracts to treat effluents is the possibility of residual organic material remaining in the treated water, which could result in sludge formation (Vieira *et al*., 2010). Although the current study did not quantify the amount of sludge generated, the quantity produced using this coagulant is generally significantly lower compared to aluminum-based coagulants. Another advantage of utilizing MO as a coagulant is that all Moringa by-products are organic and biodegradable. Therefore, if the particulates are eliminated, the effluent being treated does not contain any heavy metals, and the sludge is verified to be non-toxic via analysis, the generated sludge can be stabilized and repurposed as fertilizer or soil conditioner. Additionally, using natural coagulants like Moringa can lead to significant cost savings on chemical materials and reduce the amount of sludge generated, thereby requiring less disposal (Ndabigengesere & Narasiah, 1998; Bhuptawat *et al*., 2007; Dehghani & Alizadeh, 2016).

Table 2: Physicochemical parameters analysis of dairy effluent sample before and after treatment by coagulation with MO seed suspension and its removal efficiency of each parameter

Physicochemical parameters	Raw dairy effluent	Treated dairy effluent	Removal efficiency in %
Turbidity (NTU)	125.8	19.7	84.3
TS (mg/L)	3249	1501	53.8
TDS(mg/L)	2564	1216	52.6
TSS(mg/L)	685	285	58.4
Electrical conductivity (µmho/cm)	2872	1725	39.9
Ph	6.69	7.0	-
Alkanity (mg/L $CaCO_3$)	656	557	15.1
Total hardness (mg/L)	527	221	58.1
Ammonia (mg/L)	23.6	11.2	52.5
Nitrate (mg/L)	26	9	65.4
Chloride (mg/L)	457	338	26.0
Phosphate (mg/L)	21	7.55	64.0
BOD (mg/L)	930	450	51.6
COD (mg/L)	2989	1760	41.1
Copper (mg/L)	1.5	0.00156	99.9
Zinc (mg/L)	5.126	0.147	97.1
Chromium (mg/L)	2.05	0.00224	99.9

CONCLUSION

Overall, the results of this study highlight the efficiency of Moringa oleifera seeds as a coagulant for the treatment of dairy and petroleum effluents. The use of Moringa oleifera seed powder as a coagulant led to significant reduction of various pollutants, including turbidity, TS, TDS, TSS, copper, zinc, chromium, electrical conductivity, ammonia, nitrate, chloride, phosphate and heavy metals, from both types of effluents. Thus Plant-derived natural adsorbents like MO represent an alternative and future technology for industrial effluent treatment, and the findings of this study could be useful in the development of low-cost and effective methods for the treatment of such pollutants, helping to reduce their environmental impact.

However, standardization of products, market development, rigorous economic analyses, compliance with regulatory approvals, and multidisciplinary collaboration are essential elements for future and continued success in largescale commercialization. Further studies can be carried out by optimizing the factors that affect the coagulation process such as pH, mixing speed and time, temperature, and retention time to increase treatment efficiency, improve treatment performance and reduce treatment cost. Optimizing the MO seeds coagulant with or without non-synthetic chemicals (in less quantity) in effluent treatment process to enhance its effectiveness toward high effluent removal is recommended. Gene cloning of the Moringa proteins in other plants is also a potential avenue for investigation.

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